Linda Hobbs
Raphaela Porsch *Editors*

Out-of-Field Teaching Across Teaching Disciplines and Contexts

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Foreword

> In a nutshell, understanding the complex out-of-field teaching phenomenon in "totality" involves applying a context-consciousness and moving beyond the obvious.

Both the recent focus on out-of-field teaching practices in mathematics and science and school leaders' experiences with the phenomenon in their schools highlight the myriad concerns and implications of out-of-field teaching. Perhaps most critically, these do influence our students beyond the school environment. This book emphasizes that out-of-field teaching is an international phenomenon, and defining it globally is of the utmost importance because of the significant ramifications it has for the true reflection of the phenomenon in research information, statistics, and evidence. This book underlines the value of international research and the impact that research-informed decisions might have on teachers, quality teaching, and possible misconceptions about the field.

As the book thoroughly discusses, issues related to out-of-field teaching involve teacher quality, quality of teaching, and content knowledge—the latter of which provides teachers with a fundamental basis from which to make decisions about the implementation of curriculum, subject-related pedagogy, and the depth of knowledge to be constructed by their students. A deep or sound knowledge can be conceptualized as encompassing a teacher's broad knowledge of content, pedagogies for a specific field, curriculum knowledge, understanding of students' needs, and strong grasp of a school community and its cultures (Shulman 1986, 1987). This book embraces a focus on the value of teachers' sound content knowledge, highlighting that it provides them with a sense of efficacy, a premise that is underlined by the work of Sharplin (2014). As well, the book includes an acknowledgment of the different forms of pedagogical content knowledge, and deepens reflections, views, and understanding of the value that teachers' subject-specific knowledge brings to the teaching and learning environment.

The research involved in the development of specific chapters in this book emphasizes out-of-field teaching as a global concern. The value of the various specific chapters brings this aspect of the phenomenon into focus: Chapter 15 reports out-of-field teachers' beliefs about self-efficacy in Ireland; Chapter 14 offers new insight about the phenomenon in Poland; and, close to my own heart in the matter; Chapter 9 describes out-of-field experiences in Israel as being deeply embedded in a context-consciousness (Du Plessis 2020). These global views clearly indicate that the out-of-field teaching phenomenon not only affects mathematics and science subjects, but also has a significant influence on various subjects at all levels and phases of teaching and learning. In my view, out-of-field teaching also greatly influences efforts to create effective interdisciplinary strategies that develop links between specific subject areas or fields in both primary and secondary schools.

The chapters that capture the Australian context set out the dilemmas that accompany the effective management of the phenomenon for teachers who teach specific subjects without the necessary content knowledge or pedagogical content knowledge. High expectations for academic results and student achievements leave these teachers—who often already lack much-needed support—feeling disillusioned, isolated, and burnt-out. The book highlights these concerns while it questions issues of quality education in out-of-field teachers' classrooms, turning focus to the absence of deep learning cultures, effective implementation of the curriculum, and students' learning strategies. The book thus makes a valuable contribution to awareness of the out-of-field realities that exist in schools and the lived experiences of all stakeholders involved in the out-of-field teaching situation, paving the way for targeted decision-making, support, and improvement strategies.

I acknowledge and appreciate the work researchers are doing in this specific field and strongly advocate further research that is linked to the multilayered aspects of the phenomenon. My personal view is that out-of-field teaching will always form part of the teaching profession, and we need to use research evidence to effectively manage it. The out-of-field phenomenon is a unique and complex phenomenon, and its implications are far reaching. When we know that the out-of-field phenomenon tends to rob qualified—even highly qualified—teachers of the passion they have for teaching, how can we not pay attention?

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Preface

This edited book is a compilation of research by the members of the Out-of-field Teaching Across Specialisations (OOF-TAS) Collective. The book provides research and commentary relating to the out-of-field teaching phenomenon in primary, secondary, and tertiary education, and across different subjects—Mathematics, Sciences, Humanities, Languages, and others. 'Out-of-field' teaching refers to misalignment between teaching assignments and teachers' disciplinary and education background. Out-of-field assignments most commonly occur when teachers are specialized according to subjects or specific roles (more common in secondary school), and less commonly occur for generalist teachers (more common in primary/elementary school). The practice of assigning teachers to teach out-of-field arises for a number of reasons, including a shortage of teachers specialized in particular subjects in the education system, unequal distribution of those teachers across schools or school sectors, poor leadership practices where teachers are mismanaged within a school, and personal choice where teachers may elect to take on new subjects (see Hobbs & Törner, 2019a). What is regarded as in-field and out-of-field can also differ across contexts depending on certification, registration, and teacher education requirements and policies. The experience of teaching out-of-field is being increasingly applied more broadly to signify teachers' unpreparedness and newness, often accompanied by feelings of inadequacy or reduced effective practice, for example in primary school contexts (e.g., Hanuscin et al., 2020).

This book provides a unique collection of research occurring within this field of inquiry, now that this area of research is no longer under-researched nor under-theorized. The field is entering a period of adolescence where key lines of inquiry are being explored from different perspectives and it is becoming self-aware with an expanding number of researchers taking notice, and increasing maturity in the language used to describe, measure, and critique and this phenomenon. Early research was concerned with exposing out-of-field teaching and exploring the incidence, distribution, and causes (e.g., Broadbelt, 1990; Ingersoll, 1996, 1998) and critique of policy (Ingersoll, 2001) mainly based on results from studies having researched the effects on students' proficiency (see Porsch & Whannell, 2019). Now there is more attention given to various possible effects (on students, teachers, school development) and nature of experiences arising because of out-of-field teaching (Du Plessis, 2015; Hobbs, 2013; Rahayu & Osman, 2019; Vale et al., 2020). There is a growing body of literature capturing the effects of initiatives designed to attend to the issue (Kenny et al., 2020; Ní Ríordáin et al., 2017). Given the contextualized nature of the phenomenon, this growing body of literature informs future research, regarding where there is more work to be done in understanding the out-of-field teaching phenomenon across different contexts and subjects through nuanced quantitative studies of incidences and effects, and qualitative analyses of associated policy settings, causes, effects, and meanings.

This second edited book produced by the OOF-TAS Collective builds on the first (Hobbs & Törner, 2019b), which interrogated the out-of-field phenomenon through themes explored by international teams of authors. The first book laid out the many and varied issues and areas of research that are needed to understand and inform debate and discussion around the phenomenon. The presently proposed edited book extends on that work by showcasing the broad range of research agenda and findings currently arising in the field. The book is context-focused, with each chapter beginning with a description of the research context and how out-of-field teaching is defined/arises within that context. Contributions represent research from around the world, with contributors from seven countries: Australia, Germany, Israel, United States, Poland, Ireland, and United Kingdom. This book provides snapshots of the effects, causes, measurement, and other characteristics of out-of-field teaching in and across contexts including states and countries, school types and school levels, subjects, and specializations. In addition, the different chapters provide commentary at different units of analysis: the individual teacher level, school leadership level, school level, or system level. The different chapters focus on: the effects of out-of-field teaching for teachers and their students; the school contexts/cultures that do or do not support them; the leadership practices that assign the teachers to out-of-field subjects; and the systems that create/perpetuate the need for out-of-field teaching assignments.

The chapters have been organized into four parts, each representing a different broad context: (I) Policy contexts; (II) Personal contexts; (III) Professional learning contexts; and (IV) Teaching practice contexts. The book is future-facing, with all chapters concluding with recommendations and questions for future research policy and/or practice. These conclusions will be synthesized in a final chapter as an agenda for policy and practice, and as a model representing the out-of-field phenomenon with a roadmap for future research. Readers will benefit from this collected volume of emerging international research, the range of contexts associated with out-of-field teaching, and the various dimensions of this complex phenomenon which requires complex analysis and solutions.

Part I: Policy Contexts

The chapters in this section relate to the political context of out-of-field teaching, including the governmental policies that determine certification and qualification of teachers, and how these can be used to understand and define out-of-field teaching at a system level, at a school level and at a teacher level.

Chapter 1 (Colleen Vale, Linda Hobbs, and Chris Speldewinde) used a critical approach to problematize the policies and practices concerning out-of-field teaching in Australia. The analysis is based on documents from the Australian and selected state governments, and interviews with representatives from principal and teacher subject associations and teacher union showing among others a universal problem: the tension between maintaining the standards of the teaching profession and the need for teachers teaching-out-of-field. Based on the perception that there is a lack of common understanding of what constitutes out-of-field teaching, which can make it difficult to assess the extent and impact of out-of-field teaching, **Chapter** 2 (Linda Hobbs, Coral Campbell, Seamus Delaney, Chris Speldewinde, and Jerry Lai) provides results from an Australian project that aimed to develop of a definition of out-of-field teaching for secondary schools in Victoria. The multi-faceted definition of out-of-field teaching, based on criteria that can determine what is considered as out-of-field and associated risk factors and capacity building factors, can provide a solid foundation for similar research in other contexts/countries. **Chapter** 3 (James P. Van Overschelde) presents findings based on a rich data source with more than 5 million students from Texas. The study examined the effects of out-of-field teaching using mixed effects regression models. The study results support concerns about the effects of the phenomenon: Students earn significantly and substantially lower exam scores when taught by teachers who are out-of-field in comparison to those taught by in-field teachers. This result is alarming as teaching out-of-field has been legalized in the state of Texas as well as other states in the Unites States by a passage of the Federal Every Student Succeeds Act (2015). The Federal laws based on this Act permit schools to assign teachers to classes even if they do not possess a qualification in the subject area. Thus, out-of-field teaching appears as avoidable by changing these regulations or at least its frequency could be lowered. **Chapter** 4 (Chandra Shah, Paul Richardson, Helen Watt, and Suzanne Rice) presents findings from a study using data from PISA 2015 (Australia) and is focused at the school level. The aim of the project was to examine whether school organization practices and other school context factors along with teacher characteristics influence the assignment of teachers to out-of-field mathematics teaching. The assignment occurs unevenly across schools and can be explained by structural factors such as the schools' size and their location but also with the schools' funding. The schools with a long-term funding rarely have the need for recruiting nonqualified mathematics teachers.

Part II: Personal Contexts

The chapters relating to personal contexts refer to teacher-related concerns of support, identity, experience, and beliefs and include important messages about the effects of out-of-field teaching not just on the teacher but also others within their schools and the education system overall. The chapters show the complexity of the teachers who teach out-of-field, the struggles they face, the opportunities they glean, and the different subjects and contexts they find themselves in. The range of variables represented in this section illustrate the complexity involved when understanding this phenomenon.

Chapter 5 (Emily Rochette, Christine Redman, and Paul Chandler) presents a study on teachers of geoscience and gives exemplary descriptions of the out-of-field teacher' lived experiences and their professional development. A special focus is given to their capability of using digital technology. **Chapter** 6 (Raphaela Porsch and Eva Wilden) provides results from a quantitative study with primary teachers teaching English as a foreign language (EFL) in Germany. Three groups of teachers with different qualifications were compared with regard to their professional characteristics and assessment of instructional quality. Among others, results indicate that a fully qualified teacher is more likely to be motivated to teach English and speak the foreign language proficiently than a teacher who is formally not trained in EFL or attended a post-qualification course. **Chapter** 7 (Judith Lagies) gives insight into a qualitative-reconstructive documentary method study. The interviews show how primary school teachers from Germany negotiate being out-of-field between two poles: adhering to the subject principle and class teacher principle. In other words, the teachers possess the awareness that subject-specific knowledge is needed in order to ensure qualified teaching. Equally, an intensive student-teacher relationship is necessary. The so-called class teacher principle means that in one class most subjects are taught by a single teacher. However, most primary teachers in Germany are not trained as generalists (Porsch, 2020); consequently, elementary teachers are likely to be faced with out-of-field teaching. The chapter presents different types of teachers and how they deal with this antinomy. **Chapter** 8 (Fiona Yardley) is a personal recollection of a lived experience. The methodologyof (autobiographical) bricolage is used to reflect on the development of the author/researcher as a mathematician who also has an academic background in history along with creativity and her faith that determine her as a person.

Part III: Professional Learning Contexts

The research in this section focuses on professional learning contexts, focusing on teacher learning that occurs from pre-service to in-service. Teachers are represented as learners as they face the challenges of teaching out-of-field, firstly as new teachers transition into teaching and secondly as experienced teachers undertake professional development programs in their out-of-field subjects. The context of following alternative pathways into teaching and switching careers is also explored.

Chapter 9 (Smadar Donitsa-Schmidt, Ruth Zuzovsky, and Rinat Arviv-Elyashiv) reports on a study from Israel. Although teachers should not teach out-of-field in the induction year, their first year, the first year as a teacher, the reality is different. Consequently, the authors explored how prevalent out-of-field teaching is during the induction year in Israel. In addition, they differentiated between teachers who taught in-field, partially out-of-field, and entirely out-of-field. The comparison of these groups showed among other results that teaching partially and fully out-of-field leads to less satisfied teachers and, more alarmingly, a higher retention rate after the first year. **Chapter** 10 (Jared Carpendale and Anne Hume) presents results from a study investigating the changes of pedagogical content knowledge (PCK) of three out-of-field physics teachers after taking part in a collaborative design process. The interpretations are based on variety of qualitative data in the form of audio-recorded interviews and discussions during the workshops, field notes, and video-recorded lesson observations. The teachers' PCK enhanced, in particular their understanding of concepts improved. **Chapter** 11 (Teresa Beck) gives an insights into narratives from teachers who were alternatively qualified as teachers and their experienced biographical transition into the teaching profession in Germany. Similar to the out-of-field experience, entering the teaching profession is an experience characterized by several challenges. For example, one teacher feels a tension between habitualized practice and the normative programmatic specifications. The teachers' longing for feeling "in-field" refers both to the subjects they teach and the profession itself. As such, the study enlarges the perspective of the book as not only experienced teachers struggle with the out-of-field experience but also career switchers, who are new in a field/subject and a profession. The study presented in **Chapter** 12 (Máire Ní Ríordáin, Merrilyn Goos, Fiona Faulkner, Stephen Quirke, Ciara Lane, and Niamh O' Meara) is set in the Irish contexts and explores out-of-field maths teachers and their professional self-understanding after participating in a national professional development program. The results indicate that formerly out-of-field teachers can turn into successful in-field teachers by improving their subject and pedagogical knowledge, which also leads to an increase in theirjob satisfaction, commitment, and self-efficacy. **Chapter** 13 (Susan Caldis) focuses on pre-service teachers' experience in teaching out-of-field. Over 18 month five teacher education students from a geography methodology class at an Australian university were accompanied. Instruments included social labs, lesson observations, researcher observation notes as well as semi-structured interviews. The results that were analyzed through reflexivity theory show among others that the out-of-field experience and their reflections over time initiated by the researcher led to a greater understanding of their pedagogical practice in and outside their field. **Chapter** 14 (Barbara Barańska and Małgorzata Zambrowska) provides an insight into the situation in Poland with regard to teacher education and the out-of-field phenomenon. This informative overview is followed by a study with 160 teachers who have decided to start teaching mathematics as a second subject, which means that they had to complete a post-graduation program.

The focus of this study is on why teachers choose to take part in these studies and why mathematics was the chosen subject. The open answers show that intrinsic motives such as the interest in the math and the wish for professional development as well as extrinsic factors such as getting or maintaining a job were relevant aspects for choosing mathematics.

Part IV: Teaching Practice Contexts

The research in this section focuses on the teaching practices of teachers teaching out-of-field. Analysis of teaching practice can compare in-field and out-of-field practice of individual teachers, or just interrogate the practices and knowledge of out-of-field teaching teachers. A range of methodologies have been used across these chapters—all in the context of teaching mathematics—to interrogate these varying aspects of teaching practice.

Chapter 15 (Merrilyn Goos and Aoife Guerin) provides findings from a study set in Ireland on self-efficacy beliefs and classroom practices of in-field and out-of-field mathematics teachers as well as teachers who have taken part in a program for professional development. Apart from the results based on a case-study design, the authors provide an instrument for a structured lesson observation, the Productive Pedagogies framework, a tool that has great potential for other research projects. **Chapter** 16 (Lara Huethorst) presents a study that was conducted as part of an in-service course for (future) elementary teachers. The study focuses on the quality of solutions given by out-of-field mathematics teachers and pre-service teachers shortly before their exams in mathematics. The quality of the solutions differs significantly between the out-of-field teachers and pre-service teachers in favor of the pre-service teachers. Given these results, the need becomes apparent that out-of-field teachers attend professional development courses. **Chapter** 17 (Kim Beswick and Dennis Alonzo) draws on a project with upper primary and secondary school teachers in Australia who were teaching mathematics in-field or out-of-field but possessing different qualifications. The teachers provided background information as well as answers to items based on Shulman's seven knowledge types along with ratings on their confidence in relation to everyday mathematics and teaching mathematics. Using a Rasch analysis, based on the profile, teachers could be assigned to four different levels. Interestingly, on the highest level are in-field teachers as well as out-of-field teachers suggesting that the formal qualification does not fully explain teachers' level of knowledge.

Finally, **Chapter** 18 (Linda Hobbs and Raphaela Porsch) provides a synopsis of the key findings from the book and proposes a model of the out-of-field phenomenon and proposes areas for future research based on input from members of the OOF-TAS Collective.

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Raphaela Porsch is Professor of Education at the University of Magdeburg, Germany. She teaches education to student teachers. Her research interests include teacher education, teaching out-of-field/teaching across specializations, academic emotions, transition after primary school, and (early) foreign language teaching. She has worked in national large-scale assessment as well as projects on school development and is the editor of several anthologies on educational topics such as transition after primary school and teaching out-of-field.

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Part I
Policy Contexts

Chapter 1
Challenging the Representations and Assumptions of Out-of-Field Teaching

Colleen Vale, Linda Hobbs, and Chris Speldewinde

Abstract The practice of out-of-field teaching, that is, teaching a subject without a background in the discipline or preparation for teaching it, is an ongoing practice in secondary schools in many countries, including Australia. We used a critical approach to problematise the policies and practices concerning out-of-field teaching in Australia. Documents from the Australian and selected state governments, and interviews with representatives from principal and teacher subject associations and teacher unions, were analysed using Bacchi's "What's the problem represented to be?" approach. Stakeholders' representations of out-of-field teaching and the assumptions underlying these representations are reported along with their perspectives on the effects on teachers, students and schools. A number of silences concerning the politics of out-of-field teaching arose. Challenging the assumptions and addressing the silences requires recognition that specialist teacher supply is a long-term problem. A need to attend to teacher attrition and professional development are key actions needing further consideration.

Keywords Education policy · Equity · Out-of-field teaching · Problematisation · Teaching quality

1.1 Introduction

Out-of-field teaching occurs when teachers teach specialist subjects (or year levels) when they do not have specialist knowledge or background for teaching the subject specialisation (Ingersoll, 2002; Weldon, 2016). Its meaning is debated and differs according to the requirements for teacher knowledge and specialist (discipline) knowledge in different education jurisdictions (Ingersoll, 2002). Assigning

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or appointing teachers to teach out-of-field is a practise school leaders use to overcome limited supply of teachers with specialist qualifications (Adamson & Darling-Hammond, 2012; Chandra et al., 2020; Ingersoll, 2002; Marginson et al., 2013; Price et al., 2019). The interaction between policies and practices at system and school levels results in out-of-field teaching that does not solve the problem of limited supply.

In such situations, and from Bacchi's perspective, policies do not solve problems but produce problems that govern "what gets done or not done" (Bacchi, 2012b, p. 22). Bacchi used the "What's the problem?" approach (Bacchi, 1999), later changed to "What's the problem represented to be?" (WRP) approach (Bacchi, 2012a, 2012b), to critique policies by "revealing the assumptions about the nature of the problem in any postulated solution" (Bacchi, 1999, p. 21). The intention of problematisation here is to make visible the politics of teaching out-of-field, politics being "the complex strategic relations that shape lives" (Bacchi, 2012a, p. 1). By problematising (Bacchi, 1999) out-of-field teaching, we seek to elucidate how and why teaching out-of-field is "questioned, analysed, classified and regulated" (Deacon, 2000, p. 127) by different policies from different stakeholder groups (not just government) and under different circumstances, rather than looking for the one correct response (Bacchi, 2012a). Bacchi (2012a) emphasises that problematisation emerges as practice, so it is possible to understand the politics of, in this case the out-of-field teaching phenomenon, by examining the practices associated with it. For the different stakeholder groups, these practices may be recognisable through the various responses to the phenomenon: "what one proposes to do about something reveals what one thinks is problematic (needs to change)" (Bacchi, 2012b, p. 21). By focusing on different stakeholder practices concerning the phenomenon, we can understand what is done about the phenomenon and how people conceptualise it, as demonstrated by how out-of-field teaching is "dealt with as a specific kind of phenomenon" (Bacchi, 2012a, p. 3).

In this chapter, we use Bacchi's (2012b) WPR approach to problematise out-of-field teaching. We analyse how the practice of assigning and employing teachers to teach out-of-field as a solution to the problem of supply of specialist teachers has been represented, legitimated and contested in the Australian education context. The research questions are: How is out-of-field teaching represented by stakeholders and what are the assumptions underpinning these representations? What do stakeholders perceive the effects of teaching out-of-field to be? What are the silences, that is, what does not get done, and how might the representations and assumptions of out-of-field teaching be challenged?

1.2 Background

A myriad of research provides evidence of assigning secondary teachers to teach secondary subjects without specialist subject qualifications in Australia (Chandra et al., 2020; Du Plessis, 2015; Hobbs, 2013; Mayer et al., 2014; Weldon, 2016), the USA (Adamson & Darling-Hammond, 2012; Ingersoll, 2002), and European and other OECD countries (Marginson et al., 2013; Price et al., 2019). Weldon (2016) reported that a high proportion of Year 7 to 10 humanities and STEM[1] teachers in Australia had not completed any tertiary study of the discipline nor pre-service teacher education about teaching the subject. This involved 41% of media teachers, 40% of geography teachers, 34% of information technology teachers, 20% of mathematics teachers and 20% of physics teachers. Indeed, there was evidence of teachers in all discipline areas without specialist qualifications. The scale of out-of-field teaching in Australia is greater than other comparable countries (Marginson et al., 2013). For example, in 2015 22% of Year 8 mathematics students in Australia were taught by teachers without a tertiary mathematics major or mathematics teacher education compared to the international average of 15% of Year 8 mathematics students (Mullis et al., 2016).

Differences in the incidence of out-of-field teaching are higher within countries than between countries (Choi, 2010). In Australia, schools in remote locations (41%) are more likely to assign teachers to teach out-of-field than metropolitan schools (24%), and low socio-economic schools (31%) more likely to use out-of-field teaching than high socio-economic schools (22%) (Weldon, 2016). Teaching out-of-field is much less likely for teachers in independent schools (Chandra et al., 2020). The likelihood of out-of-field teaching also declines with more school autonomy and larger school population (Chandra et al., 2020).

Out-of-field teaching is implicated in poorer or reduced student outcomes, including student disengagement, lower levels of disposition, participation and achievement (Akiba et al., 2007; Darling-Hammond & Sykes, 2003; Hill & Dalton, 2013; Ingersoll, 2002). For example, in Australia, TIMSS 2015 reported that the 22% of Australian Year 8 maths students who were taught by out-of-field teachers in 2015 achieved significantly lower scores than students taught by teachers with majors in mathematics and/or mathematics education (Mullis et al., 2016). Attard (2013) identified out-of-field teaching as contributing to students' poor disposition and disengagement in mathematics in their early secondary years. Reliance on out-of-field teaching in low socio-economic communities contributes to the reproduction of social disadvantage (Adamson & Darling-Hammond, 2012; Ingersoll & May, 2012).

Research has also reported on the effects of out-of-field teaching on teachers. In Australia beginning and early career teachers are more likely than experienced teachers to be teaching out-of-field: 37% of teachers with one or two years teaching experience compared with only 25% of teachers with more than five years' teaching experience (Weldon, 2016). Mayer et al. (2014) reported that up to 23% of graduate secondary teachers are teaching out-of-field with secondary graduates with specialisations in humanities, the arts and health and physical education the most likely to be teaching out-of-field. Attrition of teachers following out-of-field teaching experiences is reported in the literature (Handal et al., 2013; Ingersoll & May, 2012; Quartz et al., 2005; Vale & Drake, 2019). Researchers of rural and remote schools have noted the additional pressure and stress on schools where there is an ongoing turnover of teaching staff and principals (Handal et al., 2013; Jorgensen, 2012).

[1] Science, Technology, Engineering and Mathematics.

Other studies have found that out-of-field teaching is not always a negative experience for teachers (Hobbs, 2013; Vale et al., 2020). Research has pointed to school administration and leadership as contributing to attrition or inability to retain teachers who have been assigned to teach out-of-field in their school or profession (du Plessis et al., 2015, 2019; Jorgensen, 2012; McConney & Price, 2009; Vale, 2010).

1.2.1 Policy Context

Recent Australian Government policies aim for consistency of standards in school education across the states in the era of "performativity" (Ball, 2003). The responsibility for significant elements of school education policy has shifted from state governments to the Australian government. School performance is monitored through the *National Assessment Program in Literacy and Numeracy* (NAPLAN) (ACARA, 2016). In addition, the Australian and state governments are committed to *The Melbourne Declaration* that includes the goal: "Australian schooling promotes equity and excellence" (Ministerial Council on Education, Employment, Training and Youth Affairs [MCEETYA], 2008).

As part of the move for consistency and promoting equity and excellence, national policies now prescribe common requirements for accreditation of teacher education programs concerning subject specialisation (Australian Institute for Teaching and School Leadership [AITSL], 2011) and standards for graduate teachers (AITSL, 2014). The AITSL (2011) national entry and course requirements for secondary teaching specialisation requires "at least a minor[2] study… and a minimum of one-quarter of discipline specific curriculum and pedagogy studies" (p. 14). The requirements recommend completing a major study to teach senior secondary level (Years 11 and 12) and for some disciplines, such as physical education. These requirements replaced requirements previously administered in each state jurisdiction in Australia, some of which required less tertiary study, whilst other states such as New South Wales had required more tertiary study for Year 7 to 10. The extent of out-of-field teaching in Australia is higher when out-of-field teaching is defined according to these AITSL (2011) requirements (Weldon, 2016).

State governments have retained responsibility for teacher registration. In all states, except New South Wales, graduates of teacher education programs are registered as teachers, not teachers of specialist subjects or year levels.[3] State governments continue to deliver public schooling with increasing school autonomy and school responsibility for recruiting teachers. The salary and employment conditions of teachers are also a responsibility of State jurisdictions.

[2] Minor study is defined as two years of tertiary study equivalent to two units of first year study followed by two units of second year study.

[3] See, for example, Registration Categories at the Victorian Institute of Teaching: https://www.vit.vic.edu.au/registering-as-a-teacher/registration-categories.

Within this context of interacting state and Australian government policies, and given the evidence of out-of-field teaching in Australian schools, it is important to explore the representations and assumptions of out-of-field teaching in order to problematise out-of-field teaching and challenge the assumptions.

1.3 The Study

A critical lens (Bacchi, 2012b) is used to analyse the representations and assumptions held by state and federal governments and stakeholders regarding the practice of out-of-field teaching in Australian secondary schools. The stakeholders here are organisations representing school principals, unions who represent teachers and teacher subject associations who represent teachers of discipline specific school subjects, specifically for this study, the associations of science, mathematics and technology teachers. We chose to focus on STEM-related teacher subject associations given the Australian Government strategy for enhancing STEM education (Education Council, 2015).

1.3.1 Methods of Data Collection

We determined that two data sources would provide the means to analyse the politics of out-of-field teaching. These two sources were documentary evidence and interview data, both of which were collected between 2008 and 2016. A second round of data collection for documentary evidence occurred in 2020.

1.3.1.1 Documentary Evidence

A document search concerning government policy and procedure was limited to publicly available material on the government websites of five states (New South Wales, Victoria, Queensland, Western Australia and Tasmania) and the Australian Department of Education, as well as the websites of teacher unions and teacher subject associations (see Table 1.1). We searched for documents and policy statements concerning initial teacher education, teacher certification, hiring and allocation of teachers, beginning teachers and teacher professional learning. The search terms (or derivations thereof) included: out-of-field, qualified/unqualified, specialisation/non-specialist/mis-assigned. We identified more than 150 documents for analysis.

Table 1.1 Number of documents collected from government education departments and authorities, and other stakeholders (2008–2016, 2019–2020)

Source	2008–2016	2019–2020
Victoria—Department of Education and Early Childhood	14	4
Queensland—Department of Education and Training	7	1
Tasmania—Department of Education	24	
Western Australia—Department of Education	46	
New South Wales—Department of Education	4	
Australia—Department of Education	24	
Australian Institute for Teaching and School Leadership (AITSL)	16	
Council of Australian Governments (COAG)	7	
Union Documents	17	
Mathematics Teacher Associations	25	1
Technology Teacher Associations		1

1.3.1.2 Semi Structured Interviews

We used two sets of interview questions: one set targeted principal associations, teacher unions and the mathematics and science teacher associations; the second set for government departments. The questions for principal and teacher representatives concerned organisation and members perceptions of out-of-field teaching, impact of out-of-field teaching, organisational response and government communication with the organisation about out-of-field teaching.

Questions for departments of education spokespersons aimed to understand how government acknowledged, understood and addressed out-of-field teaching. These questions asked if funding was provided to address out-of-field teaching, and what policy and procedures, projects and initiatives were in place to support out-of-field teachers. Table 1.2 lists the method and number of interviews conducted for each of the stakeholders. We conducted four interviews with teacher union representatives, four interviews with teacher associations (two science and one mathematics), four interviews with principal associations and one Education Department interview. Interviews generally took between 20 and 30 min and were transcribed for analysis.

1.3.2 Method of Data Analysis

The problem representation process (Bacchi, 1999) was used to analyse the interview transcripts and the policy documents. In order to identify the representations of out-of-field teaching, and discern the assumptions underlying these representations and the effects, we began by analysing the data collected from each stakeholder separately. Key words and phrases used in relation to the phenomenon of out-of-field

Table 1.2 Interviews conducted with stakeholders

Interview	*n*	With whom	Method
Education Department	1	Tasmania	Face-to-face
Principal Associations	4	Victoria, NSW, Queensland, Western Australia	Telephone
Science Teacher Associations	2	Tasmania	Telephone Email
Mathematics Teacher Associations	1	Victoria	Telephone
Teacher Unions	4	Victoria, Queensland, Western Australia, Australia	Telephone
Teacher educator	1	Western Australia	Telephone
Total	13		

teaching along with the explanations and justifications provided were used to identify the representations and underlying assumptions. We prepared a narrative for each stakeholder that described the representations and assumptions that emerged. We then compared the narratives of all stakeholders to reveal those representations that were common and those that were not. Differences between stakeholders signalled silences, that is, what was left as unproblematic. We analysed the second round of documentary data collected in 2019–2020 to identify any changes to representations, assumptions and silences. Finally, we considered how the representations and assumptions could be disrupted to make visible the politics of out-of-field teaching.

1.4 Findings

In this section, the findings for the first two research questions are reported, that is, the representations and assumptions in the practice of assigning teachers to teach out-of-field and the effects of this practice. We will discuss the silences and ways in which the representations and assumptions identified here might be challenged in the following section.

1.4.1 Representations of Out-Of-Field Teachers and Their Assumptions

We identified four categories of representations used by stakeholders: *teacher shortfall*, *hard-to-staff schools*, *less qualified teachers* and *teacher quality*. Only the Tasmanian Department of Education openly referred to out-of-field teaching as *teaching outside speciality* (Tasmanian Audit Office, 2013–2014). More recently, the Department of Education and Training Victoria (DETV) and the Department of Education and Training Queensland (DETQ) used the term out-of-field teaching (DETV, 2020a, 2021; Chandra et al., 2020).

1.4.1.1 Teacher Shortfall

Teacher shortfall was a representation identified in the documents of both government and non-government stakeholders. For example, in the Staff in Australian Schools (SiAS) reports (McKenzie et al., 2014) out-of-field teaching is represented as "unfilled vacancies", "major difficulty in suitably filling vacancies" and "retaining suitable staff". The meaning of "suitable" may refer to discipline specialisation knowledge or specialist teaching experience as well as knowledge of students, school and community.

The assumption underpinning this representation of out-of-field teaching as teacher shortfall is that out-of-field teaching is a short-term solution and takes advantage of flexible short-term employment contracts whilst programs to address the shortage of specialist teachers take effect. Such programs include financial incentives for graduate teachers, and professional learning programs and additional qualifications that upskill teachers of other subject specialisations. Furthermore, Prince and O'Connor (2019) modelled the supply of teachers of secondary mathematics to show that it was an ongoing, long-term problem.

An example of a policy aimed to attract more teachers is the fast-track teacher education program, Teach for Australia (Weldon et al., 2012). Participants in this program are employed for two years as an Associate Teacher with a 0.8 workload in socially and educationally disadvantaged schools (Weldon et al., 2012) whilst completing the teacher education course. However, estimates show that only 30% of these teachers stay in the targeted school after three years (Department of Education & Training, 2017).

1.4.1.2 Hard-to-Staff Schools

In the SiAS reports hard-to-staff schools are described as schools in rural locations, and metropolitan schools with a low socio-economic status (SES) with "a major difficulty in filling vacancies or retaining staff" (McKenzie et al., 2014, p. 126). According to one union representative, out-of-field teaching arises because of an unequal distribution of specialist teachers where there is "an oversupply in one part of the state…and an undersupply [in others]" (Union representative). Some state governments recognised that shortages of specialist teachers occur more often in rural and remote schools, and have tried to entice existing teachers and new teacher graduates to work in rural and remote schools including in schools with high proportions of Indigenous students (e.g. Department of Education NSW [DENSW], 2014a, 2014b; DETV, 2020b; Department of Education Western Australia [DEWA], 2016). In this representation out-of-field teaching is a problem of distribution.

The programs designed to attract teachers to hard-to-staff schools assume that these schools and communities are unattractive workplaces and that graduate teachers need financial and employment contract incentives to teach in secondary schools in rural, remote and low SES communities.

1.4.1.3 Less Qualified Teachers

In documents reporting teacher shortages out-of-field teachers are described as less qualified teachers. For example:

> 39% of Government, 36% of Catholic and 15% of Independent secondary principals indicate that they ask teachers to teach outside their field of expertise in response to shortages, and about a quarter recruit less qualified teachers, or teachers on short-term contracts. (McKenzie et al., 2014, p. 129)

> There is concern that the quality of teaching and therefore student outcomes is affected if schools have to reduce the curriculum on offer or employ *less qualified teacher*. (Teacher Education Ministerial Advisory Group, 2014, p. 11, emphasis added)

Each principal association representative interviewed described the use of less qualified, or unsuitably qualified, teachers as a reality. "It's better to have a teacher than not a teacher but it's much better to have the right teacher in the right job" (Principal Association C). Since graduate teachers are registered as teachers, not as subject specialists,[4] timetabling can conceal the shortage of specialised staff: "the problem is significantly masked because deputy principals are magicians in making timetables work when there's nothing to work with" (Principal Association B).

The teacher union representatives interviewed also made a distinction between industrial and professional issues: "So, industrially nobody is appointed in a secondary school specifically on the basis that they will teach a specific method area" (Union D). For the unions, industrial issues regarding conditions and occupational health and safety impact on out-of-field teachers.

Principal association representatives noted the importance of teaching experience and knowledge of the students when allocating teaching duties. They reported that some principals choose to allocate current staff to teach out-of-field when they thought that the qualified beginning teacher applicants for the position did not have sufficient cultural knowledge of the school community (Principal Association C).

[4] New South Wales is an exception. Graduating teachers are registered as discipline specialists.

The representation of out-of-field teachers as less qualified or unsuitably qualified assumes that a teaching qualification is suitable preparation for teaching, irrespective of discipline-specific tertiary qualifications or education training background in teaching the discipline. It assumes that registered teachers can adapt to teach different secondary subjects. This representation also challenges the assumption that only discipline content knowledge and discipline based pedagogical knowledge matters. It signals that general pedagogical knowledge and knowledge of students and community also matter.

1.4.1.4 Teacher Quality

Out-of-field teaching was represented as a problem of teacher quality in Australian government documents. This representation underlies policies directed towards increasing admission standards for teacher education and improving literacy and numeracy skills (Department of Education & Training, 2015). For example, increasing the number of STEM teachers through improving pathways for STEM graduates and “continuing to support schools to access specialist teachers” (Education Council, 2015, p. 9) was planned, though what this actually involved was not documented. In Victoria, the Department of Education funded the Secondary STEM Catalyst Professional Learning Program (Victorian State Government, 2016) but reference to engaging out-of-field teachers in this program disappeared from the information following its initial announcement.

The representation of out-of-field teaching as an issue of teacher quality assumes a deficit perspective of teacher education students that can be addressed by increasing entry requirements for teacher education. However, even though “Knowing the content and how to teach it” is one of the Graduate Professional Standards for Teaching (AITSL, 2014), with the exception of New South Wales, registration documentation does not specify subject or discipline knowledge, either for initial teacher registration or to acknowledge completion of training in a new subject.

1.4.2 Effects

The Australian Association of Mathematics Teachers (AAMT, 2005, p. 1) raised the following questions which remain pertinent: “What is the emotional cost on teachers of that school trying to fill that gap? What is the impact on children being taught science, technology or mathematics by under-qualified teachers filling in?” Documents and interviews of representatives of unions, subject teachers and principals revealed the effects of out-of-field teaching.

1.4.2.1 Effects on Teachers

Union representatives pointed to the effects of teaching out-of-field on teacher health and well-being, especially beginning teachers due to increased workload in preparation and planning, stress when teaching in this challenging context, and uncertainty due to employment status. The Union D representative acknowledged that the extent of these effects depended on school support, years of teaching experience and teacher identity and adaptability:

> You would like to be on home ground when you are learning how to teach…
>
> In some instances some of our members find it incredibly difficult. They do not cope and in some instances that causes them illness. In other cases, people are quite enthusiastic about taking on a new challenge. Typically the difference between those is the level of support and recognition and the fact they are doing something quite different… teaching out-of-field is a stress factor…You might be on a contract so you are in precarious employment to begin with. (Union D)

These concerns were also conveyed by an anonymous science teacher published in a NSW Science Teacher Association newsletter (Shattered dreams, 2013). As a graduate teacher teaching Year 11 physics out-of-field, she was admonished by a parent and belittled by her principal for not keeping one step ahead of her students, and she subsequently left the profession.

The union representatives believed that teaching out-of-field contributed to attrition, although no inquiries into teacher attrition have pinpointed teaching out-of-field as a specific reason for leaving the profession. Union D made links between this attrition and the stress generated by "The workload that's associated with getting your head around a whole new set of subject matter" (Union D). The Design and Technology Teachers Association of Victoria (DTTA Vic) reported on the health and safety risks for both teachers and their students (DTTA Vic, 2019) of teaching subjects out-of-field without the specialist training.

On the other hand, the teacher unions and the mathematics and science teacher associations indicated that "out-of-field teaching can be an enriching thing, provided teachers are getting the right support" (Mathematics association interview). Similarly Union D recognised that for some teachers experience and professional development over time potentially lessens the stressful effects of being out-of-field.

Representatives of principals noted that the capacity to provide support and professional learning is much more constrained in smaller schools and schools in rural and remote locations.

1.4.2.2 Effects on Students

Representatives of principals did note the potential effect of out-of-field teaching on students' achievement and their responsibility to be accountable:

> Our brief is to deliver good results for every kid and it is a bit hard to do that when you have people who don't know what they are doing. (Principal Association C)

> The concern I have [is that] we tend to put our less able teachers in the situation where they are required to teach out-of-area only because that's the way the timetable falls. We give our least able teachers their baptism of fire. They get the toughest classes… or we will put our specialist teachers with our most able kids because they are the ones who are going to most benefit from that. That shouldn't be the case… We shouldn't have to make those decisions. (Principal Association A)

The principal representatives had experienced the implications of out-of-field teaching for students but were more likely to see this as a problem of timetabling and performance for individual teachers rather than the collective of teachers where collaborative practices and professional learning could support all teachers including out-of-field teachers.

1.4.2.3 Effects on Schools

The principal representatives argued that they have little power to get the teachers they need because of budgetary constraints:

> We believe student results are directly related to the quality of the teacher, that's borne out in truckloads of research. But if we, I mean principals, are being held to account for student results and then that's being tied back to allocated funding from government, then surely its oxymoronic to hold us to those results when we can't put the best teachers in front of kids to maximise those results. (Principal Association B)

The principal representatives identified the need to provide support for principals charged with complex decisions around staffing and school improvement, with one state principal association organising specific support for principals in rural and remote schools. However, as noted by the Tasmanian Audit Office (2013–2014) there are no guidelines for principals in making recruitment and allocation decisions. Principal association representatives also pointed to the failure of systems to provide resources and funding to support out-of-field teachers.

1.5 Discussion

In this section, we complete the final two steps of Bacchi's WPR approach. We discuss the silences that illuminate the politics of out-of-field teaching and use the research literature to assist with this analysis and to consider how the assumptions may be challenged.

1.5.1 Silences—What's Left Unproblematic?

Comparing representations and effects of out-of-field teaching between the stakeholders revealed the silences, that is, what was not discerned as problematic. These silences are concerned with the appointment of beginning teachers to teach out-of-field, the retention of beginning and early career teachers, teacher registration requirements concerning specialist teaching, school culture and leadership, school autonomy, pre-service teacher education, employment prospects and job security of subject specialists in oversupply, and the status of the teaching profession. The first three of these silences are discussed below (see Du Plessis et al., [2019] and Vale & Drake [2019] for discussion of school culture and leadership).

Firstly, the greater reliance on teachers in their first few years of teaching remains unchallenged. How this tendency to put teachers through this initiation has become such accepted practice is untenable (Hobbs & Törner, 2019), especially since this practice is contributing to the attrition of teachers early in their career (Handel et al., 2013; Ingersoll & May, 2012; Quartz et al., 2005; Vale & Drake, 2019). Donaldson (2013) and the Principal association representatives in this study suggest that the pressure of performativity has led to prioritising seniority whereby the most experienced teachers are assigned to the senior year levels and high achieving students, and the least experienced assigned to teach out-of-field. Darling-Hammond and Sykes (2003) identified the need for policies to protect beginning teachers from being assigned to teach out-of-field and to provide extended support and professional learning for beginning and early career teachers to address attrition and promote retention.

In relation to the second silence, employment conditions need to recognise the additional planning time required when teaching out-of-field or mentoring out-of-field teachers. In 2014 the NSW Department of Education began providing workload allowances for beginning teachers and mentors for schools with significant numbers of beginning teachers, however out-of-field teaching goes unmentioned in this program (DENSW, 2014b). School funding needs to provide for the mentoring and professional learning required as well as to enact collaborative practices and culture within schools.

The provision of professional learning or certified programs of education in discipline specialisation is meaningless unless upgrading of teachers' specialist discipline and pedagogical knowledge can be recognised through teacher registration provisions, professional learning reporting and promotion criteria so that teachers and schools will value the developing expertise of their out-of-field teachers. With the exception of Tasmania, successful planning strategies to support experienced staff to teach in subject specialisations known to be difficult to fill are not promoted in policy and remain the initiative of individual schools. In contrast, the Victorian government-funded STEM Catalyst program removed reference to out-of-field teaching, suggesting a preference to shift attention away from inadequate staffing of schools to focus on the question of teacher quality.

Certainly, retraining or upskilling programs occur in some states for example, NSW, Tasmania and Victoria (DETV, 2021). Evaluation of these programs shows that they are most effective when school-based or closely related to the out-of-field teachers' school context (Adler, 2015; Vale et al., 2011) that is, "tailored, systematic, recognised and renumerated, and embedded" (Hobbs & Törner, 2019, p. 315). However, upskilling through professional learning programs can sometimes contribute to teacher "churn" as teachers with newly acquired specialist subject knowledge can be drawn away from rural locations or to schools serving higher socio-economic communities (Handal et al., 2013; Quartz et al., 2005; Vale, 2010).

1.5.2 Contesting the Prevailing Representations and Assumptions

Contesting the representations of out-of-field teaching as *teacher shortfall*, *hard-to-staff schools*, *less qualified teachers* and *teacher quality* and the assumptions underlying them requires recognising the long-term problem of teacher supply, the inequitable distribution of out-of-field teaching and the need to focus on teaching quality rather than teacher quality.

Consideration should be given to determining what rate of out-of-field teaching is tolerable for all schools and providing the funding and resources to support schools with out-of-field teaching. For example, MANSW (2014) set a target of 80% Year 7–10 classes taught by specialist secondary mathematics teachers. They found, however, that only 30% of metropolitan Sydney and 51% of rural school Year 7 classes were taught by specialist teachers. A "tolerance threshold", Hobbs and Törner (2019) claim, would raise questions around "at what point an education system is negatively impacted by out-of-field teaching, and up to which point it would be regarded that, on a system level, the impact of out-of-field teaching is not detrimental" (p. 314). Agreeing on a tolerable level of out-of-field teaching would bring the needs of schools and out-of-field teachers into the foreground. It would demand policies and procedures to enable schools and jurisdictions to meet an agreed level of out-of-field teaching, and funding and resources to support schools with out-of-field teachers.

Out-of-field teaching is more common in disadvantaged schools and therefore a problem of equity and social justice (Adamson & Darling-Hammond, 2012; Ingersoll, 2002). Currently Australian Government policy regarding school funding is debating how to account for socio-economic status of schools when setting policy on Federal funding of government and non-governments schools. Less attention is being given to the actual funding and resource needs of schools with high and prevailing incidences of out-of-field teaching. Viewing these school communities as rich environments for teacher learning and providing these schools and teachers with the resources to develop partnerships with local communities and organisations enhances retention of teachers and improves student outcomes in rural and remote schools (Sandhu et al., 2013).

Teacher quality, as distinct from teaching quality, was one of the representations of out-of-field teaching. Researchers have called for a shift in the focus on, and accountability of, the individual teacher to the collective of teachers to improve the quality of teaching (Mockler, 2018) through collaborative planning and reflection, and research of practice (Jaworski, 2016). Developing collaborative, positive professional cultures in schools including positive relations between the out-of-field teacher and subject specialists and leaders promotes out-of-field teachers' self-efficacy (Adler, 2015) and should be considered as a means of slowing attrition of teachers. "Building a culture of collaboration" is one of the priorities for improving student outcomes in the current Victorian Department of Education and Training's (2015) education improvement strategy, however, reference to this strategy as a means of providing support for out-of-field teachers is not specified.

1.6 Conclusion

For the researchers, problematisation of the out-of-field phenomenon has been a valuable "strategy for developing a critical consciousness" (Montero & Sonn, 2009, p. 80) in relation to the out-of-field phenomenon. The analysis of stakeholder documents and interviews using the WRP approach (Bacchi, 2012a, 2012b) has revealed different conceptualisations of the out-of-field phenomenon as "teacher short-fall", "hard-to-staff schools", "less qualified teachers" and "teacher quality".

Teacher Union representations acknowledged feeling conflicted about speaking out about the problem, given the risk of potentially undermining the education profession. They also recognised the cost to schools and governments admitting to the use of out-of-field teachers in schools. However, unless counter narratives that highlight the incidences, experiences, effects and inequities of out-of-field teaching are created, the assumptions underpinning these representations of out-of-field teaching will persist. The assumptions underpinning the representations of out-of-field teaching were: a short-term solution in the inadequate supply of specialist teachers; a deficit perception of some school communities; adaptability of registered teachers; and a deficit perception of teacher education students.

Despite attempts at short-term solutions in various Australian states, the analysis of policies and practices investigated here revealed that there is no long-term plan to attract people to teach disciplines in demand in schools located in inland, rural communities or low socio-economic communities in Australia. Even though there is an agreed government goal of equity and excellence, there is a failure of governments to redistribute resources to provide sustained support for schools and teachers to reduce teacher attrition and reliance on out-of-field teaching.

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Chapter 2
Defining Teaching Out-of-Field: An Imperative for Research, Policy and Practice

Linda Hobbs, Coral Campbell, Seamus Delaney, Chris Speldewinde, and Jerry Lai

Abstract A lack of common understanding of what constitutes out-of-field teaching can make it difficult to assess the extent and impact of out-of-field teaching. This project draws on existing research findings to ascertain a definition for teaching out-of-field that can be translated across jurisdictions, and which can inform policy, practice and research. Funded by the Victorian Department of Education and Training, the project uses the state's policy context to develop a definition of out-of-field teaching for secondary schools in Victoria. We conducted a review of the literature (2010–2020). Definitions of what constitutes an in-field and out-of-field teacher were developed based on criteria derived from the literature. For external validation, these definitions were presented to experts to ascertain usefulness, applicability and implications in the Victorian context. The outcome is a multi-faceted definition that provides a measure of alignment, risk and capability. Suggestions are provided for how the definition can be 'put to work' as a tool for managing the out-of-field phenomenon.

Keywords Definition · Regulations and policies · Teaching out-of-field

2.1 Introduction

Out-of-field teaching is an educational construct that highlights the mismatch between a teacher's disciplinary background and the subject, year level or specialist role that they teach. Essentially in-field teaching for secondary teachers is defined by the tertiary qualifications or industry experience that a jurisdiction deems suitable for

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preparing quality teachers. Some jurisdictions provide clear specialisation requirements based on past qualifications to gain access to teacher preparation courses (e.g., Victorian Institute of Teaching [VIT], 2015), some undertake the disciplinary training concurrently with teaching qualifications (such as double degrees), while other jurisdictions mandate required study as well as exams or tests to determine what a teacher can be certified to teach (Price et al., 2019). Also, teacher qualifications can determine the level of schooling, type of school, and specialisation or subject that a teacher is qualified to teach. Regulatory requirements are therefore essential in defining what the system deems as in-field and therefore out-of-field for a teacher.

The reality is that in most jurisdictions around the world, teachers are allocated to teach classes at the discretion of school leaders, and at times, due to a number of reasons (such as inadequate supply of teachers and timetable constraints), teachers are allocated out-of-field classes. In these situations, 'criteria' other than qualifications are used to determine suitability of a teacher to teach a subject, such as the ability of a teacher to develop rapport with a particular group of students, general teaching capability or willingness to adapt to a new subject. These other criteria need to be managed to ensure the effects of placing teachers into out-of-field contexts do not compromise the quality of instruction and learning, and teacher and student well-being.

When defining what it means to teach out-of-field, these two dimensions of the phenomenon (system-defined qualifications and on-the-ground realities) should be considered so that the definition can inform tools for determining the extent of out-of-field teaching as well as managing the phenomenon. Jurisdictional variation in regulatory requirements (Price et al., 2019) and what a system is willing to tolerate in terms of out-of-field teaching leads to a lack of common or transferrable/translatable understanding of what constitutes out-of-field teaching. This variance makes it difficult to assess and compare the extent and impact of out-of-field teaching within and across jurisdictions. A definition should be translatable across jurisdictions as well as provide transparency and consistency in how other criteria are used to determine teacher suitability so that school leaders can make decisions, monitor and reduce negative consequences of teachers teaching out-of-field subjects, as well as enable mapping of potential pathways to build the capability of teachers teaching out-of-field subjects. The definition proposed in this chapter is reflective of the regulatory requirements of the state of Victoria, Australia, but will be presented in a way that is translatable to other jurisdictions.

This project draws on existing literature to ascertain a multi-faceted definition of out-of-field teaching that can be applied across jurisdictions. Crafting a definition of out-of-field teaching requires understanding the complexity of teacher characteristics, school contextual factors and system requirements that determine teacher 'suitability' for teaching certain subjects, year and school levels, and in some countries, school types. Definitions can be communicated in different ways. Intentional definitions specify the necessary conditions that need to be met or the properties of the objects, while extensional definitions list the objects the term describes. The former is used to focus on the characteristics of what constitutes misalignment between the teacher's expertise and background and what they are assigned to teach.

The research question guiding this analysis is: How can out-of-field teaching be defined in a multi-faceted way so that it is reflective of system requirements and on-the-ground realities of teacher allocation?

The next section provides some further context around the out-of-field phenomenon and a rationale for why a multi-faceted definition is needed. This is followed by a description of the method of definition construction. A multi-faceted definition is then proposed.

2.2 An Imperative for Research, Policy and Practice

This section provides a rationale for needing a multi-faceted definition of out-of-field teaching that serves the various stakeholders who are responsible for understanding and responding to this issue, that is, to inform *policy*, *practice* and *research.*

Lacking a definition of out-of-field teaching to inform policy can lead to misrepresentation of the proportion of out-of-field teaching in the system and ill-informed government policy responses. A lack of common understanding of what constitutes out-of-field teaching exacerbates the difficulty in assessing the extent and impact of out-of-field teaching. Ní Riordáin and Hannigan (2009) from Ireland acknowledged this long-standing situation in Australia where education is controlled at the state/territory level. The implication of this variation is differing guidelines for accreditation or registration and what constitutes specialisation.

Developing a clear and agreed definition of out-of-field teaching is the first step in understanding the extent of misalignment within the system to inform policy and facilitate improvements in school management and teaching. In many states of Australia, teacher registration is not tied to specialisation nor level of schooling. Teacher specialisation data therefore is not collected at the time of registration and is not centralised. Without this data, it is difficult to determine at a system level the extent of out-of-field teaching in terms of the proportion of classes or students taught out-of-field, nor the number of teachers teaching out-of-field.

Lacking a definition can result in misunderstanding the practical implications for classroom practice, potential negative effects on students and teachers, and missed opportunities for using out-of-field teaching as professional development for teachers. Practices informed by specific issues that arise due to out-of-field teaching include those relating to school and discipline leadership, teacher allocation, professional learning and teaching practice. Research shows that the reality of teaching out-of-field for teachers is complex (Porsch, 2016) and binary labels of qualified/unqualified are less informative:

> Currently the term out-of-field implies that teachers can be simplistically categorised as in-field or out-of-field, that is, that the phenomenon is a simple binary distinction. This misconception hides the complexity of the concept, failing to include degrees of fit or misfit between appointment, qualifications and experience. (Sharplin, 2014, p. 2)

Certain factors that can make a teacher feel more in-field or out-of-field include, for example, teacher appointment and allocation (timetabling) practices, work conditions, support mechanisms, feedback and responses from students and peers, recognition of risk factors especially by leadership, teacher-related factors such as teacher knowledge, commitment and attitudes towards professional learning and security of employment (Hobbs, 2013a). Teachers can 'feel' in-field because of the support they receive as they develop subject expertise and are more capable teachers, even when technically out-of-field. There are therefore a number of criteria other than alignment between qualification and teacher allocation that influence a teacher's self-identification as teaching out-of-field (Hobbs, 2013b). Definitions of out-of-field teaching therefore should take into account the teacher-in-context as determining out-of-field-*ness*.

For research, lacking a definition means that it is difficult to compare incidences and effects, and translate responses across jurisdictions. Definitions of qualified and unqualified (or specialised and un-specialised) differ across survey tools, influencing what is measured and the incidences that emerge (Ingersoll, 2019). A definition of out-of-field teaching needs to be a characterisation of the teacher workforce that will allow for meaningful description and comparison of the phenomenon at the local, national and international level. The variation in policies and practices (Price et al., 2019) makes comparisons difficult when the contextual mechanisms are assumed or not declared by researchers. Researchers need definitions that are transparent and contextualised to enable interjurisdictional comparison.

Given these needs within and across jurisdictions, what 'work' does a definition need to do?

2.3 What Work Does a Definition Need to Do?

It is important that a definition of out-of-field teaching for secondary school teachers can be 'put to work' by signalling where change can/needs to occur. The out-of-field issue is not always explicitly stated at a system level but is represented in different ways with varying assumptions. The following representations (in italics) were identified by Hobbs et al. (2014). Table 2.1 summarises the different representations of the out-of-field phenomenon, assumed loci of change and the scope of definition needed in order to inform this change.

When represented as *an issue of supply and demand* leading to teacher shortage, ~~t~~he assumption is that the locus of change lies with the current profile of teachers in the system. This change requires a definition that can be used to indicate the incidence of out-of-field teachers as a measure of the mismatch between the teacher specifications available in the system and the teaching demand according to specialist areas or year level. This may assist with greater investment in recruiting new teachers into certain specialist areas.

When represented as *an issue of teacher distribution*, the assumption is that the locus of change lies with re-distributing the current teacher workforce. This change

Table 2.1 Scope of definition needed for the different representations of the out-of-field phenomenon

Representation of the out-of-field issue	Locus of change	Scope of definition needed
As an issue of supply and demand	Current profile of teachers in the system	Incidence across classes, subjects, sectors
As a problem of teacher distribution	Distribution of the teacher workforce	Distribution of qualified teachers across sectors, year levels, subjects
As an issue of teacher/teaching quality	Teachers and teaching practice	Specific needs of different types of out-of-field teaching allocations
As a problem of inadequate leadership practices	Leadership practices	Approaches to sustain teaching quality
As a problem of how funding is used	System approach to allocating resources	Staffing profile and teaching allocation

requires a definition that identifies the distribution of out-of-field teaching allocation within a jurisdiction and across school sectors or types (e.g. Government, Independent, Catholic schools in Victoria), across year levels and across specialist areas. This may assist with developing appropriate incentive schemes for moving certain teachers into hard to staff areas.

When represented as *an issue of teacher/teaching quality*, the assumption is that the locus of change lies with the teachers. Supporting efforts to maintain or build teacher capacity in the system requires a definition that identifies the specific needs of different teachers teaching in different out-of-field situations, within specific geographical contexts, and under different regimes of support (internal and external to the school). The definition also needs to earmark pathways for teachers to move from out-of-field to in-field and system responses that will enable and acknowledge this. Identifying potential pathways may assist with developing system level and local responses that provide, support and incentivise teachers to undertake professional development requalification programmes or school-based subject-specific and/or targeted induction and mentoring.

When represented as *inadequate school leadership practices*, the assumption is that the locus of change lies with the school's leadership so that they have improved understanding of the impact and demands of teaching out-of-field for different teachers, and recognition, acknowledgement and attention to the teachers' specific needs. This change requires a definition that provides the information and resources school leaders need to sustain teaching quality, including how professional learning and a supportive school culture might increase teacher capability and support identity expansion, and when it might be appropriate for teachers to upgrade qualifications.

Finally, when represented as *a problem of how allocated funds are used to* cover the current subject offerings with the existing staffing profile, the assumption is that the locus of change is with the system's approach to allocating resources to meet the needs of each school. A definition needs to allow analysis of the staffing profile and teaching allocation within a school and across the system in order to identify how funding can be adequately targeted and how schools can get the teachers they need.

The multi-faceted definitions we developed are informed by this complex understanding of the phenomenon by ensuring that there are clear implications for research, policy and teacher and school leadership practices.

2.4 Methodology

This project formed part of a larger project of defining and mapping out-of-field teaching in Victorian Government schools (Hobbs et al., 2020). Based on the previous rationale we felt that a multi-faceted definition was needed to capture the complexity of the phenomenon (i.e., not just determined by discipline and/or teaching qualification). The definition needed to be relevant for the Victorian Government school context, and particularly relevant for secondary schools rather than primary schools where teachers are typically prepared as generalists. The final working definition needed to be informed by research and accepted within the education community, and include accompanying explanatory notes, scenarios and evidence. The methodology is outlined below (see Hobbs, 2021, for more detail).

First, we used the literature to identify how out-of-field teaching is being defined. This involved a scoping review (Munn et al., 2018; Tricco et al., 2016) to identify relevant articles relating to out-of-field teaching (72 sources), followed by selection of sources that explicitly define out-of-field. Multiple search engines were used to identify the sources (e.g., Google, Google Scholar, EBSCO Host, Scopus, ProQuest, ERIC). Sources included reports on large scale surveys, smaller scale qualitative studies, policy documents and commentary articles on the phenomenon. Sources were deemed relevant if they provided clear definitions—either their own or referenced from another source.

The definitions described by 23 authors were extracted and collated. Consistency of definition was not always the case for an author so the definitions used across various sources were noted. Also collated was the context as country or state, specifics of state regulation (e.g., if professional development is accredited) and links with initial teacher education or policy. Examples of teacher experiences that show implications of the definition were also extracted as blocks of text—these would be used as scenarios for our multi-faceted definition.

The second stage was to find patterns, or themes, across the definitions. Two themes were identified in how out-of-field teaching is described or defined. The first theme relates to the match between qualifications and teaching assignments. A number of sub-themes highlighted differences in what was being emphasised by the definition: requirements for initial teacher education; discipline and teacher qualification; specifics for registration or certification; specialism and differentiation according to specialisation or sub-discipline; and differentiation according to year level.

The second theme referred to 'types' of teaching out-of-field. Sub-themes related to the ideas of out-of-field-ness, teacher identity with the subject, the notion of 'field', suitability and subject teaching role or school phase (primary, secondary).

The next step was to consider how the policy context, the regulatory requirements, influences how the phenomenon can be defined. Additional data was gathered that related to the policy context for Victorian Government schools, including specialisation guidelines and registration requirements. The regulatory requirements can determine what the system recognises as technically in-field (and therefore out-of-field) for a teacher and the pathways that a teacher can follow to become technically 'in-field'.

Next, we considered which elements of the complex phenomenon needed to be reflected in the definitions, including how the policy context and the on-the-ground reality for teachers and schools should be incorporated. Research- and policy-informed definitions were then developed for in-field and out-of-field teaching using the language of these criteria. This chapter will not focus on how the criteria were derived but will introduce the relevant criteria for each definition.

For external validation, the definitions and criteria were distributed to twelve experts with an interest in the out-of-field phenomenon, including five university-based researcher/teacher educators, a government employee, a discipline association employee, two researchers from national research organisation or centres, and a director of a skills training organisation. They were then interviewed to ascertain the usefulness, applicability and implications of the definitions. The interviews showed that the definitions captured the complexity of the out-of-field phenomenon and could be useful. Some suggestions for improvements were provided, including:

- Clarification of terms and suggestions for alternative terms;
- Ensuring practical application is included;
- Additional literature sources and suggestions for the literature for each of the criteria; and
- Finessing how out-of-field teaching is framed as teachers teaching in out-of-field contexts rather than as out-of-field teachers.

The final set of definitions constituting the multi-faceted definition are presented below.

2.5 Findings: A Multi-faceted Definition

A multi-faceted definition was developed that incorporates one definition for what constitutes teaching in-field and four defining out-of-field teaching. Based on the literature review, the definitions acknowledge that in-field-*ness* can be determined from initial teacher education or may be the result of upgrading as an in-service teacher. The four definitions of out-of-field show degree of misalignment to the definition for in-field and enable different aspects of the phenomenon to be foregrounded. Three constructs emerged from the iterative process of drawing together

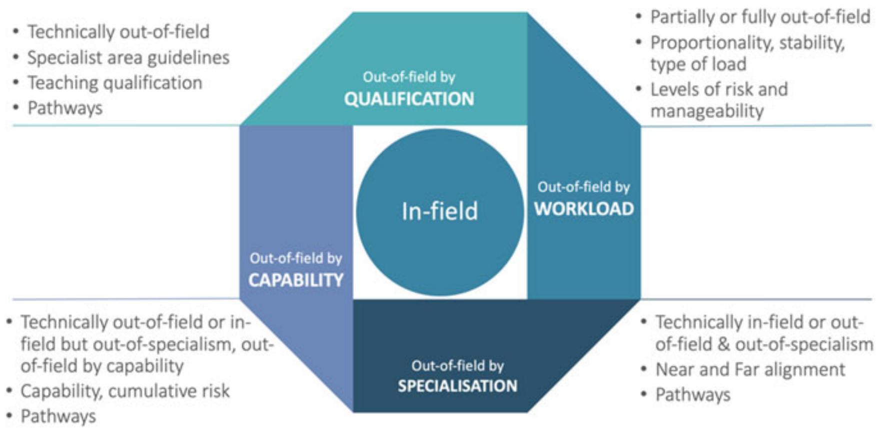

Fig. 2.1 Definitions that comprise the multi-faceted definition of teaching out-of-field

the definitions for in- and out-of-field teaching: alignment (between the allocation and teachers' background), risk (associated with proportion of load, manageability of that load and how this changes) and capability (as determined by teaching experience, ability, knowledge and identity, the supportive context of the teacher, and how these things change). These are signalled in different ways in each definition.

Each definition is provided below, beginning with the informing literature, followed by the definition, scenarios extracted from the literature as direct quotes that demonstrate how the definition might be applied. Then a description of the practical implications of the definition follows. The criteria are bolded in the definitions. Figure 2.1 summarises the main points of each definition within the multi-faceted definition of teaching out-of-field.

2.5.1 *Defining In-Field*

The in-field definition was informed by the Specialist Area Guidelines (VIT, 2015) and inspired by the structure of Weldon's (2016) definition used for analysis of the Staff in Australia's School Survey.

In Victoria, qualifications are determined by the discipline qualifications (usually a minor or major in a specialist area) and specialist methods undertaken as part of initial teacher education. The specialist area is determined on entry to initial teacher education but is not documented at teacher registration. The Victorian Institute of Teaching (VIT, 2015, p. 1) Specialist Area Guidelines 'provide advice to intending teachers about the suitability of their qualifications for entry into nationally accredited graduate-entry initial teacher education programmes and teaching in specialist areas'. They also provide the minimum level of discipline study applicable for preparation as a specialist area teacher. For most specialist areas, at least a minor in the discipline is required, which equates to:

> A total of half a year of successful full-time higher education study, usually comprising sequential discipline studies taken over two years, e.g. a part in each of the first and second years of study, or equivalent study. In most programs this equates to four units, with no more than two at first year level. (VIT, 2015, p. 3)

Teacher method studies 'should include, or be associated with, supervised teaching practice in the specialist area" (VIT, 2015, p. 2). In addition, the Specialist Area Guidelines provide advice for "teachers seeking to upgrade their qualifications and teach in a different specialist area' (VIT, 2015, p. 1). The same advice is given for students completing initial teacher education, that is, at least a minor in the discipline is required.

In comparison, the Staff in Australia's School Survey (SiAS) (Weldon, 2016) defines an in-field teacher as having either studied the subject at second-year tertiary level or above, or trained in a teaching method for that subject at tertiary level. For comparative purposes, the report considered two additional definitions of in-field teaching: teachers have studied the subject (for at least one semester) at second-year tertiary level (but may or may not have studied teaching method in that subject); OR have both studied one semester at second-year tertiary level and have studied teaching method in that subject. This was an agreed national standard for the survey to require only one unit in the discipline after first year. This definition requires only one study at Year 2 level which is not a minor, and therefore is not consistent with the VIT Specialist Area Guidelines.

The definition used by this study is based on at least a minor in the subject, which is in keeping with the VIT Specialist Area Guidelines, and a need to have completed the teaching methodology either during initial teacher education or further study. A 'technical' definition of in-field is provided (see Fig. 2.2).

2.5.2 Out-of-Field as Determined by Qualification

This definition is informed by the Victorian Specialist Area Guidelines and the specifics of the teaching qualifications undertaken by the teacher.

In relation to specialist area, this definition emphasises the misalignment, or misfit (Sharplin, 2014), between teaching allocation and teacher specialist area qualifications. The definition provided is consistent with that used in a Western Australian study by McConney and Price (2009) where out-of-field teaching was defined as not having completed tertiary qualifications that include either a major or a minor in a discipline and the appropriate teaching methods courses. This definition aligns with the Specialist Area Guidelines. Teachers teaching out-of-field classes, however, are sufficiently trained educators (McConney & Price, 2009; Weldon, 2016) and registered as Victorian teachers who: (1) demonstrate proficiency in the Australian Professional Standards for Teachers, which is rigorously assessed during initial

Definition of an in-field teacher

A teacher is considered TECHNICALLY IN-FIELD if there is full alignment between the subject required to teach and their qualifications. This means the teacher has the following:

Teaching qualification: A qualification that prepares them to teach at the appropriate school and year level (primary school, junior secondary, senior secondary).
AND a qualification from Initial Teacher Education (A) or Upgrade as a qualified teachers (B):
A. Initial Teacher Education:

- At least a minor in the relevant discipline AND accredited teaching method units that align with the subject required to teach. (Full alignment, Technically in-field)

OR

- At least a minor in the relevant discipline OR accredited teaching method units that align with the subject they are required to teach. (Partial alignment, Partially in-field/out-of-field)

B. Upgrade as a qualified teacher: A relevant Graduate Certificate that includes content knowledge and teaching method.

Fig. 2.2 Definition of an in-field teacher

teacher education; (2) have the ability to maintain professional practice; and (3) are considered suitable to teach (VIT, 2020).

In relation to teaching qualifications, the out-of-field definition emphasises the misalignment between teaching allocation and the initial teacher education qualification of the teacher. In Australia, education qualifications accredited by the Australian Institute for Teaching and School Leadership (AITSL) prepare teachers for different levels of schooling. Courses can be accredited for primary only (Foundation to Year 6), middle years (inclusive of upper primary and lower secondary, e.g., Years 5–8), secondary only (Year 7–12), primary and secondary (Foundation to Year 12), primary and compulsory secondary (Foundation to Year 10). Levels of schooling can be characterised as early childhood, primary and secondary, and sometimes middle school.

Year levels and levels of schooling are reflected in some definitions of out-of-field teaching. Year levels have been included in definitions by Du Plessis (2016, Du Plessis et al. (2014) and Ingersoll (2019). Also, Sharplin (2014) used the term 'phase' as levels of schooling (primary, secondary or tertiary), and whether a teaching allocation is congruent, displaced (misaligned) or stretched (no experience). Hanuscin et al. (2020) and Carlyon (2018) similarly address a teaching allocation that stretches primary teachers' expertise through transition to new year levels, moving from grade four to six for example, that makes them feel out-of-field.

A technical definition of out-of-field is provided that emphasises subject and type of teaching qualification (see Fig. 2.3).

Out-of-field as determined by Qualification

A teacher is considered to be teaching a subject TECHNICALLY OUT-OF-FIELD if there is misalignment between the subject required to teach and their qualifications. This means the teacher is misaligned according to the following:

- **Specialist Area Guidelines:** At least a minor in the relevant discipline AND accredited teaching method units for the subject required to teach. (Technical misalignment)
- **Teaching qualification:** A qualification that prepares them to teach at the appropriate school level and year level, for example, a secondary school qualified teacher teaching in a generalist primary classroom. (Phase misalignment)

Fig. 2.3 Out-of-field as determined by qualification

Two scenarios from the literature illustrate how this definition can be applied.

Scenario: Daniel

Daniel is a science teacher who is technically out-of-field teaching mathematics due to technical misalignment in Mathematics. He has become in-field in Information and Computer Technology (ICT) due to undertaking additional qualifications. Hobbs (2013a, p. 281) wrote

> Daniel was opposed to this allotment as a Mathematics teacher because he believed that qualifications always mattered. Daniel had made a decision part way through his teaching career to re-specialise in ICT, and he took advantage of a government initiative where he could take leave to upgrade his qualifications to include ICT as one of his methods. As a teacher of mathematics, and being technically 'untrained,' he believed that his content knowledge and pedagogical content knowledge are limited to the extent that he was resigned to a fate of never being able to be an effective mathematics teacher.

Scenario: Simeon

Simeon (teaching in a combined primary and secondary school) is technically out-of-field teaching mathematics due to phase misalignment, i.e., being a qualified primary teacher and teaching secondary mathematics. Hobbs (2013b, pp. 16–17) wrote:

> Simeon is a primary-trained teacher (students between 5–12 years old) with experience as a classroom generalist teacher, as well as mathematics specialist in the primary years, teaching mathematics to various year levels between Years 2–6. Due to a shortage of qualified mathematics teachers available to teach the junior secondary classes, Simeon was asked to take a Year 7 class. Simeon described his motivation for undertaking further studies to qualify him as a Mathematics specialist… He felt out-of-field not because of the content, but because of the different pedagogical practices that are expected at the secondary level: how to teach the more complex concepts, dealing with teenage students, use of a textbook, and timetable constraints.

2.5.2.1 Practical Application

The definition of out-of-field by qualification refers to an identifiable population according to disciplinary background and initial teacher education qualification. The definition provides a clear basis for pathways to upgrade through additional qualifications to become in-field. Qualification upgrade is the only way to becoming in-field according to this definition. The definition aligns with the VIT Specialist Area Guidelines and teacher qualifications and can be used to produce measurements as incidences of out-field teaching. It does, however, disregard teacher experience and teacher professional learning and sub-discipline variation for composite specialist areas. The information that can be sought with this definition can be used to identify teacher shortfalls when correlated with school location, school type, school size and Local Government Area.

A complication is that there are currently no centralised data on teacher qualifications in most Australian states or nationally, nor are there data collected on the qualifications of teachers teaching subjects at any one time or across a set period. Data collection of this type tends to rely on voluntarily completed surveys (e.g., Staff in Australia's School Survey [e.g., Weldon, 2016], surveys by subject associations or teachers' unions). State accreditation/registration bodies would need to enhance their data systems and registration processes to address this issue. For example, the VIT could collect teacher specialisation data through annual VIT re-registration to detect upgraded qualifications and therefore changes in in-field specialist areas.

A further complication is that, in Victoria there are few courses that provide qualifications in additional specialist areas. Further, the VIT is not endorsing Graduate Certificates for the core specialist areas that might exist. As a result, there are few pathways for in-service teachers to become in-field according to this definition.

2.5.3 Out-of-Field as Determined by Specialism

This definition is developed to acknowledge that in the state of Victoria and in many parts of the world, some subjects are combinations of a number of disciplines or sub-disciplines. The discipline denotes the teacher's specialty or specialism. Teachers who are technically in-field can feel out-of-field teaching some specialisms within these multi-disciplinary subjects (Hobbs, 2013a; Hobbs & Quinn, 2020; Hull, 2018; Nixon et al., 2017). Ingersoll (2019) differentiates between subjects in the curriculum as being *broad* in definition (and multi-disciplinary, for example, science) or *narrow* (as the individual disciplines, for example, chemistry). While the broad definition matches areas of the curriculum that teachers are expected to teach, Ingersoll questions the assumption of combining sub-disciplines into multi-disciplinary subjects at school.

Other researchers differentiate between broad and narrow conceptualisations of the subject. Mizzi (2020) identifies teachers teaching outside one's science specialism as out-of-field, for example, teaching physics with a chemistry background. Hull

(2018) draws attention to the generalist subject called 'The Humanities', which includes History, Geography, Civics and Citizenship and Economics in the Australian Curriculum. Only two universities in Victoria offer specialised training in history education as most programmes offer a single Humanities method course.

Luft et al. (2020) introduced the language of *near* and *far* to signify how close the specialist or subject area being taught is to teachers' qualified specialist area, for example, biology may be near to biochemistry, physics might be near to mathematics, and Visual Communication might be near to Visual Arts. English is far from Mathematics and Economics might be far from Geography. Nixon et al. (2017) claim that problems occur when a teacher does not have a broad science background and the administrator assumes that being certified in one science discipline is adequate for teaching other science disciplines (p. 1212). Ultimately, how close a teacher feels to an out-of-field space can determine their ability to build on what they already know.

The definition incorporates these distinctions between broad and narrow subjects and near and far misalignment (See Fig. 2.4).

Two scenarios illustrate how this definition can be applied to individual teachers.

Scenario: Seral

Seral is a psychology teacher whose mathematics teaching is out-of-specialism. She feels in-field teaching mathematics even though it is far misaligned to the subject psychology. Hobbs (2013b, p. 20) wrote:

> Seral was a graduate teacher who chose to teach mathematics even though it is technically out-of-field. Seral experienced a high degree of success with mathematics at high school. As a result, she felt capable of teaching mathematics and did not feel out-of-field. Restrictions to teaching methods imposed by her teaching qualifications are negated by her own self-efficacy—being 'good at it' and 'comfortable' with the content is central to whether she feels in-field or out-of-field… In addition, she receives support from her mother, who is a highly successful specialist mathematics teacher, who was employed as

Out-of-field as determined by Specialism

A teacher is considered OUT-OF-SPECIALISM if there is misalignment between the sub-discipline they are teaching and their specialisation qualifications. There may be

- **Near misalignment:** TECHNICALLY IN-FIELD but OUT-OF-SPECIALISM: Where a teacher in-field in a broad subject (e.g., Science) teaches a near aligned (within the same family of disciplines) sub-discipline as a subject that does not match their background (e.g., year 9-10 Chemistry subject). This is particularly relevant for composite subjects (e.g., Science, Humanities, Technologies) and subjects new to the state or locally-developed curriculum.
- **Far misalignment:** TECHNICALLY OUT-OF-FIELD and OUT-OF-SPECIALISM: Where a teacher in-field in a broad subject (e.g., Psychology) teaches a far aligned subject (similar but separated by the curriculum structure) that does not match their background (e.g., year 7-8 Mathematics).

Fig. 2.4 Out-of-field as determined by specialism

> a mathematics coach by the education department for a number of years. She also cites a number of other support mechanisms that enable her to feel confident and competent in her teaching: supportive teaching staff at the school and access to and development of a number of resources. As a result of these factors, she feels in-field teaching mathematics, even though technically out-of-field.

Scenario: Eliza

Eliza is a science, physics and ICT teacher who is technically in-field when teaching year 9–10 Chemistry due to the generalist science training, but who felt out-of-specialism in her first year when teaching chemistry due to chemistry being near misaligned to her specialist area of physics. Hobbs (2020, p. 12) wrote:

> Eliza's challenges were associated with her out-of-field teaching related to content in science disciplines she was less familiar with, in particular chemistry, when first teaching them. She also expressed difficulties when dealing with student assumptions that science teachers should know all of the sciences: 'it's easy to say someone's science but I haven't done biology since Year 8 so anything I've gained has been either just from general information or reading stuff.'

2.5.3.1 Practical Application

This definition considers sub-discipline variation for composite specialist areas so does not align with the VIT Specialist Area Guidelines and teacher qualifications. The definition can be used to produce measurements as incidences of out-field teaching. It does, however, disregard teacher experience influencing teacher capability.

This definition helps to identify the area of within-subject professional learning needs of teachers. There are two pathways that could be recognised by this definition. For near misalignment, professional development concentration could provide teachers who are technically in-field with confidence and capability to teach in less familiar specialisms or disciplines. Far misalignment will require qualification upgrade as teachers are technically out-of-field.

Data produced by this definition provides a more complex understanding of who is teaching the specific sub-disciplines when taught as separate subjects in the case of near aligned out-of-specialism subjects. Consideration of far aligned subjects requires thinking about the relationships between different subjects and which subjects might be more successfully aligned, for example, Science and Mathematics, English and Humanities.

System-wide data collection would need to be inclusive of the sub-disciplines that are taught as discrete subjects. Weldon (2016) does this by representing the individual specialisations comprising Science and the Humanities. To include teaching of these units as out-of-specialism would render virtually all teachers of these composite classes out-of-specialism given that only one of these disciplines is needed on entry to initial teacher education. However, using the phrase in-field but out-of-specialism may signal professional development needs of teachers.

Professional development concentration for near aligned teachers requires availability of sub-discipline-focused opportunities, such as chemistry, economics and history. Some expectations would need to be set as to what concentration is needed for proficiency.

2.5.4 Out-of-Field as Determined by Workload

This definition was inspired by the need to consider the effects of the amount of time a teacher spends teaching out-of-field and the stability of their teaching load.

A teacher's workload refers to the classes they are allocated to teach. Hobbs (2020) claims that teaching out-of-field should be considered in the context of a teacher's full teaching load and how this changes over time. The stability of allocation to subjects and year levels influences a teacher's opportunities to reflect and learn. A secondary teacher will teach different subjects and year levels across the year. Teaching out-of-field classes from different subjects and/or across different year levels at any one time and from year to year adds extra difficulty, especially when teaching them for the first time. Further, the proportion of a teacher's load allocated to out-of-field teaching determines their ability to learn on-the-job (Hobbs, 2020) and factors into a teacher's workload. The definition relating to workload therefore focuses on manageability, stability and type of load.

The consequences of workload pressures are represented through the construct of risk. Managing risk under these circumstances means ensuring that the expectations of the teaching load do not exceed a teacher's adaptive expertise. In the context of learning to teach out-of-field adaptive expertise is the balance between efficiency and innovation: developing efficiencies through repeated experiences and innovation as learning new things (Hobbs, 2013a). An adaptable teacher might be able to develop the expertise to teach the new subject. However, this adaptability should be balanced against how manageable the load is. Expecting teachers to adapt beyond what is manageable imposes risk. Risk in this context could be conceived of as the chance or probability that teaching out-of-field might result in negative consequences for the:

- Teacher—e.g., poor teaching performance and teacher welfare, teacher attrition;
- Students—e.g., poor student outcomes, engagement and attitudes towards the subject;
- School—e.g., strained staff relationships and negative parent response;
- Teaching profession—e.g., negative public perceptions due to seemingly unprepared teachers; or
- Education jurisdiction/country—e.g., through poor performance on national or international tests.
- Out-of-field teaching according to workload is defined in terms of management and risk (see Fig. 2.5).

One scenario illustrates how this definition can be applied to individual teachers.

Out-of-field as determined by Workload

A teacher is considered TECHNICALLY OUT-OF-FIELD and may feel PARTIALLY OUT-OF-FIELD depending on the proportion of load that is out-of-field at any one time or across a period of time, the stability of their workload allocation, and the type of load. **Proportionality** (proportion of classes) determines the level of risk and manageability of the workload, including whether there are multiple classes of one subject, multiple subjects and multiple year levels. **Stability** of a teaching load over time is also a risk factor. The **type of load** refers to phase and whether the load matches their qualification in terms of type of school (primary and secondary) and level of secondary classes (junior, middle, senior).

Managing risk means ensuring that the proportion, stability and type of load does not exceed a teacher's adaptive expertise, that is, their ability to balance the development of efficiencies in their teaching and being innovative in the face of change (Hobbs, 2013a). Schools determine the level of risk that is acceptable through assigning teachers to out-of-field classes, and how they mitigate these risks with school support structures. Levels of risk and manageability are:

- **Low risk, Manageable workload:** where a high proportion (75%) of the teaching load at any one time or across the year is IN-FIELD, the type of out-of-field load is fully aligned with their qualifications, there is stability in what is being taught from term to term or across a longer period of time, and teachers feel fully supported.
- **Medium risk, Moderately manageable workload:** where a low proportion (25%) of the teaching load at any one time or across the year is IN-FIELD, the type of out-of-field load is fully aligned with their qualifications, the teaching load may be cyclical or temporary, and teachers experience full or some support from the school.
- **High risk, Unmanageable workload:** where a low (25%) or total proportion of the teaching load at any one time or across the year is IN-FIELD, the type of out-of-field load may or may not be misaligned with their qualifications, the teaching load is temporary, and teachers feel only partially or not supported.

Fig. 2.5 Out-of-field as determined by workload

Scenario: Kate

Kate is a visual arts teacher who teaches a combination of in-field and out-of-field subjects and experiences medium to high risk due to the high proportion of out-of-field teaching load and the high degree of instability in her load from one year to the next:

- Year 1 teaching (60% in-field, Medium risk): out-of-field in VCAL, Photography, Integrated arts/science subject out-of-field; Studio Arts and Art in-field.
- Year 2 teaching (0% in-field, High risk): out-of-field in Integrated English/History/Maths/Science subject and Visual Communication and Design, no connection to her in-field area.
- Year 3 teaching (100% in-field) at a new school.

Hobbs (2020, p. 13) wrote:

> Kate's experience of learning to teach science in her first year began from a point of not expecting to teach it, in fact, to not teach anything except her arts field, although she did recognise that 'it just opened up possibilities of what you are capable of as a teacher.' Her knowledge of science content was her main challenge, but by the end of the first year she claimed 'to have a little bit more in-depth insight into the particular areas to fulfil the requirements and needs of the students.' This focus on 'the requirements', as well as referring to innovative teaching only in her in-field subjects, and her efforts to link science experiments to art, suggest that her main focus was on developing her in-field teaching practice. Beyond the first-year interview, Year 7 or 8 science did not feature in Kate's reflections of being out-of-field. She taught computer science out-of-field and reflected on how the investigative online projects in these classes could be applied to her art subject. By her third year, she was teaching totally in-field at a new school and her learning centred on being innovative, supporting students to achieve their best, and working to 'get them ignited into their learning.' This language was not used to describe her learning in relation to her out-of-field teaching.

2.5.4.1 Practical Application

This definition aligns with the VIT Specialist Area Guidelines and teacher qualifications and can produce measurements of out-of-field teaching as the proportion of classes for an individual teacher, within a discipline area, for a whole school staff or broad-scale. The school culture of support is seen as influencing the risk associated with the proportion of load. The definition, however, disregards teacher experience and teacher professional learning. Highlighting the manageability of workload in this way challenges the reactive nature of teacher allocation to out-of-field subjects, which can lead to instability in teachers' workload allocations.

This approach to defining out-of-field can be used as a management tool by government or school leaders to make out-of-field teaching manageable and to reduce the risk. Risk can be reduced by minimising the proportion of classes or subjects taught out-of-field, or teaching multiple classes of the one subject at the same year level to promote the development of expertise through repetition.

Policymakers could consider creating a tolerance threshold, that is, how much out-of-field can be tolerated by the individual teacher within the school context, across a school staffing profile, or within an education system. At the system level, Hobbs and Törner (2019b, p. 314) suggested that a tolerance threshold could indicate 'at what point an education system is negatively impacted by out-of-field teaching, and up to which point it would be regarded that the impact of out-of-field teaching is not detrimental'. The focus on workload allocation when defining out-of-field teaching can help to identify the tolerance threshold for individual teachers and individual schools, and the specific school support structures that can reduce or increase this threshold.

2.5.5 Out-of-Field as Determined by Capability

This definition was inspired by the need to recognise that teachers can develop expertise and confidence as they gain experience teaching a subject. The emphasis on capability is informed by research into the implications of out-of-field teaching on teacher identity (Bosse & Törner, 2015; Hobbs, 2013a), confidence (Ní Ríordáin et al., 2017) and capacity or expertise (Hobbs & Quinn, 2020).

A teacher's suitability for teaching a subject is based on their teaching experience or demonstrable teacher qualities rather than their qualification (Hobbs, 2020). Subject-specific teacher standards (often developed by teaching associations) may be useful to determine what a capable teacher looks like and what they would be expected to do. Capability in this definition refers to teacher experience and identity.

Teacher experience is incorporated into the definition as it plays an important role in determining teacher capability. With practice, teachers can develop a more complex, refined and experience-informed knowledge of the task of teaching the subject (Hobbs & Quinn, 2020). Weldon (2016) recognises the importance of experience by differentiating between the incidence of out-of-field teaching by teachers with zero to five years and more than five years teaching experience. Career stage is an indication of a teacher's ability to draw on general teaching skills that can enable them to maintain quality pedagogies (?) when teaching a new subject (Hobbs, 2013b; Nixon & Luft, 2015). Early career teachers experience a steep learning curve (Flores, 2006), which can be exacerbated by out-of-field teaching (Nixon & Luft, 2015). This makes graduate teaching a high-risk time for an out-of-field allocation. However, even experienced teachers allocated to a new out-of-field subject can experience re-novicing (Blazer, 2015), i.e., feel like a novice teacher again (Du Plessis et al., 2019).

Teachers' identity and work are organically bound up in what teachers know about their subject (Helms, 1998; van Manen, 1990). Teaching out-of-field, however, can affect teachers' feelings of belonging (Du Plessis et al., 2015). Also, teachers can have different levels of commitment to the subject and learning to teach it as determined by their personal interest in the subject ('pursing an interest'), a professional commitment to doing the best they can for their students ('making the most of it'), or simply because they have to teach it ('just filling in') (Hobbs, 2013a). The definition uses the language of close, peripheral and distant to indicate how closely a teacher identifies with the subject and feels like they belong.

The context of the teacher is also considered as relating to teacher experience, the supportive school culture and workload conditions, similar to Definition C above. School contextual factors, such as geographical region and school size and type, are often associated with a reliance on out-of-field teaching (McConney & Price, 2009; Vale et al., 2019). Support mechanisms and processes and school resourcing (such as student and community characteristics) can determine how a teacher feels the effects of teaching in an out-of-field subject (Hobbs, 2013a). However, it is important to note that teachers' support needs change over time (Hobbs, 2020) and with the subject they are teaching out-of-field. Du Plessis (2017) also stresses that school leaders' interaction, open communication and perceptions of quality teaching influence the effects of out-of-field teaching for teachers. Maintaining links with their in-field subject is one way of reducing risk (Vale et al., 2019).

The definition incorporates judgements of actual and perceived capability managed against levels of risk (see, Fig. 2.6).

Two scenarios illustrate how this definition can be applied to individual teachers.

Scenario: Liz

Liz is an English teacher teaching History out-of-field with moderate capability and moderate risk. History holds little interest for Liz and she is simply compliant in her commitment as there is no evidence of deliberate reflection on practice. Liz undertakes professional learning in English, but not History. She is an experienced teacher and knows where to get support which she considers to be adequate. Hull (2018, p. 2) wrote:

> Due to the staffing profile at the school and the exigencies of timetabling, Liz is always 'under loaded' after she has been allocated her English classes and is therefore allocated one or two history classes from Years seven to nine. This is not Liz's preference or choice. Though she teaches history every year, she does not think of herself as a history teacher and neither does her school. She therefore focuses her 20 h of professional learning on keeping up to date with developments in English or literacy, on the teaching of students with disabilities, on fostering student wellbeing and on learning how to use new educational software. She does no professional learning in history, year after year, relying on in-school guidance from her Head of Department (not necessarily a history teacher) and her peers (not necessarily teaching history at the same year level.

Scenario: Donald

Donald is a Design and Technology teacher teaching Art, Literacy Support and Work Studies out-of-field with low capability and high risk. He has no in-field classes and an unmanageable workload that is temporary and unstable. He works in a small school in a rural area so has limited access to professional learning and the small teaching staff means there is no support from in-field teachers. A desire for professional commitment to the subjects is evident, but thwarted by an unmanageable workload and no support. Sharplin (2014, p. 106) wrote:

> Donald was stretched to Art, Literacy Support and Work Studies…I was sent out here as a D and T teacher and it ended up I've got three lessons a week in that. A major part is Work Studies, Year 11 and 12, which is a totally different area. Then I had to teach Art for 7, 8, 9 and 10…I've got so many different areas to teach in.
>
> Donald struggled, failing to master the role demands, resulting in leaving his post during the year. Ultimately, he felt that the role expectations placed on him were not achievable in the absence of appropriate support:
>
> I think I was relieved [to leave] … the pressure of work … not having [the support] possible at a bigger school where you have people in the same learning area … if I had been in a bigger school with other subject teachers, it would have been a better situation. Other people doing the same subject with previous experience; that would have made a lot of difference. (p. 106)

Out-of-field as determined by Capability

A teacher is considered TECHNICALLY OUT-OF-FIELD or IN-FIELD but OUT-OF-SPECIALISM. They may 'feel' in-field or out-of-field depending on their PERCEIVED and/or ACTUAL CAPABILITY.

Capability is a function of a teacher's **expertise** and **confidence** to teach well gained through experience teaching the subject and engagement with professional learning; identity-related factors including sense of **self** in relation to the subject and their **commitment** and **role expansion** to teaching the subject currently and long-term. Levels of capability include:

- **High capability**, where a teacher:
    - is capable in the out-of-field subject, with substantial experience and relevant professional learning;
    - has a high degree of confidence;
    - has personal interest in the subject and professional commitment to developing and reflecting on their practice;
    - self-identifies as proximal to the subject; and
    - has accepted the role long-term and expanded their professional identity to include the role.
- **Moderate capability,** where a teacher:
    - is practiced in the out-of-field subject, with repeated experience without relevant professional development;
    - has a medium level of confidence;
    - has professional commitment to ensuring the subject is well-taught;
    - sees the subject close or peripheral; and
    - has accepted the role as part of their load long-term but without professional identity extension.
- **Low capability,** where a teacher:
    - is beginning without much experience teaching the out-of-field subject nor relevant professional development;
    - has a medium or low level of confidence;
    - has professional commitment to ensuring the subject is well taught or is compliant and just filling in;
    - self-identifies as distal to the subject; and
    - may or may not have accepted the role long-term but without professional identity extension.

Cumulative risk factors influence teacher capability: the **structures** that support and enable professional learning opportunities including school context and school support culture; the **career stage** of the teacher; and the **workload conditions**, including the proportion and stability of load, with the teacher maintaining links with their in-field subject. Managing risk means ensuring that teachers are supported so that they have the opportunities and support needed to develop the capacity expected for their career stage. Levels of risk include:

- **Low risk:** Structures are fully supportive and opportunities are created for developing capacity relevant to the teacher's career stage. The proportion of load (current and longitudinal) does not exceed the capacity of the teacher and the teacher maintains sufficient links to their in-field subject, and there is sufficient stability to develop expertise and confidence in teaching the out-of-field subject.
- **Moderate risk:** Structures provide some support and opportunities for developing capacity relevant to the teacher's career stage. The proportion of load (current and longitudinal) partially exceeds the capacity of the teacher and they may or may not maintain links with their in-field subject. The load is cyclical or temporary with moderate levels of change, limiting the development of expertise and confidence.
- **High risk:** The teacher is an early career teacher. Structures provide little support and opportunities for developing capacity relevant to the teacher's career stage. The proportion of load (current and longitudinal) exceeds the capacity of the teacher and they may or may not maintain links with their in-field subject. The load is temporary with a high degree of change, limiting the development of expertise and confidence.

Fig. 2.6 Out-of-field as determined by capability

2.5.5.1 Practical Application

This definition highlights a complex understanding of the level of capability within the system, and the factors that impact on the development of this capability. The definition focuses on capability in association with qualifications as determining suitability for teaching a subject, while taking into account objective measures of capability and subjective measures of confidence and identity. The focus shifts from proportion of out-of-field load for an individual teacher or in a school to assessing risk in terms of the career stage and experience of the teachers. Teacher capabilities are considered in relation to cumulative risk factors of teacher experiences and career stage, the school context and the nature of teacher workload.

This definition shifts the standard used to determine suitability of an out-of-field teacher to a particular subject or year level from qualification to capability gained through experience and teacher commitment. Hobbs (2020, p. 4) stated that:

> …a discourse of learning as experience recognizes that teaching experience matters, such that a teacher's suitability for teaching a subject is based on their teaching experience or inherent demonstrable teacher qualities, which then legitimises the practice of allocating teachers out-of-field.

The tension between qualification and experience underpins an unwritten and unspoken tolerance of this practice within the teaching profession. Guidelines that differentiate between levels of capability and risk management can support professional and collegial conversations between the teacher, principals, discipline coordinators and other peers. They also identify risks at a system level, for example, availability and accessibility of suitable professional learning, and adequate training for principals to understand the specific needs of teachers teaching out-of-field.

One of the limitations of this definition is that a teacher's perceived level of confidence may not correlate with their expertise (Hobbs, 2020), i.e., a teacher might over- or under-estimate their expertise, a product of the Dunning-Kruger effect (Dunning, 2011). Another limitation is that teachers may not have the opportunities to gain relevant professional learning due to the context of the school or an unsupportive school culture: 'teachers' lived experiences in their first five years of teaching are a direct reflection on school leaders' support efforts, quality leadership, engagement and management of complex teaching placements' (Du Plessis, 2019, p. 69). This can be a common experience for teachers teaching out-of-field and is the reason for assessing risk when determining suitability of teachers whilst allocating them to a subject or year level.

2.6 Discussion

These definitions can be 'put to work' in several ways. Education departments can use the Technical and Specialism definitions as the basis of data collection to ascertain the incidence and distribution of out-of-field teaching across the secondary school

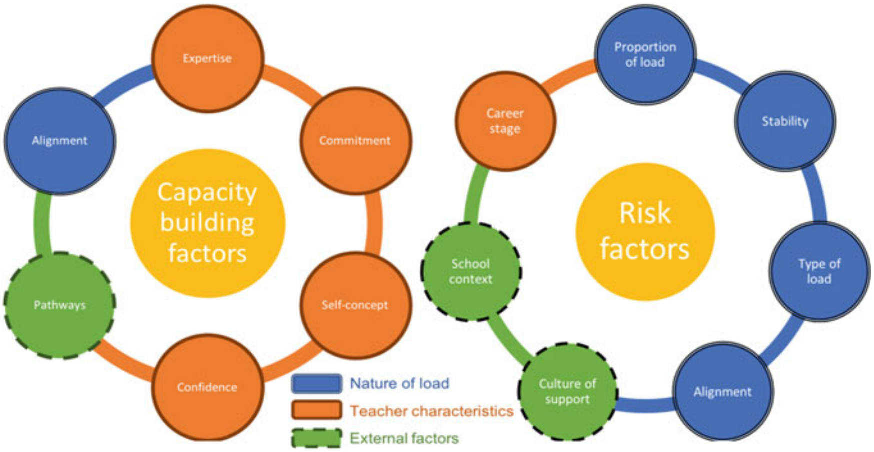

Fig. 2.7 Risk factors and capacity building factors associated with out-of-field teaching

subjects and identify target audiences for initiatives to upskill or recruit teachers. A clear delineation of what is technically in-field, and therefore out-of-field, helps to set the standard and expectation of what is considered desirable within the system. However, the Specialism definition might be useful for recognising the importance of background, for example, accepting teachers with a biology background into a professional development programme designed for out-of-field science teachers.

This approach to defining out-of-field teaching has introduced a multi-layered language to understand, measure and respond to out-of-field teaching. As summarised in Fig. 2.7 this language includes alignment between teacher allocation and teacher background, the language of risk associated with load and manageability and amelioration of risk, and capability as determined by teacher and school-related factors, such as a teacher's approach to learning and the supportive milieu of the school.

Pathways from being out-of-field to in-field are highlighted in these definitions to prompt system-wide reflection on how they might be recognised, provided and facilitated. However, there is currently little incentive in the form of remuneration or recognition for teachers to upgrade qualifications, especially given the high cost of upgrading (e.g., $10,000 for a Graduate Certificate qualification). In Victoria, there has been a history of teachers learning on-the-job instead of officially seeking additional qualifications, partly because of sporadic availability of such courses and policy settings that do not require method-based approval (like in the state of New South Wales) or certification (like in many parts of the world). Government intervention through funded qualifications can be a targeted strategy for supporting teachers to upgrade qualifications, although increased understanding of what motivates teachers to upgrade qualifications is needed to maximise the impact of incentivisation strategies.

The language of out-of-field teaching is operationalised through measures of risk as shown in the Workload and Capability definitions. The criteria can be used as the basis of school reporting to ascertain risk associated with the proportion of classes taught out-of-field either across a school or for a particular subject/department, number of teachers teaching out-of-field, and the proportion of a teacher's load taught out-of-field. Determining risks associated with the proportion of out-of-field teaching can become part of school modelling for the purposes of making more targeted decisions about hiring new staff based on current and projected need. A school or education government department may establish a tolerance threshold (Hobbs & Törner, 2019b) at which point it is understood that students and staff are negatively impacted by out-of-field teaching. Data will be needed to determine this threshold, such as proportions of out-of-field teaching correlated to teacher welfare, attrition and development, and to student achievement, attitudes and welfare.

The Capability definition can be operationalised to understand risk relative to a teacher and their capability and identity-related factors in the context of the school. Principals can be supported to ascertain risk associated with allocating a specific teacher at a particular proportion and type of load. This risk is related to teacher's qualifications and experience, as well as mediating factors. Mediating factors including the school context and culture of support can reduce risk and therefore can be factored into the threshold calculations. If a teacher feels supported by other in-field teachers, has a degree of control over their load, there is continuity in their load from one year to the next, and they are personally and professionally committed to the new subject long term, then there may be less risk of teacher burnout, low teaching quality and negative impacts on student learning. Data is needed to understand the relative impact of each of these mediating factors on reducing risk.

The Capability definition can be used by teachers in consultation with principals, heads of department or mentors to identify the key risk factors and capability-building possibilities and support needs for the teacher in their school context and career trajectory. It can be used for short-term planning by identifying immediate needs and support structures, and long-term planning as a pathway towards becoming in-field. Governments and schools can develop guidelines for risk management and teacher capacity building of early career and experienced teachers, teacher recruitment practices and allocation processes. Education departments can support principals to ascertain the risks associated with allocating a specific teacher a particular proportion and type of load. Subject associations and governments can provide and fund training for those mentoring out-of-field teachers.

Sustaining teaching quality in the face of out-of-field teaching means minimising risk and maximising teacher capacity by building capability. Risk is cumulative in the short-term and potentially in the long term, meaning that the more risks and the greater the intensity of risk teachers are exposed to, the more potential for harm for both teachers and their students. The risk factors and capacity building factors in Fig. 2.7 should be part of teacher-principal negotiations within the context of teacher allocation, career planning and potentially in performance reviews, which are required for maintaining teacher registration, to ensure any drop in performance is set within a risk-capacity building context.

2.7 Conclusion

This multi-faceted definition reflects a strengths-based perspective on out-of-field teaching as a learning process rather than an insurmountable challenge (Hobbs, 2020). Teaching is a problem-solving profession, where teachers are learners who engage in ongoing reflection and collaborate with peers, and strive to increase their level of expertise (Gore & Bowe, 2015). Teachers should therefore be able to upgrade their qualifications, build capacity and expand their professional identities (Caldis & Kleeman, 2019). Building teacher capacity can target a number of teacher characteristics. Discussions should focus on the possible pathways for moving from out-of-field to in-field, or at least increasing teacher expertise, confidence and self-concept in relation to the out-of-field subject. The factors can be related to teacher's commitment to the out-of-field subject and which pathway they would like to take. Having highly capable and adaptable teachers with a learning mindset can be an acceptable alternative to the absence of qualified teachers, at least in the short- or medium-term, as long as risks are managed effectively.

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Chapter 3
Value-Lost: The Hidden Cost of Teacher Misassignment

James P. Van Overschelde

Abstract Extensive existing evidence suggests that students are negatively impacted when taught out-of-field, but most of the extant literature is based on (a) national or international exam scores where the exams are not aligned directly with the course curriculum being taught, or (b) self-reported survey data. This study used statewide, detailed data for 5 million students who took Algebra I, Grade 8 Mathematics, or Grade 7 Mathematics and their associated state-level exams, detailed rules for who is teaching in-field versus out-of-field, and rigorous value-added modeling that consists of three-level, mixed-effects hierarchical models. The results are unequivocal: students earn significantly and substantially lower exam scores when taught out-of-field compared to peers taught in-field. Students taught out-of-field are experiencing "value lost," not "value add," relative to their peers taught in-field. The federal and state policy implications for teacher misassignment are explored, and recommendations made.

Keywords Educational equity · Quantitative methods · Student academic growth · Teaching out-of-field · Value-added modeling

3.1 Introduction

Research shows that students suffer academically when they take a class that is taught by a teacher without the requisite qualifications to teach the class (Clotfelter et al., 2010; Dee & Cohodes, 2008; Goldhaber & Brewer, 2000; Raudenbush et al., 1999; Riordan, 2009). Unfortunately, almost every rigorous, quantitative study to date has used outcomes based on national or international assessments (e.g., National Assessment of Educational Progress [NAEP], Trends in International Mathematics and Science Study [TIMSS]) that are not necessarily aligned with the curriculum the teachers taught in the class. Only one large-scale study exists that used detailed student and teacher data where the assessment data were linked to the class being

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taught (Clotfelter et al., 2010). Unfortunately, the study compared student academic growth for students of teachers who held subject-specific teaching licenses against those who held no teaching license.

The lack of outcome measures that are directly aligned with the curriculum being taught leaves a clear gap in the extant literature—is teaching out-of-field harmful for students' academic growth when the assessment is directly aligned with the curriculum? As Porsch and Whannell (2019) recently argued, the field needs "a more sophisticated approach to defining out-of-field… and methodological techniques such as multilevel regression modeling on an appropriately sized dataset" (p. 179). The present study meets this call. This study involves a more sophisticated approach to defining out-of-field (i.e., state law) and involves multilevel, hierarchical linear modeling with data on millions of students to start filling this hole in the extant literature.

Teaching out-of-field was essentially illegal in the United States between 2001 and 2015. In 2001, the United States Congress passed the federal law *No Child Left Behind Act of 2001* (NCLB) after which public schools in the US were required to assign teachers to classes only if the teacher held full state teaching certification and possessed solid content knowledge of the class's subject. These so-called *highly qualified* teachers were teaching within their field of expertise or teaching in-field. Highly qualified teachers in middle or secondary grade levels had to hold a bachelor's degree or higher degree and pass rigorous subject-specific licensure tests in each academic subject the teacher taught (NCLB, Sec. 9101[23]). As of 2002, every new teacher hired had to be highly qualified, and by 2005–06 all teachers in core academic subjects had to meet this standard. NCLB prescribed a limited number of conditions in which a principal could assign a teacher to teach a core subject out-of-field, and parents of students in these classes were required to be notified when a class was taught out-of-field. In response to this federal mandate, states developed specific rules to operationalize these mandates within each state's educational context.

In Texas, the state education agency that oversees P-12 public schools and teachers operationalized the state's teacher licensure system by codifying the teaching licenses required to teach each course subject. Texas Administrative Code (TAC §231) contains 82 pages of licensure rules by subject area and grade level. For example, to teach chemistry in Grade 9 in-field, a teacher must hold a teaching license in either chemistry, science, physical science, or math/physical science/engineering for a grade band (e.g., 7–12) that includes Grade 9. A teacher who holds a physics, biology, or English license would not be certified to teach chemistry and would be teaching chemistry out-of-field.

This detailed licensure map is important because Texas teachers can hold multiple teaching licenses. The initial license is generally awarded after the person completes a teacher preparation program and passes a subject-specific, grade banded content test, and a pedagogical test. After this first teaching certification or license is awarded by the state, a teacher can train for and take additional licensure tests to demonstrate their expertise in dozens of other content areas and/or grade levels. For example, a teacher prepared and certified to teach chemistry in Grades 7–12 could study physics education and pass a physics licensure test to earn a physics teaching license in

Grades 7–12. Or, a teacher certified to teach mathematics in Grades 7–12 can learn the math content and requirements for middle grades and take a licensure test to teach mathematics in Grades 4–8. Additional academic degrees are not required to gain additional licenses; expertise is demonstrated by passing a content-specific licensure test. This decision to allow multiple licenses without relying on additional degrees or additional higher education enrollment is supported by research that shows teaching courses within a secondary certification field results in similar levels of student academic achievement as teaching courses within the primary certification field (Sheppard et al., 2020).

In 2015, the United States Congress passed the *Every Student Succeeds Act* (ESSA) to replace NCLB. ESSA removed the highly qualified teaching requirement in order to give states and school districts more local control. Now, federal laws essentially permit schools to assign any teacher to any class regardless of the teacher's qualifications or expertise for the subject area or grade level being taught. In other words, ESSA legalized teaching out-of-field. However, ESSA does require different student groups to be treated equitably. In other words, it is acceptable under ESSA to assign teachers to teach out-of-field as long as White students, Black students, and Latiné students (for just some examples) are equitably assigned to out-of-field classes (ESSA, Sec. 1111[g][1][B]). States are required to report to the federal government plans that ensure low-income students and students of color "are not served at disproportionate rates by ineffective, out-of-field, or inexperienced teachers" (Sec. 1111).

Van Overschelde and Piatt (2020) showed this equitable assignment is clearly not happening. They found that Black students, male students, students from low-income families, students in communities other than urban and suburban, and many other groups are significantly more likely to take classes that are taught out-of-field—relative to their White or Latiné, female, and wealthier peers. To determine whether this inequitable assignment of students to out-of-field classes is inequitably impacting students' academic growth, detailed student-teacher-course-assessment-licensure data for millions of students and tens of thousands of teachers from Texas were used.

The overarching questions being examined are: Is teaching out-of-field bad for students academically when the material being tested is directly aligned with the material being taught? Are the federal ESSA mandates for student equity being effective at ensuring an equitable education for all students?

3.2 Literature Review

When "teachers [are] assigned to teach subjects for which they have inadequate training and qualifications" (Ingersoll, 2019, p. 21), they are teaching out-of-field. Out-of-field is a characteristic of a class-teacher pairing or a description of the misalignment of the teacher's qualifications with the class taught (Sanders et al., 1993). Ingersoll (1999) captured this misassignment issue succinctly with an analogy.

Ingersoll said that assigning a teacher to teach out-of-field is equivalent to requiring "cardiologists to deliver babies, real estate lawyers to defend criminal cases, chemical engineers to design bridges, or sociology professors to teach English" (p. 34). A doctor licensed in cardiology but practicing obstetrics is not an unqualified doctor, but unqualified to deliver babies. Similarly, a teacher certified to teach English but teaching Algebra I is not an unqualified teacher, but unqualified to teach Algebra I.

Therefore, a class is taught out-of-field or a teacher is assigned to teach a class out-of-field, but a teacher is not an out-of-field teacher. It is also true that a teacher can teach some classes in-field and other classes out-of-field in the same school year (Hashweh, 1987). Unpublished data from my lab show teachers can teach anywhere from 0% of their classes out-of-field to 100%, with numerous combination in between.

In the USA, research shows this misalignment of teacher and class is largely the result of decisions made by the school principal (Carey & Farris, 1994; Ingersoll, 1993, 2002, 2019). Ingersoll (2019; see also Ingersoll, 2002) argues that the misassignment is not due to a general lack of certified teachers, but more to an idiosyncratic lack of certified teachers willing to take a particular job at a particular school for the proffered salary. This makes intuitive sense. Imagine trying to convince a teacher certified to teach Algebra II to move from their current urban or suburban locale to a rural locale where they know no one, usually with a concomitant lower salary. Principals are also operating within a limited budget so that, for example, when student enrollment results in one unstaffed English class, the principal must decide among a limited set of options: hire a certified teacher to cover that one class, hire a less-qualified substitute teacher, reassign a non-English teacher who has an open period, or redistribute the students from the unassigned class to the assigned English classes (and disrupt the master school schedule).

3.2.1 Educational Equity

Why should we care about teaching out-of-field? First and foremost, teaching out-of-field is bad for students for many reasons. To summarize, students taught out-of-field appear to experience less academic growth and lower academic performance because teachers teaching out-of-field generally engage in less effective instructional practices (e.g., scaffolding, question asking, content elaboration, lower pedagogical content knowledge) and are less able to create classroom environments that are conducive to student learning and academic growth.

3.2.1.1 Student Academic Growth

Students taught in out-of-field classes experience less academic growth and lower academic performance than students taught in-field (Chaney, 1995; Clotfelter et al., 2010; Dee & Cohodes, 2008; Goldhaber & Brewer, 2000; Ingersoll et al., forthcoming, as cited in Ingersoll, 2019; Raudenbush et al., 1999; Riordan, 2009; Tsai & Young, 2015) because teachers cannot engage in more effective instructional practices (Blazar & Kraft, 2017; Du Plessis, 2014, 2017; Hobbs, 2013; Pianta & Hamre, 2009).

Clotfelter et al. (2010) conducted one of the most rigorous quantitative studies to date to explore student achievement differences between students taught in-field and students taught by a person with no teaching license. Using rich, panel data from North Carolina, they computed value-added growth scores for high school students using scores from the state's end-of-course exams. Aggregating results across multiple subject areas, they found that students experienced significantly higher academic growth when classes were taught in-field compared to when classes were taught by an unlicensed person, after controlling for a host of other variables. The magnitude of the relationship between teaching in-field (versus an unlicensed person) and student academic growth was stronger than the competitiveness of the teacher's undergraduate university, the years of teaching experience, whether the teacher held a graduate degree, the teacher's scores on the state licensure exams, and even holding National Board Certification.

Using a subset of student data from New York, Sheppard et al. (2020) found that aggregated school-level performance on the state's chemistry and physics exams was higher in schools where more students were taught in-field compared to schools where more students were taught out-of-field, and performance was similar across initial certification field and secondary certification fields (i.e., certification by exam). These analyses were based on school-level performance therefore student-level academic growth could not be evaluated directly.

Using national test data or small sets of survey data, similar patterns of results have been obtained. For example, Ingersoll et al. (forthcoming, as cited in Ingersoll, 2019) analyzed National Assessment of Educational Progress (NAEP) scores for geography, history, math, reading, and science and found significantly higher test scores on all tests when students were taught in-field compared to students taught out-of-field. Dee and Cohodes (2008) examined the National Education Longitudinal Study of 1988 (NELS) dataset and found students in Grade 8 experienced higher test scores in math and social studies when taught in-field, but no difference for English and science. Using the NELS dataset, others have found positive benefits of in-field teaching for math and science in secondary grades (Goldhaber & Brewer, 1997, 2000; Monk & King, 1994). The consistency of these findings is intriguing because the tests of academic achievement on which these studies were based were not necessarily aligned with the curriculum being taught in the year the tests were administered.

The negative relationship between academic achievement and out-of-field teaching has also been observed with younger students. Riordan (2009) analyzed data for students enrolled in kindergarten through Grade 3 and found higher achievements in math and reading for students in classes taught in-field compared to out-of-field.

None of these studies is definitive in and of itself. However, collectively they do suggest a negative relationship between teaching out-of-field and student learning.

3.2.1.2 Student Enrollment

This finding that taking classes taught out-of-field hurts student learning is important because extensive evidence indicates that students are not equitably enrolled in out-of-field classes. Students from low-income families are more likely to take out-of-field classes than students from wealthier families, students of color are more likely to take classes out-of-field than White students, and students in rural communities are more likely to classes out-of-field than students in suburban communities (Ingersoll, 2008; Ingersoll et al., 1996; Jerald & Ingersoll, 2002; Lankford et al., 2002; Nixon et al., 2017; Seastrom et al., 2004; Van Overschelde & Piatt, 2020). This pattern of results obtains despite the fact that Ingersoll used self-reported survey data from the US Department of Education's School and Staffing Survey (SASS), Lankford et al. (2002) used state-wide New York enrollment data, and Nixon et al. (2017) used a small sample of teachers from across several states. The most recent study of student enrollment in classes taught out-of-field was conducted by Van Overschelde and Piatt (2020) who used detailed student data from Texas to examine student enrollment in out-of-field classes. They found that Black students, male students, students from low-income families, student classified as English-language learners, and students receiving special education services took significantly more classes out-of-field than their peers.

3.3 Methodology

This study was conducted to address many of the data limitations that have existed in prior studies on out-of-field teaching and to explore the relationship between out-of-field teaching and student academic outcomes using rich state-wide data and a rigorous multilevel mixed-effects methodology. The research questions explored are:

1. Do students who are taught Algebra I in-field versus out-of-field experience similar levels of academic growth, after accounting for differences among students, teachers, and schools?
2. Do students who are taught Grade 8 Mathematics in-field versus out-of-field experience similar levels of academic growth, after accounting for differences among students, teachers, and schools?
3. Do students who are taught Grade 7 Mathematics in-field versus out-of-field experience similar levels of academic growth, after accounting for differences among students, teachers, and schools?

3.3.1 Data Sources

Texas is an ideal location for conducting research on teaching out-of-field because of the rich data collected by the state's education agency and because it is the second largest state in the USA from the perspective of student enrollment in public education. Specifically, in 2019–2020, 5.5 million students were enrolled in 8,900 Texas public schools and these schools employed 363,000 teachers. Since 1991, all Texas public schools have been required to send detailed information about their students to the state. These student data include, for examples, enrollment and demographics, courses taken and grades earned, educational services received (e.g., special education, gifted-talented, English language), standardized assessment scores, attendance, and discipline issues. The schools are also required to report detailed information on their teachers including courses taught (e.g., subject, grade level, days and times the classes meet), academic degrees held, salary, other non-classroom assignments (e.g., instructional mentor, assistant principal). The state also collects teaching licenses held and licensure test performance.

In 2007, the Texas Legislature authorized the creation of the largest research-only state longitudinal data system in the USA. Three Education Research Center (ERC) exist and each houses a copy of much of the state's education data as well as employment data collected by the state's workforce agency (described in detail below). To protect the confidentiality of individuals, personally identifiable data (e.g., names, date of birth) are removed so no individual person can be identified. However, to facilitate research studies and evaluations, each person is assigned two unique IDs to enable each person to be longitudinally tracked across decades. Theoretically, a person can be tracked from entry into elementary school through retirement if the person lived exclusively in Texas. The ERC data can be accessed only after receiving authorization from the ERC Advisory Board and only through secure research facilities from within one of the three higher education institutions in Texas that houses an ERC. To conduct the studies described here, I received permission from the ERC Advisory Board to access the confidential data through the University of Houston's ERC.

3.3.2 Data Preparation

Determining whether the millions of students taught by tens of thousands of teachers were taught in-field versus out-of-field required extensive data preparation. I start with an overview of the preparation process before providing the details. Summary: every student who completed Algebra I, Grade 8 Mathematics, and Grade 7 Mathematics between the fall of 2012 and the summer of 2019 was selected from the state's master dataset and the teacher of record was identified (when known). I then determined whether each teacher held the state-required teaching license to teach the course.

The details follow. The state's master dataset contains a list of every unique combination of student, school year, school, course, course sequence (e.g., fall, spring), and service code (i.e., subject taught). Hereafter, the term *course* will be used as a shorthand to indicate a unique *school year-school-course-sequence-service* record. The master *Student-Course* dataset for secondary students contains almost

235 million records. From this master dataset, only records for Algebra I, Grade 8 Mathematics, and Grade 7 Mathematics were selected; this resulted in 14.6 million course records. Student demographic data including gender, ethnicity, economic disadvantaged status, English-language learner status, and special education status were added.

The teacher or teachers of record for each course was identified if that information was reported to the state. Only courses with a single teacher were retained; this reduced the sample to 13.2 million records.

Out-of-field was determined at the student-course level by comparing all valid teaching licenses held by the teacher of record against each student's grade level, the course being taught and the state's licensure requirements for teaching that course. Current state educator licenses are valid for either one year (probationary/emergency) or five years (standard), and older licenses were issued for the educator's lifetime. Therefore, a license was considered valid if the effective date of the license was before the teacher's assignment start date for the course. Years of teaching experience and academic degree held at the time the course was taught were then added.

The outcome measure used for RQ1 was the normalized (z-score transformed) score for the state's Algebra I end-of-course (EOC) exam, for RQ2 was the normalized score for the state's Grade 8 Mathematics exam, and for RQ3 was the normalized score for the state's Grade 7 Mathematics exam. The Algebra I exam is administered to students who enrolled in Algebra I, and it is a high stakes exam; students must pass the exam to graduate from high school. As a result of the graduation requirement, students are permitted to take the exam multiple times. Only the first attempt at the EOC was used. The Grade 7 and 8 Mathematics exams are taken during the spring semester of that school year. Grade 8 Mathematics is higher stakes than Grade 7 because students are "required" to pass the Grade 8 Mathematics exam to be promoted to Grade 9. Three attempts at the Grade 8 exam are offered, and the only the first attempt was included here.

The student's prior year's normalized mathematics exam score was used as a pretest covariate. As Algebra I can be taken in different grades, only students who took it in Grades 8 or 9 were examined because 93% of Algebra I students took the course in one of those two grades. For students who took Algebra I in Grade 8, the Grade 7 Mathematics exam was the pretest used and for students who took it in Grade 9, the Grade 8 Mathematics exam was the pretest used.

Finally, because multiple course records can exist for a student during a school year (e.g., fall and spring semesters), only the last record for the spring semester were retained. This last step reduced the size of the final dataset to 5 million unique students who took either Algebra I, Grade 8 Mathematics, or Grade 7 Mathematics between spring 2013 and spring 2019, who were taught by a single teacher, who had complete demographic and prior math performance data, and who were taught by teachers who had complete data.

The demographic information for students in each of the final datasets is shown in Table 3.1. The Algebra I sample included almost 1.8 million students taught by 20,554 teachers employed by 3,820 schools. The Grade 8 Mathematics sample included over 1.4 million students taught by 14,971 teachers employed by 2,495 schools, and the

Table 3.1 Student demographic characteristics

Variable	Algebra I	Grade 8 Mathematics	Grade 7 Mathematics
Students	1,793,206	1,407,246	1,762,344
Teachers	20,554	14,971	16,966
Schools	3,820	2,495	2,556
Gender			
Female	900,385	691,015	876,792
Male	892,821	716,231	885,552
Ethnicity/Race			
Asian	65,207	25,897	58,657
Black/ African American	223,440	193,318	218,584
Hispanic/Latiné	935,939	784,820	949,989
Other	41,638	31,033	41,033
White	526,982	372,158	494,081
Economic Disadvantaged			
No	791,072	513,671	695,875
Yes	1,002,134	893,575	1,066,469
English Language Learner			
No	1,563,766	1,158,497	1,416,568
Yes	229,440	248,749	345,776
Special Education			
No	1,716,908	1,325,618	1,672,870
Yes	76,298	81,628	89,474
Grade Level			
Grade 8	422,860		
Grade 9	1,370,346		

Grade 7 Mathematics sample included just under 1.8 million students taught by 16,966 teachers employed by 2,556 schools.

3.3.3 Analytic Design

Three different sets of three-level, hierarchical, mixed-effects regression models were estimated with students at Level 1, teachers at Level 2, and schools at Level 3, with each aligned to a corresponding research question. The datasets were constructed so that the lower-level units were strictly nested within the next higher-level units. Stata v16.1 *mixed* procedure was used. Given the large number of clusters, full maximum likelihood estimation was justified (Snijders & Bosker, 2012). The sample size was more than sufficient for producing unbiased regression coefficients and variance components (Lee & Hong, 2021). Covariance structure of the random effects was treated as independent. The outcome measures were screened for outliers. The extreme values at both ends of the distribution of the test scores were earned by hundreds of students and were, therefore, treated as not outliers. All dummy codes were coded as 1 = Yes.

Unconditional (null) models without any predictors were estimated for each outcome variable to test for systematic within- and between-teacher and -school variance in outcome scores (Raudenbush & Bryk, 2002). Intraclass correlations (ICC) were then computed, one for each of the three outcome measures by dividing the variance at each level by the sum of the variances at all three levels.

For Model 1, student-level predictors known to be correlated with student enrollment in classes taught out-of-field (Van Overschelde & Piatt, 2020). These variables included normalized prior year's math score, female status, ethnicity dummy codes for Asian, Black, Other, and White with Latiné as the largest and excluded reference group, and dummy codes for economically disadvantage status, English-language learner status and special education status. Also included were dummy codes for the different school years with 2012–2013 as the excluded reference group. Because the test used for the prior score would vary substantially between students who took Algebra I in Grade 9 (Grade 8 Mathematics is the prior) and students who took Algebra I in Grade 8 (Grade 7 Mathematics is the prior), a Grade 9 variable was also added. The variable had a value of 1 if Algebra I was taken in Grade 9 and 0 if it was taken in Grade 8.

For Model 2, teacher-level, fixed- and random-effect predictors were added. The random-effect variable was a dummy code indicating whether the teacher was teaching the course out-of-field. The teaching out-of-field variable was treated as random after all three likelihood-ratio tests showed these models significantly improved model quality compared to the models with teaching out-of-field treated as a fixed effect. The fixed-effect variables were teaching experience and dummy codes for the academic degree held with the bachelor's degree as the largest and excluded reference group.

For Model 3, school-level fixed-effect dummy codes for the school's locale (e.g., urban, suburban, rural; see Texas Education Agency, 2019) were added with Suburban as the largest and excluded reference group.

3.4 Findings

A basic summary of the findings is: students who were taught out-of-field experience significantly and substantially less academic growth in Algebra I, Grade 8 Mathematics, and Grade 7 Mathematics than their peers who were taught in-field after accounting for important differences among students, teachers, and schools. The students taught out-of-field are losing ground academically relative to their peers taught in-field. The details of the different models are described next.

For Algebra I, the ICC indicates that 40.6% of the variance in scores was at the school level (among schools), 11.3% was at the teacher level (among teachers within a school), and the remaining 48.1% was at the student level (among students within a teacher's classrooms). The variance at all three levels was significant. For Grade 8 Mathematics, the ICC indicates that 12.5% of the variance in scores was at the school level, 18.7% was at the teacher level, and the remaining 68.8% was at the student level. For Grade 7 Mathematics, the ICC indicates that 12.5% of the variance in scores was at the school level, 19.8% was at the teacher level, and the remaining 67.7% was at the student level. These results indicate the necessity for using a multilevel statistical modeling approach to answer all three research questions (Snijders & Bosker, 2012). The large amount of school-level variance for Algebra I and the substantially smaller amount of school-level variance for the other two outcomes are interesting and may reflect the fact that students who take Algebra I in Grade 8 are often in different schools (e.g., middle grade schools) compared to students who take Algebra I in Grade 9 (e.g., high schools). This explanation is explored analytically below.

3.4.1 Algebra I

The modeling results for Algebra I are shown in Table 3.2. First, every student-level variable in Model 1 was significant thereby supporting their inclusion in subsequent models. The likelihood-ratio (LR) test indicates a significant improvement in the model fit between the unconditional model and Model 1 ($\chi^2 = 971{,}733.0, p < 0.0001$).

The differences in variance components across the two models are dramatic. The null model shows that 39.7% of the variance in test scores was at the school level, that is among schools, and Model 1 showed only 4.4% of the variance remained at the school-level after adding the student-level fixed-effect variables. The percentage of variance explained (PVE) was computed by computing the difference between the school-level variance of Model 1 and the null model and dividing the difference by the school-level variance of the null model. The PVE was 88.9%; this is the percentage of school-level variance explained by adding the student-level fixed effects. To determine the degree to which the PVE result was due solely to Grade 8 students being enrolled in different schools from Grade 9 students, Model 1 was rerun without the Grade9 variable. The LR test result shows that including the Grade9 variable substantially improves model fit over the model without it ($\chi^2 = 1187.7$, $p < 0.0001$), but the difference in PVE between the null model and Model 1 with versus without Grade9 showed a 5.9 percentage point difference. The vast majority of the variance explained in Model 1 came from student demographic characteristics thereby strongly implying systematic sorting of students to schools with higher scoring students enrolling in different schools than lower scoring students.

Table 3.2 Model coefficients for Algebra I end-of-course exam

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 1 (student)				
Intercept	0.135 (0.011)	−0.085 (0.005)	0.079 (0.005)	0.130 (0.005)
Female		0.053 (0.001)	0.053 (0.001)	0.053 (0.001)
Asian		0.191 (0.002)	0.191 (0.004)	0.191 (0.004)
Black		−0.024 (0.001)	−0.024 (0.002)	−0.024 (0.002)
Other		0.019 (0.003)	0.019 (0.003)	0.019 (0.003)
White		0.013 (0.001)	0.013 (0.001)	0.013 (0.001)
ELL		−0.051 (0.001)	−0.051 (0.001)	−0.051 (0.001)
SpEd		−0.170 (0.002)	−0.166 (0.002)	−0.166 (0.002)
EcoDis		−0.039 (0.001)	−0.039 (0.001)	−0.039 (0.001)
Prior Score		0.552 (0.001)	0.552 (0.001)	0.552 (0.001)
Grade 9		−0.180 (0.005)	−0.179 (0.005)	−0.177 (0.005)
SYear 2014		−0.020 (0.002)	−0.023 (0.002)	−0.023 (0.002)
SYear 2015		−0.012 (0.002)	−0.017 (0.002)	−0.017 (0.002)
SYear 2016		−0.006 (0.002)	−0.013 (0.002)	−0.013 (0.002)
SYear 2017		0.082 (0.002)	0.072 (0.002)	0.073 (0.002)
SYear 2018		−0.009 (0.002)	−0.002 (0.002)	−0.002 (0.002)
SYear 2019		−0.004 (0.002)	−0.010 (0.003)	−0.010 (0.003)
Level 2 (teacher)				
TOOF (random)			**−0.111 (0.006)**	**−0.104 (0.006)**
Teaching Experience			0.003 (0.000)	0.003 (0.000)
No Degree			−0.026 (0.007)	−0.025 (0.010)
Masters			−0.005 (0.003)	−0.004 (0.003)
Doctorate			−0.086 (0.018)	−0.085 (0.018)
Level 3 (school)				
Urban				−0.015 (0.014)
Central				−0.029 (0.013)
Central Suburban				−0.090 (0.012)
Independent				−0.084 (0.017)
Fast Growing				−0.062 (0.017)
Stable				− 0.080 (0.013)
Rural				−0.068 (0.013)
Charter				−0.116 (0.015)
Level 1 variance (student)	0.470 (0.000)	0.275 (0.002)	0.275 (0.000)	0.275 (0.000)

(continued)

Table 3.2 (continued)

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 2 variance (teacher)	0.111 (0.002)	0.040 (0.001)	0.037 (0.001)	0.037 (0.001)
TOOF			0.025 (0.002)	0.025 (0.002)
Level 3 variance (school)	0.397 (0.011)	0.044 (0.002)	0.042 (0.002)	0.041 (0.001)
χ^2 for model improvement		971,733.0	1264.9	126.5

Note SpEd = special education, ELL = English-language learner, EcoDis = Economically disadvantaged, SYear = school year where the digits represent the year of the spring semester (e.g., SYear2017 = school year 2016–2017), $^{\#}p > 0.10$, $^{*}p < 0.10$, $^{***}p < 0.01$. If the coefficient is not marked, then $p < 0.0001$

Research Question 1 asks whether students taught Algebra I out-of-field experience similar levels of academic growth as students taught in-field, as reflected in their Algebra I EOC exam scores and controlling for their Mathematics performance the prior year. The results for Model 2, which included all of the variables in Model 1 plus a random-effect variable for teaching out-of-field and teacher-level fixed-effect variables for teaching experience and academic degree held, show that teaching out-of-field reduces student academic growth in Algebra I significantly ($Z = -17.61, p < 0.0001$), with test scores reduced by 11.1% of a standard deviation after accounting for the student-level variables. The LR test indicates a significant improvement in model fit between Model 1 and Model 2 ($\chi^2 = 1264.9, p < 0.0001$). After accounting for the student- and teacher-level variables, only 3.7% of the variance is left at the teacher level.

The results of Model 3, which included Model 2's variables plus dummy codes for each school's locale (e.g., urban, suburban, rural), show that teaching out-of-field was still highly significant ($Z = -16.40, p < 0.0001$) with teaching out-of-field associated with a reduction in scores equivalent to 10.4% of a standard deviation. LR test shows Model 3 resulted in a significant improvement in model fit over Model 2 ($\chi^2 = 126.5, p < 0.0001$). The PVE result for school-level variance comparing Model 2 and Model 3 shows only a 3.0% reduction in variance, further strengthening the argument that students are sorted into different schools and the rural/urban/suburban nature of the school is not the primary reason for this sorting.

3.4.2 Grade 8 Mathematics

The modeling results are shown in Table 3.3. First, consistent with the Algebra I results, the student-level variables in Model 1 were all significant. The likelihood-ratio (LR) test indicates a significant improvement in the model fit between the

Table 3.3 Model coefficients for Grade 8 Mathematics

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 1 (student)				
Intercept	−0.278 (0.008)	0.070 (0.004)	0.073 (0.005)	0.092 (0.008)
Female		0.065 (0.001)	0.065 (0.001)	0.065 (0.001)
Asian		0.174 (0.004)	0.174 (0.004)	0.174 (0.004)
Black		−0.046 (0.002)	−0.046 (0.002)	−0.046 (0.002)
Other		0.016 (0.003)	0.016 (0.003)	0.016 (0.003)
White		0.014 (0.001)	0.014 (0.001)	0.014 (0.001)
ELL		−0.045 (0.001)	−0.045 (0.001)	−0.045 (0.001)
SpEd		−0.241 (0.002)	−0.237 (0.002)	−0.237 (0.002)
EcoDis		−0.043 (0.001)	−0.043 (0.001)	−0.043 (0.001)
Prior Score		0.756 (0.001)	0.756 (0.001)	0.756 (0.001)
SYear 2014		−0.080 (0.002)	−0.083 (0.002)	−0.083 (0.002)
SYear 2015		−0.055 (0.002)	−0.062 (0.002)	−0.061 (0.002)
SYear 2016		−0.051 (0.002)	−0.060 (0.002)	−0.059 (0.002)
SYear 2017		0.053 (0.002)	0.041 (0.002)	0.041 (0.002)
SYear 2018		−0.023 (0.002)	−0.036 (0.002)	−0.036 (0.002)
SYear 2019		−0.037 (0.003)	−0.053 (0.003)	−0.054 (0.003)
Level 2 (teacher)				
TOOF (random)			**−0.151 (0.009)**	**− 0.149 (0.009)**
Teaching Experience			0.003 (0.000)	0.003 (0.000)
No Degree			−0.085 (0.010)	−0.084 (0.010)
Masters			−0.006 (0.004)	−0.006 (0.004)
Doctorate			−0.001 (0.022)	−0.000 (0.022)
Level 3 (school)				
Urban				−0.021 (0.012)
Central				−0.046 (0.012)
Central Suburban				−0.012 (0.012)
Independent				−0.051 (0.017)
Fast Growing				−0.015 (0.018)
Stable				−0.015 (0.013)
Rural				−0.027 (0.011)
Charter				−0.033 (0.014)
Level 1 variance (student)	0.606 (0.001)	0.322 (0.000)	0.322 (0.000)	0.275 (0.000)

(continued)

Table 3.3 (continued)

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 2 variance (teacher)	0.165 (0.003)	0.041 (0.001)	0.038 (0.001)	0.037 (0.001)
TOOF			0.026 (0.003)	0.025 (0.002)
Level 3 variance (school)	0.111 (0.005)	0.020 (0.000)	0.019 (0.001)	0.041 (0.001)
χ^2 for model improvement		899,601.5	1160.95	126.5

Note SpEd = special education, ELL = English-language learner, EcoDis = Economically disadvantaged, SYear = school year where the digits represent the year of the spring semester (e.g., SYear2017 = school year 2016–2017), $^{\#}$ $p > 0.10$, $^{*}p < 0.10$, $^{***}p < 0.01$. If the coefficient is not marked, then $p < 0.0001$

unconditional model and Model 1 ($\chi^2 = 899{,}601.5$, $p < 0.0001$). The school-level variance component was dramatically reduced again (PVE = 82.1%) from the null model to Model 1 with the addition of the student-level fixed effects. The PVE for the teacher-level variance was reduced 74.8%.

Research Question 2 asks whether students taught Grade 8 Mathematics out-of-field experience similar levels of academic growth as students taught in-field, as reflected in their Mathematics exam scores. The results for Model 2, which included all of the variables in Model 1 plus a teaching out-of-field variable, show that teaching out-of-field reduces student academic growth in Grade 8 Mathematics significantly ($Z = -20.78$, $p < 0.0001$), with test scores reduced by 15.1% of a standard deviation after accounting for the student-level variables that are correlated with test performance. The LR test indicates a significant improvement in the model fit between Model 1 and Model 2 simply by adding the teaching out-of-field variable ($\chi^2 = 937.5$, $p < 0.0001$). After accounting for the student characteristics and teaching out-of-field, only 3.8% of the variance is left at the teacher level. The PVE between Model 1 and Model 2 for the variance at the teacher level showed it was reduced to 8.1%.

The results of Model 3, which included Model 2's variables plus dummy codes for each school's locale (e.g., urban, suburban, rural), show that teaching out-of-field was still highly significant ($Z = -20.36$, $p < 0.0001$) and associated with a reduction in scores equivalent to 14.9% of a standard deviation. LR test shows Model 3 resulted in a significant improvement in model fit over Model 2 ($\chi^2 = 44.7$, $p < 0.0001$), but the PVE at the school level was only 0.6%.

3.4.3 Grade 7 Mathematics

The modeling results are shown in Table 3.4. First, the student-level variables in Model 1 were all significant thereby supporting their inclusion in subsequent models.

Table 3.4 Model coefficients for Grade 7 mathematics

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 1 (student)				
Intercept	−0.169 (0.008)	0.052 (0.003)	0.046 (0.003)	0.047 (0.007)
Predictors				
Female		0.031 (0.001)	0.031 (0.001)	0.031 (0.001)
Asian		0.198 (0.002)	0.198 (0.002)	0.198 (0.002)
Black		−0.063 (0.001)	−0.063 (0.001)	−0.063 (0.001)
Other		0.016 (0.003)	0.016 (0.003)	0.016 (0.003)
White		0.026 (0.001)	0.026 (0.001)	0.026 (0.001)
ELL		−0.053 (0.001)	−0.053 (0.001)	−0.053 (0.001)
SpEd		−0.154 (0.002)	−0.153 (0.002)	−0.152 (0.002)
EcoDis		−0.063 (0.001)	−0.063 (0.001)	−0.063 (0.001)
Prior Score		0.775 (0.001)	0.775 (0.001)	0.775 (0.001)
SYear 2014		−0.014 (0.002)	−0.016 (0.002)	−0.017 (0.002)
SYear 2015		−0.006 (0.002)	−0.011 (0.002)	−0.011 (0.002)
SYear 2016		0.003 (0.002)	0.004 (0.002)	0.005 (0.002)
SYear 2017		0.079 (0.002)	0.070 (0.002)	0.069 (0.002)
SYear 2018		0.049 (0.002)	0.038 (0.002)	0.037 (0.002)
SYear 2019		0.059 (0.002)	0.046 (0.002)	0.044 (0.002)
Level 2 (teacher)				
TOOF (random)			**−0.045 (0.005)**	**−0.051 (0.005)**
Teaching Experience			0.003 (0.000)	0.003 (0.000)
No Degree			−0.033 (0.007)	−0.033 (0.007)
Masters			−002 (0.003)	−0.002 (0.003)
Doctorate			−0.026 (0.020)	−0.030 (0.020)
Level 3 (school)				
Urban				−0.025 (0.010)
Central				−0.033 (0.010)
Central Suburban				−0.002 (0.010)
Independent				−0.011 (0.015)
Fast Growing				−0.013 (0.015)
Stable				−0.012 (0.011)
Rural				−0.007 (0.009)
Charter				−0.069 (0.010)
Level 1 variance (student)	0.663 (0.001)	0.268 (0.001)	0.268 (0.001)	0.268 (0.001)

(continued)

Table 3.4 (continued)

	Null Model	Model 1	Model 2	Model 3
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Level 2 variance (teacher)	0.194 (0.003)	0.023 (0.000)	0.023 (0.000)	0.023 (0.000)
TOOF			0.012 (0.001)	0.012 (0.001)
Level 3 variance (school)	0.122 (0.005)	0.014 (0.000)	0.014 (0.000)	0.014 (0.000)
χ^2 for model improvement		1,614,744.9	587.1	103.9

Note The predictor variables are fixed effects, except where noted. TOOF = Teaching out-of-field, SpEd = special education, ELL = English-language learner, EcoDis = Economically disadvantaged, SYear = school year where the digits represent the year of the spring semester (e.g., SYear2017 = school year 2016–2017), $^{\#}p > 0.10$, $^{@}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. If the coefficient is not marked, then $p < 0.0001$

The likelihood-ratio (LR) test indicates a significant improvement in the model fit between the unconditional model and Model 1 ($\chi^2 = 1{,}614{,}744.9$, $p < 0.0001$). The PVE results show the variance was reduced 88.4% at the school level and 87.6% at the teacher level.

Research Question 3 asks whether students taught Grade 7 Mathematics out-of-field experience similar levels of academic growth as students taught in-field, as reflected in their mathematics exam scores. The results for Model 2, which included all of the variables in Model 1 plus a teaching out-of-field variable, show that teaching out-of-field reduces student academic growth in Grade 7 Mathematics significantly ($Z = -9.64$, $p < 0.0001$), with test scores reduced by 4.5% of a standard deviation after accounting for the student-level variables that are correlated with test performance. The LR test indicates a significant improvement in the model fit between Model 1 and Model 2 simply by adding the teaching out-of-field variable ($\chi^2 = 587.1$, $p < 0.0001$). After accounting for the student characteristics, teaching out-of-field, and teacher variables, only 2.3% of the variance is left at the teacher level.

The results of Model 3, which included Model 2's variables plus dummy codes for each school's locale (e.g., urban, suburban, rural), show that teaching out-of-field was still significant ($Z = -10.74$, $p < 0.0001$) and associated with a reduction in scores equivalent to 5.1% of a standard deviation. LR test shows Model 3 resulted in a significant improvement in model fit over Model 2 ($\chi^2 = 44.7$, $p < 0.0001$), but the PVE at the school level was only 0.6%.

3.5 Discussion

Using detailed, student-level enrollment and assessment data for 5 million unique students from Texas who completed Algebra I, Grade 8 Mathematics, or Grade 7

Mathematics between 2013 and 2019 and rigorous hierarchical linear modeling, the present study shows that students who were taught mathematics out-of-field experienced significantly and substantially less academic growth than their peers who took the same courses taught in-field.

For Algebra I, students who took the course taught out-of-field earned Algebra I end-of-course (EOC) exam scores that were 11% of a standard deviation below their peers taught in-field. To put this finding into perspective, the magnitude of the negative relationship between teaching out-of-field and Algebra I test scores is 285% larger than the negative relationship between economic disadvantaged status and those test scores. In other words, putting a teacher certified to teach Algebra I into Algebra I classrooms would have almost three times the positive effect on Algebra I EOC scores as lifting students out of poverty. This pattern exists even after accounting for important differences among students, teachers, and schools.

For Grade 8 Mathematics, students who took the course taught out-of-field earned exam scores that were 15% of a standard deviation below their peers taught in-field. For Grade 7 Mathematics, students who took the course taught out-of-field earned exam scores that were 5% of a standard deviation below their peers taught in-field. These three results are important for a number of reasons.

First and foremost, students who are taught Algebra I, Grade 8 Mathematics, and Grade 7 Mathematics out-of-field experience less academic growth and therefore are losing ground academically relative to their peers who are taught in-field. The pattern of results was consistent across all three courses. This finding is similar to several other studies (e.g., Clotfelter et al., 2010; Ingersoll, 2019; Tsai & Young, 2015), but the present results advance the field because this study combined four important characteristics. First, this study involves a direct comparison of state-wide standardized exam scores between students taught in-field versus out-of-field. Second, the content covered by the exams are directly linked to the curriculum being taught in the course taught in-field or out-of-field. Third, the results are based on 1.4–1.8 million students in each course. Finally, the results are based on rigorous hierarchical linear modeling that address the nested structure of the data (students taught by teachers, teachers employed by schools). Clotfelter et al. (2010) came to a similar conclusion using detailed student-level data from North Carolina and comparing outcomes for students taught in-field against students taught by uncertified teachers. Tsai and Young (2015) came to a similar conclusion using international TIMSS results in science even though there was no guarantee that the science curriculum being taught was aligned directly with the exam's content. Ingersoll (2019) drew a similar conclusion using NAEP scores, and this same curricular alignment issue exists with this test.

Second, Van Overschelde and Piatt (2020) recently showed that students are not equitably enrolled in classes taught out-of-field and the inequity is growing with each passing school year since the US Congress legalized teaching out-of-field in 2015. Specifically, they found that Black students, male students, low-income students, students who are not native-English speakers, students receiving special education services, and students in most locales except urban and suburban were significantly more likely to take classes taught out-of-field than their peers. Given the present study's findings, the groups of students who are taking more classes taught out-of-field are essentially receiving an inferior education—these student groups are losing ground academically relative to their White, female, suburban, native-English speaking, and wealthier peers.

Third, the negative relationship between teaching out-of-field and exam scores is larger in magnitude than factors like poverty and race. Given that the cost of ensuring all teachers are teaching in-field would be much lower than addressing student poverty, a federal or state policy that requires all teachers to teach in-field would dramatically improve students' learning and increase their subsequent test performance. Principals who have hiring authority over their teachers could work to ensure, to the greatest degree practicable, that all teachers are teaching in-field. This is easier said than done as principals attempt to balance budgets and teacher workloads, but larger school districts could maintain a reserve pool of teachers who can teach a class or two in each of several different schools. Any scheme to address the negative impacts of teaching out-of-field is likely to have a financial cost, but the cost of not addressing the issue is arguably much larger.

Fourth, the results strongly suggest that policymakers need to address the allocation of teachers in particular subject areas so as to create an equitable education system for all student groups. For example, the government could incentivize teachers to move to rural communities, like they have done to get teachers to teach in urban communities.

Finally, the present research shows the importance of having state longitudinal data systems (SLDS) available for researcher and for evaluating large-scale, policy-relevant educational issues. Only be collecting longitudinal data at the student-, teacher-, school-, and school district-levels is this type of research possible. An SLDS with researchers' access is an important policy issue that other countries may want to consider when addressing teaching out-of-field and its impacts on students and teachers.

3.6 Conclusion

The legalization of teaching out-of-field since the passage of the federal Every Student Succeeds Act (2015) is negatively impacting students' academic growth and the impact is not equitable. Black students, male students, and low-income students are much more likely to take classes taught out-of-field (Van Overschelde & Piatt, 2020).

Teaching out-of-field is an issue of equity. Out-of-field teaching is bad for students. Out-of-field teaching reflects a lack of equity in the way students are educated. The removal of the federal mandates to ensure each core course was taught by a highly qualified teacher has resulted in a dramatic increase in the number of courses taught out-of-field and this change negatively impacts students of color, male students, and students in low-income families and rural communities. The value lost for these student groups and for society by the legalization of teaching out-of-field is substantial.

Much research has been conducted to understand the cause of teaching out-of-field. Research on why principals assign teachers to teach classes out-of-field indicates two primary reasons for this decision: (1) to save money (e.g., Bush, 2003; Du Plessis, 2014, 2017; Ingersoll, 2002; Shepherd, 2013) and (2) because of a lack of sufficiently qualified teachers willing to fill a particular school's job opening (e.g., Du Plessis & Sunde, 2017; Ee-gyeong, 2011; Ingersoll, 1998, 2002; Ingersoll & Curran, 2004; Jimerson, 2003; Nixon et al., 2017; Sharplin, 2014; Zhou, 2014).

With these reasons in mind, let us return to Ingersoll's analogy of cardiologists being assigned to deliver babies. Imagine a hospital administrator who assigns cardiologists to deliver babies in order to either (1) save the hospital money or (2) because an insufficient number of obstetricians is available. Would state and federal policymakers and we, as a society, treat this administrator's decision as prudent or ethical? Now, imagine that the hospital administrator makes the decision to assign obstetricians to deliver most of the babies of high-income mothers and cardiologists to deliver most of the babies of low-income mothers? Would we believe this administrator's decision was ethical? I believe rational people would say that the administrator was acting unethically, and they might argue that the person should be arrested.

By legalizing teaching out-of-field, ESSA has resulted in the unethical and inequitable treatment of some student groups. The present findings show that the current education system in Texas violates the educational equity requirements in federal education policy for a "fair, equitable, and high-quality education" (ESSA, Sec. 1001) as well as the state's own education code (Texas Education Code, Sec 1.002) requirement for "equal educational services or opportunities."

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Chapter 4
'Out-of-Field' Teaching in Mathematics: Australian Evidence from PISA 2015

Chandra Shah, Paul W. Richardson, Helen M. G. Watt, and Suzanne Rice

Abstract 'Out-of-field' refers to teachers teaching subjects for which they do not hold a subject-specific qualification. Theory and empirical evidence suggest it can adversely affect teachers' work and students' learning. Teacher shortages and aspects of school organisational practice have been explanations linked to out-of-field teaching. We draw on Australian PISA 2015 data to examine the extent to which these, together with teacher characteristics and other school context factors, influence the assignment of teachers to out-of-field mathematics teaching. While the results show that schools' experiences of teacher shortages were unrelated to out-of-field mathematics teaching assignment, greater school autonomy, which captures aspects of school organisational practice, reduced the likelihood of out-of-field assignment. The results show other school context variables implicated in the relationship between school autonomy and out-of-field teaching are school sector and students' parents' educational level. Particular teacher characteristics also associated with their risk of assignment to teach mathematics out-of-field. Implications for policy are advanced.

Keywords Mathematics · Multilevel logistic model · Out-of-field teaching · School autonomy · School sectors

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4.1 Introduction

Calls to lift teacher quality in Australia generally follow whenever there is a decline in the country's international ranking in student performance in, for example, the Programme for International Student Assessment (PISA) which has shown a continuing decline in reading, science and particularly mathematics (Thomson, 2021). The Minister of Education and Youth initiated yet another inquiry into initial teacher education partly in response to declining school standards (rankings) over the last two decades (Tudge, 2021). However, not all declines in school rankings may be related to teacher quality, especially in mathematics. An important contributing factor in the decline could be the assignment of teachers to teach subjects for which they are not qualified (Cobbold, 2017). In the literature, out-of-field teaching refers to when teachers teach subjects (content) for which they do not hold the subject-specific qualifications—for example, if a teacher is assigned to teach mathematics when he or she is instead qualified to teach chemistry and biology. In contrast, 'in-field' teachers have subject-specific qualifications and pedagogical content knowledge relevant for the subject.

The importance of teachers having subject qualifications is underscored by the fact that most learning in the secondary school context is content-specific and thus, depends on the corresponding knowledge domain. Student learning in the domain of mathematics involves a set of constructive processes in which individuals sequentially build, activate, elaborate and organise knowledge systematically. This requires teachers to create an environment in which students are able to engage in domain-specific learning activities and build on previous knowledge (Seidel & Shavelson, 2007). To do so effectively, teachers need to have content knowledge, among which Shulman (1986) distinguishes (1) subject matter content knowledge, (2) pedagogical content knowledge[1] and (3) curricular knowledge. By definition, out-of-field teachers of mathematics will lack the deeper knowledge of the subject that is necessary for teaching students at senior levels and inspiring them to continue studying the subject at the tertiary level. Teachers asked to teach out-of-field will lack content knowledge and be less effective in that situation, even if they are brilliant communicators and classroom managers. Empirical evidence has shown that students taught by in-field teachers achieve better in mathematics than those taught by teachers teaching out-of-field (Clotfelter et al., 2010; Dee & Cohodes, 2008; Goldhaber & Brewer, 2000).

Students taught by more knowledgeable teachers are more likely to achieve and be motivated to undertake higher-level mathematics (Baumert et al., 2010; Hill et al., 2005), which in turn is important for ensuring a steady supply of not only mathematics graduates, but graduates of other physical and social science disciplines which have strong mathematical underpinning. These graduates have an important role in a modern economy and the demand for them continues to grow (Audit Office of New South Wales, 2019; Ingersoll & Perda, 2010; OECD, 2012; Office of the Chief

[1] Pedagogical content knowledge goes beyond the knowledge content per se to include the dimension of subject knowledge content that is most germane for *teaching*.

Scientist, 2014; Productivity Commission, 2012; Queensland Audit Office, 2013; Smith, 2017; The Royal Society, 2007).

Out-of-field teaching also affects teachers. Teachers assigned to teach out-of-field in mathematics in the Teach for America programme were found to be at a higher risk of leaving the profession altogether than those assigned to teach in-field (Donaldson & Johnson, 2010). Such teachers often feel a loss of professional identity and confidence (Du Plessis, 2019; Hobbs, 2013; Sharplin, 2014).

Despite the adverse effects of out-of-field teaching on both students and teachers, as we discuss in the literature review, the practice is widespread in many countries, including Australia (see Shah et al., 2020; Weldon, 2016). Ingersoll (2004) proposed two mechanisms to explain the prevalence of out-of-field teaching in the United States—teacher shortages and schools' organisational practices—but found support for only the second hypothesis. There is a knowledge gap in Australia about what drives the practice of out-of-field teaching in general and in mathematics, and which teachers are most affected by this practice. In particular, the two hypotheses proposed by Ingersoll (2004) remain untested in the Australian context. These are important to investigate because, as Ingersoll (1999) noted, many people including in Australia (e.g., Prince & O'Connor, 2018) assume the problem of out-of-field teaching is poorly prepared teachers or not enough teachers, that can be remediated with higher training standards and expanded recruitment.

In this chapter, we draw on Australian PISA 2015 data, which for the first time included an optional teacher survey in addition to the principal and student surveys, to address this knowledge gap about the practice of out-of-field teaching in mathematics in Australia. In particular, we investigate the role of teacher shortages and aspects of school autonomy together with other school context characteristics (e.g., size, location, whether it is in the government, Catholic or independent sector) and teacher characteristics (e.g., age, gender, employment contract) to predict the probability of teachers' assignment to out-of-field teaching in mathematics.

4.2 Literature Review

Research on out-of-field teaching in the United States goes back many decades (Brodbelt, 1990; Council for Basic Education, 1986; Gardner, 1983; National Commission on Teacher Education and Professional Standards. Special Committee on the Assignment of Teachers, 1965; Robinson, 1985). It grew from a concern for equality in education, an enduring challenge for education policy not only in the United States but in many other countries as well (e.g., Coleman et al., 1966; Kozol, 1991; Teese et al., 2007). Evidence from the United States has shown that students from poor, minority and disadvantaged backgrounds are often taught by the least qualified teachers, which has contributed to poorer educational outcomes for those students (e.g., California Commission on the Teaching Profession, 1985; Darling-Hammond, 1987).

In 2001, the United States Congress passed the *No Child Left Behind Act*, with specific incentives for states to eliminate out-of-field teaching by requiring 'highly qualified'[2] teachers in all core academic subjects across all income groups. After nearly a decade and a half, it seems the situation—rather than becoming better—may in fact have worsened, at least in science and mathematics (Shah et al., 2019). The act was replaced by the *Every Student Succeeds Act* in 2015, designed to increase local control by states and school districts and consequently improve student outcomes and teacher quality. The new act so far, according to Van Overschelde and Piatt (2020), seems to have produced perverse outcomes. Using administrative data for Texas, they showed out-of-field teaching increased considerably across all subjects after the act was passed compared to the situation before its introduction.

Most research on out-of-field teaching in the United States has used data from the National Teacher and Principal Survey (formerly known as the *Schools and Staffing Survey* (SASS)) which has been conducted periodically since the mid-1980s. Estimates from these data show the proportion of mathematics classes taught by out-of-field teachers (without a major or minor in mathematics) ranged from 18% in 1988 to 35% in 2015, and the proportion of students taught mathematics by out-of-field teachers ranged from 16% to 33% over the same period (Hill & Gruber, 2011; Hill et al., 2015; Morton et al., 2008; Seastrom et al., 2004; Shah et al., 2019).[3] The rate has tended to vary across teachers, schools and students. Less experienced teachers and those teaching low-track classes were more likely to be teaching out-of-field, and the practice has been found to be more prevalent in smaller schools and schools with high proportions of students from low socioeconomic backgrounds (Ingersoll, 1999).

Internationally, the 2008 *Teaching and Learning International Survey* (TALIS) revealed an average out-of-field teaching rate of 10% in mathematics and science in lower secondary schools across 21 countries—from 0.2% in Poland to 16% in Brazil (Zhou, 2012).[4] The rate was generally higher in schools that were small, in rural areas and in schools with large numbers of part-time and temporary teachers. As the TALIS data exclude casual relief teachers, who tend to have higher rates of out-of-field teaching, the estimates derived from TALIS will generally be smaller than those derived from data with a broader scope. This is one reason why the 5% combined rate for mathematics and science in Korea in TALIS is only half of the 10% in mathematics and one-fifth of the 25% in science that Kim (2011) reported, using a different country-specific Korean dataset. Kim similarly reported that out-of-field teaching in Korea was more common in small schools, outside big cities and in public schools. Using data from the 2013 survey of *Staff in Australian Schools* (SiAS), Weldon (2016)

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[2] The Act defined this term to mean that teachers hold a bachelor's degree and state certification, and demonstrate content knowledge in the subjects they teach.

[3] Out-of-field teaching has variously been measured in terms of the proportions of students, teachers or classes that are affected by the phenomenon. The choice of the measure depends on the data available, meaning that one has to be careful when comparing results from different studies (Ingersoll, 2019).

[4] Out-of-field teaching rate was measured as the percentage of mathematics and science teachers teaching out-of-field in the school.

reported an out-of-field teaching rate of 20% in secondary school mathematics in Australia. The rate was higher among teachers of lower grades, younger and less experienced teachers, and teachers in rural and regional schools. While he found some variation in the rate across states, the differences across government, Catholic and independent sectors were small.

As mentioned, the two major sets of explanations put forth to explain the phenomenon (Ingersoll, 2004) have related first to teacher shortages and recruitment difficulties in particular specialisms and second, to school organisational practice and administrative leadership, including the degree to which schools enjoy autonomy to make decisions concerning teacher appointments and deployment. However, both Ingersoll (2004) and Zhou (2014) found a lack of evidence to support the teacher shortage hypothesis. It is possible that school principals faced with a need to cover a mathematics class may assign an out-of-field teacher from the existing staffing pool to cover the class rather than hiring an additional mathematics teacher from the external labour market, thereby saving on costs. In fact, when budgets are tight, this may be the only option available to the school. In such situations, the principal may not report having experienced recruitment difficulties. Interestingly, Kim (2011) found high rates of out-of-field teaching in mathematics and science despite an apparent oversupply of teachers in Korea. Similarly, Ingersoll (2004) observed high rates of out-of-field teaching in English and social studies, subjects not generally known for having shortages. What this also means is that better training and recruitment of large numbers of new mathematics teachers, while worthwhile, may be unlikely to address the issue of quality mathematics teaching if teachers continue to still be assigned to teach out-of-field (Hoxby, 2004; Ingersoll, 2019).

Schools' organisational practices are an alternative explanation for out-of-field teaching. Decisions about these practices are made at different levels, including at the system level and the school level by principals. Regression analyses of data on secondary-level teachers from the *Schools and Staffing Survey* (SASS) in the United States found aspects of school leadership practices related to significantly lower rates of out-of-field teaching (Ingersoll, 2004). Unsurprisingly, Ingersoll found that schools that hired or assigned underqualified teachers (i.e., those who do not have a minor or a major in the subject they are assigned to teach) to cover vacancies had higher out-of-field teaching, and schools governed by district-level policies requiring new teachers to hold a minor or a major in the subject to be taught tended to have less out-of-field teaching. Using the TALIS data, Zhou (2012, 2014) investigated the effect of school leadership (administrative tasks, enforcing rules and procedures, and principal accountability) and school autonomy (for teacher hiring and determining teacher salaries) on out-of-field teaching in mathematics and science.[5] He found administrative leadership did not have a significant independent effect on school-level out-of-field teaching. The aspect of school autonomy that mattered most was who had responsibility for teacher salary increases. Schools in which the principal had this responsibility tended to have lower rates of out-of-field teaching. In contrast, when

[5] The 2012 study included data for 21 out of 24 countries that participated in TALIS; the 2014 study included data for only 15 countries. Both studies modelled fixed effects for countries in analyses.

teacher salary increases were decided by regional authorities, schools tended to have higher rates of out-of-field teaching. The Korean context provides further insights into the negative outcomes of central control and institutional rigidities pertaining to teaching hours, teacher contracts and the allocation of teachers to schools, all of which are associated with higher rates of out-of-field teaching (Kim, 2011). Du Plessis et al. (2014) alluded to the role of school leadership in managing out-of-field teaching, noting that current practices are often about 'crisis management' rather than finding long-term strategic solutions.

Ingersoll (2004) found a strong relationship between class size and out-of-field teaching, with less out-of-field teaching in schools which had larger classes. Maximum class sizes are often mandated in industrial relations agreements, and therefore, increasing class sizes may not be an option for schools where such agreements exist. School size may also limit the extent to which class sizes may be increased. This means some schools may opt to cancel classes or increase class sizes to avoid out-of-field teaching. Ingersoll found larger schools had less out-of-field teaching, but this relationship was weaker when the model included school organisational variables. Zhou (2012) also showed that smaller school size was significantly and independently associated with higher rates of out-of-field teaching. However, Zhou's subsequent study (2014) found school size to be unrelated. Whether the different result was due to differences between the samples or to other factors is unclear, and no explanation was suggested by Zhou (2014).

This literature review has highlighted the phenomenon of out-of-field teaching in mathematics in different countries and illustrated how its prevalence varies across different kinds of teachers, school contexts and datasets. While there has been little evidence to suggest teacher shortages as a significant factor in the assignment of teachers to out-of-field teaching, aspects of school organisational practices, particularly those related to school autonomy, seem to play a significant role.

4.3 Data

The Australian PISA 2015 consisted of surveys of students, teachers and principals.[6] A sample of 14,530 grade 10 students was drawn from 758 schools to complete the student survey. A total of 738 principals completed the school survey. The teacher sample included 16,234 teachers, of whom 11,715 responded to the teacher survey, a response rate of 72%. A unique common school identifier allowed the linking of school context data from the students' and principals' surveys to the teachers' data.

[6] The full technical details of the survey, including the sampling method, are in OECD (2017). Weights to account for the sampling design and non-response in the teacher survey are unavailable. However, student weights are available from the student survey. We use these to approximate teacher weights. We do this by assuming the same weight for each teacher in groups defined by state, sector and location of school. The sum of student weights in each group is divided equally among all teachers in the group.

The teachers' survey did not contain a specific question about out-of-field teaching in mathematics, but it included the following question:

> Were any of the following [subjects] included in your teacher education or training programme or other professional qualification and do you teach them to Year 10 in the current school year?

Teachers' responses were collected in a matrix of two columns and eleven rows. The two columns were headed 'Included in my teacher education or training programme or other professional qualification' and 'Teach it to Year 10 in the current school year'. The rows listed eleven subjects, including mathematics. Respondents ticked all relevant boxes in this matrix. From teachers' responses to this compound question, 2,313 teachers were identified to be teaching mathematics to Year 10 in the current school year with 20% teaching it out-of-field. For teachers teaching mathematics to Year 10, a binary variable was constructed for the variable 'out-of-field' in mathematics. It was assigned a value 1 for teachers for whom mathematics was not included in their teacher education or training programme or other professional qualification; otherwise, a value of 0 was assigned. Clearly, these data are limited to the extent that they do not reveal the number of classes these teachers were teaching, the number of students in classes, or whether they were teaching the subject at any other grade level.

4.3.1 Personal Characteristics of Teachers Assigned to Teach Mathematics

For our investigation of out-of-field teaching in mathematics, our effective sample consisted of data for 2,313 teachers. Teachers teaching mathematics out-of-field were, on average, younger than those teaching mathematics in-field (see Table 4.1). Relatively more of those teaching mathematics out-of-field were women and on temporary contracts, including fixed-term and casual contracts.

4.3.2 School Context of Teachers Assigned to Teach Mathematics

Australia's school education system consists of three sectors: government (public), Catholic systemic, and other independent systems, with complex government and private funding of each (Thomson, 2021). In 2020, the proportions of secondary students enrolled in each of the respective three sectors were 59%, 22% and 19%.[7]

[7] https://www.acara.edu.au/reporting/national-report-on-schooling-in-australia/national-report-on-schooling-in-australia-data-portal/student-numbers.

Table 4.1 In-field and out-of-field teachers teaching secondary school mathematics by personal characteristics, Australia

Characteristic		n			%		
		In-field	Out-of-field	Total	In-field	Out-of-field	Total
Gender	Female	876	249	1125	47.8	53.2	48.9
	Male	956	219	1175	52.2	46.8	51.1
	Sample size[a]	1832	468	2300	100	100	100
Qualification level	Lower than bachelor	89	22	111	4.9	4.7	4.8
	Bachelor	1416	353	1769	77.2	75.9	76.9
	Higher than bachelor	330	90	420	18.0	19.4	18.3
	Sample size	1835	465	2300	100	100	100
Hours of work	Full-time	1573	397	1970	86.0	85.9	86.0
	Part-time	257	65	322	14.0	14.1	14.0
	Sample size	1830	462	2292	100	100	100
Employment contract	Permanent	1592	377	1969	86.6	80.2	85.3
	Temporary	247	93	340	13.4	19.8	14.7
	Sample size	1839	470	2309	100	100	100
Professional development activities	≤3	768	185	953	41.8	39.7	41.3
	>3	1071	281	1352	58.2	60.3	58.7
	Sample size	1839	466	2305	100	100	100
Age (years)	Mean	43.8	40.4	43.1			
	Standard deviation	11.8	10.9	11.7			
	Sample size	1832	470	2302			

Note [a]Sample size excluding missing values. The full sample has data on 2,313 teachers
Unweighted estimates
Source PISA 2015

Assignment to out-of-field teaching was relatively less in independent than government schools. The schools where teachers were teaching mathematics out-of-field were, on average, smaller than the schools where they were teaching in-field (see Table 4.2). The proportion of teachers in each state and territory in the sample was not representative of the population because schools from smaller jurisdictions were oversampled to ensure reliable estimates for these jurisdictions. For example, New South Wales' share of teachers in the sample is 22%, which is less than its share (about one-third) of the total population. The weighted shares (not shown in the table), however, reflect the population shares more closely. Overall, relatively more teachers in New South Wales and Queensland schools were assigned to out-of-field teaching than in the other states and territories.

Table 4.2 In-field and out-of-field teachers teaching secondary school mathematics by school context, Australia

School context		n			%		
		In-field	Out-of-field	Total	In-field	Out-of-field	Total
State	New South Wales	391	111	502	21.2	23.6	21.7
	Victoria	333	87	420	18.1	18.5	18.2
	Queensland	409	93	502	22.2	19.8	21.7
	South Australia	270	69	339	14.7	14.7	14.7
	Western Australia	206	40	246	11.2	8.5	10.6
	Tasmania	125	27	152	6.8	5.7	6.6
	Northern Territory	34	20	54	1.8	4.3	2.3
	Australian Capital Territory	75	23	98	4.1	4.9	4.2
	Sample size	1843	470	2313	100	100	100
Sector	Government	1078	303	1381	58.5	64.5	59.7
	Catholic	417	105	522	22.6	22.3	22.6
	Independent	348	62	410	18.9	13.2	17.7
	Sample size	1843	470	2313	100	100	100
Location[b]	Metropolitan	1310	316	1626	71.1	67.2	70.3
	Provincial	490	128	618	26.6	27.2	26.7
	Remote	43	26	69	2.3	5.5	3.0
	Sample size	1843	470	2313	100	100	100
School type	School type	1504	393	1897	87.3	90.6	87.9
	Girls only	112	17	129	6.5	3.9	6.0
	Boys only	107	24	131	6.2	5.5	6.1
	Sample size	1723	434	2157	100	100	100
Shortage of teachers	No	1255	301	1556	77.1	74.5	76.6
	yes	372	103	475	22.9	25.5	23.4
	Sample size	1627	404	2031	100	100	100
Indigenous students	≤25%	1779	443	2222	96.5	94.3	96.1
	>25%	64	27	91	3.5	5.7	3.9
	Sample size	1843	470	2313	100	100	100
Students not speaking English at home	≤25%	1592	417	2009	86.7	89.5	87.3
	>25%	244	49	293	13.3	10.5	12.7
	Sample size	1836	466	2302	100	100	100

(continued)

Table 4.2 (continued)

School context		n			%		
		In-field	Out-of-field	Total	In-field	Out-of-field	Total
Parents with higher education	≤75%	1586	429	2015	86.4	91.7	87.5
	>75%	250	39	289	13.6	8.3	12.5
	Sample size	1836	468	2304	100	100	100
Students taking vocational subjects	≤25%	1492	366	1858	81.2	77.9	80.5
	>25%	346	104	450	18.8	22.1	19.5
	Sample size	1838	470	2308	100	100	100
School autonomy	Mean	0.75	0.73	0.75			
	Standard deviation	0.21	0.21	0.21			
	Sample size	1699	428	2127			
School size (X 100 students)	Mean	10.2	9.1	9.9			
	Standard deviation	4.4	4.2	4.4			
	Sample size	1723	434	2157			

Source PISA 2015
Notes [a]Sample size excluding missing values. The full sample has data on 2,313 teachers. Unweighted estimates
[b]Metropolitan locations generally have populations of more than 100,000; provincial locations between 25,000 and 100,000; remote locations less than 25,000

The binary variable ‘shortage of teachers’ represented principals’ responses to the question of whether a school’s capacity to provide instructions to students was hindered by a lack of teachers. It was coded as 1 if the response to the question was either ‘to some extent’ or ‘a lot’, and 0 if the response was either ‘not at all’ or ‘very little’. The question was about a general perception of teacher shortages, and not about a shortage in any specific subject. While this is less than ideal for capturing information on the shortage of mathematics teachers, it provides a reasonable proxy.

In the school survey, each principal was required to indicate who among the principal, teachers, the school board, local education authority and the national education authority had ‘considerable’ responsibility for each of twelve school organisational practices. The principal could indicate multiple parties having responsibility for each of the practices. The twelve practices included decisions on hiring and firing teachers, setting staff salaries, allocating budget, setting the curriculum and operating student admission and discipline. The school autonomy variable was constructed by the OECD to measure the collective responsibility of the principal, teachers and the school board for these practices. Its value ranged from 0 to 1, with higher values indicating more autonomy. Schools that assigned teachers to out-of-field teaching were generally less autonomous than schools that assigned them to in-field teaching.

The four variables in Table 4.2 relating to student composition and students' parents' qualifications were derived from the student survey. They capture aspects of the socioeconomic profile of the schools. For example, only 8% of out-of-field teachers compared to 14% of in-field teachers were in schools where more than 75% of parents of students possessed higher education qualifications.

4.4 Method

The assignment of a teacher to teach out-of-field can be conceived as a joint decision of the teacher and the principal (school) with each party acting to maximise their own utility. Principals will assign teachers to out-of-field teaching if they think there are net benefits (utility) to the school from taking that action. In assessing the net benefits, the principal may consider the effect of the decision on factors such as the school's budget, the quality of instruction to students, parental expectations and teacher industrial relations. The principal may also take into consideration the state of the teacher labour market in the location of the school. The teacher's consideration may include factors such as the avoidance of retrenchment, career enhancement and the additional workload from out-of-field teaching.

The assignment of a teacher to out-of-field teaching can thus be put into a structural framework of supply and demand to be determined simultaneously. We can use the following to specify the principal's demand for, and the teacher's supply of, out-of-field teaching services:

$$y_{ip} = \boldsymbol{X}_i \boldsymbol{\beta}_p + \boldsymbol{Z}_i \boldsymbol{\gamma}_p + \epsilon_{ip} \tag{4.1}$$

$$y_{it} = \boldsymbol{X}_i \boldsymbol{\beta}_t + \boldsymbol{Z}_i \boldsymbol{\gamma}_t + \epsilon_{it} \tag{4.2}$$

where y_{ip} is the principal's utility from assigning teacher i to teach out-of-field; y_{it} is teacher i's utility from teaching out-of-field; $\boldsymbol{X}_i$ is a vector of individual teacher characteristics; and $\boldsymbol{Z}_i$ is a vector of school context characteristics, the elements of which can vary in each equation; $\boldsymbol{\beta}_p$, $\boldsymbol{\beta}_t$, $\boldsymbol{\gamma}_p$ and $\boldsymbol{\gamma}_t$ are vectors of parameters to be estimated; and ϵ_{ip} and ϵ_{it} are the error terms in Eqs. (4.1) and (4.2), respectively.

In practice, we do not observe y_{ip} and y_{it}. Instead, what we observe is a binary variable indicating whether a teacher is assigned to teach out-of-field or not. We can thus specify the decisions of the principal and the teacher as two binary variables:

$$I_{ip} = \begin{cases} 1 \text{ if } y_{ip} > 0 \\ 0 \text{ if } y_{ip} \leq 0 \end{cases} \quad (4.3)$$

$$I_{it} = \begin{cases} 1 \text{ if } y_{it} > 0 \\ 0 \text{ if } y_{it} \leq 0 \end{cases} \quad (4.4)$$

There are four possibilities with respect to the above specification:

a) $I_{ip} = 1$ and $I_{it} = 1$ (both the principal and the teacher derive a net benefit from out-of-field teaching)
b) $I_{ip} = 0$ and $I_{it} = 1$ (only the teacher derives a net benefit from out-of-field teaching)
c) $I_{ip} = 1$ and $I_{it} = 0$ (only the principal derives a net benefit from out-of-field teaching)
d) $I_{ip} = 0$ and $I_{it} = 1$ (neither the principal nor the teacher derives a net benefit from out-of-field teaching).

Only in situation (a), in which the net benefits for both parties are positive, do we observe out-of-field teaching in the current data. In all other instances, there is no assignment to out-of-field teaching because the net benefit for at least one of the parties is not positive. For example, we do not observe teachers who may have assessed the net benefits to be non-positive and consequently resigned. This means we cannot distinguish between situations (b), (c) and (d) in the current data, and hence, it is impossible to identify the demand from the supply.

Assuming situation (a), which we observe in the current data, represents the equilibrium between the supply and the demand, we can estimate a reduced form logit model and calculate the probability of assignment to out-of-field teaching conditional on individual teacher characteristics and the school context. As the supply cannot be identified from the demand, we cannot determine, for example, whether a teacher's age is a significant factor in the decision of the teacher versus the principal.

Our data have a two-level hierarchical structure, with teachers in the same school sharing similar school-level random effects, which makes it suitable for specifying the reduced form model as a multilevel logistic model. Multilevel models contain both fixed effects and random effects, which can be in the form of random intercepts and random coefficients. Assuming random intercepts only, for the sake of simplicity we can specify the model algebraically as:

$$y^*_{ik} = \boldsymbol{\alpha}_{0\boldsymbol{ik}} + \boldsymbol{X}_{ik}\boldsymbol{\beta} + \boldsymbol{Z}_{ik}\boldsymbol{\gamma} + \epsilon_{ik} \quad (4.5)$$

$$\alpha_{0\boldsymbol{ik}} = \boldsymbol{\alpha}_0 + \vartheta_{0k} + \mu_{ojk} \quad (4.6)$$

In this equation, y^*_{ik} is the underlying, unobserved latent utility of the joint decision of the principal and the teacher in the assignment of teacher i, in school k, to teach out-of-field; $\boldsymbol{X}_{ik}$ is a vector of individual teacher characteristics; and $\boldsymbol{Z}_{ik}$ is a vector of school characteristics. $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are vectors of parameters; ϵ_{ik} is the residual term whose distribution is standard logistic with mean 0 and variance $\pi^2/3$; and with $\vartheta_{0k} \sim N(0, \sigma_\vartheta^2)$ and $\mu_{oik} \sim N(0, \sigma_\mu^2)$. The first term, ϑ_{0k}, is the school effect and the second term, μ_{oik}, is the teacher effect.

In practice, y^* is unobserved, and instead, we observe the binary variable:

$$I_{ik} = \begin{cases} 1 \text{ if } y_{ik}^* > 0 \\ 0 \text{ otherwise} \end{cases} \tag{4.7}$$

where 1 indicates assignment of teacher i to out-of-field teaching and 0 indicates assignment to in-field teaching.

The probability of assignment to out-of-field teaching is:

$$\text{Prob}(I_{ik} = 1) = \Phi(\boldsymbol{\alpha}_{0\boldsymbol{ik}} + \boldsymbol{X}_{ik}\boldsymbol{\beta} + \boldsymbol{Z}_{ik}\boldsymbol{\gamma}) \tag{4.8}$$

where Φ is the logistic cumulative distribution function. Using maximum likelihood, we can estimate the parameters in this equation.

4.5 Results

The results below come from estimating the multilevel logit model with random intercepts as in Eq. (4.8). Several versions of the model are estimated, each nested in the one following. The models are estimated using the sample of teachers teaching mathematics, with missing data deleted listwise, which reduced the effective sample size from 2,313 to 1,965.[8] We first discuss the proposed relation of school autonomy to out-of-field teaching followed by an assessment of other fixed effects.

4.5.1 Effect of School Autonomy

Model 1 is the unconditional mean model without any explanatory variables (see Table 4.3). It shows the intraclass correlation (ICC) of 5.3%, which is the proportion of the total variation in out-of-field teaching due to differences between schools. Although this is relatively small, a multilevel model is still appropriate because it will provide statistically efficient estimates of the effects and the model is theoretically justifiable.

The results from Model 2, which includes school autonomy as the only explanatory variable, show very little change in the ICC from Model 1. However, the likelihood ratio test comparing Models 1 and 2 is highly significant, which means that Model 2 is a significant improvement in fitting the data. The results also show that school

[8] Approximate weights as explained in footnote 5 are used in the calculations.

Table 4.3 Effects of school autonomy on assignment of teachers to out-of-field teaching in secondary school mathematics, Australia

Explanatory variable	Model 1	Model 2	Model 3	Model 4
	Log odds (SE)	Log odds (SE)	Log odds (SE)	Log odds (SE)
School autonomy	Excluded	−0.99 (0.41)**	−0.93 (0.40)**	−0.10 (0.44)
Level 1 variables	Excluded	Excluded	Included	Included
Level 2 variables	Excluded	Excluded	Excluded	Included
Constant	−1.478 (0.08)***	−0.70 (0.32)**	−1.79 (0.98)**	−1.63 (1.00)
Random effects parameter				
School (variance)σ_{ϑ}^{2}	0.18 (0.16)	0.16 (0.15)	0.13 (0.15)	0.01 (0.12)
Intraclass correlation (ICC)	0.05 (0.04)	0.05 (0.04)	0.04 (0.04)	0.00 (0.04)
Information criterion				
Akaike (AIC)	1932	1928	1899	1897
Bayesian (BIC)	1943	1945	1960	2065

Notes *Significant at 10%; **significant at 5%; ***significant at 1%
Standard errors in parentheses
Source Authors' calculations based on data from PISA 2015

autonomy is a statistically significant factor in the assignment of teachers to out-of-field teaching in mathematics, whose probability is significantly lower in schools reporting higher levels of autonomy. In a variation of Model 2, we replaced school autonomy by shortage of teachers as the only explanatory variable to assess the teacher shortage hypothesis. The results (not shown in the table) supported findings of previous studies that reported teacher shortage was not a significant factor in the assignment of teachers to out-of-field teaching (e.g., Ingersoll, 2004; Zhou, 2014).

Model 3 extends Model 2, by adding all individual teacher characteristics (gender, age, qualification, employment contract, hours of work, professional development activities) as explanatory variables. Age and age-squared are included to capture potential nonlinear effects of age. The results show that school autonomy continued to exert an independent significant effect of similar magnitude on out-of-field teaching as in Model 2. The likelihood ratio test showed improved model fit when teacher characteristics were included versus the previous model. The effects of the teacher characteristics are discussed in the next section.

In Model 4, school context variables (school size, state, school sector, location, school type, % Indigenous students, % students not speaking English at home, % students' parents with higher education qualifications, % students taking vocational subjects) were added as explanatory variables at level 2. The effect of school autonomy was considerably reduced and became statistically non-significant, suggesting that the relationship between school autonomy and the assignment of teachers to out-of-field teaching is confounded by school context factors. Two potential confounders were the school sector and education level of students' parents. Bivariate analyses (not included here) show the school sector to be a strong predictor of both school autonomy and assignment of teachers to teach out-of-field, confirming its confounder role. Parallel analyses with respect to education level of students' parents similarly confirmed its confounder role.

The school autonomy composite measure captured overall organisational practices for which the school (principal, teachers and school board) had considerable responsibility. The composite measure included 36 constructs. To assess the effect of each, Model 5 was re-estimated 36 times, with the school autonomy variable substituted by the construct coded as a binary variable. For example, a value of 1 for the first construct indicated that the principal had considerable responsibility for hiring teachers and 0 indicated otherwise. The results showed only 5 out of 36 constructs had significant independent effects on out-of-field teaching, after controlling for teacher characteristics and the school context (see Table 4.4 for abridged results).[9] In Table 4.4, Models 5 to 8 relate to school practices for which either the principal or teachers had considerable responsibility. Each of these practices was associated with a reduction in a teacher's probability of being assigned to out-of-field teaching. In contrast, the practice for which the school board had considerable responsibility increased the probability of out-of-field teaching (see Model 9). These results raise interesting issues about the agency of the principal, teachers and the school board in relation to the assignment of teachers to out-of-field teaching.

4.5.2 Mean Marginal Effects

The effects of explanatory variables in logit models are often expressed in terms of log odds. Marginal effects, on the other hand, summarise the effects of explanatory variables in terms of the model's predictions (Mize, 2019). They allow us to express the results in the probability metric, often the original measure of the dependent variable, and are particularly useful for interpreting the effects of categorical variables. The marginal effect is the difference in the prediction of an event at two levels of an explanatory variable, controlling for all other variables in some way. The nonlinearity of the logit model means that the marginal effect is not constant over a range of values of other variables in the model. Several methods are thus used to report the marginal effect. A common practice is to calculate and report the mean marginal effect because of its better statistical properties compared to the alternatives (Cameron & Trivedi, 2005). Mean marginal effects are estimated by calculating marginal effects for every observation in the sample and then averaging those effects. For continuous explanatory variables, the adjusted predictions at representative values of the variables are instead calculated.

The mean marginal effects in Table 4.5 relate to Model 4. The constant term, 0.194, represents the overall probability of assignment to out-of-field teaching in mathematics. Statistically, men and women were equally likely to be assigned to

[9] Analyses showed that none of the practices for which the local or the national education authority had considerable responsibility had a significant independent effect on out-of-field teaching.

Table 4.4 Effects of constructs of school autonomy on assignment of teachers to out-of-field teaching in secondary school mathematics, Australia

Explanatory variable	Model 5	Model 6	Model 7	Model 8	Model 9
	Log odds (SE)	Log odds (SE)	Log odds (SE)	Log odds (SE)	Log odds (SE)
Formulating school budget (principal)	−0.28 (0.15)*	Excluded	Excluded	Excluded	Excluded
Selecting teachers for hire (teachers)	Excluded	−0.55 (0.18)***	Excluded	Excluded	Excluded
Deciding budget allocations within school (teachers)	Excluded	Excluded	−0.52 (0.18)***	Excluded	Excluded
Approving students for admission to school (teachers)	Excluded	Excluded	Excluded	−0.51 (0.24)**	Excluded
Firing teachers (school board)	Excluded	Excluded	Excluded	Excluded	0.84 (0.34)**
Level 1 variables	Included	Included	Included	Included	Included
Level 2 variables	Included	Included	Included	Included	Included
Constant	−1.48 (0.97)	−1.66 (0.97)**	−1.56 (0.97)	−1.65 (0.97)*	−1.83 (0.95)*
Random effects parameter					
School (variance)σ_{ϑ}^2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Intraclass correlation (ICC)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Information criterion					
Akaike (AIC)	1892	1886	1885	1889	1890
Bayesian (BIC)	2054	2048	2046	2051	2052

Notes * Significant at 10%; ** significant at 5%; *** significant at 1%
Standard errors in parenthesis
Source Authors' calculations based on data from PISA 2015

out-of-field teaching. Similarly, teachers' qualification levels had little effect on the assignment. On the other hand, teachers on temporary contracts were 6.3% points more likely to be assigned to out-of-field teaching than those on permanent contracts. This is a substantial difference as the overall probability of assignment was only 19.4%. The result may reflect the lack of bargaining power of temporary teachers in the teacher labour market.

Age had a significant effect on whether a teacher was assigned to out-of-field teaching. Although correlated with length of teaching experience, it should be noted that age is not identical, given different career entry points and career interruptions. Its effect is illustrated in Fig. 4.1, which shows the adjusted predicted probability of assignment to out-of-field teaching at different ages. While the probability generally

Table 4.5 Mean marginal effects: the probability of assignment of teachers to out-of-field teaching in secondary school mathematics, Australia

Characteristic	Level	Estimate	SE	*p*-value
Gender (base = Female)	Male	−0.015	0.019	0.422
Age (Years)		−0.003	0.001	0.000
Qualification level (base = Bachelor)	Lower than bachelor	0.020	0.047	0.676
	Higher than bachelor	0.020	0.024	0.386
Employment contract (base = Permanent)	Temporary	0.063	0.030	0.034
Hours of work (base = Full-time)	Part-time	0.022	0.030	0.453
Professional development activities (base = ≤ 3)	>3	−0.002	0.019	0.903
School size (X 100 students)		−0.007	0.002	0.001
State (base = New South Wales)	Victoria	−0.003	0.031	0.929
	Queensland	−0.024	0.030	0.430
	South Australia	−0.004	0.032	0.901
	Western Australia	−0.048	0.032	0.141
	Tasmania	−0.040	0.035	0.253
	Northern Territory	0.001	0.091	0.988
	Australian Capital Territory	−0.005	0.049	0.924
Sector (base = Government)	Catholic	0.005	0.026	0.838
	Independent	−0.043	0.030	0.151
Location (base = Metropolitan)	Provincial	−0.042	0.023	0.060
	Remote	0.099	0.107	0.357
School type (base = Coeducational)	Girls only	−0.077	0.037	0.039
	Boys only	0.018	0.050	0.724
Shortage of teachers (base = No)	Yes	0.002	0.025	0.940
School autonomy		−0.016	0.023	0.476
Indigenous students (base = < 25%)	>25%	−0.017	0.055	0.756
Students not speaking English at home (base = < 25%)	>25%	−0.047	0.025	0.058
Parents with higher education (base = ≤ 75%)	>75%	−0.048	0.030	0.109
Students taking vocational subjects (base = ≤ 25%)	>25%	0.044	0.026	0.088
Constant		0.194	0.009	0.000

Source Authors' calculations based on data from PISA 2015

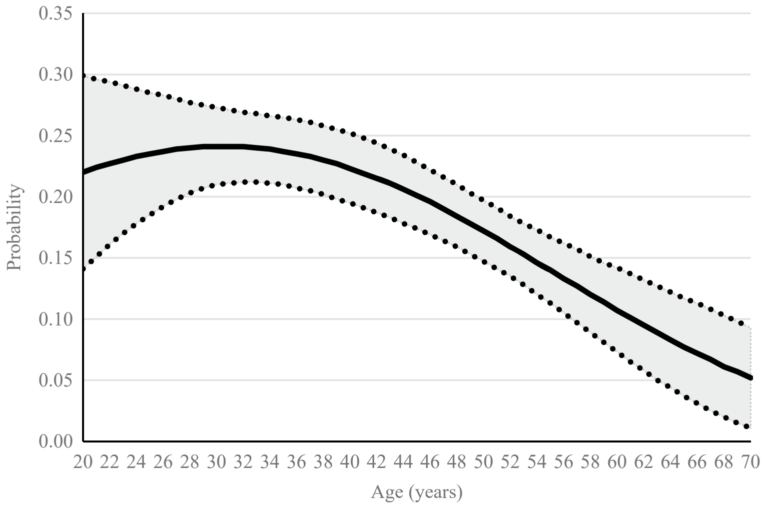

Fig. 4.1 Adjusted prediction of assignment to out-of-field teaching in secondary school mathematics with 95% confidence interval by age of teacher, Australia

declined with age, the change was not linear. The youngest group of teachers (20–24 years), which included a large majority of first-year teachers, was somewhat less likely to be assigned to out-of-field teaching than those in the adjacent 25–29 years group. This suggests that schools are perhaps more sensitive to the needs of first-year teachers than is commonly believed. If this is true, and further research can validate, then it is an acknowledgement by schools of the significant challenges of pedagogy and classroom management faced by new teachers without the additional burden of out-of-field teaching, which has the potential to reduce their chances of a successful transition and retention in the teaching profession. Teachers aged 60 years or older were significantly less likely to be assigned to out-of-field teaching. This perhaps reflects the preferences of older, senior teachers, who often carry more weight in schools' decisions. On the other hand, it may also reflect schools' preferences to assign their most senior and experienced teachers to senior classes where subject specialist teachers are believed to be more important.

Teachers in the states of Western Australia and Tasmania were more than 4% points less likely to be assigned to out-of-field teaching than teachers in the base state of New South Wales. The differences, while not large, were statistically significant and could be reflecting institutional factors not evident from the current data. Similarly, teachers in provincial school locations were 4.2% points less likely to be assigned to out-of-field teaching than teachers in metropolitan schools, despite generally 'thinner' teacher labour markets in provincial locations. In contrast, Ingersoll (2004) found out-of-field teaching rates in United States provincial and city locations were not significantly different, a result which could have been affected by the inclusion of district size, a variable which is likely to be strongly correlated with school location, as an independent variable in his model.

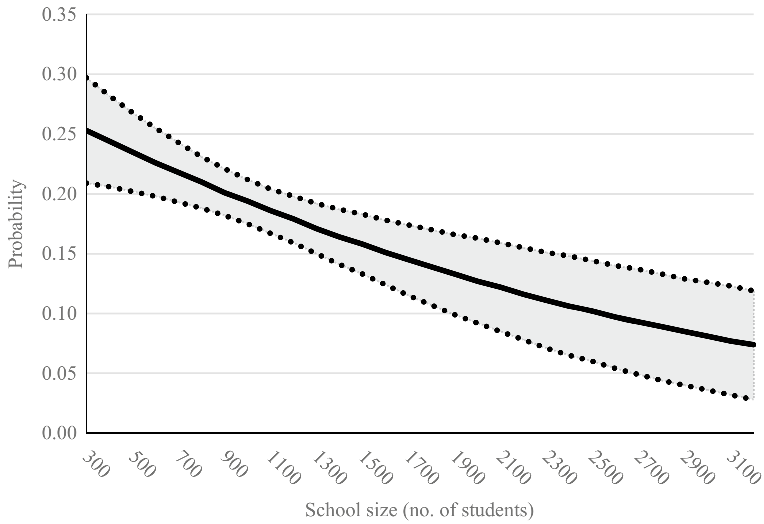

Fig. 4.2 Adjusted prediction of assignment to out-of-field teaching in secondary school mathematics with 95% confidence interval by size of school, Australia

While teachers in Catholic schools were just as likely to be assigned to out-of-field teaching as teachers in government schools, those in independent schools were 4.3% points less likely to be. Interestingly, unlike teachers in all-boys schools, those in all-girls schools were 7.7% points less likely to be assigned than those in coeducational schools. In schools where more than 25% of students spoke a language other than English at home, teachers were 4.7% points less likely to be assigned to out-of-field teaching; in schools where more than 25% of students studied vocational subjects, they were 4.4% points more likely to be assigned, compared to the corresponding base categories. The average probability of assignment to out-of-field teaching declined by the size of school, from 25% in the smallest schools to approximately 8% in the largest (Fig. 4.2). The difference was highly significant, and the results are consistent with the findings of Zhou (2012) but not those of Ingersoll (2004) or Zhou (2014). Whether the results are different because different model specifications and data were used in each study is difficult to ascertain.

4.6 Discussion

We designed this study to explore the assignment of a teacher to out-of-field teaching in mathematics, conceived as a joint decision between the teacher (supply) and the school (demand). As identification of the supply from the demand was not possible, we used a reduced form multilevel logistic model to determine which teacher characteristics and school context factors associated with the assignment of a teacher to out-of-field teaching in mathematics. Two school context factors that were of particular interest were the school's reported teacher shortage and level of autonomy.

Consistent with what others have reported in the literature (e.g., Ingersoll, 2004; Zhou, 2014), we did not find supporting evidence to suggest that the assignment of a teacher to out-of-field teaching in mathematics was related to the school's general subject-wide perception of teacher recruitment difficulties. Thus, as noted by Ingersoll (1999), in the Australian context too, increasing the total supply of qualified mathematics teachers may not reduce out-of-field teaching in the subject, nor address the structural and systemic problems of uneven distribution of in-field mathematics teachers across different types of schools.

Aspects of school autonomy, especially those related to budget allocation, significantly reduced a teacher's probability of assignment to out-of-field teaching in mathematics. These effects were confounded by other school context factors—mainly, whether the school was in the government, Catholic or independent sector, and the educational level of the students' parents in the school. These confounders strongly correlate with the differential funding allocations that schools receive, which we believe makes a difference to whether a school assigns a teacher to teach out-of-field in mathematics. When private and public funding sources are combined, non-government schools (especially independent schools) are much better funded than government schools (Thomson, 2021). We conjecture that the better funding and its certainty enable these schools to develop long-term plans for recruiting, and holding onto, suitably qualified staff. It also allows them to operate with more staff than the bare minimum, using this spare capacity to meet short-term needs. Unlike government schools with very tight budgets, independent schools thus need to rely less on the short-term teacher labour market, which is inherently riskier in terms of finding qualified teachers when needed. Our analyses show temporary teachers were at a much higher risk of being assigned to out-of-field teaching than teachers on permanent contracts. Highly educated parents have more agency to influence schools with regard to the quality of the teachers hired by the schools their children attend. It should be noted that these parents, because of their higher incomes and socioeconomic status, often choose well-resourced, independent schools for their children (Thomson, 2021).

School size and location are structural factors which were found to be significant determinants of the assignment of teachers to out-of-field teaching. Schools that were small and in remote locations were more likely to have teachers teaching mathematics out-of-field. These factors were also identified by Kim (2011) in the context of Korea and are challenging to address from a policy perspective. Smaller schools have smaller budgets and can only employ a limited number of teachers. When this is combined with mandated restrictions on class size, the compulsory curriculum that each school is required to deliver, and student subject choices, the task of assigning teachers to classes in small schools so that all classes are taught by in-field teachers becomes difficult, if not impossible. In remote locations, with low population densities and smaller schools, an additional problem is that of thin teacher labour markets. Addressing these issues requires system-wide incentives for recruiting and retaining qualified teachers in these locations. Many teachers prepare for two subject methods as part of their initial teacher education course, the first related to their major undergraduate study and the second to their minor. However, mathematics teachers typically qualify to teach only mathematics (as a 'double major'). One criticism of the idea for mathematics teachers to qualify in an additional subject is that it risks producing teachers who have breadth of knowledge but may lack depth. Online learning for students provides an alternative solution for some of these structural problems. However, the jury is still out about its effectiveness for all students. Lessons from the current COVID-19 pandemic may provide greater understanding about what works and for whom in this regard.

Teachers in schools containing a high proportion of students who speak a language other than English at home had lower probability of teaching out-of-field in mathematics than teachers in other schools. While on first reflection this result seems counterintuitive, many recent migrant families from East, South East and South Asia are highly 'aspirational' and tend to enrol their children in high-performing, well-resourced, non-government schools (see Ho, 2020). These, as discussed above, tend to assign relatively fewer teachers to out-of-field teaching.[10]

Upskilling and professional development to bring teachers' content knowledge and qualifications to an acceptable level are possible policy options that have been suggested for reducing the prevalence of out-of-field teaching and consequent adverse effects on student outcomes (Goos et al., 2020; Kim, 2011; Prince & O'Connor, 2018). Faulkner et al. (2019) provided examples of such programmes in Ireland, England and Australia, which in the first two countries led to in-field qualifications. A programme was introduced in the Australian state of Victoria in 2021 that leads to in-field qualifications in mathematics for teachers who are currently teaching mathematics out-of-field to Years 7–10.[11] For retraining programmes to be successful, they must be well-designed and participating teachers carefully selected (Du Plessis, 2019; Faulkner et al., 2019; Hobbs, 2013; Hobbs & Quinn, 2020; Schueler et al., 2015). Goos et al. (2020) outlined several design principles underpinning the development and delivery of these programmes and stressed the importance of properly coordinating face-to-face and computer-mediated instruction in a blended programme to support active learning, peer interaction, access to a wide range of resources and opportunities to apply new knowledge in the workplace to enhance pedagogical richness. Professional development which does not necessarily lead to in-field qualifications, and mentoring for in-field and out-of-field teachers of mathematics, can surely only improve outcomes for students. The STEM Professionals in Schools programme organised in conjunction with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), which is the premier, public science research

[10] Some families enrol their children in government schools, but these tend to be highly selective and well-resourced.

[11] https://www.education.vic.gov.au/school/teachers/classrooms/Pages/pd-secondary-maths-science-initiative.aspx.

organisation in Australia, is one that offers mentoring by professional scientists to teachers.

4.7 Conclusion

Out-of-field teaching of mathematics is a serious and pervasive issue in Australia, affecting both teachers and students. The analyses reported in this chapter show that the problem is manifested unevenly in terms of which teachers are assigned to teach mathematics out-of-field, and in which contexts. While structural factors such as size of school and location play a major role, our analyses highlighted other important contextual factors having indirect association with schools' funding. We deduce that schools having better, long-term funding have an advantage in recruiting qualified mathematics teachers on permanent contracts, reducing out-of-field mathematics teaching in those schools. In contrast, schools on tighter and less predictable budgets having short-term funding are at a disadvantage. As these schools tend to rely on the temporary teacher labour market to fill short-term vacancies, they run a higher risk of not being able to find a teacher with the right subject qualification at the right time. The resulting disparity in the distribution of qualified mathematics teachers across schools exacerbates the existing divide in the quality of education across socioeconomic groups. While eliminating out-of-field teaching in mathematics across all schools may be a daunting aim, the uneven distribution of in-field mathematics teachers and resulting inequitable effects on students should be a policy concern in its own right. This should be prioritised in the deployment of teachers to schools and funding decisions. Schools can also monitor each student's exposure to out-of-field teaching to ensure no student is cumulatively inequitably exposed. These data would be useful to inform the system level, especially in government run schools, on where to best allocate resources to reduce the incidence and effects of out-of-field teaching in mathematics.

School principals' decisions on whether to assign teachers to teach subjects for which they are not qualified vary not only with the level of funding available to them but also on whether there is medium- to long-term certainty in this funding. Current funding decisions tend to favour non-government schools, providing them with more and predictable funding per student, which enables them to plan stable and secure staffing. Out-of-field teaching of mathematics is unlikely to improve until school systems acknowledge that principals and school communities can find themselves between a 'rock and a hard place' when assigning teachers to classes because of their circumstances. Identifying which teachers, in which contexts, are most likely to be assigned to out-of-field teaching in mathematics is the first step to inform policymakers and school leadership who have the agency to address the issue.

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Part II
Personal Contexts

Chapter 5
Understanding the Complexity of Science Teachers' Lived Experience as They Navigate Two Out-of-Field Areas: Implications and Possibilities

Emily Rochette

Abstract In the Australian state of Victoria, science teachers have professional duties to teach across biology, chemistry, Earth and space sciences and physics while seamlessly integrating digital technologies into their practice. Geoscience is the study of Earth's solid components and processes acting on them. It is a discipline that, like digital technologies, has been historically documented to be taught by out-of-field teachers. This chapter seeks to unpack the complexities of science teachers' lived experience by exemplifying how interview data from four 'in-field' teachers were analysed along the positioning triad (Harré & van Langenhove, 1999) as they reflected on their rights and duties teaching across this curricular intersection. Findings indicate implications for workplace professional learning and a need for pragmatic approaches to support this unique cohort of in-service teachers. The chapter concludes with recommendations for school leadership, theoreticians and policy makers to monitor and support teachers toward enacting the intended curriculum such that teachers' professional expertise in specialist areas can be translated and extended to out-of-field areas.

Keywords Digital technologies · Geoscience · Teaching across specialisations · Teaching out-of-field · Positioning theory

5.1 Introduction

Results from the Programme for International Student Assessment (PISA) in 2015 indicated "a substantial proportion of teachers in Australian schools are teaching STEM [science, technology, engineering and mathematics] subjects out-of-field" (Shah et al., 2020, p. 1). Teaching out-of-field refers to teachers, either assigned to or by choice, teaching subjects with little to no disciplinary training (Hobbs, 2014). However, the border between in- and out-of-field teaching can be difficult to identify (Ingersoll, 2019) particularly for multidisciplinary subjects like science. In

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Australia,[1] secondary science teachers are expected to teach across biology, chemistry, Earth and space sciences and physics. These teachers share similar experiences with their international colleagues where the historically accepted reality is that they may be highly accomplished in some science disciplines but not others (Carlsen, 1992; Kind, 2014; Nixon & Luft, 2015; Nixon et al., 2016; Sanders et al., 1993).

Here a distinction is made between *out-of-field science teacher* and *science teacher teaching out-of-field*. An *out-of-field science teacher* refers to a teacher who does not have a specialisation in any of the four disciplines of science. These teachers make up roughly 10% of science teachers in Australia (Weldon, 2016). A *science teacher teaching out-of-field* includes those teaching science disciplines for which they do not have a specialisation. For instance, a chemistry specialist teaches Earth science out-of-field when s/he does not have a personal history studying topics such as geology, meteorology, oceanography, soil and environmental science. As such one may call one to question whether any science teacher could be considered in-field. Although instances of teaching out-of-field are not of equal magnitude, understanding them "is essential to accurately assessing the quality and performance of teachers, schools and students" (Ingersoll, 2019, p. 27).

Added to this complexity is the expectation that science teachers seamlessly integrate digital technologies into their regular teaching practice. For example, teachers have a professional duty to scaffold students typically aged between 15 and 16 to:

> Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately. (Australian Curriculum and Assessment Reporting Authority [ACARA], n.d.-a)

This expectation has been placed on science teachers for some time (Australian Institute for Teaching and School Leadership [AITSL], 2011; Australian Science Teachers Association [ASTA], 2002). However, the literature demonstrates that teachers' use of technology varies considerably (Ertmer & Ottenbreit-Leftwich, 2013; Inan & Lowther, 2010; Somekh, 2008; Waight et al., 2014; Zhao & Frank, 2003) suggesting that the goals of the intended curriculum are met with varying success in the enacted curriculum.

Thus, an additional complexity may arise when a teacher's successful pedagogical practices enacted in their specialist discipline are not recognised as transferrable to an out-of-field discipline. For instance, a chemistry specialist might teach students how to use pH metres and data logging equipment to analyse the salt concentration in river water. Yet s/he may be unaware that the same data logging equipment used with distance sensors could model bathymetry studies mapping the ocean floor. In this sense, teachers might be considered to be teaching out-of-field across two areas of the curriculum: science and digital technologies.

[1] In 2009, the Australian federal government oversaw the establishment of a national curriculum from foundation to year 10 (Australian Curriculum and Assessment Reporting Authority, n.d.-a). Apart from the states of Victoria and New South Wales, the Australian Curriculum has been adopted by all other states and territories, however the content descriptions for these state-mandated curricula are comparable to the Australian Curriculum.

This chapter examines the curricular intersection between science and digital technologies. Interview data from four secondary science teachers are analysed through the lens of positioning theory (Harré & van Langenhove, 1999) to understand the intricacy of science teachers' lived experience as they interpret their personal capacity and professional duties to teach across this intersection. The findings have implications for workplace professional learning and highlight a need for pragmatic approaches to be in place to support out-of-field teachers to successfully attend to their professional duties.

5.2 Literature Review

Internationally teaching out-of-field has been shown to have implications for policy, initial teacher education, leadership, student outcomes and teacher identity, knowledge, practice and professional development (Hobbs & Törner, 2019a). However, there does not seem to be a consensus whether the phenomenon is a deficit or an opportunity. Hobbs (2013a, 2013b, 2014) describes teaching out-of-field as a boundary crossing event where specialist skills may not be applied to the out-of-field area. Boundaries are also porous, and teachers may reject the out-of-field label self-identifying as in-field and perpetuating unreflective practice (Hobbs, 2013b, 2014; Ríordáin et al., 2017). Many factors influence a teacher's appropriateness to teach out-of-field including context, support mechanisms and personal resources, yet when supported at their point of need teachers may reconceptualise their identity and practice (Hobbs, 2013a). This section introduces readers to some of the literature about geoscience and digital technologies education to unpack the curricular intersection which Australian science teachers are expected to navigate.

Geoscience is the study of the solid components of the Earth and the processes acting on them (King, 2008). It is a sub-discipline of Earth science that is becoming more prominent in schools internationally (King, 2008, 2013). Currently geoscience occupies a small, compulsory part of national science and geography curricula and may be available as additional or optional courses (King, 2015). Worldwide geoscience has been documented to be largely taught by non-specialist general science teachers (King, 2008, 2013, 2015). As such, geoscience tends to be viewed as less rigorous than other physical sciences (Lewis & Baker, 2010; Underwood, 2008).

Despite children having an interest in geological events (Trend, 2005) and possibly placing more value on Earth science than their teachers (Betzner & Marek, 2014), geoscience may be offered to students who are "unmotivated and unable to do *real* science like chemistry and physics" (Lewis, 2008, p. 446). In the state of Western Australia, data from 27 teachers and 243 students suggest that by secondary school students perceive Earth and environmental science concepts as difficult, boring or irrelevant possibly due to a lack of content knowledge from lower secondary school

(Dawson & Carson, 2013). Yoon and Peate's (2015) study of 300 American undergraduate students indicates that school experience has limited influence on students' conceptual understanding of Earth science.

In the state of Victoria, the Earth science content descriptions and achievement standards from the Australian Curriculum are more specific than those of previous curriculum documents (Victorian Curriculum and Assessment Authority [VCAA], n.d.-a; n.d.-b). However, this may not equate to better teaching and learning. In England and Wales, King (2001) reported that 10 years after introducing an Earth science component in the National Curriculum for Science, teachers' content knowledge continued to remain poor. Jenkins' (2000) survey exploring the effects of this curriculum on teachers' work indicated that chemistry teachers perceived Earth science to be taught at the expense of chemistry and that it presented difficulties for designing practical work. Geoscience is an historical, interpretive science (Dodick & Orion, 2003; Frodeman, 1995; Thompson et al., 2000) drawing on evidence to understand the structure and processes acting on the Earth, however this may not be apparent to science teachers teaching out-of-field because geoscientific epistemic practices are distinct from other science disciplines (Baker, 1996).

Teachers and students of geoscience must understand the interaction of Earth's biogeochemical systems (King, 2008). They need to be able to apply methodologies and attributes of fieldwork in multifaceted contexts, develop three-dimensional spatial thinking and use retrodictive reasoning often drawing on large, incomplete data sets that span vast timescales. Some scholars have called into question how teachers who have not had authentic geoscience experiences themselves can provide these learning opportunities for their students (Thomas et al., 2013). In their comparison of expert and novice Earth science teachers' problem-solving skills, Barba and Rubba (1993) caution against assigning teachers trained in other disciplines to teach Earth and space sciences. Crisan and Hobbs (2019) explain that "the school subject will be a simplified form of the discipline, according to how curriculum designers see fit to present a discipline to pupils" (p. 155). Yet, in schools teachers are the designers of the enacted curriculum and when they teach out-of-field, even the "simplified form of the discipline," they may not identify or draw on transferrable skills from specialist areas nor possess the capacity to model and develop students' geoscientific epistemic practices.

Geoscience is a modern science where cutting edge technologies yield evidence about Earth's structure and history. As such teaching geoscience with digital technologies could enable teachers to enact policy expectations placed on them to continually develop their capacity to utilise digital technologies (AITSL, 2011) and teach students' digital skills for understanding and communicating science in authentic contexts (ASTA, 2002) including inquiry (ACARA, n.d.-b). However, an underlying assumption within these policies is that science teachers have the personal capacity to teach inquiry with digital technologies.

Teachers' use of digital technologies varies considerably and depends on a number of factors (Ertmer & Ottenbreit-Leftwich, 2013; Inan & Lowther, 2010; Somekh, 2008; Waight et al., 2014; Zhao & Frank, 2003). Although teachers with constructivist beliefs tend to be active users of digital technologies (Ertmer & Glazewski, 2015;

Tondeur, van Braak, et al., 2017), the constructivist/traditionalist dichotomy is not clearly defined (Ertmer & Ottenbreit-Leftwich, 2013; Ertmer et al., 2014; Hermans et al., 2008; Tondeur, Hermans, et al., 2008) and teachers' beliefs about the nature of science do not always translate into constructivist practices (Chen et al., 2014). For some time the literature has suggested that teachers' digital technology use has focused on low-level, teacher-centred tasks (Russell et al., 2003; Tondeur et al., 2007) disconnected from best practice (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2010; Hermans et al., 2008; Prestridge, 2017; Tondeur, Pareja Roblin, et al., 2017; Tsai & Chai, 2012).

Brantley-Dias and Ertmer (2013) and Ertmer and Ottenbreit-Leftwich (2013) distinguish between *technology integration*, increased frequency of digital technology use, and *technology-enabled learning*, employing pedagogies to support students' content-based learning through the use of digital technologies. Here, these distinctions are used to differentiate between the appropriation of digital technologies and emphasise the quality of pedagogy when technologies are harnessed for technology-enabled learning. Google Earth, for instance, can be used to gather elevation profiles of volcanos and qualitative observations of the surrounding area challenging students to explain how different types of volcanos erupt through scientific reasoning rather than using technologies for drill-and-skill-type activities.

Ratinen and Keinonen's (2011) study of 10 pre-service teachers using Google Earth found that they had inadequate technological knowledge and required continued support to interpret and analyse data during problem-based learning. In Peters-Burton and Burton's (2016) study, a teacher with five years' experience in geology reflected that her planning was not influenced "much" by the nature of science. Both of these studies suggest that teachers may struggle to engage students in inquiry practices with digital technologies, highlighting that even when teachers are in-field with transferrable content and technological knowledge, policy expectations may not materialise. This chapter seeks to contribute to the discussion where scholars have called for more research into the nuances of digital technology use in the sub-disciplines of science (Waight et al., 2014).

5.3 Methodology

Positioning theory (Harré & van Langenhove, 1999) was the overarching methodology for this qualitative study and the lens through which teachers' interview data were analysed. To understand the meaning ascribed to individuals' actions, positioning theorists are guided by two principles (Harré & Moghaddam, 2003):

1. What people say and do hinges on judgement; and
2. Identity is a product of interpersonal interactions including what a person is permitted or forbidden to do, is physically and temperamentally able to do; and has done, is doing or will do (Harré, 2015; Harré & Slocum, 2003; Harré & van Langenhove, 1999).

Figure 5.1 illustrates the positioning triad, a framework to better understand an

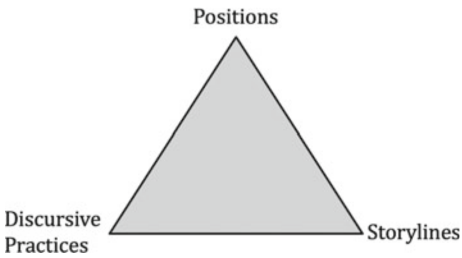

Fig. 5.1 The positioning triad

individual's interpretation of the system of rights and duties within which intentional acts are done (Davies & Harré, 1990; Harré & Slocum, 2003; Harré & van Langenhove, 1999).

Meaning making becomes evident through *discursive practices*, an individual's verbal and non-verbal symbolic exchanges, indicative of the normative frames through which people think, feel, act and perceive (Harré et al., 2009). The intended outcome of a discursive practice depends on how it is perceived by others (Davies & Harré, 1990; Harré & van Langenhove, 1999) and can span more than one conversation (Harré & Slocum, 2003; Harré & van Langenhove, 1999) exhibiting distinct effects. The discursive practices exemplified in this chapter were recorded from interviews as teachers reflected on their digital technology use in specialist areas and prepared to teach geoscience with digital technologies.

Positions arise from discursive practices and indicate power imbalances connected to perceptions of agency within the socio-temporal context (Davies & Harré, 1990; Harré & Slocum, 2003; Harré & van Langenhove, 1999). When individuals are positioned they have a limiting repertoire of acts to negotiate the social episode (Harré & Slocum, 2003). Herbel-Eisenmann et al. (2015) draw on more recent work by Harré (2002) to emphasise the rights and duties individuals claim while being positioned and positioning others. For example, curriculum documents assign teachers duties to teach across four disciplines of science. However, the extent to which teachers accept this positioning may depend on their interpretation of the assigned duty, perhaps some disciplines are given more attention than others, and their personal capacity to assume it, the extent to which teachers feel out-of-field. Thus, positions are distinct from roles in that they are dynamic and change moment-to-moment in conversation.

Notably, material objects like digital technologies may be positioned and re-positioned depending on how and by whom they are utilised (Harré, 2002). Material objects are non-living and thus unable to reflexively position themselves. As such, the repositioning of them arises from the personal agency expressed by the individual/s utilising them in distinct ways at certain times and places. Thus, material objects may enable individuals to position and re-position self and others. For example, *Google Earth enables me to teach inquiry skills as students collect elevation profiles to calculate the slope of volcanos*, i.e. the use of Google Earth positions a teacher to assume a duty to teach students geoscientific inquiry.

The extent to which positions are accepted or rejected is influenced by the history of interactions (Redman & Rodrigues, 2008) signalling plots in *storylines*. I draw on distinctions between cover, sacred and secret stories (Clandinin & Connelly, 1996) to understand the storylines emerging from teachers' lived experience. Cover stories are promoted by school administrators to the wider community: ***At our school, teachers are experts in their specialist areas, as a result students' standardised test scores are high***. Sacred stories are the theory-driven view of practice shared by teachers, policy makers and theoreticians: ***Science teachers should teach content knowledge and inquiry skills in the classroom***. Secret stories are about classroom practice and can indicate tension between the cover and/or sacred stories: ***What are the three types of rock? Classic, punk and hard… I'm a chemistry teacher!***

Pronoun grammar analysis (Mühlhäusler & Harré, 1990; Redman, 2013; Redman & Fawns, 2010) is an analytical tool that aids in the fine-grained analysis of textual data (Redman & Fawns, 2010). Positioning theorists focus acute attention to participants' un/intentional use of pronouns, phrases, qualifying words and paraverbals. These language features signify shifts in storylines within and between conversations as participants interpret their own and others' rights and duties. For instance, an individual's use of "I", "me" or "my" may indicate that ideas under discussion are personally located in the speaker's narrative, signalling personal beliefs and commitment to ideas.

5.4 Preparing to Teach at the Geoscience/Digital Technologies Curricular Intersection: Analysis and Key Findings

The data collated and analysed in this chapter are drawn from a wider study of 10 secondary science teachers at an inner-city, government school in Melbourne, Australia. Like other contexts internationally (King, 2008, 2013, 2015; Lewis & Baker, 2010; Underwood, 2008) geoscience had yet to earn its way into the enacted curriculum as a topic approached with the rigour of biology, chemistry and physics. The study aimed to support science teachers teaching out-of-field with digital technologies. Table 5.1 summarises the teaching experience and specialist areas of

Table 5.1 Teachers' experience and specialist areas

Pseudonym	Teaching Experience* (years)	Specialist Area(s)
Isabelle	13+	Junior science and senior chemistry
Olivia	10+	Junior science, senior chemistry and psychology
Mary	7	Junior science and senior chemistry
William	10	Junior science and senior physics

*The '+' sign indicates teachers had more experience than stated but did not specify further four teachers who participated in interviews to reflect on their digital technology use as they prepared to teach geoscience. Despite varying years of experience, all participants identified as science teachers teaching geoscience out-of-field.

5.4.1 Teachers' Use of Digital Technologies in Specialist Areas

This section presents examples of teachers' reflections about their digital technology use in science alongside analyses informed by positioning theory. The reflections have been organised along a continuum from technology integration, increased frequency of digital technology use, toward technology-enabled learning, using technology to teach inquiry skills.

Isabelle explained how she draws on the textbook, a trusted resource, to utilise interactive software produced by publishers:

> Even for, um, chemistry, um, modelling the periodic table, there's different activities. I can't remember 'em off the top of my head but I've got a whole heap of them that I use and, um, putting compounds together and there's different websites [...]

Isabelle positions herself as a chemistry specialist. Despite the abstract nature of the subject, there are "even" activities modelling the periodic table and formation of compounds. However, she struggles to articulate how these interactive activities develop students' science understanding beyond "emphasising points." As such, a secret story emerges that indicates Isabelle may integrate digital technologies into her lessons, "I've got a whole heap of them," rather than utilise them for technology-enabled learning.

Like Isabelle, Olivia seemed to require support to utilise digital technologies for technology-enabled learning. She reflected on the data logging equipment the science department had purchased a few years ago:

> I don't use them [data loggers] very much, um, and I'm not all that excited about them. [A]nd sometimes they mess up, they don't work. [A]nd the whole thing's, m-um, the whole lesson's wrecked.

Olivia defers to her professional duty to assess the value of the technology and her right to choose whether or not to use it. She positions the data loggers as barriers to technology-enabled learning because she perceives them to compromise her lessons. Olivia's lack of personal history using the data loggers, however, indicates tension between the sacred and secret stories: ***Some of my colleagues use data loggers for science inquiry, but I'm not sure how they work***.

Unlike Isabelle and Olivia who reflected on specific technologies, Mary self-assessed her use of digital technologies:

> [M]aybe I'm not u-I-I'm not facilitating its use to the potential that it could have the best outcome for the child. I think that sometimes it's easy for you to use something and then it's not really tapping into their higher-order thinking [...]

When planning with a team of colleagues, Mary explored digital technologies new to her practice and she seemed confident to manipulate them. However, Mary's perceptions about her ability to facilitate digital technology use may constrict her capacity to incorporate them in her classes to foster technology-enabled learning. Tension between the sacred and secret stories emerged: ***I have a duty to facilitate higher-order thinking with digital technologies; I'm interested in exploring this, but I require assistance***.

William harnessed the affordances students' personal devices in physics experiments:

> [A]ll-all smart phones have accelerometres on them, but they [students] don't know about this, so you have to actually physically tell them.

Using the qualifying word "actually" William implies certainty that students are unaware that their mobile phones can act as data loggers. He reflexively positions himself with a professional duty to teach inquiry through the use of mobile phone technology. Here a sacred story emerges: ***Students' personal devices can be harnessed to teach inquiry in physics***.

As a confident digital technology user, William is empowered to produce lessons to teach inquiry with digital technologies, setting him apart from Isabelle, Olivia and Mary who were teaching science in-field but out-of-field with digital technologies. Figure 5.2 summarises these findings.

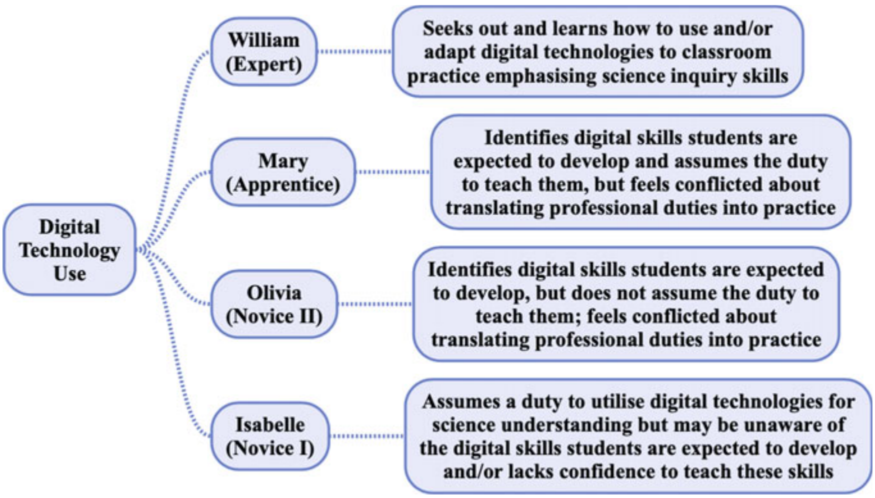

Fig. 5.2 Continuum of digital technology use in specialist areas

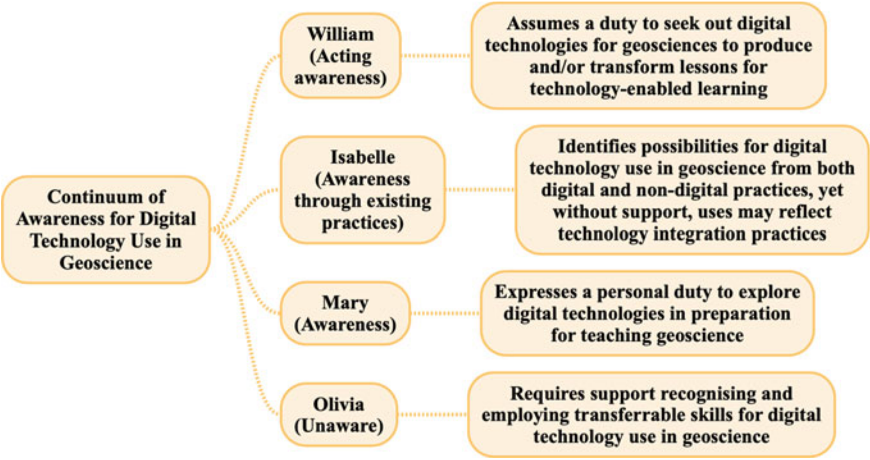

Fig. 5.3 Continuum of awareness for digital technology use out-of-field

5.4.2 Teachers' Perceptions and Use of Digital Technologies in Geoscience

In the previous section, teachers' reflections of their digital technology use were closely linked to their specialist areas. Teachers participating in this study had varying professional histories teaching geoscience and so were invited to respond to the prompt: "Digital technologies that could be used in geoscience are…" Below teachers' reflections are organised along an awareness continuum for digital technology use from being unaware toward an awareness for technology-enabled learning, see Fig. 5.3.

Olivia was an experienced classroom teacher and had held the role of science coordinator prior to entering school leadership, however she did not yet have a professional history teaching geoscience. Olivia explained that prior to the implementation of the Australian Curriculum, geoscience "didn't have much of a […] presence" in state-mandated curriculum documents and she did not position herself as able to respond to the prompt, "I don't know. […] I can't help with that." Notably, Olivia did not reflect on her current digital practices, using educational games and online websites, as transferrable to the geoscience classroom. A secret story emerged: ***Although I'm a science specialist, I'm not aware of digital technologies that could be used to teach geoscience***.

Mary was committed to offering students an equitable curriculum: "What gives one area of science more merit than another?" Like Olivia, she did not have a professional history teaching geoscience, yet Mary explained:

> I think there is-there are things out there. Um, I-do I know what they are? Maybe not. [...] I would say that honestly, I would need to do a bit of research into that.

Here, Mary uses the personal pronoun "I" as she positions herself with a professional duty to research digital technologies. A sacred story emerges: ***I anticipate sourcing classroom materials to incorporate digital technologies into my out-of-field practice***. What that might look like in the classroom, however, would depend on Mary's confidence with the discipline. She reflected: "I find that I need to have almost a bit of a traditionalist approach to begin with," suggesting that digital technologies would be integrated rather than used for technology-enabled learning.

Isabelle had a recent history teaching geoscience with year nine students, typically aged between 14 and 15 years old. She reflected on her classroom use of a blockbuster video:

> [T]hat's [Dante's Peak] more of entertainment rather than anything else [... A]lthough it has got volcanos and so forth, I don't think it actually goes into the plate tectonics that much. It was a reward at the end [of the year].

Isabelle assumes a self-ascribed duty to reward students knowing that doing so does not reflect what she perceives to be best practice, utilising digital technologies for revision. For teachers with a strong geoscience content knowledge, the film could be used as a provocation for students to demonstrate their understanding by evaluating the media industry's portrayal of science. Yet, for Isabelle, a secret story emerged: ***Sometimes I use digital technologies as a reward without learning intentions***.

William also had a recent history teaching geoscience, however, unlike Isabelle, he endeavoured to engage students in technology-enabled learning. Reflecting on a Christmas cake mining activity in the year eight rocks and minerals unit he explained:

> [I]t was all about "How much money have I got?" and then I had random, (laughs) it was so funny, at one stage I said: "Ok, there's been a-there's been a major weather incident." And I went around with a random calculator and then I said: "Push this button," and a random number [came up] and I said: "Oh, no! It's cost you $1,000 in the mine! No!" And then they'd go: "Oh, it's only cost us 100 bucks!"

William used a random number generator on a calculator to model reclamation costs and rehabilitation fines as students mined Christmas cake for precious metals. Although William seemed to be unaware of digital technologies that could be used to collect real-time data with students, such as Google Earth, he is well-known for seeking out and learning how to utilise/adapt digital technologies for inquiry. This is a self-ascribed professional duty that seemed to inspire a sense of job satisfaction and reflects the sacred story: ***My digital practices are transferrable even when I'm developing a personal history teaching out-of-field***.

5.5 Discussion

The continua illustrated in Figs. 5.2 and 5.3 are grounded in the fine-grained analysis of William, Mary, Isabelle and Olivia's reflections of their digital technology use across both their science specialist areas and in geoscience, an out-of-field discipline. Comparing the sacred stories with emergent secret stories highlights tensions between teachers' professional duties identified in policy documents and their perceived personal capacity to enact them. To my knowledge, utilising Clandinin and Connelly's (1996) stories as a framework within the positioning triad (Harré & van Langenhove, 1999) has not yet been applied to understand the out-of-field teaching experience. As such, these continua offer insight to the degree these teachers were teaching out-of-field as they negotiated their sense of empowerment and awareness to produce and transform their lessons from technology integration toward technology-enabled learning.

William's experiences seemed to set him apart from Isabelle, Olivia and Mary. Across both his specialist and non-specialist areas William was able to seek out and learn how to use and/or adapt digital technologies for technology-enabled learning. Unexpectedly, Isabelle, Olivia and Mary seemed to be teaching out-of-field in two areas of the curriculum: digital technologies and geoscience. In their specialist areas, Isabelle and Olivia planned experiences for students to explore content understanding through educational games and drill-and-skill-type activities. They did not reflect on this use of digital technologies as transferrable to geoscience nor were they aware of technologies that could be used for geoscientific inquiry. Mary also seemed to be traversing a new pedagogical environment where the technology-enabled inquiry practices she explored in chemistry, albeit tentatively, would take time to develop in geoscience, if at all. These findings support the work of Sanders et al. (1993) who have found that experienced teachers approach unfamiliar science disciplines in ways that resemble their novice colleagues. In addition, they are worthy of consideration as teachers are expected to offer STEM experiences to students while negotiating the distinct content knowledge to meaningfully integrate engineering and mathematics into their science and technology lessons (Luft et al., 2020).

Hobbs and Törner (2019b) explain that out-of-field teachers face challenges that can "restrict, hinder or work against teacher learning" (p. 5); attention has also been drawn to the importance of the school context including the support mechanisms, structures and patterns of engagement to determine how out-of-field teachers feel part of their subject areas (Hobbs, 2020). For some time it has been understood that teachers who have participated in the planning process for implementing information and communications technology (ICT) policies in their schools use technology more regularly and in innovative ways (Kozma, 2003; Tondeur, van Keer, et al., 2008).

Notably, the secondary school within which these teachers were working had not yet developed an institutional policy for digital technology use across the learning areas. In the absence of a formal programme of digital experiences for students *and* teachers' varying degrees of personal and professional history utilising them Mary, Isabelle and Olivia were not able to identify the pedagogical possibilities for digital technology use and/or intuit successful practices from their specialist areas to apply them to the out-of-field teaching context. Hobbs (2020) has explained that specific to the learning needs of out-of-field teachers is understanding the importance of "cross-fertilisation of pedagogies between in- and out-of-field teaching" (p. 738). What might this mean for teachers who may be unable to identify and confidently apply these skills to out-of-field areas?

Du Plessis et al. (2019) report that teachers' enjoyment and confidence teaching out-of-field improved when:

> [...] they saw their knowledge of curriculum, content and teaching approaches improving; they sought and received support from colleagues; there were productive relationships with colleagues especially where there were mentors; and there were positive outcomes and relationships with their students'. (p. 223)

Similarly, teachers' decisions to utilise digital technologies are largely influenced by a practicality ethic where they acknowledge feasibility and benefits of use within the constraints of classroom practice (Pareja Roblin et al., 2018). Ertmer (2016, 2017) and Ertmer and Glazewski (2015) suggest that teachers require support with initial steps toward change if they are to explore pedagogical possibilities with digital technologies and negotiate new roles for themselves and their students. Perhaps expert digital technology users, like William who harnessed his right to explore and utilise a range of digital technologies while planning for and skilfully refining his practice, could serve as mentors offering their in-service colleagues support to cultivate pedagogical skillsets in out-of-field areas. This in-house professional learning, however, requires the support from the broader institutional setting within which teachers work.

5.6 Conclusion and Recommendations

Luft et al. (2020) call for research into professional learning programmes for in-service teachers teaching out-of-field. This exploration of teachers' reflections about their personal capacity and professional duty to enact state-mandated curricular expectations demonstrates that the experiences of in-service science teachers teaching out-of-field is better understood as a complex, ongoing development and refinement of classroom pedagogies. It highlights a need for pragmatic approaches to be in place to support teachers to attend to their professional duties and supports the work scholars who explain that professional learning must be tailored and respond to the needs of individual teachers (e.g. Darling-Hammond et al., 2017; Du Plessis et al., 2014; Kenny et al., 2019; Korthagen, 2017; Ríordáin et al., 2017). As such the following recommendations are offered to school leaders, administrators and those in positions with responsibilities to monitor and support teachers toward enacting the intended curriculum equitably:

1. School leadership, including information technology support and those responsible for finance, must work toward offering and sustaining formal programmes of digital experiences for students that are informed by subject-specialists;
2. Theoreticians and school leadership should develop and provide differentiated professional learning opportunities for teachers which take into account not only their teaching experience but also their pre-existing skillsets for targeted professional growth; and

3. Teachers must be afforded the time and space to meaningfully plan for and enact these experiences together *and* with subject-specialists through supportive timetabling practices such that they consistently develop and refine their pedagogical practices.

The findings presented here[2] and the recommendations offered reflect a respect for teachers' work and their capacity as professionals to make informed choices to act when they are supported at their point of need. In this way, out-of-field teachers can be afforded opportunities to re-position themselves as increasingly agentic professionals implementing effective use of digital technologies across specialist and out-of-field areas. Notably, these recommendations may have international implications, particularly in a time when a variety of stakeholders rely on teachers' digital technology use to help combat global health issues.

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[2] For further insight into the wider study, see Rochette, E. (2020). *Teaching geoscience out-of-field with digital technologies: Understanding agency through positioning theory* [The University of Melbourne]. Melbourne, VIC.

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Chapter 6
Teaching English Out-of-Field in Primary School: Differences in Professional Characteristics and Effects on Self-Assessed Instructional Quality

Raphaela Porsch and Eva Wilden

Abstract First, this paper seeks to explain why a substantial number of primary English as a Foreign language (EFL) teachers in Germany are not or not fully qualified for teaching EFL. Second, it presents empirical findings on the question of whether subject-specialist teachers and non-specialist teachers differ in relevant professional characteristics. Findings will be reported from the 'Teaching English in Primary Schools' (TEPS) study conducted in Germany in 2017. The study surveyed 844 primary school teachers teaching EFL with and without subject-specific training. The results show statistically significant differences in subject-specific enthusiasm and self-reported EFL proficiency. Furthermore, perception of instructional quality of the teachers was found to be positively related to their subject-specific enthusiasm and EFL proficiency. The article concludes by giving recommendations for the design of in-service professional development courses for out-of-field teachers.

Keywords English as a foreign language (EFL) · Enthusiasm · Germany · Instructional quality · Out-of-field teaching · Primary school teachers

6.1 Introduction

Parents and students alike expect that teachers who teach a foreign language are proficient speakers of the language and are passionate about teaching it. However, this might not be the case when teachers teach a language without the respective subject-specific qualification. In the context of this study, such teachers will be referred to as out-of-field teachers. The present study focuses on professional characteristics and instructional quality of German primary school teachers who regularly teach EFL (English as a foreign language) but differ in their formal qualifications. More

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precisely, in our survey of more than 800 primary school teachers currently teaching EFL only about 40% had completed a university degree in English. The study specifically seeks to explore potential differences in professional characteristics, such as subject-specific enthusiasm and foreign language (FL) proficiency, among primary EFL teachers with different qualifications. Three types of qualifications were identified, that is, fully trained EFL teachers, teachers who had completed post-graduation courses in teaching EFL and teachers who had been trained only in subjects other than English. In addition, we investigate the relationships between these personal characteristics and the self-reported instructional quality of their EFL teaching.

Research on teacher education has emphasised the link between teachers' professionalism, classroom practices, and students' competencies (Kunter, Klusmann et al., 2013). National and international large-scale-assessment studies that investigated teachers with different qualifications have predominantly analysed the effects on students' proficiency and have found mixed results (Porsch & Whannell, 2019). Robust results in secondary STEM education suggest that students can be disadvantaged by being taught by out-of-field teachers (e.g. Richter et al., 2019). Also, some studies have found differences in students' proficiency scores at primary level that can be explained by the lack of teachers' subject-specific qualification (e.g. Klusmann & Richter, 2014). Researchers have shown lower student scores with the potentially less adequate teaching practices and lower instructional quality of teachers teaching a subject without having been adequately trained. However, there are only a few studies that look at the professional competences (e.g. Porsch & Wendt, 2016) or practices (e.g. Du Plessis, 2013) of teachers with various qualifications. Even less attention has been paid to the assumption that instructional quality might be lower when teaching out-of-field.

This article first introduces primary teacher education in Germany with a special focus on teaching EFL out-of-field. Following this, the constructs considered in our study will be sketched out, that is: teacher enthusiasm, self-reported EFL proficiency as well as instructional quality. Next, research methods will be described followed by the findings of the present study. The paper concludes by giving recommendations for designing in-service professional development courses targeting out-of-field EFL primary teachers.

6.2 Context of the Study

6.2.1 Primary School Teacher Education in Germany

In Germany, education and teacher education is based on the federal system. As a result, teacher education programmes and other features of the educational systems differ between the 16 federal states. However, there are a few general characteristics across states: children attend primary school starting around the age of six. After four years (in 14 states) or six years (in two states) of primary education, they move on to secondary school. After 12 or 13 years of education, students obtain the 'Abitur', an equivalent to the high school diploma in the US.

At the university level, prospective teachers study for about five years to obtain both a Bachelor's and Master's degree (the so-called first phase). Within this time most universities require pre-service teachers to complete at least three practical trainings.[1] Relatively new in a majority of states is the so-called practical semester. Teacher students spend about five months observing and teaching at a school and conducting an empirical or action-research study. After graduating from university, prospective teachers then attend a pre-service school-based teacher training course that lasts 16–18 months (depending on the state; the so-called second phase). After passing a state exam, teachers receive a teaching certificate that allows them to teach at primary level.

A high degree of diversity among the states exists with regard to the number of obligatory subjects primary student teachers study as part of their teacher training. It depends on the state whether the pre-service teachers study two or more subjects and whether there are any limitations on their choice of subjects. A recent review of the primary teacher education models in the 16 states, based on official documents (Porsch, 2020), revealed the existence of three main models of primary teacher education classified by the number of school subjects included in the first phase (at university) and second phase (post-graduate teacher training):

1. An education for specialists of two subjects (1 state);
2. An education for generalists with a training in three or more subjects (11 states); and
3. Hybrid models in which three or four subjects are studied at university but only two subjects are part of training in the second phase (4 states).

At present, both Mathematics and German, as the only official language in Germany, are compulsory for primary teacher training (year 1–4/6) in 15 states. However, a similar analysis conducted in 2016 showed that this was only the case in 12 states (Porsch, 2017). This development can partly be explained by recommendations from 2013 of The Standing Conference of the Ministers of Education and Cultural Affairs (KMK) as the central coordinating committee for the 16 states.

6.2.2 *Teaching English Out-of-Field in German Primary Schools*

Strictly speaking, the term out-of-field only applies to primary school teachers who did not participate in any subject-specific training and thus did not obtain a certification for a school subject which they teach regularly. As outlined in the previous section, a small shift from specialist to generalist education can be observed as one

[1] 1 Practical trainings or internships are periods where teacher students spend time in a school and other professional domains and are mentored by both school and university teachers.

way to prevent teachers from teaching out-of-field. However, with some exceptions, in many German states teacher students are given the freedom to choose their third subject at university. Depending on the size of the university, a wide range of subjects such as EFL, physical education, social and science studies, music, or arts are offered. In-field teachers or 'experts' (Porsch, 2016) are teachers who obtained their subject-specific training in the first and second phase of initial teacher education. Thus, internationally they would be characterised as teachers with a major in EFL plus a state examination. A further group of primary school teachers who teach EFL regularly can be called 'semi-experts' (Porsch, 2016). These teachers were initially qualified for subjects other than English. When already working as primary teachers they then participated in short-term post-graduate, in-service trainings. However, these professional development courses for primary school teachers mainly focus on EFL teaching methods and provide only little training in the target language.

Another aspect increases the diversity among primary EFL teachers' qualifications even further. Due to the so-called class teacher principle, the teacher in a given primary class will teach the majority of lessons (and subjects). Thus, while primary school teachers may not possess any or a full training in EFL, they are teaching EFL regularly due to the class teacher principle. Therefore, due to the structure of German teacher education as outlined above, out-of-field teaching is likely to happen. In addition, a general lack of teachers or teachers trained for certain subjects is a phenomenon in many states at the moment and also causes out-of-field teaching in many contexts. Based on this situation in Germany, one can expect a relatively high proportion of teachers teaching EFL out-of-field in primary schools. Unfortunately, only a limited number of statistics about the prevalence in primary schools and in particular in teaching EFL are available (see Table 6.1). Official documents rarely give the respective numbers for the primary level and justify this on the class-teacher principle.

Table 6.1 shows that the proportion of out-out-field teachers teaching EFL in primary school differs between the studies. This also relates to the underlying definition of out-of-field teaching as well as to the question of whether alternative ways to obtain a subject-specific teaching certificate were considered. Overall, the proportion of out-of-field primary EFL teachers is rather high considering that the standard is a two-phase teacher training.

6.3 Literature Review

6.3.1 Teachers' Professional Competence

The competence-oriented perspective focuses on teachers' knowledge, competencies, beliefs, and characteristics such as motivational aspects necessary for effective teaching (Baumert & Kunter, 2013). According to this notion not only is teachers' knowledge, but also other characteristics such as motivational characteristics, vital

Table 6.1 Overview of studies reporting the qualification of EFL teachers in primary school in Germany

Author and year	Year of survey	Year, State (proportion or number of students/teachers/schools)	Qualification of EFL teachers
May (2006)	2003	Year 4, Hamburg (teachers of 5,410 students; n not given)	29.9% EFL major vs. 70.1% major in other subjects (79.4% post-graduation in EFL, 18.6% EFL major + post-qualification, 24.4% other qualifications)
Kolb (2009, 2011)	2007	Year 4, Baden-Wuerttemberg (787 teachers)	22% EFL major 59% post-graduation in EFL 19% no EFL education
Nieder-sächsisches Kultus-ministerium (2011) [Ministry of Lower Saxony]	2010	Year 1–4, Lower Saxony (2,332 teachers: 2,042 from primary school, 121 from schools for SEN students, 169: no information given)	60% out-of-field (major in other subjects than EFL)
Barucki et al. (2015)	2013	Year 4, all states except Saarland (98 teachers)	50% had studied English as a major or minor vs. 50% major/minor in other subjects
Ziegler et al. (2019)	2012/2013 to 2016/2017	Years 1–6, Berlin (all 359 primary schools)	40 to 32% of lessons taught out-of-field (no major obtained for EFL, no certification after a post-graduation course, or no further certification type, e.g. being a native English speaker)

Note Length and contents of post-graduation courses differ between the states but are mostly focused on methods (teaching EFL in primary school)

for high-quality teaching. Kunter, Kleickmann et al. (2013) provide a model of the determinants and effects of teachers' professional competence (see Fig. 6.1) that illustrates this relation.

The model assumes that professional competence develops when learning opportunities are provided and utilised during pre-service education or after initial teacher education. These learning opportunities are essential for professional practice such as teaching and further tasks in the school context (e.g. counselling). Based on this model is the assumption that teachers who teach a subject without having a subject-specific qualification were not provided with sufficient learning opportunities. As a

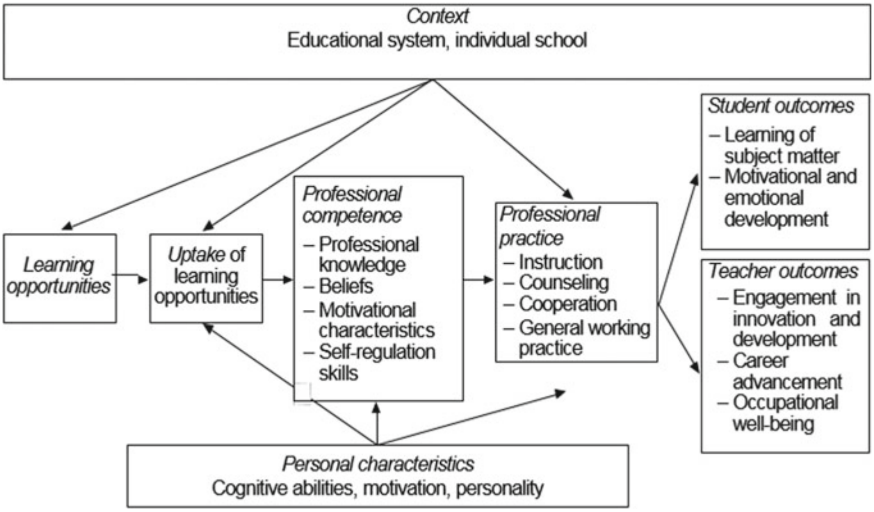

Fig. 6.1 Model of the determinants and consequences of teachers' professional competence (from Kunter, Kleickmann et al., 2013, p. 67)

consequence, they may lack professional competence. Teachers professional competence comprises 'specific declarative and procedural knowledge (competence in the narrow sense: knowledge and skills), professional values, beliefs, and goals, motivational orientations, professional self-regulation skills' (Baumert & Kunter, 2013, p. 28).

Even though researchers on teachers' professionalism seem to agree on the idea of multiple facets, research on the phenomenon of out-of-field teaching has mainly focused on the impact of teachers' subject qualification on students' proficiency (Porsch & Whannell, 2019). However, various teacher characteristics should be considered in order to fully understand why a number of studies have shown that students taught by out-of-field teachers tend to be less proficient than those taught by subject specialists (Porsch & Whannell, 2019). Only a small number of studies have analysed individual characteristics, such as the self-efficacy beliefs of teachers with different qualifications. Findings indicate that the majority of out-of-field teachers consider themselves as less proficient in comparison to in-field teachers (e.g. Porsch & Wendt, 2016). Hobbs (2013) also suggests in her qualitative work that 'teacher commitment' (Hobbs, 2013, p. 290) or 'passion' is important to being a good teacher, also referred to as teacher enthusiasm in other studies (e.g. Keller et al., 2016).

In this article, findings are reported from the 'Teaching English in Primary Schools' (TEPS) study conducted in Germany in 2017. In particular, we will focus on three constructs, namely teacher enthusiasm, FL proficiency, and instructional quality. As pointed out, we consider teacher enthusiasm, and in particular enthusiasm for teaching English and proficiency in the foreign language, as crucial for successful language teaching. Ultimately, teachers are expected to provide high quality teaching. Thus, we further look at how teachers with different qualifications perceive instructional quality in their EFL teaching.

6.3.2 Teacher Enthusiasm

Researchers differentiate between experienced and displayed enthusiasms (see Keller et al., 2016, p. 745). Based upon the idea of 'teacher commitment' and 'passion' (Hobbs, 2013, p. 290), or the 'energy' (Rosenshine, 1970, p. 499) teachers invest in their teaching, displayed enthusiasm refers to 'the degree of enjoyment, excitement, and pleasure that teachers typically experience in their professional activities' (Kunter et al., 2008, p. 470). In general, studies have shown that teacher enthusiasm has positive relations to students' interest, motivation, and level of enjoyment (Keller et al., 2016, p. 761). Moreover, teachers' experienced enthusiasm is positively related to instructional quality, namely learning support and classroom management (Kunter, Klusmann et al., 2013). In addition, Kunter et al. (2011) 'theoretically and empirically differentiate two forms of experienced enthusiasm, namely topic-related enthusiasm in which teachers can be excited about the subject that they teach and activity-related enthusiasm in which teachers are excited about teaching itself' (Keller et al., 2016, p. 748). Thus, one can further differentiate between subject-specific enthusiasm and teaching enthusiasm.

'When teaching out-of-field, there is no taken-for-granted alignment with the subject, so justification for teaching a subject must come from somewhere else in the teacher's background, some positive interaction, interest or pattern of success that enables the teacher to relate to it or identify with it' (Hobbs, 2013, p. 290). Accordingly, enthusiasm is important to consider in the context of out-of-field teaching because if teachers are only 'filling in' (Hobbs, 2013, p. 291) when asked to teach in contrast to those who 'pursue an interest' (Hobbs, 2013, p. 291), teachers' enthusiasm might be low. Teaching a subject out of interest can be particularly expected from those who have obtained a major in this subject. In particular, we assume that teachers with a subject-specific qualification score higher on the subject-specific enthusiasm scale than participants who obtained no training at all or only a short-term training in teaching EFL. Two reasons can be provided for why out-of-field teachers might be less enthusiastic about teaching subjects for which they had no or incomplete training. First, the choice of (school) subjects highly depends on personal interests (Winteler et al., 1988). As specific interests are positively correlated with achievement (Köller et al., 2001), it is likely that teachers on purpose excluded EFL (or any subject they have to teach out-of-field later in their career) from their choice before starting teacher education. Second, out-of-field teachers may have had no or less positive experience(s) in teaching the out-of-field subject or perceive shortcomings and feel insecure which might prevent positive emotions while teaching. Besides, they may have not received any constructive feedback from experts as mentoring is mainly implemented in the second phase of teacher training.

6.3.3 Foreign Language Proficiency

EFL teachers need language processing and production skills, knowledge of language learning strategies, of language teaching strategies, knowledge about learners' development, and ways to communicate in different cultural settings (Roters, 2017). FL proficiency is considered an essential element of a teacher's professional competence as the FL should be the main language of instruction. Rossa (2013, p. 30) emphasises the double function of the target language in FL education as both the learning objective and medium of communication. Thus, in the context of EFL education learners' development highly depends on their teachers' target language skills. An interview study by Deters-Philipp (2018) in German primary schools reveals that EFL teachers' confidence in speaking English is closely related to the teachers' formal qualification. Some out-of-field teachers feel less secure in using the target language, a fact that can be explained by the likelihood that these teachers learned English at school but not at university. In lower secondary EFL education out-of-field teachers use the target language less often in the classroom than in-field teachers and have a lower language proficiency than those with a major in EFL (Dörr, 2018). Unsworth et al. (2015) in a study in the Netherlands found a positive relation between the FL primary school students' language skills and the level of oral language proficiency of EFL teachers in primary school. A further analysis from our project reveals that primary school teachers with an EFL major reported using the FL more often in the primary EFL classroom than formally less or unqualified teachers who reported a more frequent use of the German language (Wilden & Porsch, 2020). This underlines that a fully qualified EFL teacher is more likely to provide adequate language input than teachers who did not partake of such a subject-specific training.

6.3.4 Instructional Quality

Professional competencies of teachers are considered relevant to ensure high quality of teaching and learning. Various aspects or criteria have been suggested that determine instructional quality valid for all subjects (e.g. Brophy, 1999). Klieme et al. (2001) introduced a model describing qualitative teaching using three dimensions that became known as deep structures of instructional quality: supportive climate or individual learning support, (potential for) cognitive activation, and (effective) classroom management.

Supportive climate relates to learners experiencing autonomy, e.g. through positive and appreciative teacher feedback or a constructive recognition of mistakes as a resource for learning. Cognitive activation refers to challenging tasks which allow learners to explore and change subject-specific concepts. Classroom management relates to the prevention of interruptions and discipline issues, e.g. through routines and swift transitions in order to ensure as much time on task as possible (Wilden et al., 2020, p. 32).

Kunter and Voss (2013) point out: ‘In order to empirically examine instructional quality, we need to reduce this complexity to make the construct measurable. This requires a domain-specific approach’ (p. 100). However, these three core dimensions have proved to provide a solid basis for developing reliable scales to measure the instructional quality in a variety of subjects as numerous studies have shown (e.g. Fauth et al., 2014). With regard to the EFL context Thaler (2014) claims that the notion of cognitive activation is only partly applicable to EFL education (also see Wilden, 2021). Instead, he suggests the term communicative-cognitive activation, thus addressing the aforementioned double function of the target language and taking the subject-specific kind of activation by means of providing stimulating language tasks into account. So far, no studies could be identified that have researched the instructional quality of primary EFL education based on the model. In order to provide their students with learning opportunities that include these three dimensions, teachers need professional competencies to then implement these dimensions in their professional practice. Again, no studies could be found that explicitly focused on the instructional quality of EFL out-of-field teachers.

6.4 Research Questions and Hypotheses

This study addresses the following research questions about the possible effects of teacher qualification on enthusiasm, FL proficiency, and instructional quality:

1. Do EFL primary school teachers with different professional qualifications differ in their subject-specific enthusiasm?
    a. H1a: Teachers with a major in EFL are more enthusiastic about teaching than EFL teachers who majored in other subjects.
    b. H1b: There is no difference between teachers with and without an EFL major in their teaching enthusiasm.
2. Do EFL primary school teachers with different professional qualifications differ in their self-assessed FL proficiency?
    a. H2: Teachers with a major in EFL consider themselves as being more proficient in English than those who majored in other subjects.
3. Does the subject-specific qualification, teacher enthusiasm, teachers’ FL proficiency, and the teaching experience explain the (self-assessed) instructional quality of EFL lessons?

6.5 Methods

6.5.1 Sample and Procedure

Data was gathered in 2017 through a computer-based survey among German primary teachers who were at that time teaching EFL in grade 4. Participation in the study was voluntary. For all 844 primary school teachers surveyed German was the L1 (95.9% were female; age: $M = 40.68$ years, $SD = 10.09$). Furthermore, they differed as follows in their professional qualifications: 40.2% ($n = 339$) obtained English as a major, 47.8% ($n = 404$) participated in a post-graduation course in EFL, and 12% ($n = 101$) had obtained no professional training for teaching EFL. The teachers differ in their teaching experience. Teaching experience was measured by the number of years of teaching EFL after the second phase of teacher training ($M = 9.28$, $SD = 6.44$). The teachers with a major in EFL had about 8 years of teaching experience ($M = 8.35$, $SD = 7.98$). Teachers who participated in a post-graduation course in EFL were more experienced with about 10 years ($M = 10.53$, $SD = 4.64$). The fully out-of-field teachers have taught EFL at schools for about 7 years ($M = 7.38$, $SD = 5.79$).

6.5.2 Instruments

Enthusiasm: 'Subject-specific enthusiasm' was measured with a four-point Likert scale (5 items, $\alpha = 0.90$, $M = 3.07$, $SD = 0.69$). The same applies to 'Teaching enthusiasm' (6 items, $\alpha = 0.88$, $M = 3.64$, $SD = 0.41$). The items were translated from Kunter et al. (2016, pp. 103–107). Only the wording of items measuring subject enthusiasm was changed slightly to fit the context. For example, the item 'My subjects are important to me.' was changed to 'English as a subject is important to me.'

FL proficiency: All teachers were asked to self-assess their FL proficiency (English). To this end, the Common European Framework of Reference for Languages (CEFR) for speaking was adapted covering the levels A1 to C2 (Council of Europe, 2001; 6 items, $\alpha = 0.88$, $M = 3.38$, $SD = 0.56$). The teachers were asked the following question (in addition to the six items): 'To what extent do these statements apply to your ability to speak English?' The teachers could answer on a four-point Likert scale ranging from 1 ('I do not agree.') to 4 ('I totally agree.').

Instructional quality: Instructional quality was surveyed from the teachers' perspective using three 4-point-likert scales items (adapted from Fauth et al., 2014): communicative-cognitive activation [4 items; $\alpha = 0.43$; $M = 3.57$; $SD = 0.37$; e.g. 'I encourage students to speak freely by not correcting pronunciation errors at certain stages.'], classroom management [5 items; $\alpha = 0.74$; $M = 3.08$; $SD = 0.41$; e.g. 'The students rarely disturb lessons.'] and supportive climate [7 items; $\alpha = 0.81$;

$M = 3.55$; $SD = 0.36$; e.g. 'While teaching English, I regularly praise the students for their learning progress.'].

There is no missing data for these variables. All scales showed good or sufficient reliability with the exception of communicative-cognitive activation.

6.5.3 Analysis

The data analysis was conducted using SPSS (version 26.0). In order to answer research questions 1 and 2, a multivariate analysis of variance (MANOVA) was conducted to compare multiple group means and three dependent variables followed by multiple comparisons (t-tests with Bonferroni correction). The dependent variables in the model were 'subject-specific enthusiasm', 'teaching enthusiasm', and 'foreign language proficiency'. Research question 3 was addressed by testing a number of linear regression models that include teacher qualification, subject-specific enthusiasm, teaching enthusiasm, FL proficiency and teaching experience as predictor variables, and indicators of instructional quality such as communicative-cognitive activation, classroom management, and supportive climate as dependent variables.

6.6 Results

6.6.1 Teacher Enthusiasm

For the dependent variable 'subject-specific enthusiasm' the MANOVA shows a main effect for teacher qualification ($F(2, 843) = 68.493$, $p < 0.001$, $\eta^2 = 0.167$). Comparisons between the three groups (t-tests with Bonferroni correction) confirm that there are statistically significant differences in the means between the three groups. The level of subject-specific enthusiasm differs clearly between the in-field and the out-of-field teachers ($p < 0.001$) as well as between the post-graduation group and the EFL majors ($p < 0.001$), each with a difference of 0.51 and 0.60 respectively on the 4-point Likert scale. There is no statistically significant difference between the out-of-field EFL teachers and the post-graduation group ($p = 0.650$). Those with a major in EFL show the highest level of subject-specific enthusiasm ($M = 3.42$, $SD = 0.53$) and rate their interest in EFL considerably higher than those without any training in EFL ($M = 2.91$, $SD = 0.68$) or the teachers of the post-graduation group ($M = 2.82$, $SD = 0.69$) confirming our Hypothesis 1a. With regard to 'teaching enthusiasm', the MANOVA shows again a main effect for teacher qualification ($F(2, 843) = 2.167$, $p < 0.001$, $\eta^2 = 0.016$). Thus, the null hypothesis (H1b) must be rejected. However, the explained variance is very small. In addition, the pairwise comparisons only show a statistically significant difference between the post-graduate teachers and the EFL majors ($p < 0.05$) indicating that the fully qualified teachers are the most enthusiastic teachers. Overall, the results indicate that a higher professional qualification in teaching EFL is related to higher teacher enthusiasm.

6.6.2 Foreign Language Proficiency

The MANOVA shows a main effect for teacher qualification ($F(2, 843) = 46.889$, $p < 0.001$, $\eta^2 = 0.176$). Comparisons between the three groups (t-tests with Bonferroni correction) show that the fully qualified EFL teachers rate their FL proficiency significantly higher compared to the other groups ($p < 0.001$). The difference in the means of the post-qualification group and the out-of-field teachers is not significant ($p = 0.065$). On the 4-point Likert scale the teachers with an EFL major rate their FL proficiency highest ($M = 3.67$, $SD = 0.37$) followed by the teachers without EFL-specific training ($M = 3.25$, $SD = 0.61$) and those who participated in a post-graduate training ($M = 3.18$, $SD = 0.57$). In sum, the fully qualified teachers rate their proficiency in speaking English higher than the post-graduate and unqualified EFL teachers.

6.6.3 Instructional Quality

Table 6.2 shows the results of the linear regression analysis. We calculated three models (A, B, C) that differ with regard to the dependent variable (dimensions of instructional quality), the predictor variables are held constant. Any significant regression coefficients of the teachers' characteristics can be regarded as effects on the instructional quality of the EFL lessons. Of particular interest to us is the question of whether the teachers' subject-specific qualification is relevant if the other characteristics of the teachers are controlled.

Model A shows that only the subject-specific enthusiasm and the FL proficiency of the EFL teachers can explain differences in the evaluation of the instructional quality with regard to the question of whether teachers think that their lessons stimulate communication in the foreign language. Model B surprisingly reveals a negative effect of teacher qualification. In other words, teachers with a higher formal qualification rate the classroom management of their EFL lessons lower. The authors interpret this finding as evidence that the fully qualified EFL teachers are more critical of their teaching with regard to effective classroom management compared to those with lesser qualifications for EFL. In addition, a positive effect for teacher enthusiasm, subject-specific enthusiasm as well as teaching enthusiasm, was found. Model C explains differences in the evaluation of the supportive climate in EFL classes. Both types of teacher enthusiasm and FL proficiency explain about 20% of the variance. The teachers' qualification does not explain differences.

Table 6.2 Results of linear regression predicting instructional quality

Predictors	(A) Communicative-cognitive activation			(B) Classroom management			(C) Supportive climate		
	B	*β*	*p*	*B*	*β*	*p*	*B*	*β*	*p*
Teacher qualification	0.017	0.038	0.28	−0.104	−0.168	**< 0.001**	−0.008	−0.015	0.659
Subject-specific enthusiasm	0.097	0.223	**<0.001**	0.119	0.200	**<0.001**	0.071	0.138	**<0.001**
Teaching enthusiasm	0.092	0.123	**<0.001**	0.272	0.268	**<0.001**	0.309	0.351	**<0.001**
FL proficiency	0.055	0.103	**<0.05**	0.040	0.054	0.15	0.049	0.078	**<0.05**
Teaching experience	0.001	0.059	0.067	0.00005	0.010	0.762	0.00006	0.014	0.660
R^2	0.13			0.16			0.20		

Note B = unstandardised beta coefficients; β = standardised beta coefficients

In sum, results indicate that, in particular, enthusiastic teachers and those who believe they are proficient English speakers tend to assess the instructional quality of their EFL lessons positively. With the exception of classroom management, the subject-specific qualification does not explain why teachers differ in the evaluation of their instructional quality. Surprisingly, the more qualified teachers are, the less well they assess their classroom management.

6.7 Discussion

This study investigated primary EFL education and in particular focused on the relationships between the subject-specific qualification of EFL teachers, their professional characteristics, and the self-assessed instructional quality of their primary EFL teaching. For this purpose, 844 primary school teachers from Germany with and without training in EFL were surveyed on their enthusiasm for teaching English, their proficiency in speaking EFL, and the instructional quality of their EFL lessons. The study found that the subject-specific qualification of EFL primary school teachers is related to differences in the teachers' enthusiasm for teaching EFL and their FL proficiency. Findings suggest that a fully qualified teacher is more likely to be motivated to teach English and speak the FL proficiently than teachers who teach EFL out-of-field or attended a post-qualification course. These findings are in line with previous findings which indicated that out-of-field EFL teachers are less proficient in the target language, English (e.g. Dörr, 2018). In addition, a further analysis from the TEPS project revealed that out-of-field teachers are less likely to use English for the purposes of communication and instruction in the EFL classroom than in-field teachers (Wilden & Porsch, 2020). Instead, they tend to speak German (L1) more often when teaching EFL.

The present study also looked at the effects on the self-assessed instructional quality. Only one correlation between teachers' qualification and instructional quality is significant at the 1%-level. The negative correlation between teacher qualification and classroom management could mean that teachers with higher qualifications are more critical of their classroom management than out-of-field teachers. As in-field teachers more often use the FL in the classroom (Wilden & Porsch, 2020), it may be that students who are struggling with EFL have difficulties in understanding the instructions and become distracted. Thus, the teachers' notion might be correct.

The results also show a positive relationship for all dimensions of instructional quality to subject-specific enthusiasm, teaching enthusiasm, and English proficiency. Thus, the formal qualification only indirectly affects the teachers' perception of their instructional quality. On the one hand the more enthusiastic and more proficient in speaking English EFL teachers are, the higher they rate their instructional quality. On the other hand, teachers who are very enthusiastic and proficient in English are more likely to have studied EFL. Hence, the study underlines the necessity of obligatory post-graduate courses particularly designed for out-of-field teachers. These courses ought to focus on both teaching methodology and developing teachers' FL proficiency. Also, the courses should aim to spark teachers' enthusiasm about teaching the target language. Even if teachers possess sufficient competencies in speaking an L2, they may not be proficient enough to communicate or interact in an L2 classroom ('classroom discourse').

Prior research on enthusiasm has not yet considered the subject-specific qualification of teachers as a result of their subject interest as a relevant variable to explain differences. Our findings show that qualified teachers are especially enthusiastic about teaching a subject they were trained for. As this trait is significant for instructional quality, future research ought to investigate in more depth the reasons for being enthusiastic about teaching a specific subject. Furthermore, research should focus on the effects of professional development programmes beyond competence growth. Such programmes could for example explicitly address the significance of subject enthusiasm by inspiring teachers. Also, training on how to express and show enthusiasm could be an option as 'displayed enthusiasm has positive effects for students' ratings of clarity and structure and their emotional experiences' (Frenzel et al., 2019, p. 264).

Finally, we recommend that in-service teacher training programmes include lesson observations even though it is more expensive and takes more time. Our findings show that on average out-of-field teachers evaluate their professional traits and their instructional quality lower than those who are formally qualified for a subject. However, it can be expected that a number of out-of-field teachers already participate in professional development activities, thus gaining knowledge by self-study, and receiving peer support through colleagues and school management. Thus, they possess sufficient professional competence and teach effectively in a subject they formally teach out-of-field (e.g., Hobbs, 2013). However, we consider it important that they receive feedback from experts in the classroom. If this does not happen teachers might feel less competent which in turn potentially affects their teaching practice as prior research has found a strong link between self-efficacy beliefs and instructional quality (e.g. Künsting et al., 2016). Thus, ideally professional development programmes provide numerous learning opportunities combined with constructive feedback in real-classroom situations (Ross & Bruce, 2007).

In discussing these findings, a number of limitations of the present study ought to be considered. In particular, the reliability of the scale measuring communicative-cognitive activation needs to be improved in further studies. An additional constraint is that the teachers self-assessed both their FL proficiency and the instructional quality, thus only the teacher perspective is accounted for. An alternate method, which for pragmatic reasons could not be implemented in the present study, would be the use of a standardised language test or rating instructional quality as well as the teachers' FL use in the classroom. However, the perspective of the teachers still can be regarded as a valid indicator of teaching quality. In a study by Fauth et al. (2014), the teachers' evaluation of instructional quality, in particular classroom management, could also predict the students' proficiency reliably. Still, a combination of student ratings and/or external raters may provide a more realistic and objective picture of the instructional quality than the teachers can provide.

6.8 Conclusion

Findings of the present study indicate differences between fully qualified teachers teaching EFL and those who teach EFL out-of-field. The findings suggest that individual aspects of teacher competence are negatively affected if teachers lack the subject-specific training. Therefore, we looked at two current structures of primary education and primary teacher training in Germany. Firstly, the existence of the class-teacher principle should be reconsidered as it causes teachers to regularly teach out-of-field in a number of subjects, including EFL, in German primary schools. Secondly, as the teacher shortage continues and unqualified teachers (in German called 'Seiteneinsteiger') increasingly take up primary teaching positions, the quality of EFL education might additionally suffer.

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Chapter 7
Out-of-Field Teaching Between Relationship Work and Subject Principle in Primary Schools: Insights into a Qualitative-Reconstructive Documentary Method Study

Judith Lagies

Abstract In German primary schools, teachers mainly teach many subjects in one learning group (class teacher principle). Relationship work is central to this. It arises from the appreciation and the empathy that the teachers give to the children through their pedagogical actions and is made possible by the fact that they are in the class for many hours because they teach almost all subjects. The subject principle only structures the training of teachers and the everyday school life of children. This chapter will first demonstrate the example of mathematics teaching to show how the two principles lead to out-of-field teaching. Secondly, a reconstructive, qualitative interview study with primary school teachers is presented, which shows how these primary school teachers negotiate being out-of-field between these two poles. What guides their actions? Does out-of-field-teaching devalue the primary school teaching profession? Within these areas of tension, recommendations are formulated for policy, research and practice.

Keywords Class teacher principle · Out-of-field-teaching · Primary school · Professionalism · Qualitative-reconstructive interview study · Relationship work

7.1 Introduction

A unique feature of the primary school profession is the contradictory and ambivalent structures that primary school teachers have to reconcile: prospective primary school teachers are trained in two to three subjects in a theoretical study at the university (five years) and a school-based practicum experience (18 months). All actions are guided by a subject-oriented logic in which the subject structure provides the framework for action both professionally ('As a teacher I teach different subjects') and organisationally (the school plans the deployment of teachers and the day of pupils by subjects). This subject logic is also reflected later in the structuring of the school

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day in everyday working life: the canon of subjects and the timetable of the pupils, the assignment plan and the working time model of the teachers, and meetings and conferences are largely oriented towards subjects. School is understood as an organisational framework. At odds with this logic is the class teacher principle, which has its origins primarily in reform pedagogical legitimation and places relationship work as the basis of pedagogical activity. This means that a class teacher teaches many subjects in a learning group on the basis of pedagogical principles, even if he or she has not been trained in those subjects. School is understood here as a professional framework. The following applies here: relationship beats subject. These opposing structures give rise to the phenomenon of out-of-field-teaching.

According to Porsch (2016), a teacher without a formal teaching qualification could be considered to teach a subject out-of-field. However, since Germany has federal structures in the education system (there are 16 federal states), there is a different definition of 'formal teaching qualification' for each federal state. How exactly do universities train teachers? How is the assignment as a graduate teacher then structured? In which policy documents is there anything about the regulation of out-of-field-teaching in primary school? Is it the primary school teacher who decides or the school management? In Germany alone, it is difficult to compare and evaluate the definition, occurrence, cause and effect of out-of-field-teaching, because these decisions are made by the Ministries of Education of the individual state governments.

In addition, there is the logic of investigating the phenomenon of out-of-field-teaching through semantic use alone (in Germany, it is described as foreign): if something is foreign, there is often an automatic attribution of a negatively connoted feeling, something unknown and an uncertainty. Furthermore, a reference value is set as a norm; here it is the subject. The evaluation takes place through the lack of subject matter. Within a discourse specific to primary schools, the same phenomenon could also be approached via a closeness to the relationship: the strength of the pedagogical relational work between teacher and pupils is emphasised and this is shown as a pedagogical premise. The fact that teaching takes place without a formal teaching qualification would be secondary for the time being. It is argued that a prospective primary school teacher is trained in subjects, but because of the raising mission of primary schools, the focus is primarily on qualifications that are independent of subjects, such as counselling and diagnosis. If the teacher then teaches a subject in which she has not been trained, she is expected to be able to cope with the subject level in primary school so that she can also advise and diagnose in this subject. However, this can also become a problem if the teacher lacks subject-didactic considerations and misjudges the learning levels and prerequisites of the pupils.

However, both perspectives show that there is an organisational and professional rupture in the primary school context. This chapter will focus on this rupture and raise various questions and possibilities for future primary school teaching.

7.2 Literature Review

The power of the class teacher principle derives from historical development and is legitimised through pedagogical discourse: while its origins go back to the late nineteenth century when the class ordinariate was created as an administrative relief function in the Prussian grammar school (Martin, 1996), the primary school not only has organisational legitimations, but also pedagogical ones: the foundation of the primary school in Germany in 1919 as a school for all centred on reform pedagogical considerations that united relational work as the core (Schorch, 2009). Thus, the traditions for example of Pestalozzi (1781), Rousseau (1762) and Montessori (1948) find their way into school design by granting children a protective space that protects and cares for them. Action maxims such as pedagogical love (Nohl, 1933), the importance of image solitude (Herbart, 1986) or an intensive experience of values (Kerschensteiner, 1927) characterise the early days of the unified primary school movement.

The subject encounter takes place in the pre-subject area by striving for a holistic and interdisciplinary discussion. Due to their work and their professional field, the class teacher is attributed a mediating function that can be classified between primary socialisation (family) and systematic subject learning in the secondary school (Duncker, 2007). Children may encounter the class teacher as the first reference person outside the family in their role as a pupil, alongside educators from the elementary sector (Kindergarten or day care centre [age 0–6]), and thus learn to enter into a relationship with specific parts, while diffuse relationships exist at the time especially in the family (Oevermann, 1996). For this transition, special sensitivity is needed on the part of the class teacher so that the relationship is not confused with a family relationship and still allows a certain closeness. This is also where the educational mandate of primary schools can be placed, which, according to the German Basic Law assigns schools and the parental home a roughly equal status (§ 6 and 7, Basic Law).

Due to certain developments in the second half of the twentieth century, there was a shift from child orientation to more scientific orientation. Children are constructed as social actors and active designers of their living environment (Bründel & Hurrelmann, 2017), recommendations of the nationwide Conference of Ministers of Education (in German KMK) (1970) for the work in primary schools are adopted, the training of prospective primary school teachers experiences a 'gain in status' through integration at universities and an orientation towards the subject principle prevails. Nevertheless, the class teacher principle persists in practice. In the 1980s, the discourse was given a new emphasis on child orientation; concepts such as changed childhood (Fölling-Albers, 2008), attachment theories and pedagogical moratoria (Bründel & Hurrelmann, 2017), which provide protection and care.

The maxims of action are relationship sensitivity (Graf, 2012), appreciation (Tausch & Tausch, 1998), recognition, holism (KMK, 1994) and person orientation (Weigand, 2004). The class teacher principle legitimises itself through pedagogical, relationship-sensitive work—the fact that this involves teaching in subjects in which the teacher has not been trained is hardly mentioned in the literature, studies or educational policy papers. In the state-recognised alternative schools in independent sponsorship Waldorf education for example, there is special training for class teachers, but not in the mainstream school system. Waldorf schools work according to a principle of anthroposophical study of the human being and set different priorities than state-run mainstream schools (Helsper et al., 2007).

Why do we now speak of out-of-field-teaching in the context of primary school? In the educational mission of primary schools, the core task of teachers is to pass on and convey knowledge and to train and strengthen competences (Schorch, 2009). This maintenance of cultural techniques, knowledge, values, norms and interpretations is organised by the subject principle: this means that the acquisition of knowledge is structured within subject logics (Tenorth, 1999). A subject system offers a framework for action and creates a space for encounters in which binding, regulative and bundled responsibilities can function (Hopmann & Riquarts, 1999). As a rule, trainee teachers are trained in two to three subjects and later also teach in subjects at school. The entire planning apparatus in schools is based on subject structures: Who is assigned and when in the timetable? When are there specialist conferences for teachers? Which folders does the child need for which subject? Whether the teachers have been trained in these subjects or not is resolved by the handling with the class teacher principle.

The professionalisation of teachers can be classified through different perspectives. In the following, three readings (Competencies; Habitus; Biographical Developmental Assignments) are presented that place different perspectives and emphases on teacher professionalisation: the training of teachers can be structurally classified in a competence-oriented way of thinking. The course of study is divided into subject sciences (e.g. What is arithmetic?), subject didactics (e.g. How do you teach arithmetic to children?) and educational resp. pedagogy science components (e.g. Which different offers and tasks does the individual child need in order to understand arithmetic?). Subject-specific knowledge is constructed as explicit knowledge that teachers can acquire by systematically passing through it in order to acquire competences (Hericks et al., 2020). In this context, teaching subjects in which teachers are not trained would be teaching outside the subject and, due to the lack of subject-specific scientific and didactic components, would be a deprofessionalising activity. For example, for mathematics teachers this would mean they teach stochastics without having taken a course in it. And so it can be transferred to all areas of mathematics if no studies have been completed in this subject and in the associated subject didactics. This orientation of teacher training is derived primarily from the higher education system and suggests a gain in status if the primary school teaching profession is also oriented towards it.

If, on the other hand, professionalism is constructed as implicit and experience-based knowledge, it is about the formation of a teacher habitus in the structural-theoretical sense, which enables teachers to (vicariously) cope with crises, to deal with uncertainty and to endure antinomies (Hericks et al., 2020). The central task for primary school teachers would therefore be to establish their own weighting of subject and relationship and to act as a person from outside the subject in uncertain subject boundaries. The extent to which this action then has a (de)professionalising effect is currently unclear and also requires a normative classification. The formation of such a teacher habitus does not take place through the acquisition of subject knowledge and the formation of convictions and attitudes, but through a constant self-examination of one's own ideals, values, norms, world and self-relationships in relation to the profession (Hericks et al., 2020). In order to initiate professional understanding and educational processes in students, teachers must go through these processes themselves (Hericks et al., 2020). This can be achieved, for example, through casuistic formats, therapeutic self-exploration and learning workshops. Casuistic learning formats use either foreign or own cases. A case can be a teaching situation, a class, a reward system, etc. The work is done from the individual case to the general case and the action is looked at in slow motion using exemplary excerpts. By slowing down and being reflexive, routines are practised that will later contribute to professional action (Helsper, 2018).

From a professional biographical perspective, professionalism as a developmental task comes into focus: passing through subjects as students, the previous choice of subjects and a certain inclination and interest usually favour social constructions of identity and meaning that help to enter into conversation with laypeople about the content to be taught. Professionalism can act as a biographical and communicative resource (Hericks et al., 2020). If teachers have not gained this experience in a structured way during their teacher training, because they teach subjects out-of-field, it would be interesting to see whether subject matter acts as a barrier to action and whether it collides with the expected professionalism. In Germany, the research situation for the primary level is very thin, so that the potential of out-of-field-teaching and primary school would also have to be illuminated. So, what developmental tasks would arise for primary school teachers who teach out-of-field? For example, their own confrontations with subject content, which could lead to a biographical and communicative resource.

As early as 20 years ago, the persistence of the subject principle was placed in the German school pedagogical discourse and interdisciplinary teaching was demanded (Huber, 2001). Structurally, however, hardly anything has changed. Training continues in subjects for primary school. Teachers continue to teach subjects that they have not studied. Neither is the consistent holistic view of the child chosen as a maxim for action in the primary school, nor is the teachers' lack of (subject) knowledge systematically addressed. Therefore, out-of-field-teaching in primary schools exists as a self-evident and consensual practice without any need for action being identified by 'those affected' or the decision-makers (for example education politicians or school headmasters). In this way, responsibility is attributed to the individual and not to the structural and collective system. Primary school teachers themselves are responsible for ensuring appropriate teaching—regardless of their qualifications. Relief support through fixed structures and school management is not given.

Out-of-field-teaching in the primary school context can thus be placed between relational work and subject principle. It is thus subject to both organisational regulation processes and the observance of professional legitimation. The structural rupture of primary school theoretically culminates in the class teacher teaching out-of-field. Various national and international, qualitative and quantitative studies have been attempting to describe and evaluate the phenomenon of out-of-field-teaching for several years. For example, teacher identities (e.g. Bosse, 2017), student performance (e.g. Rjosk et al., 2017), further education and training formats (e.g. Eichholz, 2018) or school leadership actions (e.g. Du Plessis, 2013) are related to out-of-field-teaching. However, the studies seem to be related mainly to secondary schools, where out-of-field-teaching exists because of the avoidance of lesson cancellations and the absorption of the shortage of subject teachers (Porsch, 2016). This reconstructive, qualitative study presented in this chapter addresses the research gap that still needs to be clarified and focuses on the implicit and action-guiding knowledge that orients the actions of out-of-field primary school teachers. The article focuses on the following question: What actions do out-of-field primary school teachers show in relation to relational work and subject principle, and what logic (profession or organisation) frames their actions?

7.3 Methodology

The methodology presented in this article refers to the documentary method according to Bohnsack (2010) and Mannheim (1968). This is a qualitative and reconstructive survey and evaluation method within the social sciences and has become established in teacher research in Germany. 'The documentary method aims at reconstructing the implicit knowledge that underlies everyday practice and gives an orientation to habitualized actions independent of individual intentions and motives' (Bohnsack et al., 2010, p. 20). These recurring routines and practices (habitualised actions) can be documented in speech acts, so that interviews can be considered a protocol of life practice (Nohl, 2010). In order to make implicit knowledge tangible for researchers, Bohnsack (2010) drafts the concept of the orientation framework and understands orientations as organisational principles of conjunctive experiential spaces. Orientations are considered to guide action. A person has an overarching framework of orientation that guides action. Thus, through different spaces of experience (e.g., country child, poor parental home, few siblings, Catholic boarding school) it was possible that patterns could be developed and habitualised. No matter what the situation, people always act according to a certain principle.

The habitus plays a central role in Bohnsack's concept. Habitus is understood in Bourdieu's (1977) sense as schemata of perception, thought, action and evaluation and is understood as a double structure: it functions both as a product of action (opus operatum) and as a generative principle of production for practice (modus operandi). With the habitus concept, Bourdieu attempts to sketch a theory of practice. Bohnsack approaches the actions of actors not only on a theoretical level like Bourdieu, but also attempts to make the habitus empirically accessible: through his model of 'conjunctive spaces of experience and frames of orientation', he creates a differentiated access to various levels of implicit knowledge. For example, implicit—or tacit—knowledge is how a person ties a shoe. But to explain this linguistically without showing it seems impossible. This knowledge of action is captured in a methodically controlled way

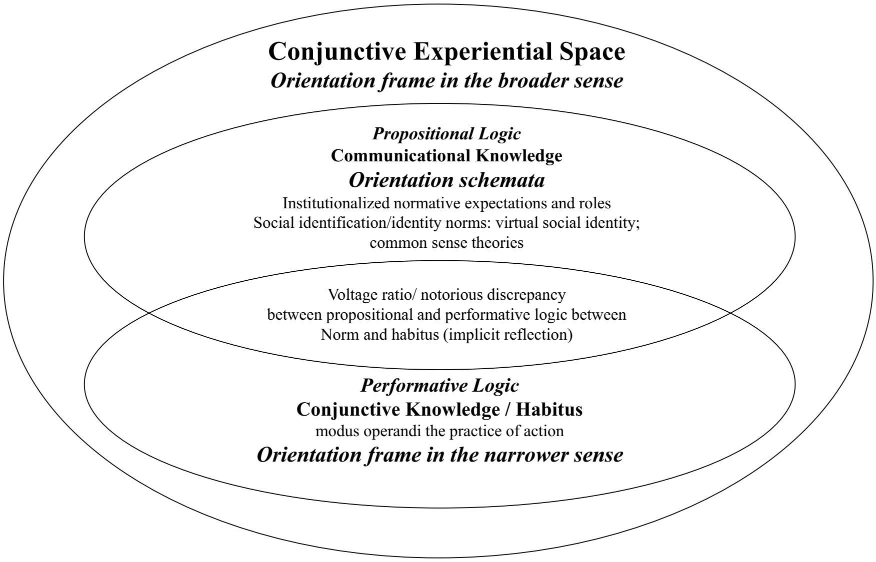

Fig. 7.1 The conjunctive experiential space (Bohnsack, 2017, p. 103) (Figure translated by J.L.)

by the documentary method. Bohnsack understood these conjunctive spaces as pre-reflexive, atheoretical and subjunctive knowledge in the style of Mannheim (1968). In doing so, actors act in the field of tension between norm and habitus (Bohnsack, 2010), in his vocabulary between 'orientation schemes' and 'orientation framework in the narrower sense' as well as the shaping of this tension by the 'orientation framework in the broader sense' (see Fig. 7.1).

Bohnsack describes his methodological premises in his Praxeologische Wissenssoziologie [praxeological sociology of knowledge] (2017). The concrete evaluation procedures (method level) are carried out by the documentary method. This classification serves to make the actions of teachers methodologically tangible and should show which orientations at an implicit level lead to action. In order to reconstruct an orientation framework, what is especially needed is a protocol of life practice, such as a transcribed interview and various inductive steps of analysis. Within the documentary method, roughly **five analytical steps** can be identified, which should not be understood in the sequence presented here as a linear sequential process, but must be carried out according to the principles of qualitative research in a circular and open process. In the following, examples from the underlying study are given for each step of the analysis to provide better illustration.

At the level that allows initial access to the material, the explicit confrontations with the expectations and norms of the institution and with processes that affect, for example, identity are revealed at this explicit level: what is formulated by the respondents? One maths teacher said quite explicitly in an interview: 'I just think maths is awesome'. His theme for this part in the interview is first of all the joy of mathematics (**1st analysis step** of the documentary method: formulating interpretation).

In addition, the ‘like the what’—i.e. the habitus or orientation framework in the narrower sense—is sought: What is documented in the treatments, the types of texts used and the production of the proposals, elaborations and conclusions of the interviewees? In later sections of the interview, it becomes apparent that the maths teacher has a positive attitude towards primary school maths in particular, but meets the demands of higher maths with excessive demands, unbearable frustration and irritability. He did not manage to study mathematics and then had to choose another subject (**2nd analysis step** of the documentary method: reflective interpretation).

Finally, these interpretations are compared with other cases so that the horizons and counter-horizons raised can be outlined and the ‘how of the how of the what’—i.e. the frame of reference in the broader sense—can be worked out. Which teachers from the study process teaching mathematics in a similar way as the maths teacher? Where does frustration show? Where is there a positive approach to mathematics at first glance? Who reacts passively in the system rather than acting actively and dominantly? Who serves a broad concept of mathematics and does not see it as one-dimensional? (**3rd analysis step** of the documentary method: comparative analysis).

Within the documentary method, the aim is to form a type that provides information on how the group to be examined, primary school teachers teaching mathematics out-of-field, deals with the problem. In other words, how they create an out-of-field area where the framework of orientation in the broader sense is developed in a homologous way: Which cases—interviews—are similar, which contrast? What connects them? (**4th analysis step** of the documentary method: genesis of meaning).

In a further step, the aim is to find out why these types are supposedly so homologous: What connects the respective types? Age, work experience, gender, migration background? (**5th analysis step** of the documentary method: sociogenesis) (Bohnsack, 2010; Nohl, 2010).

A total of 16 primary school teachers who teach mathematics out-of-field were interviewed using guideline-based individual interviews with narrative episodes based on Schütze (2008) and Flick (2000). The teachers were recruited on a voluntary basis through an appeal to all primary schools in a given district. School administrations established the contact, often as a mediating authority. The teachers form a representative group in terms of age and experience (8 novices/8 experts), gender (13 female/3 male) and the socio-spatial location of the school (8 city/8 country). The interviews, which are regarded as protocols of life practice (Nohl, 2010), were then evaluated on the basis of the various analytical steps of the documentary method and condensed to form types.

7.4 Key Findings

The study inductively formed four types of genetic meaning from the interview material, which participants homologously negotiated out-of-field-teaching in their own way: the curious-reflecting pragmatic type (P), the humble-doubtful idealistic type

(I), the resigned-passive stoic type (S) and the controlled-resource-saving realistic type (R) (see Lagies, 2020, 2021).

In the following, the individual types are presented in relation to relationship work, subject principle and professional and organisational logic.

7.4.1 The Curious-Reflecting Pragmatic Type (P)

Teachers who belong to Type P can be described by a lot of commitment, curiosity and reflexivity in relation to their activity as a 'subject stranger'. They act calmly, pragmatically and do not allow themselves to be ruffled. In order to organise school, teachers of this type need subject boundaries in which professional demands can be asserted. Here, subject-didactic considerations are central as to how the child can establish contact with the subject. Primary school therefore needs both a subject orientation and a child orientation. As a class teacher, participants of the type therefore show a willingness to make an effort to teach a subject in which there have not been trained to mediate between child and subject through relational work. They thus deconstruct the phenomenon of out-of-field-teaching by not constructing it as a problem, but rather as an opportunity to meet professional challenges and limits in a positive sense and thereby develop their professionalism. They understand their actions in the profession as lifelong learning. Overall, their actions are guided by a professional logic in which pedagogical demands are negotiated through relationship-sensitive work and subject-didactic questions. Teachers who belong to this type have themselves decided to teach mathematics outside the subject, tend to be young in age and in work experience compared to the other participants and have a positive attitude towards mathematics.

Compared to the other types, Type P can be attributed to a medium closeness to relationships and subject orientation. Teachers of this type have in common that they enable their students to access mathematics both through their relational closeness as a classroom teacher and through their own closeness and love for the subject of mathematics. Here, there seems to be a balanced practice between relationship and subject. The phenomenon of out-of-field-teaching is resolved by their negotiation. For them there is no problematic foreign teaching.

7.4.2 The Humble-Doubtful Idealistic Type (I)

Teachers who can be classified as Type I show excessive demands, fears and high expectations of themselves when it comes to their work as subject outsiders. They agree that they did not choose this situation themselves, but, for example, had to fill in overnight for colleagues who were seriously ill. They did not have time for in-depth preparation, as, for example, Type P teachers do. As a result, they see out-of-field-teaching as a threat and an attack to which they are at the mercy of. Their claim that the school must continue to function and that it depends on them brings them to their own stress limits. Nevertheless, they try to live up to their high ideals of giving good lessons, as they are used to doing in their in-field subjects. This results in a feeling of powerlessness, little self-efficacy and other negative feelings. It is documented that during their assignment as a subject stranger, they choose the narrative that access to the subject can only be achieved through relationship work and that they are therefore the right person for this task. When the stress threshold is overstretched, they argue that the children have a right to subject-specific correctness and can establish contact with the subject through experts in subject-didactic approaches. Teachers who belong to this type tend to be inexperienced and have very negative feelings towards mathematics.

Compared to the other types, Type I can be attributed a genuine and high level of closeness to relationship and, at the same time, of a total perceived alienation from the subject. However, the subject principle is thereby unconsciously upgraded, since these boundaries are used as a reference point for evaluating one's own actions.

7.4.3 The Resigned-Passive Stoic Type (S)

Teachers who belong to Type S can be characterised by passivity, avoidance of effort and self-overestimation in relation to their activities as non-specialists. In the interviews, they report cheerfully about their mathematics lessons, but they document confused structures and few anchor points. They show an indifferent and stoic orientation when it comes to the framing of subject or relationship. Their main concern is to ensure the maintenance of frictionlessness both in the classroom and in school life. In doing so, they place the organisational logic of school in the foreground. Their teaching is small-step and textbook-bound. On the surface, out-of-field-teaching is no problem at all, it is even fun, but implicitly there is a great deal of insecurity. Neither subject boundaries nor a child or relationship orientation is negotiated by them. There is no actual self-ascribed identity with the subject of mathematics. They act as passive actors in the field of school and orient their actions to an organisational logic. They reduce complexity and thereby construct a feasible radius of action for their actions as out-of-field teachers. It would be interesting to know whether they understand their profession in this way and do not limit it to teaching out-of-field. Other questions in the interviews would have been necessary to focus on this perspective. Teachers of this type tend to be more experienced teachers and do not show any particular liking or disliking for mathematics.

Compared to the other types, Type S can be attributed with a great deal of out-of-field-teaching and no closeness to relationships. Organisational processes orient their actions.

7.4.4 The Controlled-Resource-Saving Realistic Type (R)

Teachers who can be assigned to Type R can be characterised by self-confidence, a claim to power and composure in relation to their activity as subject outsiders. Unlike the Types P, I and S, they clearly argue about the class teacher principle and the relationship work associated with it in their use in mathematics lessons. However, this structure has its origin primarily not in pedagogical legitimations, but in administrative organisational arguments (for example: 'decide for yourself when to teach which subject if you have many lessons in the class'; automatically be class teacher to fulfil organisational simplicity for school management). These principles are not questioned, but simply accepted. Subject boundaries play no role in their negotiations and do not frame their actions. The possibility of bundling and centralising all decisions for one's own class guides the teachers' actions. They accept or de-dramatise the fact that teaching must take place in non-trained subjects. Out-of-field-teaching is needed so that primary schools can function in relationship-oriented class groups. Professionalism and expertise, on the other hand, do not play a role or are devalued, since experience and intuition are the main guiding principles for their profession. Teachers of this type tend to be more experienced and older colleagues and do not show any particular affinity or aversion to mathematics. Overall, mathematics is constructed as one-dimensional (there is only right and wrong, calculation procedures, no doing/operating mathematics) and thus becomes manageable—in contrast to the, in their opinion, 'complex' school subject German. Small side note: the main subjects German and mathematics have both content-related and general competence areas and thus map a certain complexity of the scientific reference disciplines. For example: speaking & listening, writing texts, reading (German); probability, geometry, arithmetic, quantities, communicating, arguing (mathematics). Those who are not (!) familiar with the respective subject might think that the respective subject is not complex.

Compared to the other types, Type R can be attributed a superficial closeness to relationships and a non-problematic out-of-field-teaching. Here, the class teacher acts as an organisational multi-talent who centralises all decisions for the child and the daily routine.

7.5 Discussion

The results of the study show that there is a differentiated picture when it comes to the extent to which out-of-field (mathematics) teaching is negotiated in primary school and shows the diffuseness of the break between subject principle and class teacher principle. In the orientation frameworks and in the self-understandings of the teachers, it becomes apparent that they have not clarified questions regarding the traditions out of which their work is based. Overall, however, it is evident that out-of-field-teaching is actually reproduced as a consensual practice and only in some cases becomes a problem due to different conditions (see various studies above). These conditions are on both an individual and a structural level (see Lagies, 2020). Does this mean that the primary school profession is devalued by out-of-field-teaching?

If primary school is categorised through the lens of secondary schools and the subject principle that dominates with it, out-of-field-teaching devalues the primary school profession in any case. The qualifications acquired during studies lose value and teaching does not come close to the professional demands. If primary school is classified through the lens of the original, reform pedagogical considerations, out-of-field-teaching constitutes the primary school profession. Only in this way can holistic and child-oriented subject encounters be made possible through the sensitive relational work of classroom teachers. The question here would be at which point in the training (university, study seminar or school) a German primary school teacher could acquire pedagogical and didactic competences independent of the subject.

If the various professional theories mentioned above are used as a reference, the primary school profession is definitely devalued within the competence-oriented professional approach due to the fact that out-of-field teaching exist. The fact that training in Germany is primarily based on these structures (subject science and subject didactics), but that in practice it is primarily the classroom teacher principle that is effective, directly counteracts the subject principle. If it is a matter of teachers having to endure antinomies in the structural-theoretical sense and strike a balance between subject and child, this could be independent of the subject-oriented study. Within the professional biographical approach to professions, it is indispensable for each individual teacher to cope with their own developmental tasks—so for primary school teachers it would definitely be dealing with out-of-field teaching.

The current training practice at primary schools in Germany is mainly oriented towards the competency-based model and trains in two to three subjects. Thus, the use of primary school teachers who teach out-of-field would be deprofessionalised. However, since this deployment continues to occur, the underlying study (Lagies, 2020) attempts to focus on the contradictions and antinomies that must be endured (structural-theoretical professional approach) and the individual developmental tasks (biographical professional approach). Within the type formation, it becomes apparent that Type P very consciously deals with the antinomy of subject and child and is able to reflect on this field of tension and formulate their own needs for action arising from it. Type P teachers need intensive preparation in order to be able to meet the subject-specific and subject-didactic demands and at the same time consider the children's prerequisites. Teachers who design those lessons out-of-field do not devalue the primary school profession, but find a space that makes this structurally generated break visible and thus manageable.

Type I teachers are also very aware of the antinomy of subject and child/relationship, but they cannot resolve it. They cannot derive any suitable and healthy possibilities for action in order to be able to professionally meet the demands of out-of-field teaching. Their developmental task would be to distance themselves from these requests and to protect themselves for their own well-being and that of the children. Structures that ensure that teachers are manoeuvred into this situation from one day to the next through external determination devalue the primary school profession.

Type S teachers neither act out the antinomy of subject and child/relationship, nor do they formulate possible developmental tasks that guide their professional actions. By orienting their actions to an organisational logic, no space is created in which these questions can be given a place. Teachers of this type thus devalue the primary school profession by prescribing their actions neither to one tradition nor to the other.

Type R teachers position themselves clearly on the pole of child and relationship orientation and rank the subject as subordinate. Through this positioning, they resolve the antinomy and act for themselves according to a congruent compass. Developmental tasks tend not to be formulated, if they are, then they concentrate on the general work as a primary school teacher, but not as a person acting mainly out-of-field. By appealing to experience and intuition, they even devalue the subject-specific pole. If primary school is understood as a total teaching organisation, these teachers do not devalue primary school. If the widespread logic of the subject principle has an effect and certain demands on teaching are levelled by the teachers, they also devalue the primary school profession.

These different schools of thought and different evaluations show that the primary school profession is perhaps constituted precisely by this rupture and the associated out-of-field teaching. It is therefore all the more important that decision-makers, institutions and those 'affected' are aware of this situation and want to continue or change this practice according to certain pedagogical reasons. In the following, a thought experiment will give an idea of what congruent solutions for the primary school profession might look like.

7.5.1 Thought Experiment: Primary School of Tomorrow

Just because a practice is constantly reproduced—like out-of-field teaching—does not mean that it is not a problem. In primary school, there is an obvious rupture in training and practice that makes for incongruent structures. Is it now a question of enduring or resolving these incongruities? A thought experiment can be carried out as two congruent approaches to a solution, whereby both solutions represent very contrary possibilities, and solutions in between are certainly conceivable.

If we orient ourselves towards the closeness to the relationship, this means for the training structures an adaptation and a retention in the place of practice. Studies at the university could be oriented towards exemplary situations and cases that enable a holistic, well-founded, self-reflective and personal confrontation. In this way, subject boundaries are dissolved and the subject is thought of from the scientific and didactic point of view in terms of the appropriation of children. In the preparatory service, an accompanied assignment in the class with all the tasks and functions of a class teacher would be possible, such as conducting parent talks, introducing rules and rituals, organising class trips, writing support plans, cooperating with the social services, etc. In the school practice, it remains as it is in the classroom. In school practice, it remains the same as before: the focus is on relationship work and the class teacher is primarily deployed in a class. Only through the relationship work can the children establish contact with the subject. This format could favour the use of project-oriented learning across subject boundaries, which could, for example, address epochal key problems. Further and continuing education would be oriented towards making subject encounters exemplary on the basis of relational work.

If we wanted to create congruence in the subject principle, then an adjustment would only occur in the school setting. The studies and the preparatory service would continue to be organised in subject structures, only the assignment in the school would function in teaching as a subject teacher. The question here would be who would take over the administrative and relationship-building functions of class management? Pedagogical staff? Or would it be conceivable here, as a thought experiment, to dissolve class groups and have project-oriented workshop lessons take place? Breakfast and break time would then take place in cosy corners, independent of classes, architecture and rooms would be adapted to this format, and the whole day could take place rhythmically between tension and relaxation. For further education and training formats, the question would be, in addition to professional discussions, how a holistic personality development could take place? And by the way, can't a subject teacher also do relationship work?

7.6 Conclusion and Recommendations

The class teacher principle that exists in primary schools in Germany ensures that primary school teachers usually teach some subjects out-of-field, as they are only trained in two to three subjects. This is justified pedagogically within a professional logic, because it is only through the relational work that the subject matter can come into focus with the children. Subordinately, the class teacher principle creates an administrative relief for the school management and thus serves an organisational logic. The subject logic, which is widespread in the school system, serves as a structuring of everyday school life and as a point of orientation for the training of prospective primary school teachers. The phenomenon of out-of-field teaching thus takes on a different dimension in primary schools than in secondary schools. The relationship aspect in teacher action is considered a pedagogical law. Yet it cannot be ruled out that the phenomenon of out-of-field teaching could devalue the primary school profession. So, what should be done to begin to resolve this structurally generated and pedagogically intended break?

Within **research**, it would be interesting to capture the value of relational work in primary school alongside the look logic of out-of-field teaching and to research from this point of view. What can relational work achieve in the absence of professional qualifications, if anything? What values fit into an inclusive, digital and progressive school system? Both qualitative and quantitative research would be needed to explore this complex field. The methods of videography and observation in particular lend themselves to capturing interactions. How can the subject aspect be taken into account? From a research perspective it would be interesting to look not only at the level of action in practice, but also at universities, seminars and educational policy interfaces: Who has what level of knowledge? Why and out of which tradition do certain decisions exist? Are these still (or again) up-to-date?

In **practice**, in the sense of the New Government, it is possible to start at a low-threshold level in the individual school: Where can spaces be created in everyday school life where encounters can take place? How should a subject conference be structured so that both laypeople and experts can work together to prepare and implement lessons? What arrangements could there be in schools? At least one trained specialist teacher per year group? What models of deployment would be conceivable here? Rotation models in which one teacher offers a lesson for all classes? Can new ideas and concepts be implemented here? How can the subject be used as a framework for action in primary schools and how can relational work be used? So how should learning be organised in primary schools? Perhaps with subject and/or learning workshops? Where can both principles come into play? Or is it good the way it is? That, too, would be an answer from practice that needs to be explored.

Education policy has several construction sites when it comes to out-of-field teaching: First of all, education policy should make the phenomenon visible and remove it from the individual responsibility of teachers. Out-of-field teaching should be given a collective and structural space in which school administrators and teachers are given a framework for action, what possibilities there are for support or what alternatives there are. Out-of-field teaching is a tacit and taboo practice in education policy. In some federal states, there are decrees or regulations for the use of out-of-field teachers. Secondly, it would be interesting to see whether, for example, an educational policy statement could be written on the reasons for the existence of out-of-field teaching in primary schools. And thirdly, reflections could be called for as to whether this break between training and practice is actually desired or whether moving towards each other would be a way of creating more congruence. Here, cooperation with universities, seminar centres and schools would be indispensable in order to do justice to the complexity of the phenomenon. In this way, teachers such as Type P could be used with a clear conscience as out-of-field teachers by the school management. Teachers such as Type I, S and R could be spared the situation of being overtaxed if education policy rules ensured that teacher health and professional conduct are a top priority and that the use of out-of-field teaching may only be undertaken under certain criteria. Here, the formulations in legal texts would have to be tightened up: What does an imposition or confidence mean? These are vague and normative terms. For example, further training could be imposed before mathematics, for example, is taught.

The phenomenon of out-of-field teaching experiences a particular explosiveness: on the one hand, the primary school with an acquired status gain (training at universities, approximate salary like secondary school teachers) has to assert itself in the scientifically oriented subject principle. On the other hand, the primary school is making a pedagogical argument for existing practice that provides for holistic and sensitive relational work in the function of the class teacher, far removed from subject structures. The German primary school is in an ambivalent crisis, trying to serve both poles at the same time. Either way, there is a need for action.

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Chapter 8
Maths, History, God, Knitting and Me: A Reflexive Bricolage of Identity

Fiona Yardley

Abstract Recent research into the lived experiences of out-of-field teachers aims to make recommendations for increasing the quality and effectiveness of the phenomenon of out-of-field teaching (Du Plessis, *Understanding the out-of-field teaching experience* (Unpublished doctoral thesis). University of Queensland, 2015; *Research in Science Education* 50:1465–1499, 2020; Hobbs et al., *Examining the phenomenon of 'teaching out-of-field?': International perspectives on teaching as a non-specialist*. Springer, 2019). This chapter builds on this research by taking an autobiographical approach, seeking the embodied authentic voice of someone who has experienced teaching mathematics both in- and out-of-field. Using bricolage as methodology (Berry and Kincheloe, *Rigour and complexity in educational research: Conducting educational research*, Open University Press, 2004) to reflect on my identity as a mathematician (Grootenboer et al., *Identities, Cultures and Learning Spaces* 2:612–615, 2006), I explore how others have struggled to situate my passion for mathematics alongside my academic background in history, my creativity and my faith. I reveal a glorious, complex, sometimes contradictory, shifting, fuzzy bundle of intellectual, personal and professional interactions defying traditional subject boundaries. I conclude that the autobiography of one out-of-field teacher can shed light on the centrality of confidence and emotion to lived experience and the importance of the identity work undertaken by the out-of-field teacher (Beauchamp and Thomas, *Cambridge Journal of Education* 39:175–189, 2009) and recommend that structures developed by policy makers and education leaders embrace the existing knowledges that out-of-field teachers bring with them as an opportunity, not a threat.

Keywords Autobiography · Bricolage · Mathematical identity · Reflexivity

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8.1 Introduction

Sometime in 2006, towards the end of an ultimately unsuccessful interview for some secondary mathematics consultancy work in London, the interviewer said "will the real Fiona Yardley please stand up?". At that stage, I had a history degree and post-graduate certification in teaching history, experience of teaching history, geography, combined humanities and mathematics, experience as a head of mathematics and a masters in curriculum studies. The interviewer wanted to categorise me within their internal classification system (Jenkins, 2014) but could not. I was, to use the phrase commonly used in the UK to describe out-of-field teaching, a non-specialist. While there is no official definition of non-specialist in the UK (Higgins & Taylor, 2007), the term is generally used to describe those teaching a subject in which they do not have a degree and/or teaching qualification (Department for Education, 2016).

Having identified that the literature tends not to focus on the lived experience of the out-of-field teacher, Du Plessis and colleagues (Du Plessis, 2015, 2020; Hobbs et al., 2019) are seeking to address this. Their research considers the lived experience of not only out-of-field teachers, but also key stakeholders such as managers, colleagues, students and parents, using interviews, observation and document analyses, with the stated aim of offering recommendations for educational leaders to inform education policy and strategies, and improve the quality of teaching (especially in STEM subjects). This chapter uses an autobiographical approach, shifting the research problem from trying to understand someone else's point of view to trying to understand my own embodied experiences. As with all research participants, we do construct ourselves, interpreting our constructed narrative as we would that of any participant, but in this case we are closer to the participant! Through the autobiographical lens, I explore how as an out-of-field teacher of mathematics I have conceptualised the subject, how my identity has changed over time, and the impact of both of these on how my identity is perceived by others. For example, the potential employer who asked "will the real Fiona Yardley please stand up?" struck at the heart of my mathematical identity (Boaler et al., 2000) and the intensive identity work I was already undertaking as an out-of-field teacher. The interviewer's question becomes my point of entry text (POET) creating an entry point into an inquiry into a complex field, allowing the researcher to keep threading back, providing some structure without losing complexity (Berry & Kincheloe, 2004).

I use bricolage to explore my own lived experiences of teaching mathematics out-of-field and my responses to the perceptions of others, before concluding by considering how my experiences can contribute to influencing educational policy and leaders to uncover and embrace the complex, original, unique knowledges that out-of-field teachers bring with them. I identify three key themes in my own identity work: that confidence and emotion were more central to my lived experience as an out-of-field teacher than subject knowledge, that I brought with me and built on a rich seam of existing mathematical and other identities, and that the identity work I undertook as I developed as an out-of-field teacher of mathematics led me to question the nature of disciplinary boundaries. I recommend that policy makers and education leaders strengthen structures to support out-of-field teachers' identity work by embracing their existing knowledge, recognising the opportunities inherent in what they bring to their new role.

8.2 Literature Review

Put simply, identity is our understanding of who we are, who others are, and how others perceive themselves and others (which includes us) (Jenkins, 2014). However, there is nothing simple about identity. While providing the necessary warnings against reductionism, Grootenboer et al. (2006) suggest that theoretical perspectives of identity can be categorised as psychological, socio-cultural or post-structural (which they also refer to as postmodern). They claim that it is only the latter that is stereoscopic, seeing identity not only as a feature of the individual, which is how they characterise psychological theories such as Erikson's (1968) or as being a product of collectivity and social relationships, which they describe as socio-cultural, such as Wenger (2011) or Beauchamp and Thomas (2009). The post-structural conceptualisation of identity, Grootenboer et al. (2006) argue, understands it to be relative, subjective, dynamic and unstable. Identity is always constructed. Our multiple identities are constructed by the self and by others in complex feedback loops, as an ongoing process: identity is always emergent.

Consistent with Berry's warning that, "because of the complexity of being human, social beings cannot be reduced" (Berry & Kincheloe, 2004, p. 126), I seek to avoid reducing identity to simplistic notions such as biological naturalism. Notions of mathematical ability prevalent in the society in which I live and work do, however, have a tendency towards biological naturalism (Boaler, 2016). Researchers often cite participants claiming "I don't have a maths brain" or "I'm no good at maths" (e.g. Mendick, 2005; Solomon, 2007). A person's mathematical identity is thus intimately related to how they conceptualise mathematics itself:

> Most students in the US schools, despite being relatively successful mathematics learners, reported disliking mathematics, not because the procedural nature denied them access to understanding, although that was important, but because their perceptions of the subject as abstract, absolute and procedural conflicted with their notions of self, of who they wanted to be. (Boaler et al., 2000, p. 8)

Conceptualising mathematics as abstract, absolute and procedural is consistent with what Ernest (1991) terms as an absolutist philosophy of mathematics. An absolutist conceptualisation of mathematics perceives mathematics to be "real", to have an existence beyond the human mind. In contrast, fallibilists understand mathematics to be a culturally informed human construct. Ernest argues that the vast majority of educators are absolutists, including social-constructivists. While I would contest the latter assertion, my experiences as a learner, teacher and observer of mathematics education in English classrooms suggest that learners are rarely given even a glimpse of how mathematics has been constructed by humans and how it is culturally informed. Mathematics is presented as having been discovered (usually by Western white men [Hottinger, 2016; Walkerdine, 1988]) and as presenting a rational, internally consistent mechanical system (Kuhn, 2007). The nature of mathematics is a huge and complex field beyond the scope of this paper, which holds mathematics to be a culturally informed human construct. I would like to touch on a small number of aspects that have direct relevance in the context of my own mathematical identity: creativity and subject boundaries.

The claim that mathematics is inherently creative (Halmos, 1968; Lockhart, 2009) can be baffling to those whose only experience of mathematics is school mathematics—which is the only access most of us have to mathematics (Davis & Renert, 2014). As a discipline, school mathematics is distinct from mathematics (Lerman, 2000; Lerman & Zevenbergen, 2004), privileging processes and algorithms and conceptual understanding of a finite body of knowledge: from a critical perspective, preparing children for a future of unthinking rule-following (Noyes, 2009). Mathematicians do not follow the rules: they make the rules. Mathematical modelling is a process that strips a phenomenon of features until it is possible to express a relationship. In school, learners are presented with the relationship and are not exposed to the creative process that chose which features to retain, which to reject, the process that wondered about what would happen if a different feature was selected. Pythagoras' theorem ($a^2 + b^2 = c^2$) is usually presented as fact to school children. Even when a teacher reproduces a proof, they do not question why we chose to model triangles as having a perfect right-angle, as existing as a closed polygon in a two-dimensional plane. Right-angles, closed polygons, two-dimensional planes, these are all human constructs created to simplify our complex, dynamic three-dimensional world. Mathematicians challenge these assumptions, playing with them to push the frontiers of mathematics. An example of this that resonates with me is how mathematicians had for years failed to create representations of the hyperbolic plane using the mathematical tools available to them: Taimiņa achieved this using yarn and a crochet hook (Taimiņa, 2018).

As an academic mathematician, Taimiņa had the freedom to cross the boundaries that shape our education system. In education systems with a strong collection code, a hierarchical structure of distinct, clearly differentiated subjects is accepted without question (Bernstein, 2000), leading to identity conflict when crossing boundaries (Crisan & Hobbs, 2019; Hobbs, 2013). In his case study of the rise and fall of environmental science as a school subject, Goodson (1993) eloquently contradicts assumptions about subject boundaries and the constitution of the school curriculum as set in stone.

8.3 Methodology

Denzin and Lincoln's (2000) adaptation of Levi-Strauss's (1966) analogy of bricolage as a qualitative research methodology fascinated Kincheloe (2001). The development of the methodology can be traced woven through subsequent editions of the Sage

Handbook of Qualitative Research (Denzin & Lincoln, 2005, 2011, 2017) and output from Kincheloe and Berry (Berry & Kincheloe, 2004; Kincheloe, 2005, 2010, 2011). Berry and Kincheloe stress that "bricolage has structure" (2004, p. 103). I introduce a honeycomb model to structure my exploration of my mathematical identity and explain my use of Berry's point of entry text (POET) method.

"The POET acts as the pivot, the axis for the rest of the application of the bricolage. It is anything that has or can generate meaning" (Berry & Kincheloe, 2004, p. 108). The story about the interviewer asking "Will the real Fiona Yardley please stand up?" provides a pivot. It was a factor in my decision to study for a degree in mathematics and so is an axis that encapsulates my fragile sense of identity as a mathematician. It will be my POET. The question of my mathematical identity is a complex one that I have grappled with for many years, distracted by contradictory evidence and alternative viewpoints. There is no single, obvious way to enter into my inquiry. In Berry's metaphor, the POET is post-structural, with no beginning, middle or end. It creates an entry point which I can keep threading back to in order to provide some structure without losing complexity.

Denzin and Lincoln's assertion that the researcher "may be seen as a bricoleur, as a maker of quilts" (2011, p. 4) resonates with me. Quilts make me think of collaboration and sharing. My family created a patchwork quilt for my mother-in-law: twenty-two children and grandchildren working collaboratively across the globe to create a single object (Fig. 8.1). Quilts are often tilings of regular hexagons, and the honeycomb

Fig. 8.1 Quilt created with my family for my mother-in-law

conjecture proves that the regular hexagon is the most efficient tiling (Hales, 2001). The hexagon has the greatest relative perimeter and so can *share* more intersections than any other regular shape—it is the most collaborative shape! Quilts speak to me of collaboration and sharing, and so I used congruent regular hexagons on which to record the data I gathered to explore my mathematical identity before analysing by arranging and rearranging it.

As a bricoleur, I gathered data from a variety of sources using a range of methods, including:

- Reflective journaling (Bassot, 2016)
- A one-question questionnaire distributed by email to colleagues, students, family and friends: *do you have any anecdotes/stories/memories that feature both me and mathematics?*
- Discussion and private correspondence
- Timelining (Sheridan et al., 2011)
- Artefacts (influenced by Hottinger, 2016)
- Quantitative analysis of textbook questions
- Historical analysis of documents.

Berry and Kincheloe (2004) use the imagery of a butterfly to illustrate the method of bricolage, repeatedly returning to the POET before visiting different research methods (Fig. 8.2). Avoiding mixing insect metaphors, and critiquing this structure for giving the POET arbitrary centrality, I instead structure my bricolage as a honeycomb (Fig. 8.3). Individual cells hold data from a wide range of sources and research methods. As a tiling, the honeycomb is infinite: a post-structural framework with no beginning, middle or end, and one that provides the greatest degree of linkage between pieces of data.

Having recorded my data on individual hexagons, I placed the POET at the centre and then built the honeycomb (Fig. 8.4), traveling around the cells, noticing continuities and disruptions, "blending, overlapping, and forming a composite, a new creation" (Denzin & Lincoln, 2011, p. 5). This process could have continued infinitely, continually moving cells around, and engaging in further reflection with myself and others, encountering links, tensions, patterns and discontinuities. Through this multi-layered approach, I was able to use diverse knowledges and observe relationships and narratives emerging from my own storytelling symbiotically with those of others, which is redolent of yarning (Barlo et al., 2020). Throughout the rest of this chapter, I borrow the term yarning as I untangle and knit together my data to analyse my lived experience as an out-of-field teacher of mathematics.

8.4 Yarning: Identity

The interviewer in the POET could have been questioning my identity. Aspects of my dynamic and complex identities include as family member (mother, wife, daughter, sister, etc.), educator (teacher, lecturer), academic (mathematician, educationalist,

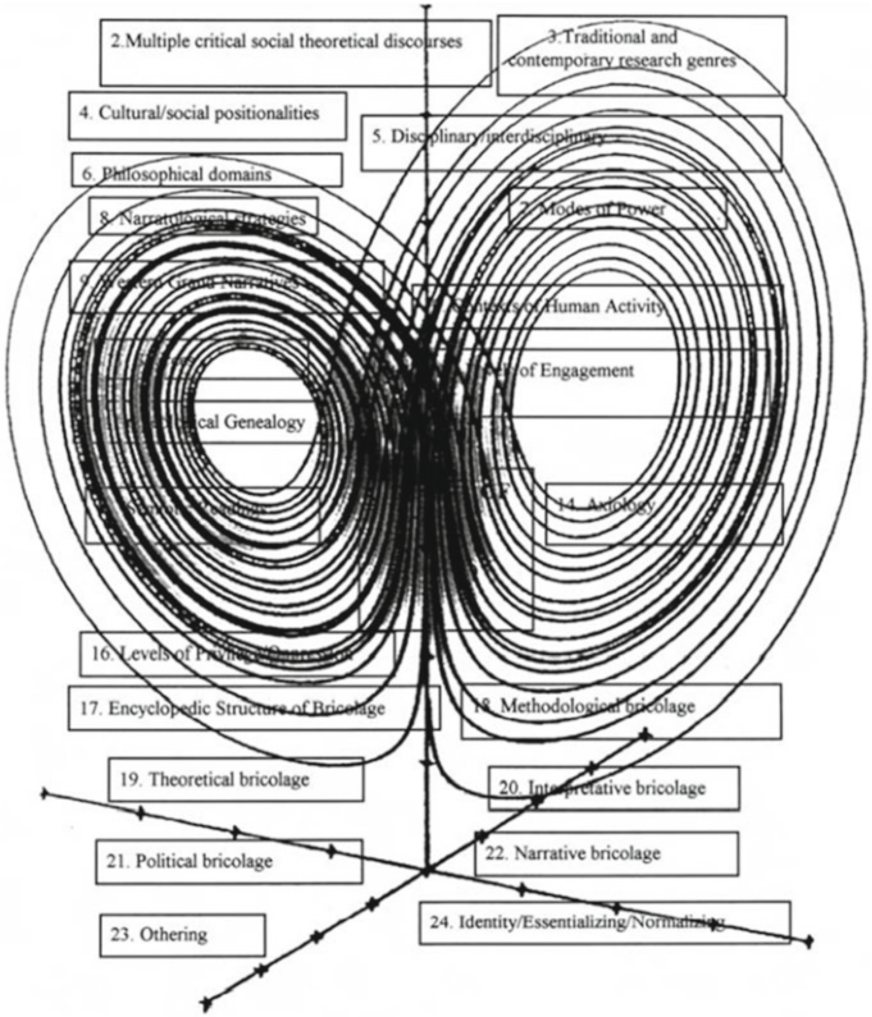


Fig. 8.2 Butterfly image of complexity (Berry & Kincheloe, 2004, p. 113)

historian) and Christian. Three characteristics that I value in myself are nurturing, intellectual curiosity and creativity. I do not find my identities as family person, educator or Christian problematic, but have always felt an imposter in my identity as mathematician. I asked my mother and husband whether they had any thoughts on why this contrast exists in me.

> Maybe it's a female thing to doubt yourself in that way? Teacher and wife are caring roles which women know they can do. Mathematician is skills- and knowledge-based and men are brought up to believe that's what they can do, and should. Mother, private correspondence.

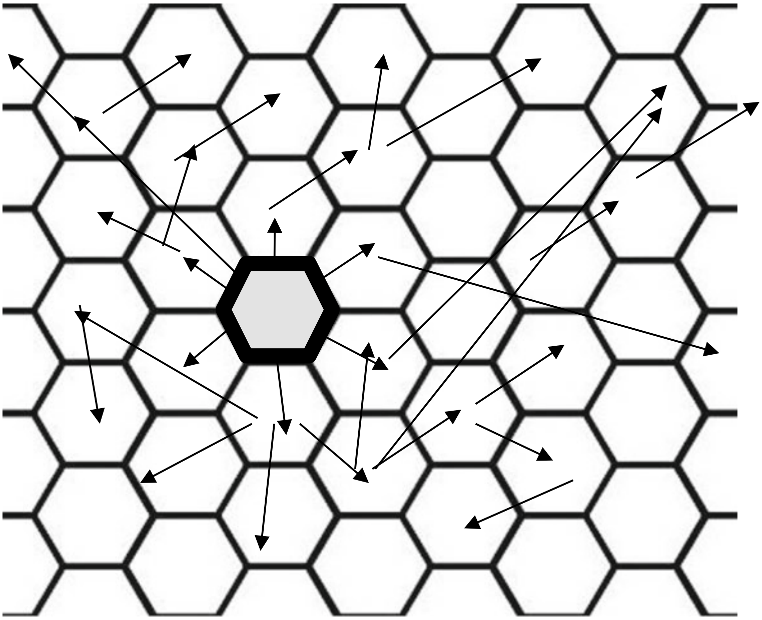


Fig. 8.3 Honeycomb bricolage structure

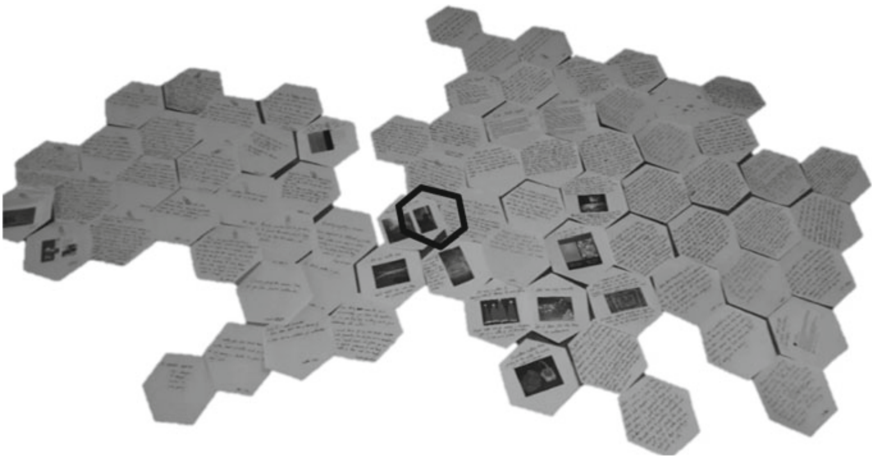


Fig. 8.4 My honeycomb of data

> Is 'mathematician' the same as 'maths educator'? Do you have to be the former in order to be the latter? Husband, private correspondence.

My mother raises the possibility that my gender identity may influence my mathematical identity. Female participation in mathematics drops sharply at 16+ and 18+

(Brown et al., 2008). At the age of 16, mathematics was the only subject I definitely wanted to continue to study. By the time I was selecting university courses two years later, I did not even consider mathematics. In his response to the questionnaire, one of my former teachers said he thought of me as an historian. It is not possible to know whether my gender influenced my decision not to study mathematics for my first degree. I hold up two pieces of evidence which feel relevant:

- No reason was given for me not being allowed to study Further Maths, an additional A-Level (academic qualifications taken at age 18 in England and Wales, usually associated with university entry) which at my school was by invitation only. My mother suggests it may be because the course was tailored to those taking physics, not history (questionnaire response).
- In the book I used to revise for A-Level mathematics (Norton, 1987), 93% of the 577 practice questions were abstract. Only 15 questions (2.6%) referred to people. The only references to females were in two questions, where they only existed to be put into combinations with males. The mathematics I experienced was rarely about people, and when it was, it was about males.

In the above quote, my mother also raised questions about the nature of mathematics (see section below), confidence and upbringing. I use timelining (Sheridan et al., 2011) on the first day of every initial teacher education course I teach to help trainees explore their own mathematical identity (Fig. 8.5). Although I generally rate my confidence as high until the age of 16, my year 8 (age 13) mathematics report read "I would like to see a little more confidence in herself". The only other data I collected that suggested I lacked confidence came from my own journaling. For example:

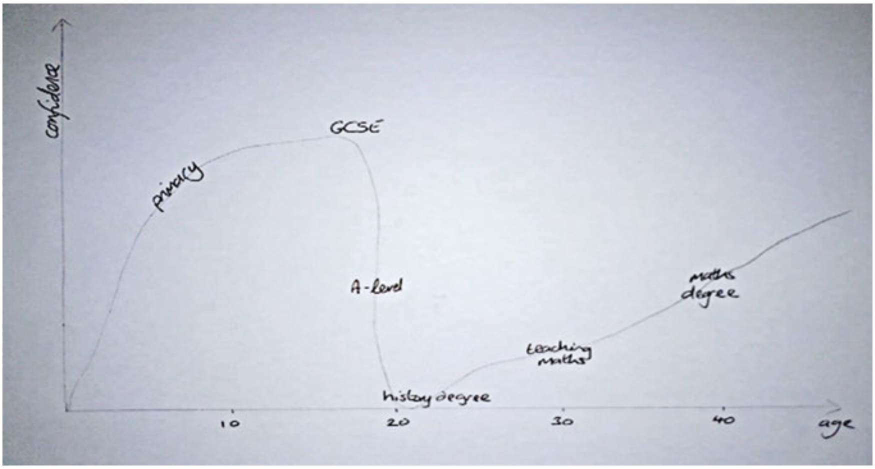


Fig. 8.5 My mathematical confidence timeline

> At a Mathematics Association conference in a keynote session, a man in the audience questioned the meaning of some mathematical notation used by the speaker(♀). I had also not recognised the notation, but would never have asked its meaning so publicly as I would have assumed that it was me being ignorant. Reflective Journal.

My timeline (Fig. 8.5) shows high confidence throughout childhood (also reflected in some of my mother's questionnaire responses). I remember being positive about mathematics from a young age:

> One morning in infants the teacher told us to write down our counting numbers starting at 1 and seeing how high we could go. By playtime I was in the 90s and both anxious and excited – what would happen after 99? I asked Mrs Warriner, a dinner lady. She explained what happened next in a way that made me realise that I could now carry on counting forever. I can still remember how mind-blowing and exciting this realisation was. Reflective Journal.

I grew up in a household organised along traditional gender lines. My mother stayed at home until I started school and then worked part-time as a modern languages teacher. She did the cooking and domestic work. My father was an electrical engineer who did the driving and DIY. My linguistic and creative abilities were nurtured and my elder brother's curiosity about plumbing and machines satisfied. In spite of this, and the fact that it was my mother's quote that opened this line of enquiry, I cannot bring myself to argue that my interest in mathematics was in any way suppressed during my childhood. My brother and I had equal access to education and were encouraged to hold, express and defend opinions and emotions. The values of my family have changed so considerably since my childhood, however, that this may make it difficult to imagine myself as having had an upbringing that instilled values that now lead me to feel insecure about my identity as a mathematician. While my mother considered my gender as being a barrier to me identifying as a mathematician, my husband questioned whether mathematician was the same as mathematics educator and whether the two must coexist. I now turn to this.

8.5 Yarning: Mathematician or Mathematics Educator?

Most questionnaire responses from colleagues and students referred to my identity as a mathematics educator rather than as a mathematician. For example:

> Fiona is able to use her knowledge to break things down, make suggestions for how complex matter can be taught, and how to address misconceptions. Colleague, questionnaire.

This is understandable: mathematics education is the lens through which colleagues and students see me. However, many non-teaching family and friends also related their responses to me as an educator, such as:

> Fiona always talks with such enthusiasm about loving the lightbulb moment when a child understands a maths concept they haven't previously 'got'. Family member, questionnaire.

My immediate understanding of the POET, *Can the real Fiona Yardley please stand up?* was that the interviewer expected mathematics educators also to be *mathematicians* in that he expected them to have a degree in mathematics. This is one of the three main reasons that influenced me to study for a degree in mathematics, which I did over 7 years with the Open University studying part-time alongside the demands of work and a young family. Another was the feeling at the conference described above in which I lacked the confidence to know when to ask questions without fearing I would appear stupid. The third, and the one I credit with keeping me going until the end, was reading the amazing fact that there were exactly 17 wallpaper patterns possible. I tried to read a proof but realised I needed a deeper foundation in mathematics.

In Table 8.1, reflect on my experiences as a teacher of mathematics with, without and while studying for a mathematics degree. As a framework, I use Loewenberg Ball et al.'s (2008) model of knowledge for teaching mathematics. The only one of their six areas of knowledge in which I reflect on my mathematics degree making a significant positive impact is horizon knowledge, which Loewenberg Ball et al. propose only tentatively and do not place on their diagram of knowledge for teaching mathematics. Two main themes can be identified in my reflections. The first is that *teaching* mathematics appears to have a greater impact on my developing knowledge than *studying* mathematics. A second theme that occurs throughout the table is self-confidence as well as emotions such as embarrassment and excitement. Feelings appear to have a greater impact on my pedagogical content knowledge than qualifications or mathematical knowledge, recognising the powerful role of emotion in the construction of identity (Beauchamp & Thomas, 2009).

When one of his students got an answer wrong or was struggling, my GCSE and A-Level (ages 14–18) mathematics teacher would say "come on, it's really easy". I interpreted this as being because he had successfully studied for a degree in mathematics and considered the content we were wrestling with to be basic. This has been an important negative role model throughout my career. I have always endeavoured to empathise with learners' difficulties, made it clear that mathematics is a challenging subject. For example, when lecturing I refer to the *fundamentals* rather than the basics of mathematics, explaining that there is nothing basic about the subject. In 2002, I joined a team writing a guide for heads of mathematics departments (Bevan, 2005) specifically in order to address the discourse of deficiency surrounding non-specialist teachers of mathematics. I wrote "it is liberating for a student to have a teacher who understands his or her difficulties, because he or she has had the same experience" (ibid., p. 157).

As noted above, more responses to the questionnaire referred to me as a mathematics educator than mathematician represented quantitatively in Table 8.2. The type of responder will determine how they respond. Colleagues past and present who have taught alongside me and my students all know me in the context of educator, and so would be more likely to see my mathematical identity through that lens. I designed the survey question (*do you have any anecdotes/stories/memories that feature both me and mathematics?*) and covering email carefully to only refer to mathematics, not

Table 8.1 Reflection on changes in my mathematical knowledge for teaching

	No mathematics degree 1999–2004	Studying for degree 2010–2014	With mathematics degree 2014–2017
Common Content Knowledge (CCK): being able to actually do the mathematics being taught, knowing the facts, processes and concept	Easily revised from my own school mathematics	To borrow a sporting term, I was at peak mathematical fitness. All mathematics I taught was easily accessible to me	Now I have a degree I feel embarrassed if I can't instantly recall a process or fact
Specialised Content Knowledge (SCK): identifying errors in student thinking, choosing representations to aid learning	I felt confident that I had the pedagogical skills to use diagnostic questioning and assessment to establish this knowledge quickly	I became aware of a wider range of representations and connections between areas of the curriculum	Confident in this knowledge, although hard to tell whether this is due to teaching experience or study of mathematics
Knowledge of Content and Students (KCS): anticipating how students will learn the content and what they will find difficult	Awareness that I had found elements of the curriculum difficult at A-Level enabled me to empathise with learners and build confidence	Empathy for learners' difficulties and opportunity to reflect on how to overcome issues	Already felt confident in this knowledge
Knowledge of Content and Teaching (KCT): the knowledge to sequence learning, plan and enact explanations and tasks	Learnt through reflective practice and engaging with mathematics education community (e.g. through subject associations)	Able to reflect on what worked for me as a learner	Already felt confident in this knowledge
Knowledge of Curriculum: how and when the local curriculum requires mathematical content to be introduced and assessed	This had changed little from when I was at school. Major changes to the curriculum occurred during this time and all teachers received training	No impact, although I could better understand why some content was included in the curriculum	Delivering initial teacher education had a greater impact on this than my mathematics degree
Horizon Knowledge: an awareness of how content is interrelated, the concepts content is built on and building on it, and how it relates to other disciplines	My teaching style draws heavily on a story-telling approach and I missed the horizon knowledge I had had as a history teacher. Read a lot of popular mathematics books	Shared with my students my excitement of learning new things and being able to share with them where the current content was leading to	Love being able to share the bigger picture and present mathematics as a connected, exciting, creative and dynamic subject

Table 8.2 Analysis of questionnaire responses

	Colleagues	Students	Friends and family	Total
Total responses	9	14	20	43
Responses referring to me as educator	8 (89%)	11 (79%)	9 (45%)	28 (65%)
Responses not referring to me as educator	1 (11%)	3 (21%)	11 (55%)	15 (35%)

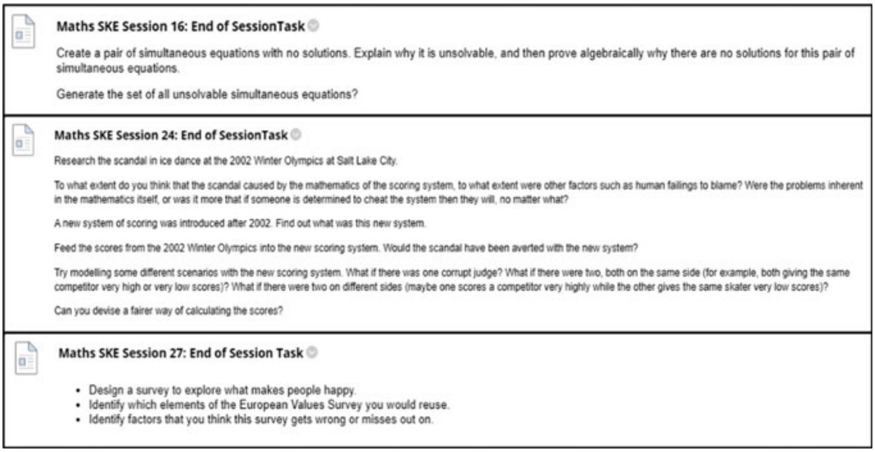
education. I attempted to put the focus on my mathematical identity while asking a question that was open and not leading in the hope of mitigating this to some extent.

Nevertheless, I was disappointed by the outcome. I wanted to be seen as a mathematician, not as an educator. However, the more I read, the more I began to notice that the characteristics that I value most in myself (nurturing, intellectual curiosity, creativity) were coming up again and again in responses, and that these characteristics were present whether the context of the response was teaching or not. I began to realise that my role as educator used all three, *and* that my understanding of the discipline of mathematics involves the latter two elements, and so I now turn to consider my conceptualisation of the subject.

8.6 Yarning: Mathematics and Creativity

It is possible that the interviewer in my POET had a different conceptualisation of mathematics to me. A common view of mathematics is, as my mother put it, that it is skills- and knowledge-based. It is commonly perceived as being about speed and accuracy (Boaler, 2019). My school reports focus on accuracy and comment on exam performance. It is perceived largely abstract (78% of my GCSE revision textbook questions and 93% at A-Level were abstract). It is presented as a binary, right or wrong (Hottinger, 2016).

While I was researching this paper, an image appeared on my Twitter feed with a picture of a long, straight pristine staircase on the left and a Penrose, or "impossible" staircase on the right. The clean, linear picture was captioned "What K to 12 math is like", while the complex image on the right had "what K to 12 math *should* be like". I retweeted it with the comment "*I love this. To me this is all maths*" and an arrow pointing to the Escher print on the right. It resonated with my reading of Levi-Strauss' intellectual bricolage (1966). My mathematical thinking is not linear and I generally do not follow a prescribed route to reach a single solution. I am less interested in solutions. In 2010, I worked with a team of mathematics educators to produce subject knowledge enhancement materials for people coming to mathematics teaching from different academic disciplines. Our aim was to provoke mathematical thinking, creativity and curiosity. Figure 8.6 gives some examples of end of session tasks.


Maths SKE Session 16: End of SessionTask

Create a pair of simultaneous equations with no solutions. Explain why it is unsolvable, and then prove algebraically why there are no solutions for this pair of simultaneous equations.

Generate the set of all unsolvable simultaneous equations?

Maths SKE Session 24: End of SessionTask

Research the scandal in ice dance at the 2002 Winter Olympics at Salt Lake City.

To what extent do you think that the scandal caused by the mathematics of the scoring system, to what extent were other factors such as human failings to blame? Were the problems inherent in the mathematics itself, or was it more that if someone is determined to cheat the system then they will, no matter what?

A new system of scoring was introduced after 2002. Find out what was this new system.

Feed the scores from the 2002 Winter Olympics into the new scoring system. Would the scandal have been averted with the new system?

Try modelling some different scenarios with the new scoring system. What if there was one corrupt judge? What if there were two, both on the same side (for example, both giving the same competitor very high or very low scores)? What if there were two on different sides (maybe one scores a competitor very highly while the other gives the same skater very low scores)?

Can you devise a fairer way of calculating the scores?

Maths SKE Session 27: End of Session Task

- Design a survey to explore what makes people happy.
- Identify which elements of the European Values Survey you would reuse.
- Identify factors that you think this survey gets wrong or misses out on.

Fig. 8.6 Examples of open-ended self-assessment tasks from the Subject Knowledge enhancement materials

Figure 8.7 shows two objects that I created and have on display at home. The tetrahedron in the foreground is made from Geomag (https://www.geomagworld.com/en/), a construction toy which I bought for myself. It makes me think of my sense of fun and excitement for mathematics. In the background is my button-covered button box, an example of my creative approach to mathematics.

> Fiona's approach to textiles is based, I think, on a love of patterns, even though they seem somewhat random at times. Mother, questionnaire.

My craft projects are influenced by mathematics. For the knitting projects in Fig. 8.8, I did not use instructions, preferring to explore patterns by myself. For the blanket, I used a 5:7 ratio grid to design proportional lettering. The other two projects were explorations of rates of change. One was to see the effects of a repeating pattern (I cast on an unknown number of stitches on circular needles and then repeated (k10 k2tog) until I ran out of stitches). The other was to match the shape of wine, beer and spirit bottles to create gift bags. The family quilt project (Fig. 8.1) had a strict algorithm and is not a craft project I would have undertaken by choice. But as my rosette (Fig. 8.9) shows, it did allow me to express my sense of mathematics as fun and made my contribution immediately recognisable to my family.

Responses to my questionnaire included the words fun, passionate, enthusiastic and magic, and one recalled a joke when we devised a new measuring system based on bananas. Several respondents cited my mathematics clothing (Fig. 8.10) as illustrating my attitude towards mathematics.

Can my attitude to mathematics reveal my conceptualisation of the subject? I believe mathematics to be a method that humans have created in order to describe and interact with our world, and as such, it is culturally informed. We can describe it with a sense of awe and wonder, such as the proof of the five platonic solids or 17 wallpaper tilings (Grünbaum & Shephard, 1987) which I studied for the final paper of

Fig. 8.7 Objects on display in my home

Fig. 8.8 Some recent knitting projects

my mathematics degree. We can use it to create useful objects and beautiful works of art (Orne, 2019). The most useful objects created by engineers depend on the creative leap of imaginary numbers—your phone relies on microprocessors that would not exist were it not for numbers which do not exist (Karam, 2020). And the beautiful art of the Renaissance owes so much to mathematical advances such as perspective and the golden ratio (Meisner, 2018). One of the most intense spiritual experiences

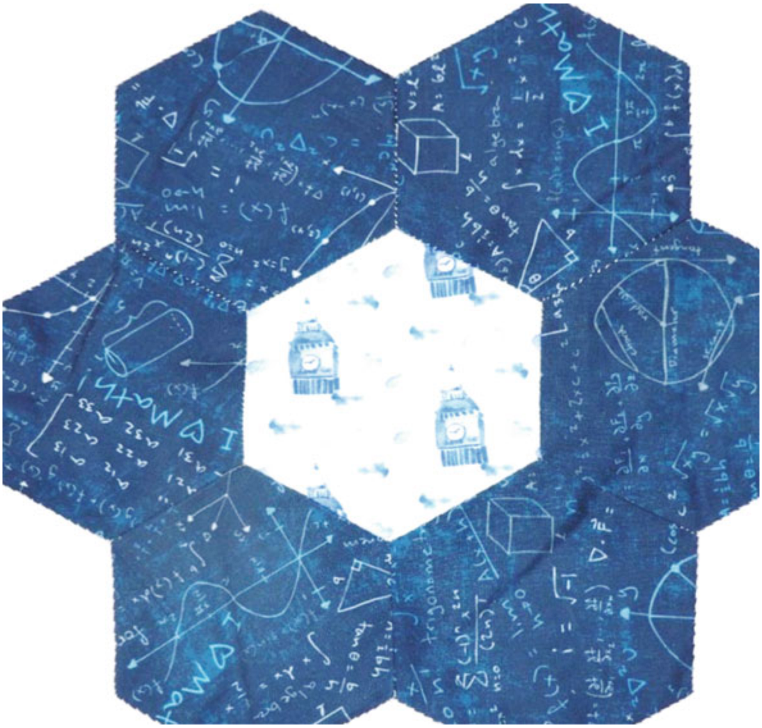


Fig. 8.9 My rosette for the family quilt

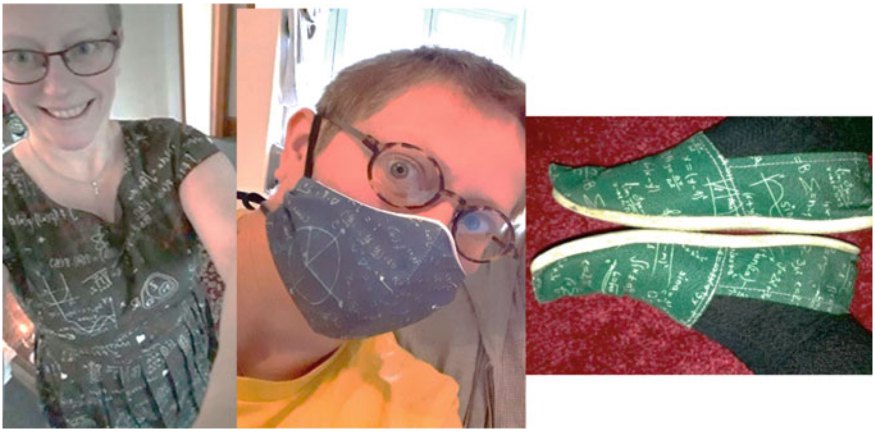


Fig. 8.10 Maths mask, dress and shoes

of my life was watching the parabola traced by a fountain and realising how God created such perfection in nature that we were able to create a way to describe it with a single algebraic equation.

My conceptualisation of mathematics therefore pushes disciplinary boundaries, which will be my last area of this discussion.

8.7 Yarning: Subject Boundaries

> I remember being quite amazed that you are actually a historian whose passion for maths led you to following a second career path as a maths teacher. Not sure I fully expected passion for two such different subjects to be able to exist together in one human being. Colleague, questionnaire.

I wonder if the interviewer in my POET did not expect this either. He followed up his request for *the real Fiona Yardley* to stand up by explaining that he could not work out whether I was a historian or a mathematician. Is this an example of Bernstein's (2000) strong collection code?

> People often commented on how unusual the combination of maths, history and German was – was I an arts or a science student? This made no sense – my choices were logical to me. Maths and history fitted together particularly well. Reflective Journal.

The two university friends who responded to my questionnaire commented on how as a history undergraduate I "fought the corner" to do the optional paper for which you needed mathematics, Quantification in History. And at the end of my degree, I fruitlessly sought to train to teach history *and* mathematics.

A colleague responded to my questionnaire with the following:

> I obviously have lots of examples of 'you and mathematics.' I think, though, the one thing that has stood out for me is the cross-over I see with your knowledge of history as well. A specific example of this which springs to mind is your knowledge of the history of our number system and why one = first, two = second but from third, fourth, fifth onwards we start to see the 'name' of the number appear in the place descriptor. Colleague, questionnaire.

However, in spite of my teenage truculence and professional use of the history of mathematics, I feel that I am at the very beginning of my journey asking why we have subject boundaries, the extent to which they are natural, ways in which they are necessary, what we can learn about ourselves and the nature of subjects and knowledge by exploring the boundaries. Is school mathematics different to mathematics? And if so, what does that mean for my conceptualisation of mathematics as a discipline and my identity as a mathematician and/or a mathematics educator?

8.8 Conclusion and Recommendations

In this autobiographical bricolage, I hope to have provided some insight into my lived experience as an out-of-field teacher of mathematics. By focusing on my relationship with the subject itself rather than the experience of teaching it in the classroom, I have further revealed the complexity inherent in the subject knowledge of an out-of-field teacher. One key theme to emerge is my deep, shifting, contradictory, fuzzy sense of identity and its complex interrelationship with others. I note how this appeared through confidence and feelings rather than measures of mathematical knowledge such as qualifications. A second key theme is my ongoing struggle to conceptualise mathematics, only building a strong identity when empowered to challenge existing conceptualisations in the context of previous experiences as a learner of mathematics, as a knower of other academic subjects, in the context of my personal and professional identity. When entering a new field, I did not discard my old field or the old me at the gate, and I recommend further research into the opportunities and threats (but emphasising the opportunities) carried in the knowledges that out-of-field teachers bring with them. Rather than directing professional development at changing them to fit their new discipline, how can we work with out-of-field to use their existing knowledge and skills to enhance learning and teaching in their new field? A final key theme is how my experiences have led me to question the existence of disciplinary boundaries. Out-of-field teaching as a phenomenon exists because we have a schooling system with strong boundaries between subjects. In a system with softer borders, with an understanding of interdisciplinarity, where the learner was expected to think across borders and draw on eclectic knowledges, as an out-of-field teacher I would be the specialist.

This research was highly personal, undertaken reflexively to explore positionality at the early stages of doctoral study. Although I refer to myself as an out-of-field teacher of mathematics, with a degree and many years' experience as teacher and teacher educator in mathematics I no longer am. Can my personal reflections give insight that might help policy makers and education leaders to provide greater support for people in my situation? My main recommendation is to urge a recognition of what an out-of-field teacher brings with them to their new field, not to use a deficit model such as "non-specialist". An important part of this is simply to recognise the challenging identity work that an out-of-field teacher is likely to be experiencing. Structures to support this identity work through mentoring and professional development should recognise and embrace the out-of-field teacher's existing knowledge beyond their generic pedagogical knowledge. It should lead the out-of-field teacher and others to reflect on the relationships between disciplines and other knowledges. Non-standard conceptualisations of the new field that they bring with them should be explored, not rejected, with an openness to how softer boundaries between disciplines could positively impact learning and teaching.

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Part III
Professional Learning Contexts

Chapter 9
First-Year Out-of-Field Teachers: Support Mechanisms, Satisfaction and Retention

Smadar Donitsa-Schmidt, Ruth Zuzovsky, and Rinat Arviv Elyashiv

Abstract The study investigated the prevalence of out-of-field teaching among newly qualified teachers (NQTs) during their induction year in Israeli schools. It compared the extent of support in-field teachers, partially out-of-field teachers and entirely out-of-field teachers perceived they received from different school parties, their satisfaction with the induction and their attrition rates in the year following the induction. The study also explored the differences between subject and year-level out-of-field teachers. Participants included 2,710 NQTs who were in their induction year in 2016–2018. Findings revealed that despite strict MoE regulations, a third of the NQTs were assigned to teach out of their field. Both entirely and partially out-of-field teachers were less satisfied with the induction year and reported a lower sense of support. A significantly higher percentage of them quit teaching after the induction year. Both subject and year-level out-of-field teaching came up as detrimental, but they were at their worst when they occurred together.

Keywords Beginning teachers · Mentoring · Out-of-field teaching · Teacher induction programs · Teacher retention

9.1 Introduction

In the past few years, a chronic and ongoing teacher shortage in Israel has resulted in a contingency strategy of school principals who systematically assign out-of-field teachers to fill vacant teaching positions (Donitsa-Schmidt & Zuzovsky, 2016). Out-of-field teaching is defined in the Israeli context when teachers teach school subjects or school levels they were not trained for (MoE, 2015). Training requires holding a teaching certificate to teach a specific school subject at a certain school level. The out-of-field phenomenon is highly prevalent in the Israeli context in core school subjects such as science, mathematics and English as a second language, where teacher shortage is particularly acute but it is also present in all other school

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subjects. Out-of-field teaching has spread to the point that over half of the science and mathematics teachers and a third of all English teachers at all school levels lack proper qualifications (State Comptroller, 2019). As the State Comptroller noted, this situation 'is harmful to the students and may cause them long-term damage in terms of the quality of the knowledge, the skill they acquire, and their future academic achievements' (State Comptroller, 2019, p. 937). Although the Ministry of Education is plainly dissatisfied with the situation, it does not take measures against the schools to enforce its regulations. Turning a blind eye, the MoE allows the problem to persist. The only regulation the MoE has issued against the out-of-field phenomenon regards the induction year which is the first of year of teaching (MoE, 2015).

The first year of teaching is acknowledged as a major undertaking for all new teachers. Newly qualified teachers (NQTs) entering schools for the first time face countless challenges. Professional, personal and emotional challenges push many of them to quit the profession at the end of their first year (Ingersoll & Strong, 2011; OECD, 2005; Sutcher et al., 2019). To alleviate the pressures of beginning teachers and ensure their smooth integration into the profession, many countries have initiated mentoring or induction programs. Underlying the induction programs is the rationale that teaching is complex, preparation programs rarely provide the necessary knowledge and skills for successful teaching, and a smooth transition into the profession requires support mechanisms. Induction programs have had positive effects on job satisfaction, commitment and retention of novice teachers (Ingersoll & Strong, 2011; Kearney, 2014).

If teaching is complex work for new teachers, teaching a school subject or year-level for the first time as an out-of-field teacher without adequate background or qualifications adds more layers of complexity to the situation (Napier et al., 2020). While out-of-field teachers are likely to profit from a first-year induction program similar to all new teachers, the degree and nature of this profit remain to be investigated. In this study, we focused on a particular group of NQTs—both in-field and out-of-field—who participated in an induction program within the Israeli education system. The study investigated the prevalence of out-of-field teaching during the induction year and compared in-field and out-of-field teachers in terms of level of satisfaction, perceived support from different school parties and their attrition rates in the year following the induction. The study also explored the differences between out-of-field teachers teaching a school subject or specialisation out of their qualification (subject out-of-field teachers) and those teaching a year-level they were not prepared for (year-level out-of-field teachers). Given the growing number of out-of-field teachers, the study sheds light on diverse layers of out-of-field teaching and adds insights into this field of research.

9.2 Out-of-Field Teaching

Teaching outside one's field of expertise has proliferated in many countries due to a continuing shortage of teachers (e.g., Ingersoll & May, 2012; Taylor et al., 2020;

Zhou, 2014). While out-of-field teaching may offer a contingency solution for teacher shortage, it adversely affects the quality of the teaching workforce (Liu et al., 2008). Scholars and policymakers have noted that out-of-field teachers lack subject-matter knowledge (Du Plessis et al., 2017) or pedagogical content knowledge (Kola & Sunday, 2015), with unwelcome effects on the teaching standards (Napier et al., 2020). Other than poor quality instruction, researchers have observed that students of out-of-field teachers had lower achievements than those taught by qualified teachers (Darling-Hammond & Youngs, 2002; Ronfeldt et al., 2013). Research has also shown that out-of-field teaching negatively affects teachers' stress levels, self-efficacy and well-being (Burn et al., 2007; Pillay et al., 2005; Sharplin, 2014). Finally, out-of-field teachers admit to having difficulties handling their students (Burn et al., 2007) and maintaining good relationships with parents and colleagues (Donaldson & Johnson, 2010; Sharplin, 2014). Consequently, the out-of-field teaching phenomenon has implications for teacher burnout, turnover, well-being, satisfaction and attrition.

Since even highly qualified teachers assigned to teach subjects outside their field of expertise risk being unable to meet their students' academic needs (REL Northeast & Islands, 2020), it may prove an even more pressing issue for beginning teachers. Novice teachers assigned out-of-field classes face additional difficulties during the already challenging and vulnerable phase shared by all new teachers (Luft et al., 2015; Napier et al., 2020). Tasked with teaching school subjects and year-levels for which they are inadequately prepared, these teachers find themselves in a vulnerable position with adverse outcomes to their confidence, self-esteem, job satisfaction and burnout rate (Du Plessis & McDonagh, 2021; Flook et al., 2013; Zee & Koomen, 2016). A sense of belonging and collegial support plays a crucial role in determining the satisfaction and likelihood of retention among beginning out-of-field teachers (Skaalvik & Skaalvik, 2015).

As some researchers have noted, the out-of-field status is not always a binary either-or situation. In some cases, teachers receive combined in-field and out-of-field assignments (Kim, 2011; Nixon et al., 2017; Sharplin, 2014). Nixon and colleagues (2017) proposed an out-of-field teacher scale ranging from 1 to 5 representing the following: 1—all in-field; 2—mostly in-field; 3—half and half; 4—mostly out-of-field; and 5—all out-of-field teacher. As the researchers note, this scaling system is more accurate and expands previous work by allowing a spectrum of out-of-field designations. Their research examined newly qualified science teachers over their first five years of work and found that 36% of the teaching assignments were all in-field, 22% were all out-of-field and 42% per cent featured a combination of in-field and out-of-field subject teaching (Nixon et al., 2017). While this categorisation provides a more accurate description of the complex situation in school, it only addresses subject out-of-field teaching and does not mention year-level out-of-field teaching. Sharplin (2014), in contrast, proposed a categorisation that regards both 'role congruency' (i.e., the school subject) and 'phase congruency' (i.e., the year-level teachers were prepared for, primary or secondary). She then splits each category into three options: 'congruency' (=in-field), 'displacement' (=entirely out-of-field) or 'stretched' (=partially out-of-field). The findings of her small-scale study of 29 teachers, of whom only a few were novices, showed that compared to in-field teachers, a higher percentage of fully or partially misassigned teachers left their appointed school within the first 12 months. In an earlier study (Sharplin, 2014), she found that role-displaced or role-stretched teachers were more likely to leave their job than phase-displaced or phase-stretched teachers.

Adapting Nixon et al.'s terminology (2017) and Sharplin's six categories (2014), the current study conducted in Israel investigated the differences between subject and year-level in-field, entirely out-of-field and partially out-of-field teachers who were in their induction year.

9.3 Induction Programs for NQT

The theory–practice gap between the initial pre-service training and the reality in school, coupled with a sense insufficient pedagogical, emotional and administrative support, discourages many newly qualified teachers (NQTs) from maintaining their teaching position. Moreover, there is abundant evidence that the first few years of teaching, and not just the first one, continue to be challenging for most teachers (e.g., Schuck et al., 2012). Consequently, an alarming number of teachers quit the profession in the first three years after graduating from pre-service programs (Darling-Hammond & Sykes, 2003; Dupriez et al., 2016), most of them at the end of the first year of teaching (Ingersoll et al., 2014). Given the strong evidence that teacher effectiveness increases sharply after a few years in the profession (Rivkin et al., 2005), teacher attrition bears significant adverse effects on the education system.

Realising that pre-service teacher training is unable to create an environment that fully simulates the reality of full-time teaching, various countries began developing induction and mentoring programs to cater to the needs of NQTs. Although the programs of different countries vary considerably, they generally intend to orient, support and guide beginning teachers (e.g., Ingersoll & Kralik, 2004; Ingersoll & Smith, 2004; Ingersoll & Strong, 2011; Kearney, 2014; Long et al., 2012; Sutcher et al., 2019). The purpose of these induction and mentoring programs is to ease the pressures of beginning teachers, facilitate their transition to the teaching profession, socialise them into the school system and ultimately lower their attrition rates (EC, 2010; Howe, 2006; Serpell, 2000). They are designed to provide new teachers with quality support and mentoring, help them overcome their initial professional, emotional and administrative challenges, and encourage them to remain in teaching where they are desperately needed. With the growing complexity of schools and the higher expectations from teachers, induction programs have become favourite policy initiatives in many school systems worldwide (Kane & Francis, 2013) including Israel.

The induction program in Israel which is a one-year program was launched by the MoE in 2000 as a mandatory nationwide program for all NQT. During this year, the NQTs are assigned the same tasks as their more experienced colleagues and bear full responsibility for their teaching. Many of them, particularly in primary schools, are also appointed as homeroom teachers of specific classes, which requires them to collaborate with the pupils' parents and see to the children's well-being at school. The official purpose of the induction year is to 'help the newly qualified teachers to cope with the numerous difficulties of their first year of teaching – professionally and personally' (MoE, 2015, p. 2). The MoE also acknowledges the induction year has the potential of decreasing number of NQTs quitting the education system. During the induction year, the NQTs are required to teach for at least one-third of a full-time teaching job. Support mechanisms are available during the induction year to ease the entry of the NQTs into the profession: the school principal assigns every new teacher a school mentor (paid for by the MoE) and teacher colleges hold weekly workshops throughout the year. The MoE also encourages school principals to actively engage in integrating the NQTs into their school and provide them with the professional, social, emotional and administrative support they need (MoE, 2015). The mentoring teachers and the school principals observe and evaluate the inductees throughout the year. Having successfully completed the induction period, the inductees receive their MoE licensure. Although the MoE, which authorises the participation of every inductee in the program, does not permit out-of-field teaching during this year, this undesired phenomenon is not completely eradicated as a result of the ongoing teacher shortage.

Research has shown that, in most cases, teacher induction programs have a positive impact on NQTs. They enhance teachers' job satisfaction and sense of commitment, strengthen their resilience, self-esteem and confidence, and prevent burnout and attrition (e.g., Frederiksen, 2020; Greenfield, 2014; Guarino et al., 2006; Ingersoll & Strong, 2011; Schaefer et al., 2012; Shockley et al., 2013). Mentoring by experienced teachers, often an inseparable part of the induction program, has proved helpful in new teachers' socialisation into the school culture, enhancing their self-efficacy and providing emotional support (Anthony et al., 2011; Wang et al., 2008). Mentoring has also been shown to decrease attrition (Ingersoll & Smith, 2004). While research reveals that induction programs positively affect NQTs, the question remains how beneficial they are to NQTs who teach out of their field during their induction program.

9.4 Purpose of the Research and Research Questions

The current research, which is a large-scale nationwide study conducted in the Israeli context, had three purposes: to investigate the incidence of subject and year-level out-of-field teaching among NQTs in their induction year; to detect differences, if any, in the way in-field, partially out-of-field and entirely out-of-field NQTs perceived the extent of support they received during their induction, their level of satisfaction with the induction program, and whether they went on teaching in the following year; and to examine the differences between subject out-of-field and year-level out-of-field teaching. The issue of out-of-field teaching during induction has not been studied to date in Israel. Three research questions were asked:

1. How prevalent is out-of-field teaching during the induction year?
2. What are the differences in the way in-field, partially out-of-field and entirely out-of-field NQTs perceive the support they receive during their first year of teaching, their satisfaction with the induction year, and what was their retention rate in the education system in the following year?
3. Which of the two out-of-field teaching types—subject and year-level—has a more significant impact on the above variables?

9.5 Methodology

9.5.1 Participants

Based on data received from the Ministry of Education, we contacted the nationwide population of NQTs who were in their induction year in schools in 2016–2018 (15,408 NQTs in total). A total of 2,710 NQTs completed our questionnaires, a response rate of 18%. Eighty-three per cent were Jews teaching in Hebrew-speaking schools, and 17% were Arab teachers of the Arabic-speaking sector. Eighty per cent were females, aged 33 in average (standard deviation 8). Forty-five per cent taught in primary schools (grades 1–6) and the remaining 55% taught in secondary schools (grades 7–12). Half of the participants were graduates of four-year Bachelor of Education programs; the others were graduates of one-year Certificate of Education programs designed for postgraduates. We did not find any significant demographic differences between the induction participants of each of our studied years, and the findings, therefore, cover the whole sample.

9.5.2 Research Instrument

As a research instrument, we used an online anonymous self-report questionnaire developed by the researchers especially for the current research. In this chapter, we present only those of its parts that are relevant to the present investigation, namely the five following sections:

1. Demographic information (e.g., gender, age) and educational background (e.g., type of training program, school subjects and grade level they were trained for).
2. Details of the school of induction (e.g., primary vs. secondary, location) and participant's employment characteristics during the induction year (e.g., school subject and grade levels the teacher taught).
3. Professional, emotional and organisational support provided to the NQT during the induction year by three school partners: the school management, the mentor teacher and school colleagues. This part included 21 5-point Likert scale items

(5 = very high sense of support; 1 = no support) and underwent an exploratory factor analysis that yielded the following three factors:

(a) The school management (8 items; α = 0.94)—e.g., providing administrative help, support and back-up vis-à-vis pupils and parents, having an open-door policy, acquainting NQTs with the organisational culture;
(b) The mentor teacher (6 items; α = 0.93)—e.g., supervising the new teacher, providing ongoing feedback, being available and responsive;
(c) School colleagues (6 items; α = 0.95)—e.g., sharing professional experience and learning materials, collaborating, warmly welcoming in the teachers' room.

4. Satisfaction with the induction year—one item on a 5-point Likert scale (5 = very high degree of satisfaction; 1 = very low degree of satisfaction).
5. Retention in the education system in the year following the induction—a yes/no question.

9.5.3 Independent and Dependent Variables

In the current research, the independent variable was the degree of out-of-field teaching, comprising three values: (1) in-field, i.e., teachers who only teach subjects and year-levels specified in their teaching certificate; (2) partially out-of-field teachers, i.e., teachers who teach subjects and year-levels they are qualified for as well as ones out of their qualification range; (3) entirely out-of-field teachers, i.e., teachers who only teach subjects and year-levels they were not trained for and are out of their qualification range. Table 9.1 presents the categories used in the current study for out-of-field teaching.

The five dependent variables used are: perception of management support, perception of mentor teacher support, perception of colleagues' support, degree of satisfaction with the induction year and retention in the school system in the year following induction.

Table 9.1 Out-of-field teaching categories

	In-field	Partially out-of-field	Entirely out-of-field
School subjects	Teachers who only teach subjects they were trained for	Teachers who teach subjects they were trained for and ones they were not trained for	Teachers who teach exclusively subjects they were not trained for
Year-levels	Teachers who only teach year-levels they were trained for	Teachers who teach year-levels they were trained for and ones they were not trained for	Teachers who exclusively teach year-levels they were not trained for

9.6 Findings

9.6.1 *Prevalence of the Out-of-Field Phenomenon During the Induction year*

Table 9.2 shows the prevalence of the out-of-field phenomenon during the induction year, namely the percentage of NQTs who taught the school subjects and year-levels they were not trained for. Of the 2,710 NQTs who were in their induction year between 2016 and 2018, 592 (22%) reported teaching school subjects they were not trained for—either as entirely or partial out-of-field teachers. The findings also show that 379 (14%) taught only or partially year-levels they were not trained for. The remaining NQTs were identified as fully in-field teachers.

Further findings showed that subject out-of-field teaching was significantly more frequent among NQTs teaching in primary schools [$\chi^2(2df) = 45.28$; $p < 0.05$]: 27% of the primary school teachers taught school subjects they were not trained or partially trained for against 17% NQTs teaching in secondary schools. The year-level situation was similar: out-of-field teaching was significantly more prevalent among NQTs teaching in primary schools [$\chi^2(2df) = 65.75$; $p < 0.05$]—19% against 9% in secondary schools.

Subject out-of-field teaching emerged as more prevalent in the Jewish schools than in the Arab schools [$\chi^2(2df) = 16.11$; $p < 0.001$] 23% vs. 16%. No significant differences were found between the two sectors in year-level out-of-field teaching. In addition, subject out-of-field teaching was found to be particularly widespread among NQTs who specialised in the humanities (e.g., history, literature) and in the social sciences (e.g., psychology, sociology, civic education), where 36% and 41% respectively found themselves teaching school subjects they were not trained for, mostly core school subjects such as Hebrew, English, mathematics and science. Subject out-of-field teaching was far less frequent among NQTs who were trained to teach the core school subjects of English (4%), mathematics (11%) and sciences (18%), since these are the subjects where teacher shortage is most evident and qualified teachers usually teach in-field.

Table 9.2 Distribution of in-field and out-of-field teachers by school subjects and year-levels

	In-field	Partially out-of-field	Entirely out-of-field	Total
School subjects	2,118 (78%)	389 (14.5%)	203 (7.5%)	2,710 (100%)
Year-level	2,331 (86%)	196 (7.2%)	183 (6.7%)	2,710 (100%)

9.6.2 Differences Between In-Field, Partially Out-of-Field and Entirely Out-of-Field Teachers

Tables 9.3 and 9.4 display the results of two Multivariate Analysis of Variance (MANOVA) that checked the differences between entirely out-of-field, partially out-of-field and in-field teachers. Table 9.3 relates to subject and Table 9.4 relates to year-level out-of-field teaching. In both cases, the dependent variables were those listed above. The division into the Jewish and Arab sector was inserted as a covariate.

In the analysis, the multivariate effects were significant [$F(3,2581) = 4.67$; $p < 0.001$], pointing to a total effect among the three groups. As Table 9.3 shows, all the univariate effects were significant as well. The three groups' means and group contrasts reveal that the subject in-field NQTs reported having received more support

Table 9.3 Differences between subject in-field and subject out-of-field NQTs

	In-field	Partially out-of-field	Entirely out-of-field	F(p) contrasts
Management support	3.56 (1.07)	3.40 (1.09)	3.33 (1.16)	6.25*** INF > par = OOF
Mentor teacher support	3.59 (1.14)	3.45 (1.14)	3.28 (1.31)	7.34** INF > par > OOF
Colleague support	3.76 (1.10)	3.57 (1.14)	3.57 (1.19)	6.02** INF > par = OOF
Satisfaction	3.95 (1.17)	3.63 (1.28)	3.66 (1.23)	14.16*** INF > par = OOF
Retention	0.86 (0.34)	0.81 (0.39)	0.77 (0.41)	8.34** INF > par > OOF

** $p < 0.01$ *** $p < 0.001$

Table 9.4 Differences between in-field and out-of-field year-level NQTs

	In-field	Partially out-of-field	Entirely out-of-field	F(p) contrasts
Management support	3.55 (1.07)	3.35 (1.17)	3.34 (1.15)	5.13*** INF > par = OOF
Mentor teacher support	3.58 (1.09)	3.40 (1.23)	3.35 (1.26)	4.51** INF > par = OOF
Colleague support	3.75 (1.14)	3.47 (1.23)	3.56 (1.19)	7.26** INF > par < OOF
Satisfaction	3.92 (1.18)	3.62 (1.36)	3.72 (1.26)	6.83** INF > par < OOF
Retention	0.86 (0.35)	0.76 (0.42)	0.81 (0.40)	6.81** INF > par = OOF

** $p < 0.01$ *** $p < 0.001$

than the two other groups. In-field NQTs were also significantly more satisfied with the induction year, and 86% of them on average went on teaching in the education system in the year that followed their induction, as opposed to 81% of the partially out-of-field NQTs and only 77% of the entirely out-of-field NQTs. Notably, in three of the dependent variables, the percentage values of partially out-of-field NQTs were as low as those of the entirely out-of-field ones, while in the other two dependent variables, they were significantly higher than those of the entirely out-of-field NQTs, yet considerably lower than those of in-field NQTs.

The total MANOVA effect of the year-level in-field vs. out-of-field NQTs was also significant [$F(2,2606) = 2.99$; $p < 0.001$). As Table 9.4 shows, all the univariate effects were significant, revealing that the year-level in-field NQTs reported receiving greater support than the two other groups, were more satisfied with the induction year, and more of them remained in the education system in the year following induction. In three of the dependent variables, there were no significant differences between the year-level entirely and partially out-of-field NQTs, and the results for both groups were lower than those of the year-level in-field NQTs. In two dependent variables (colleague support and satisfaction), the means of partially out-of-field NQTs were the lowest.

9.6.3 *Differences Between Subject Out-of-Field and Year-Level Out-of-Field NQTs*

Having established the significant differences between in-field and out-of-field NQTs, we proceeded to investigate the type of out-of-field teaching that has a more substantial impact on the NQTs, i.e., subject vs. year-level out-of-field teaching. The distinction between in-field and out-of-field teaching and between school subjects and year-levels yields four types of NQTs: (1) subject and year-level in-field; (2) subject in-field and year-level out-of-field; (3) subject out-of-field and year-level in-field; and (4) subject out-of-field and year-level out-of-field. Table 9.5 summarises the number of participants in each of the four groups.

We conducted a MANOVA to examine the differences among the four. The Jewish–Arab sector division was inserted as a covariate. The total multivariate effect emerged as significant [$F(3,2580) = 4.10$; $p < 0.001$]. Table 9.6 shows the means, standard deviations and univariate effects.

Table 9.5 Distribution of subject and year-level teaching

	Year-level in-field	Year-level out-of-field
Subject in-field	Group 1; N = 1942 Subject INF & Year-level INF	Group 2; N = 176 Subject INF & Year-level OOF
Subject out-of-field	Group 3; N = 389 Subject OOF & Year-level INF	Group 1; N = 203 Subject OOF & Year-level OOF

Table 9.6 Means, standard deviations and univariate effects of the four groups

	Subject INF YL INF (Group 1)	Subject INF YL OOF (Group 2)	Subject OOF YL INF (Group 3)	Subject OOF YL OOF (Group 4)	F(p) contrasts
Management support	3.57 (1.07)	3.47 (1.08)	3.45 (1.06)	3.25 (1.22)	6.43*** 1 > 2,3 > 4
Mentor support	3.60 (1.14)	3.51 (1.18)	3.47 (1.15)	3.27 (1.28)	5.89*** 1 > 2,3 > 4
Colleague Support	3.77 (1.09)	3.66 (1.11)	3.68 (1.08)	3.40 (1.29)	7.55*** 1 > 2,3 > 4
Satisfaction	3.95 (1.17)	3.94 (1.20)	3.75 (1.20)	3.42 (1.36)	13.39*** 1,2 > 3 > 4
Retention	0.87 (0.34)	0.81 (0.39)	0.82 (0.38)	0.77 (0.42)	7.51*** 1 > 2,3 > 4

*** $p < 0.001$

As Table 9.6 shows, all the five univariate effects are significant. Results indicate that the effects of NQTs who taught school subjects and year-levels in-field (group 1) were significantly higher than those of all the other groups in the three types of perceived support and rates of retention. At the other extreme, the consistently lowest group was that of NQTs teaching out of their field in both subject and year-level (group 4). The two remaining groups (groups 2 and 3) stand in the middle and their results are very similar, with no significant differences between them (except in level of satisfaction where group 2 expressed higher levels than group 3).

9.7 Discussion

The findings of the current research indicate that most NQTs worked as in-field teachers during their induction year, teaching the school subjects and year-levels they were qualified for. Less than a third taught out-of-field. This percentage of out-of-field teaching is below the norm prevailing in Israeli schools, where out-of-field teaching is common, sometimes involving more than half of the teachers (Donitsa-Schmidt & Zuzovsky, 2020; State Comptroller, 2019). This percentage is also lower than those found in some international research studies that examine the out-of-field teaching phenomenon among novice teachers in their early career stages (e.g., Nixon et al., 2017). Yet, while this phenomenon is less frequent among NQTs during induction, the very fact that school principals assign novice teacher to teach school subjects and year-levels they were not trained for remains a cause of concern, defying the clear written instructions of the MoE. This state of affairs is a constant reminder of the ongoing teacher shortage that forces school principals to fill all vacant teaching positions by bypassing the regulations. Previous research of the Israeli context has shown that school principals are aware of the adverse effects of out-of-field teachers’ employment, such as disrupted school routine and damage to the quality of teaching (Donitsa-Schmidt & Zuzovsky, 2016).

Yet, teacher shortage is not the only reason for the out-of-field teaching phenomenon. Another hurdle is the absence of quotas per school subject. Teachers' colleges train future teachers in subjects such as social sciences that are not as essential, and those teachers end up teaching out of their field, finding no available positions in their disciplines (Donitsa-Schmidt & Zuzovsky, 2016). To ensure training the correct number of teachers for each school subject and to eradicate out-of-field teaching, educational policy makers should take action and set appropriate quotas. The findings of this study reinforce the global concerns about the teacher shortage in core school subjects such as mathematics and science (e.g., Banilower et al., 2015; Zhou, 2014). However, we must keep in mind that out-of-field teaching sometimes results from decision-making in the schools and not exclusively from factors associated with teacher supply and demand (Ingersoll et al., 2014; Sharplin, 2014). Such school-based decisions occur, for example, in the Arab sector, which surprisingly also has out-of-field teaching despite its years-long surplus number of teachers (Donitsa-Schmidt & Zuzovsky, 2020).

Finally, the higher prevalence of out-of-field teaching that this research discovered in primary schools as opposed to secondary schools substantiates previous research results, which indicated that the out-of-field phenomenon existed more frequently in lower-grade classrooms (e.g., Kim, 2011; Nixon et al., 2017). A possible explanation for the latter finding is that secondary school teachers need to be more specialised. It could, however, also spring from the prevailing primary school culture where the homeroom teacher (class teacher) also teaches her class a variety of school subjects regardless of her specialisation.

The present study also found significant differences between the in-field and out-of-field NQTs in their induction year. The NQTs who had to teach subjects or year-levels they were not qualified for felt mistreated from every possible aspect, and their retention rate was lower. The worst situation was found among those who were teaching out of their field in both the subject and the year-level they were trained for. Since there is no reason to believe that out-of-field inductees were purposely treated differently, it is safe to assume that they were in greater need of support during that year. Teaching out-of-field is a significant hurdle for novice teachers who go through an already challenging and vulnerable phase in their teaching careers. As Nixon et al. (2017) noted, an out-of-field assignment 'may influence their development as teachers in unexpected ways – some possibly positive, others potentially undesirable' (p. 1210). The present research investigated only teachers who benefited from the support of an induction program, which has proved a significant help to new teachers. We are, therefore, unable to assess the situation without induction. The much-needed support to be offered to out-of-field NQTs should focus on developing their subject-matter knowledge and pedagogical content knowledge (Du Plessis et al., 2017), and boosting their self-confidence (e.g., Hobbs, 2013; Lane & Ríordáin, 2019; Sharplin, 2014). These measures might help lower the high attrition rates observed among out-of-field teachers (Donaldson & Johnson, 2010; Ingersoll et al., 2014).

One other purpose of the present study was to examine differences between entirely out-of-field and partially out-of-field teaching to allow a more subtle categorisation in discussing the latter. Our findings revealed that the results for the partially and entirely out-of-field teachers were similar and consistently lower than those of in-field teachers. These findings show how detrimental the state of out-of-field teaching is. It is unfair to put NQTs in a position that puts their well-being at risk and jeopardises the odds of their remaining in the profession they chose and invested a few years studying. As new teachers, they are in no position to resist school principals who impose on them teaching school subjects they were not trained for. Yet, the present study has shown that even partial out-of-field teaching must be strictly avoided, at least in the first year of teaching. Most at risk were out-of-field teachers in both subject and year-level.

9.8 Conclusion and Recommendations

In terms of education policy, the study demonstrated the importance of assigning teachers, particularly novices, to teach school subjects and year-levels they specialised in. Results showed that even a partial assignment as out-of-field teachers bears negative consequences on satisfaction and attrition. The most detrimental situation is a dual out-of-field situation, i.e., in both subject and year-level. The support that out-of-field NQTs received as part of the induction year did not bring them up to par with their in-field counterparts. The varied types of assistance offered, including collegial support and mentorship, vital as they may be, cannot satisfy the immense needs of novice teachers teaching out of their field. School principals should be advised and cautioned from hiring out-of-field teachers altogether and particularly during their first year of teaching. Policy makers should be aware of these findings and tighten their regulation when it comes to NQT.

9.9 Limitations and Follow-Up Studies

Firstly, although the questionnaires were distributed nationwide, the sample is not necessarily representative as the response rate was only 18%. More research is required to explore further the intricate differences between different types of NQT out-of-field teaching. Secondly, the study data were based on participants' self-reporting and risk bias, particularly in the self-reported perception of support received from the administration, mentors and colleagues. Future studies should investigate the perceptions of the other school parties regarding the socialisation of entirely and partially out-of-field teachers in the school. Finally, it might prove beneficial to conduct longitudinal follow-up studies that examine out-of-field teachers over a more extended period, including the retention rates in the first few years and not only during the first year following the induction.

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Chapter 10
Collaborative Content Representation Design to Support Out-of-field Teachers' Pedagogical Content Knowledge in Science

Jared Carpendale and Anne Hume

Abstract Out-of-field teachers without suitable content knowledge may have underdeveloped pedagogical content knowledge (PCK) and student learning may be compromised. Developing teachers' PCK is a challenging task and many researchers call for strategies that encourage collaboration, reflection, and discussion about teaching and learning. In this study, out-of-field physics teachers collaborated with in-field colleagues using a Content Representation (CoRe) as a scaffold for teachers' discussions and decision-making to generate a collective form of PCK. To investigate using a CoRe in this way, qualitative data were collected from recorded group discussions and interviews, and lesson observations with the individual out-of-field teachers. Findings show the CoRe design process prompted participants to explicitly share their PCK and aspects of the out-of-field teachers' PCK were enhanced, noticeably: improved understanding of concepts; more effective representation of concepts; and greater attention paid to students' understanding. The discussions also promoted teachers' PCK development by stimulating integration of different PCK components. These findings point to the important role a framework can play in promoting the rich discussion that encourages in-field teachers' tacit PCK to be explicitly shared for the purpose of transforming out-of-field teachers' PCK.

Keywords Collaboration · Content Representation (CoRe) · Pedagogical Content Knowledge (PCK) · Physics · Professional learning and development · Science

10.1 Introduction

Past research identifies concerns that the quality of out-of-field teaching in science may be compromised by the lack of the teachers' content knowledge (CK) (e.g., Ingersoll, 1996, 2001). In science education, there has been a recent resurgence of

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interest in out-of-field teaching given the worldwide shortage of teachers in science subjects (Hobbs, 2013; Shah et al., 2020), particularly in physics (e.g., Banilower et al., 2015; Price et al., 2019). This renewed interest focuses on exploring the relationship between out-of-field teaching and student learning (Porsch & Whannell, 2019) to understand what aspects of out-of-field teaching may have detrimental effects on student learning and how these can be addressed to strengthen the quality of teaching (Shah et al., 2020). To this end, pedagogical content knowledge (PCK) is a construct worth considering in out-of-field science teaching (Du Plessis, 2015; Kola & Sunday, 2015; Ní Ríordáin et al., 2019), given many science educators regard PCK as a key consideration for quality teaching and learning (Kind, 2009; Luft et al., 2011). Shulman (1986, 1987) originally conceptualised PCK as an amalgam of pedagogy and content knowledge. In the intervening years, the concept has been expanded upon by researchers who argue that other knowledge forms contribute to a teacher's PCK, notably curriculum and assessment knowledge, along with dispositions such as recognising how students may learn specific content and reflecting on teaching (e.g., Carlson et al., 2019). This highly specialised form of professional knowledge for teaching draws on various knowledge bases (including CK) and teaching experiences (Carlson et al., 2019; van Driel et al., 1998).

Teachers with a rich PCK have the ability to select appropriate concepts and sequence them in ways to develop students' understanding and use instructional strategies to promote understanding and elicit student thinking, while varying instruction as needed (Chan et al., 2019; Lee et al., 2007; Loughran et al., 2006). Out-of-field teachers with underdeveloped PCK can experience feelings of anxiety and low self-efficacy, as they find it challenging to engage meaningfully with students' questions and cater for the range of their students' learning needs (Du Plessis, 2015; Sanders et al., 1993) and they do not understand content well enough to recognise the important emphasis (Hobbs & Törner, 2019). For some out-of-field teachers, their lack of content knowledge may also result in a focus on students' learning information through direct instruction (Du Plessis, 2015).

Research exists that explores understanding and capturing science teachers' PCK (e.g., Lee & Luft, 2008), and how PCK may develop over time (e.g., van Driel et al., 1998). However, there is limited research on how to best support out-of-field teachers' PCK development, and exploring potential strategies for such support has been identified as an important research avenue (Donitsa-Schmidt et al., 2020; Du Plessis, 2015; Ní Ríordáin et al., 2019). One potentially useful strategy for out-of-field teachers' PCK development involves purposeful discussion and reflection about the teaching and learning of particular content to promote metacognition (Desimone, 2009; Nelson, 2009; van Driel et al., 2012). However, research findings indicate that teachers find this type of discussion demanding. For example, Nelson (2009) found that while her teachers engaged collegially, their interactions were not transformative. She concluded that to address these limitations teachers needed to go beyond 'sharing' teaching ideas by engaging their pedagogical reasoning to critically examine their teaching strategies through the lenses of their personal learning goals and intended student learning (Nelson, 2005, 2009; Nelson et al., 2012). Thus, this present study sought to investigate an intervention that features collaborative groups of teachers critically discussing and reasoning pedagogically about their teaching and learning of science using a Content Representation (CoRe) framework. To provide insights about how discussions between colleagues can be framed in ways to support out-of-field teachers' PCK development, the research question asked is: How does a CoRe framework, when used within a collaborative discussion environment, support out-of-field teachers' PCK development for teaching electricity and magnetism?

10.2 Literature Review

10.2.1 Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) has been widely researched in science education and findings have led to much discussion, debate, and divergent interpretations of the nature of PCK (e.g., see Carlson et al., 2019; Gess-Newsome, 2015; Magnusson et al., 1999; Park & Chen, 2012). For example, some researchers view PCK as being personal, unique, or private to a particular teacher (e.g., Hashweh, 2005), while others might see it as a collective form of knowledge held by a group (e.g., van Driel et al., 1998). Smith and Banilower (2015) accept that PCK can be seen as personal, but argue there is also a canonical form of collective PCK agreed upon through research and collective wisdom. In other interpretations, some authors perceive PCK as a static or declarative form of knowledge (e.g., Schmelzing et al., 2013; van Driel et al., 2014), in contrast to those who regard it as a dynamic form of knowledge manifested in the act of teaching (e.g., Alonzo & Kim, 2016; Loughran et al., 2001). In an effort to reconcile various researchers' views on PCK and strengthen it as a construct, Gess-Newsome (2015) reported on a consensus model of PCK built on researchers' rich discussion at a PCK Summit (see Carlson et al., 2015). Four years later, a second PCK Summit refined that model resulting in what became known as the Refined Consensus Model (RCM) of PCK for teaching science (Carlson et al., 2019). The RCM (Fig. 10.1) serves as the conceptual framework for this study.

The RCM identifies three realms of PCK: personal PCK, enacted PCK, and collective PCK. Personal PCK (pPCK) represents the complete repertoire of knowledge that a teacher possesses related to the teaching of particular topics, which aligns with the previous view of PCK as a static form of knowledge. In contrast, enacted PCK (ePCK) represents a subset of knowledge and skills that the teacher accesses and uses in the moment when teaching a particular group of students a particular concept in a given learning context, that is, a dynamic form of knowledge. The collective knowledge of multiple teachers for teaching a particular topic is represented as collective PCK (cPCK), including authenticated canonical PCK and other forms of contextually bound knowledge shared by groups of teachers (e.g., in a science department).

The RCM also indicates that knowledge can be exchanged across these different realms of PCK, by the inclusion of double-headed arrows in the diagrammatic form of the model. These arrows signal that one realm of PCK can influence another realm,

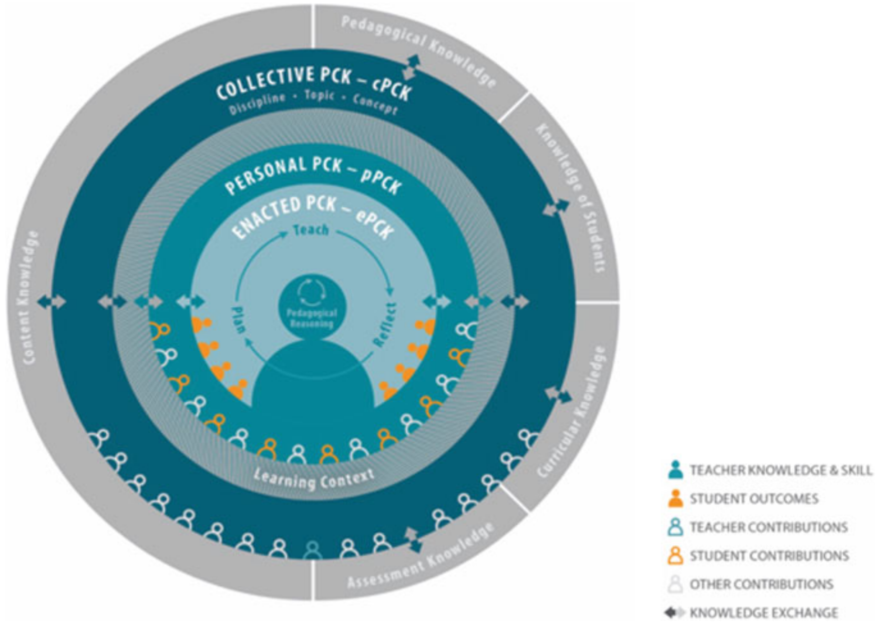

Fig. 10.1 Refined Consensus Model (RCM) of Pedagogical Content Knowledge (PCK) for teaching science (Carlson et al., 2019, p. 83)

and the degree of transformation effected by that influence is mediated through amplifying and/or filtering factors. For example, teachers' personal beliefs about teaching science will mediate the influence of cPCK on their own pPCK and subsequent ePCK (Carlson et al., 2019; Gess-Newsome, 2015). Similarly, different learning contexts will influence what aspects of canonical cPCK are likely to be transformed into teachers' pPCK and ePCK.

While the various conceptualisations and models of PCK have epistemic differences, they do all compartmentalise PCK into components (Chan & Hume, 2019), the most common being content knowledge (CK), knowledge of students' understanding and learning (KS), and knowledge of topic-specific instructional strategies (KI) (e.g., Carlson et al., 2019, Chan & Hume, 2019; Gess-Newsome, 2015; Lee et al., 2007; Magnusson et al., 1999). As a component of PCK, CK refers to knowledge germane to the content or subject matter for a particular topic and group of students. This content expertise enables a teacher to identify what concepts are appropriate for a particular age group, to explain those concepts in scientifically accurate and age-appropriate ways, and to articulate connections to other pertinent concepts (Alonzo et al., 2012; Chan et al., 2019; Lee et al., 2007; Loughran et al., 2006). KS allows teachers to elicit students' prior knowledge about content to identify possible knowledge gaps (e.g., alternate conceptions) and strengths, and to use such information to inform their teaching (Chan et al., 2019; Lee et al., 2007). Similarly, teachers' KI gives them the ability to select, adapt, and use specific instructional strategies for supporting students' conceptual understanding and promoting metacognition (Gardner & Gess-Newsome, 2011; Lee et al., 2007). Note, although CK, KS, and KI have been presented here as discrete constituents of PCK, it is the connections teachers make between them as they integrate them while teaching that contributes to a well-developed PCK (Chan & Hume, 2019; Magnusson et al., 1999; Park & Chen, 2012). To inform this study, it is important to understand what is currently known about the nature of out-of-field teachers' PCK for teaching physics, the relationship between their PCK and the quality of their teaching in physics, and professional learning strategies for promoting PCK development.

10.2.2 Teaching Science and Physics Out-of-Field

Internationally, science education researchers have found evidence that out-of-field teachers often have underdeveloped PCK for teaching science and need support to develop their PCK for helping their students achieve quality learning outcomes (e.g., Du Plessis, 2015; Hashweh, 1987; Ní Ríordáin et al., 2019; Sanders et al., 1993). These teachers tend to focus on rote learning and can find it challenging to develop students' deep conceptual understanding through pedagogies informed by constructivist views of learning (Carpendale & Hume, 2019; Du Plessis, 2015; Hobbs & Törner, 2019). Such pedagogies are considered cornerstones of effective teaching in science (Duit & Treagust, 1998; Posner et al., 1982) while traditional approaches, typically featuring the use of books to present information to students (Nielsen & Thomsen, 1990; Whitaker, 1979), do not reflect rich PCK and often do not lead to the intended outcome (Dykstra et al., 1992). In physics education, conceptual understanding is considered the primary goal (Bao & Koenig, 2019), and progressive physics educators advocate that students need to engage in a conceptual change process to develop their understanding (Dega et al., 2013).

Teaching to promote conceptual change requires a rich PCK as it involves consideration of students' prior ideas, including alternate conceptions (see Pfundt & Duit, 1994) and using that information in a meaningful way to promote students' conceptual understanding (Scott et al., 2007). To enrich their PCK, out-of-field teachers need effective professional learning support (Daehler et al., 2015; Du Plessis et al., 2019; Faulkner et al., 2019). Interventions are recognised professional learning tools, but whatever form they take, van Driel and Berry (2012) emphasise that if PCK development is going to occur teachers must be encouraged to collaborate with colleagues, take part in discussions, and reflect on their own knowledge and practice to promote metacognition. Evens et al. (2015) concur and add that in such interventions the PCK construct should be made explicit and an experienced facilitator should be involved.

10.2.3 Developing Teachers' Pedagogical Content Knowledge

Teacher collaboration has been a long-standing consideration for developing teachers' professional knowledge. However, for collaboration to have impact on teachers' professional knowledge, it needs to be collegial and position teachers as interdependent professionals, rather than forcing or contriving teachers into collaboration by organisational structures (see Hargreaves, 1994; Little, 1990; Vangrieken et al., 2015). For transformative effects on their knowledge and practice, Nelson (2009) recommends teachers take on an 'inquiry stance' in collaborative activities. This stance shifts the nature of teachers' discussions from simply 'sharing' teaching activities to engaging their pedagogical reasoning where they critically examine the activities through the lenses of personal learning goals and intended student learning (Nelson, 2005, 2009; Nelson et al., 2012).

Since adopting an inquiry stance to discuss teaching and learning may not come naturally to teachers, Nelson (2009) suggests the shift may be achieved through the use of critical questions that initiate and promote in-depth discussion. In the PCK literature, such a set of questions exists in a tool known as Content Representations (CoRes) (see Loughran et al., 2006). CoRes feature a framework of critical questions that address the teaching of big science ideas and were initially developed to represent a holistic view of a teacher's PCK for teaching a particular topic to a particular group of students. The framework calls for teachers to unpack a topic by identifying big ideas and addressing key pedagogical questions, ranging from what ideas they want students to learn to potential instructional and assessment strategies. Various PCK researchers have investigated how creating a CoRe collaboratively between pre-service and experienced teachers might lead to pre-service teacher PCK development (e.g., Hume & Berry, 2011, 2013; Hume et al., 2013; Nilsson & Loughran, 2012; Pitjeng-Mosabala & Rollnick, 2018). These studies showed that as participants created a CoRe, rich discussion about teaching and learning particular content for particular groups of students was stimulated that led to some PCK development by the pre-service teachers. However, these studies also highlighted some logistical demands related to using CoRe design effectively (e.g., difficulties associated with teachers and content experts from different locations collaborating effectively). Some researchers (e.g., Donnelly & Boniface, 2013; Donnelly & Hume, 2015) investigated the use of CoRe design online to counter these demands, but they found that much of the rich collaborative discussion was lost, limiting the participating teachers' PCK development. The following research methodology attempted to address these limitations.

10.3 Methodology

10.3.1 Background: Content, Participants, and Intervention

Three out-of-field physics teachers from the same public school in New Zealand were recruited for this study (Table 10.1). Within their school's science department, all teachers, irrespective of their particular content expertise in teaching senior classes, were required to teach general science (comprising elements of biology, earth sciences, chemistry, and physics) to junior students. Thus, it was common for these teachers to be teaching topics to junior students outside of their content specialisation, and for the purposes of this study, such teachers are considered to be teaching out-of-field (see Luft & Roehrig, 2004; Nixon et al., 2017). Each of these teachers taught two junior science classes, and they taught electricity and magnetism to one class prior to taking part in the intervention, and then taught the same topic to the second class after the intervention.

The three recruited out-of-field physics teachers collaborated with other teaching colleagues from their science department, including some who were also out-of-field physics teachers and some who were experienced in-field physics teachers using the CoRe framework to inform their planning.

All of the teachers participated in two four-hour CoRe design workshops, which were used to establish an environment that promoted discussion, reflection, and metacognition where participants could share aspects of their PCK in a collaborative way. Within each workshop, three working groups were created; each contained out-of-field and in-field physics teachers, where one out-of-field teacher per group was reported on as a case in this study. In these working groups, teachers were asked to identify important concepts and skills that should be taught to their students, which were then shared and discussed within the whole group. Once consensus was reached, the content was organised into groupings where each was characterised by an overarching big idea. The working groups were then asked to discuss and respond to the following pedagogical prompts from a CoRe for each big idea (Loughran et al., 2006, p. 28):

1. What do you intend students to learn about this idea?
2. Why is it important for students to know this?

Table 10.1 Out-of-field participants in this study

Name (pseudonym)	Senior subject specialisations	Years teaching
Tony	Biology	6
David	Horticulture and Agriculture	29
Alan	Physical Education	10

3. What else you know about this idea (that you do not intend students to know yet)?
4. Difficulties and/or limitations connected with teaching this idea.
5. Knowledge about students' thinking which influences your teaching of this idea.
6. Other factors that influence your teaching of this idea.
7. Teaching procedures (and particular reasons for using these to engage with this idea).
8. Specific ways of ascertaining students' understanding or confusion around this idea.

The first workshop was purposefully set up to introduce the participants to PCK, CoRes, and the process of CoRe design. This workshop was mediated by an experienced CoRe design facilitator (second author), and it was contextualised using the nature of science as a CoRe topic. One week after this workshop, a second CoRe design workshop was held that focused on teaching the topic of electricity and magnetism, moderated by the same facilitator. This topic was chosen for investigation because its abstract concepts meant students were more likely to develop misunderstandings if learning was not carefully scaffolded (Cosgrove & Osborne, 1985). In this workshop, teachers identified pertinent concepts and skills from the topic for students to learn, which were shared with the whole group to sort out commonalities and differences, and reach consensus about key learning objectives. This whole group discussion led to collective agreement about a set of seven big ideas for the electricity and magnetism topic. The teaching and learning of these ideas were then scrutinised by each working group as they discussed and addressed the same set of pedagogical prompts for each big idea. During this analysis, the facilitator promoted discussion and supported collaboration by encouraging the teachers to use the prompts to reflect on their own views and understanding about teaching this topic. Throughout this process, the participants added their thoughts to a blank CoRe grid that was provided. Three partial CoRes were created, which were combined by the researchers to show a complete CoRe.

10.3.2 Research Design and Data Collection

This study focused on investigating the changes to pPCK and ePCK (notably CK, KS, and KI) for each of the three out-of-field physics teachers after they took part in the collaborative CoRe design process. Underpinning this approach was an interpretivist-based methodology (Guba & Lincoln, 1989; Treagust et al., 2014) as the study sought to make interpretations about participants' knowledge and experiences, particularly changes to the out-of-field teachers' pPCK and ePCK as a result of generating cPCK. Qualitative data in the form of audio-recorded interviews and discussions during the CoRe design workshops, field notes, and video-recorded lesson observations were collected over three phases (Table 10.2) to make these interpretations.

Table 10.2 Research phases and the data that were collected

Phase	Timing	Data collected
1	June	Audio-recorded, semi-structured interviews with out-of-field participants about teaching electricity and magnetism
		Video recordings of out-of-field participants' classroom lessons when teaching electricity and magnetism (Class 1)
2	August	Audio-recording and observations using field notes of all teachers participating in the collaborative CoRe design workshop about teaching electricity and magnetism
3	September	Audio-recorded, semi-structured individual interviews with out-of-field participants to explore their perceptions of CoRe design and its effectiveness for enhancing PCK
		Audio-recorded, semi-structured interviews with out-of-field participants to explore how they think their pPCK and ePCK had developed for electricity and magnetism as a result of collaborative CoRe design
		Video recording of Group One teachers' classroom lessons when teaching electricity and magnetism (Class 2)

Phase 1 involved gathering data using interviews and observations to capture the recruited out-of-field physics teacher's initial pPCK and ePCK (e.g., Chan et al., 2019; Henze & van Driel, 2015). Semi-structured interviews, conducted by the first author, were each audio recorded and transcribed for analysis to investigate the nature of their pPCK for teaching electricity and magnetism (see Appendix A). The questions were informed by the literature review and focused on their KS in physics, KI for teaching electricity and magnetism, and appropriate physics CK for the year level of the students. Lesson observations were conducted by video recording the teachers as they taught electricity and magnetism to capture data for inferring the nature of their existing ePCK. Most (approximately three quarters) of the lessons taught by these teachers were video recorded. Video recording was done using a video camera on a tripod, which was directed towards the teacher. The teacher wore a lapel microphone, and the camera also had a microphone to capture class discussions. A research assistant set this equipment up and retrieved it at the end of the lesson. These data, in combination with interview data, were gathered to build a rich data set regarding the teachers' PCK related to the study topic and to improve the trustworthiness of the conclusions drawn (Bryman, 2016; Henze & van Driel, 2015).

In Phase 2, all nine participating teachers (i.e., the focus out-of-field physics teachers and colleagues from their school) took part in the CoRe design workshops described earlier. All discussions during this workshop were audio-recorded, and the first author was present to take field notes and collect artefacts created by the participants. The completed CoRe that was collated from all of the discussions was given to the out-of-field physics teachers to inform their future planning for teaching and learning activities.

Phase 3 involved the exploration of any changes to the out-of-field physics teachers' pPCK and ePCK from involvement in CoRe design, along with their experiences of the process. In interviews, they were asked to reflect on their own pPCK and ePCK development, and data from interviews and lesson observations were collected to make comparisons to Phase 1. Interviews were semi-structured and audio recorded, and explored the same components of PCK mentioned earlier. The lessons were video recorded in the same way as Phase 1, and again, most of the electricity and magnetism lessons taught by these teachers were captured. Questions also explored their self-perceived changes to their knowledge and their experiences during the process (see Appendix B). Observational data were gathered in the same manner as Phase 1. Teaching commenced one week after the workshop, and again, most of their lessons were video recorded.

10.3.3 Data Analysis

A deductive analysis (Bryman, 2016) of data from each research phase was conducted to explore the impact of collaborative CoRe design on the out-of-field teachers' pPCK and ePCK. From the literature review, nine quality indicators for PCK that aligned with the three components of PCK being investigated in this study (Table 10.3) were identified and used to guide this deductive analysis. The means by which each data set was analysed is described below.

Interview data
All audio-recorded interview data from Phases 1 and 3 were transcribed verbatim and analysed using the quality indicators for PCK in Table 10.1. This process allowed teachers' pre- and post-CoRe design pPCK to be characterised and compared for possible developments. In addition, interview data in Phase 3 about the participants' self-reported pPCK and ePCK development resulting from interactions with other participants were also analysed using the quality indicators in Table 10.1 in the same way. This analysis was checked against findings from other interview and observational data to highlight areas of corroboration.

Observational data
An observational protocol featuring a scoring rubric was developed to make inferences about the out-of-field teachers' ePCK from the video-recorded lesson observations in Phases 1 and 3. The rubric design was informed by several sources: previous PCK research that used rubrics in their methodology (e.g., Alonzo et al., 2012; Gardner & Gess-Newsome, 2011; Lee et al., 2007; Park et al., 2011); the pedagogical prompts from the CoRe (i.e., Loughran et al., 2006); and the grand rubric for analysing PCK developed by Chan et al. (2019). Several experienced PCK researchers were invited to provide feedback during the rubric design process to increase the trustworthiness of the rubric. This feedback led to refinement of the language in the rubric to reduce ambiguity, and examples were provided to mitigate bias. The authors decided

Table 10.3 Three components of PCK used in this study, along with quality indicators and abbreviations

Component of PCK	Indicator	Abbreviation
Content Knowledge (CK)	Appropriateness of the concepts	Appropriateness
	Scientific accuracy of the explanation of concepts	Accuracy
	Links and/or connections made to other concepts	Concept links
Knowledge of Students' Understanding and Learning (KS)	Recognition of possible prior knowledge, difficult concepts, or alternate conceptions	Prior knowledge
	Variations in student understanding and learning is identified which is used to guide instruction	Variations
	Questions are used to probe or extend student understanding	Questions
Knowledge of Topic Specific Instructional Strategies (KI)	Appropriate sequence for teaching concepts	Sequencing
	Relevant examples and/or representations are used, which appear to be pedagogically effective at portraying the concept	Representations
	Strategies that allow for metacognition	Metacognition

to score each quality indicator as limited, basic, proficient, or advanced, in keeping with how observed actions in the lesson compared with the information in the rubric. The rubric was trialled by three researchers using the same video data, and the results were compared. This process revealed that there was extensive agreement amongst these researchers in their analysis of the lessons using the rubric, indicating high levels of inter-rater reliability. Minor inconsistencies in judgement occurred when identifying quality indicators as proficient; thus, to counter these variations, appropriate clarifications and refinements were made to the scoring rubric and the final version of the rubric (see Appendix C) was used to analyse the lesson recordings. During this analytical process, the researchers frequently met to discuss this analysis to ensure trustworthiness.

For the purpose of this study, four lessons from Phase 1 and four from Phase 3 were selected for each teacher (i.e., eight lessons for each teacher) to illustrate the influence of CoRe design on teachers' PCK. The four pre- and post-lessons selected for analysis included: the introductory lesson; a lesson featuring practical work (e.g., making circuits); and two lessons that represented specific conceptual ideas discussed by that teacher during the CoRe design workshop (e.g., explaining voltage or current), as these were relevant for exploring the impact of the collaborative CoRe design workshop.

Collaborative CoRe design workshop
All of the audio recordings from the electricity and magnetism CoRe design workshop in Phase 2 were transcribed verbatim and analysed in a similar way to the interviews, using a deductive approach informed by the quality indicators in Table 10.1. A discourse analysis (Fairclough, 2013) of the discussion was carried out to identify instances of pPCK sharing between participants and to highlight and capture instances where the out-of-field teachers' pPCK may have been influenced. These instances were mapped using a discussion flow chart strategy (Daehler & Shinohara, 2001) to show how the different components of PCK investigated in this study (see Table 10.1) featured in discussions.

10.4 Findings

10.4.1 Phase 1: Out-of-Field Physics Teachers' PCK Pre-collaborative CoRe Design

Phase 1 interviews revealed that the three out-of-field teachers were reliant on school-based supplied learning outcomes when teaching electricity and magnetism. They discussed the influence of these outcomes on their teaching, revealing their intent to cover these outcomes without going beyond their scope. For example, this excerpt from David is representative of their responses:

David: I tend to follow these learning outcomes more than I do with others. I tend to make it a one-hour package each time and tick them off as I go down. Whereas in the biology topics, I am much more inclined to improvise and do my own thing, or give them anecdotes.

These teachers recognised that students would have some prior knowledge about electricity and magnetism concepts before starting this topic, although they did not elaborate on the nature of that prior knowledge nor how it may influence their teaching. They all acknowledged that students have different learning needs, and each offered brief suggestions about how they support student learning and described specific activities that had been successful in their previous teaching of this topic. While it was not explicitly asked, the teachers did not mention ways of representing complex concepts (e.g., using analogies or models). All three briefly talked about their views about eliciting student thinking. Both Tony and David indicated they used informal formative assessment approaches to monitor and plan for student learning. Alan's focus was on the use of question-based tasks during lessons, although he did not elaborate on how those tasks affected future teaching.

The video-recorded lessons from the out-of-field participants were analysed using the rubric to infer their ePCK. The results of this analysis are shown in Table 10.4 (along with comparisons to post-CoRe design lessons). The electricity and magnetism concepts taught by these teachers were seen to be mostly *appropriate*

Table 10.4 Results for inferring the out-of-field teachers' ePCK pre- and post-collaborative CoRe design, and an indication of development

	Tony									David									Alan								
	Pre-CoRe				Post-CoRe					Pre-CoRe				Post-CoRe					Pre-CoRe				Post-CoRe				
Lessons	1	2	3	4	1	2	3	4		1	2	3	4	1	2	3	4		1	2	3	4	1	2	3	4	
Content Knowledge (CK)																											
Appropriateness	P	P	A	A	A	A	P	A	-	A	P	A	P	A	A	A	A	-	A	A	P	A	A	A	A	A	-
Accuracy	P	P	P	P	A	A	A	A	↑	A	P	P	A	A	A	A	A	-	A	A	P	B	P	A	B	L	-
Concept links	B	B	B	P	A	A	A	P	↑	P	B	B	B	P	A	A	A	↑	A	A	B	B	A	A	P	B	-
Knowledge of Students' Understanding and Learning (KS)																											
Prior knowledge	B	B	P	L	P	B	P	P	↑	P	L	B	L	P	B	B	P	↑	P	P	P	L	P	P	B	P	↑
Variations	L	L	B	L	B	P	A	P	↑	P	L	L	B	P	L	P	P	↑	B	B	B	B	P	A	P	P	↑
Questions	B	B	B	B	B	B	P	A	↑	A	P	P	B	B	P	A	P	-	P	P	B	L	A	A	B	B	↑
Knowledge of Topic Specific Instructional Strategies (KI)																											
Sequencing	B	P	B	P	A	B	P	P	↑	P	B	P	L	P	A	P	P	↑	P	A	B	B	P	P	P	P	↑
Representations	P	P	B	P	A	P	A	P	↑	B	P	B	B	A	A	A	A	↑	A	P	P	B	P	A	P	P	↑
Metacognition	L	L	L	L	B	B	B	P	↑	B	B	P	L	B	B	P	P	-	B	L	B	L	P	P	P	B	↑

Legend A = Advanced, P = Proficient, B = Basic, L = Limited, dash (-) = no change, arrow (↑) = development (according to curriculum guidelines) for the age group they were teaching; there were only a few instances where concepts taught were too challenging (e.g., Tony discussing transformers or David discussing electrical power). Similarly, the explanations were generally *scientifically accurate*, with only a few occasions revealing inaccuracies (e.g., Alan incorrectly explained how to connect a voltmeter to a circuit) or explanations that were too brief on the part of the teacher (e.g., David briefly mentioning current pathways in different circuits without elaborating). The observational data from Tony and David's lessons revealed similar results for *linking and connecting* concepts. Both teachers made some links and connections; however, others were overlooked (e.g., Tony not making links between voltage, energy, and energy conservation in a closed circuit). Alan made more links and connections in his lessons than Tony and David, although in lessons three and four (mostly practical work) he made fewer links and some were overlooked (e.g., not linking brightness of a bulb to voltage or energy).

All three participants gathered and acknowledged *students' prior ideas* at different times throughout their lessons (e.g., asking students about terms they have heard before or their experiences with electricity and magnetism). However, data revealed that they used that information in either a limited way or not at all. Similarly, there were few instances throughout all 12 pre-workshop analysed lessons where teachers were seen to be pedagogically responsive to students' needs and *varying* instruction. Both David and Alan used multiple *questions* from simple recall to more in-depth questions. In contrast, Tony rarely asked questions in his lessons. The few he asked were factual recall questions, which he sometimes answered himself.

All participants *sequenced* their concepts in similar ways. At times, the conceptual flow was suitable and the relationships between concepts were well explained (e.g., Alan transitioned effectively from a discussion about atomic structure to the phenomenon of static electricity). In other instances, the connections and relationships were unclear, and the observational data showed students became confused during the lesson (e.g., in David's fourth lesson, which was mostly practical work, the lesson had little structure or explanations, resulting in the students' lack of focus and their inability to complete tasks and achieve understanding). They all used *examples and representations* in their teaching, with varying degrees of success. For example, Alan's explanation of energy transformations in circuits related to household appliances appeared helpful to students. In contrast, David's attempt to use diagrams to represent actual circuits left students frequently confused about the ideas he was presenting.

Strategies to elicit *metacognition* were rarely observed in any of the recorded lessons. There were no instances in Tony's recorded lessons that showed him using strategies to promote students to think about their own understanding. The few instances of such practices in David and Alan's lessons appeared to promote metacognition, but only in a limited way. For example, on one occasion near the very end of the lesson, David tried to encourage students to explain what their voltage and current readings meant by thinking about the circuits that they made. Unfortunately, students were reluctant to engage in discussions with him.

10.4.2 *Phase 2: The Electricity and Magnetism CoRe Design Workshop*

There was a plentiful discussion amongst the teacher participants in this collaborative environment about the teaching and learning of electricity and magnetism. Throughout the four-hour workshop, the facilitator's role was to encourage interactions amongst the teachers using the CoRe framework to scaffold reflective thinking. The facilitator explicitly talked about the CoRe design process initially to the whole group and then joined each working group for short time periods at various stages. As discussions proceeded, it was primarily the physics teachers who took the lead (with or without the facilitator present) sharing their knowledge and asking their colleagues questions.

The first hour of the workshop focused on developing shared big ideas within the whole group, by working collaboratively in their workshop groups to identify pertinent electricity and magnetism concepts and skills for students to learn in junior science. Their discussions revealed how the physics teachers continually encouraged their colleagues to focus on teaching underlying principles as opposed to definitions. For example, when first asked about what was important for students to learn, Tony replied 'definitions of current and voltage', and a physics teacher responded with 'it's not definitions. It's understanding of what it actually is'. This focus on needing to teach underlying principles is further exemplified by the following excerpt:

Physics Teacher: Electric fields cause charges to move. The big idea with circuits is actually conservation of charge. You can't make the charges out of nothing, and you can't destroy them. So, in a series circuit, there is only one way for them to go. All the ones that go in have to come out. So, the current has to be same all the way around.

Tony: See that is why having a physics specialist is good, because you actually understand the big ideas. So, explain a parallel circuit, what is going on there?

Physics Teacher: So, with parallel, again your charge is going around and it gains energy. Now because it is either going through that or through there [drawing diagrams], it is going to lose its energy, isn't it? So, it will have the same voltage.

Working groups then shared the concepts and skills that they identified in the whole group forum to discuss and debate their suitability for students. This task sometimes required clarification of particular concepts and consensus around meaning, as happened when a debate about the 'best way to explain voltage' arose between the three in-field physics teachers. This debate ended when one physics teacher provided an explanation that was acceptable to all, where voltage was explained as the potential energy difference between two points with parallels drawn to gravitational potential energy using diagrams.

After discussing the teaching and learning of voltage, with guidance from the facilitator, participants created an agreed upon list of concepts and skills. The working groups were then tasked with organising concepts and skills into groupings based on commonalities and creating an overarching big idea for each grouping. In a similar fashion to the first part of the workshop, working groups shared their big ideas with each other, then amalgamated, and refined them into the following seven big ideas to represent the whole group's thinking:

1. Charges produce electric fields, which exert a force on other charges;
2. Current is the flow of charge;
3. Voltage is the difference in electrical potential energy between two points;
4. Ohm's law is the relationship between current, voltage, and resistance in a closed circuit;
5. Circuit diagrams are representations of electrical circuits;
6. Electrical circuits can be constructed to solve problems; and
7. Magnetism is another effect of moving charge.

Participants suggested to the facilitator that the big ideas should be divided amongst the groups to make the process more efficient. The facilitator heeded this suggestion, and for the remainder of the workshop, the working groups discussed and addressed the pedagogical prompts for their allotted big ideas (Tony's group 1, 2, and 3; Alan's group 4 and 5; and, David's group 6 and 7). In these discussions, there were many instances where the nature of the CoRe prompts allowed the in-field physics teachers to explicitly share aspects of their pPCK with colleagues. For example, physics teachers discussed their use of analogies and representations, how they purposefully sequence concepts, and how they accurately explain complex ideas in appropriate ways.

Since this stage of the workshop continued for over an hour, reporting each discussion between participants about each prompt is not feasible. However, several key findings can be attributed to each discussion: first, clear indications of the different PCK components investigated in this study (i.e., CK, KS, and KI), and second, dynamic and iterative elements where discussions regarding one component of PCK led into another. Figure 10.2 highlights how the dynamic nature of discussions about PCK components was promoted by addressing the CoRe prompts collaboratively. In this figure, the symbols represent interactions amongst participants where the PCK component is: ■ the primary focus of discussion (these are joined); □ being discussed, but not the focus; or ○ implied or briefly mentioned in the discussion.

10.4.3 Phase 3: Collaborative CoRe Design Effects on Out-of-Field Physics Teachers' PCK

All three out-of-field teachers reported positive experiences from the collaborative CoRe design workshop. Most notably, they appreciated the opportunity to collaborate with colleagues and learn from others and recognised the CoRe framework supported the processes by atomising the topic in ways that highlighted important teaching and

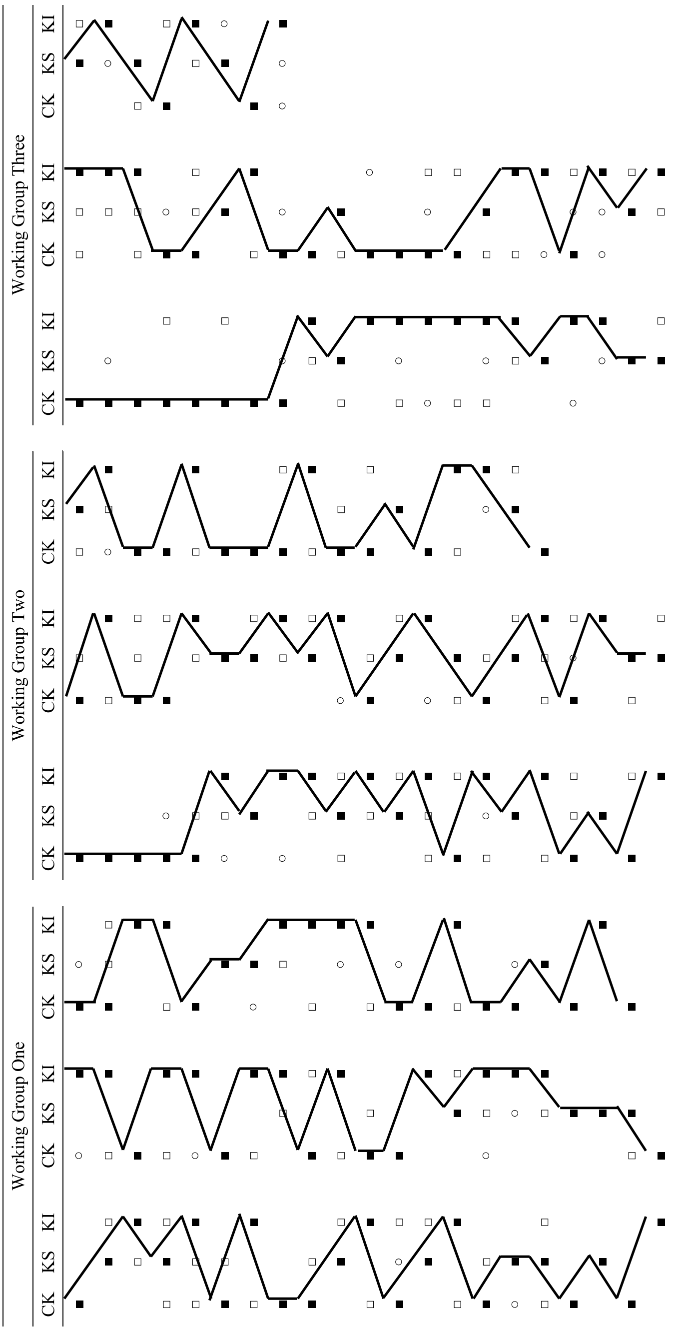

Fig. 10.2 Discussion flow chart of the nature of discussions as participants discussed the CoRe pedagogical prompts (the three columns per working group show one continual discussion). CK refers to content knowledge, KS refers to knowledge of students' understanding and learning, and KI refers to knowledge of instructional strategies (see Table 10.3)

learning considerations for them. The following excerpts from their post-CoRe design interviews exemplify these findings.

Alan: I always enjoy working collaboratively, especially the situation that I am in compared to the others because they have got their experience; or more experience than I have on their content knowledge… I think if anything, it is important for me personally to learn off everybody and their knowledge. And take what everyone has to offer and then create something… It was very worthwhile for me. In fact, I know that with a couple of them, I am going to continue doing some PD [professional development] for electricity.

Tony: The process was good… A CoRe enables you to break a topic into smaller bits, so it seems less overwhelming… So, breaking it up into the big ideas, and then from there it's a good way of putting it all together.

David: I was quite impressed with the CoRe process. It seems to be a very sensible and productive way about going about things… I think it has got potential. I think that there is a tendency to not think through what we actually want to achieve, and why we want to do it… So having a formal set up whereby you can't avoid doing that, without intentionally avoiding doing that, that is where the real value lies. Just having things to prompt you, to prime you to think about what we are trying to achieve and why; that sort of thing.

As they reflected, the out-of-field teachers saw potential for collaborative CoRe design to enhance PCK by making teachers explicitly aware of the pedagogical considerations, which may have been previously unfamiliar to them. David identified how the process highlights areas for development, allowing teachers to be supported prior to teaching a topic. Additionally, he suggested that involving other teachers is a useful strategy for developing the cPCK of the science department, and the pPCK of individuals, which supports student learning:

David: I don't think we do enough of it [collaboration] now… I think it would be more productive for us to pick a unit and go through it, and have a regular programme of reviewing them. Not only would that develop PCK, but also review units to make sure we are still doing what is relevant. It would get you in regular contact with people so you could develop your pedagogy; you would be in the habit of consulting and sharing… I think a programme of this nature encourages that… I would like our faculty to talk about whether CoRe is good, because I think it is. I think there is real value for kids there.

Tony held a similar view and recommended CoRe design for other teachers:

Tony: I would like to do it in the future. I think it would be good to do a CoRe for every topic that we do, especially topics that are problematic, or ones where we are the weakest… I think that everyone who is teaching it needs to be involved. You've got to involve everyone that is teaching it, so they can all get something from it.

In their post-workshop interviews, all out-of-field teachers reported self-perceived enhancements to their pPCK and ePCK, citing specific examples of change. For example, they spoke about how their specific CK had been enhanced (e.g., Tony said his understanding of voltage, current, and energy improved; for David, it was his understanding about magnetism; and Alan felt he developed a better understanding about the topic as a whole). Similarly, they reported that their KI had also improved and all gave specific examples learned during the workshop that would influence their future practice. In contrast to these two components of PCK, their responses about their KS were limited. Although there was a consensus that the CoRe design process made them more aware of student ideas, they did not provide examples. This segment from David's interview is representative of the data indicating participants' development:

First Author: Can you give any specific examples where you think your PCK has changed?

David: I was confused about magnetic field lines. I thought I knew what was going on, but when I looked in the book, I found what appeared to me, to be contradictory, and I wasn't quite sure. I thought, what should I be teaching? I am better off now.

First Author: Do you think the CoRe design process made you more aware of what students.
may be thinking?

David: I tried to be more responsive to what the kids were saying about things… I thought that would be more effective in terms of their learning. If they [students] had put something into it in the first place, then they are much more likely to get something out of it.

The out-of-field teachers' ePCK was inferred from lesson observations after the CoRe design workshop and is summarised in Table 10.4, including a comparison with pre-CoRe results. The analysis showed that there were no apparent developments in *appropriateness* for the out-of-field teachers, indicating a key step in the CoRe design (i.e., agreement on appropriate key ideas and content to teach) had little influence on this aspect of their ePCK. Only Tony appeared to make significant developments around scientific *accuracy*. Data revealed that working with a physics teacher during the CoRe design workshop influenced the way he explained concepts. Tony's explanations were now more in-depth and scientifically correct as he focused on the underlying principles leading to rules and definitions—a point stressed by his physics teaching colleagues during the workshop. Post-CoRe, David spent additional time accurately explaining the scientific underpinning of the concept, rather than focusing on note taking. Comparison of Alan's pre- and post-CoRe teaching showed no change to this indicator. After taking the workshop, he explained voltage and voltage sharing in circuits incorrectly to his students, suggesting this aspect of his ePCK continued to be underdeveloped.

Enhancement was seen in the quality indicator of making *links and connections* between concepts for Tony and David. After the workshop, these teachers were able to make more links between concepts and offered students well thought-out explanations. In comparison, there was only a slight difference seen for this indicator in Alan's lessons, with greater conceptual links only occurring in his practical lesson after taking part in the workshop.

Changes were apparent in the way all three out-of-field teachers utilised students' *prior knowledge*. The degree of enhancement for each teacher varied, with Tony and David appearing much more aware of students' existing ideas and attempting to use the information in ways that informed their actions and strategies during their lessons. Alan used strategies to elicit student thinking in pre- and post-CoRe lessons, although pre-CoRe design he erased students' ideas from the board and continued to follow his lesson agenda. Post-CoRe, he retained their ideas and continually returned to them to make links to concepts covered throughout the lesson.

Being responsive to students' learning needs and *varying approaches* to pedagogy during lessons followed a similar trend, with all three teachers showing improvements in this area. After the workshop, they became more aware of students' learning needs and difficulties, and pedagogies for addressing them. This heightened awareness meant they were more disposed to, and capable of, changing their teaching approach to deal with possible issues. For example, in his pre-CoRe design lessons, Tony was reluctant to engage with students' ideas. After CoRe design, when asked a question indicating students were experiencing difficulty understanding voltages in series and parallel circuits, he quickly diverted from his prepared notes and opted to use the diagrams that he learned during the workshop to assist his students.

There was little difference in the manner that David asked *questions* to probe or extend student understanding between his two classes. Tony and Alan both developed in this area and in similar ways. These two teachers used more and varied questions with their students in class, evolving from simple recall questions that required one-word answers to more sophisticated questions where students had to predict and explain phenomena and justify their thinking.

All participants enhanced their *sequencing* of concepts. In their pre-CoRe design lessons, the order and manner in which these teachers presented concepts resulted in students being confused in their learning (evident from students' questions). After CoRe design, the scaffolding and sequencing of concepts were more appropriate for students in all classes. For example, in his post-CoRe design lessons, Tony explained why they were changing concepts and explored the relationship between those concepts. Meanwhile, David adopted an idea from the workshop to work with 'series' and 'voltage' concepts before 'parallel' and 'current', to support students' conceptual understanding. This strategy was starkly different to his pre-CoRe approach and resulted in less student confusion. Alan organised his practical lessons into more manageable segments and students completed tasks with more understanding and efficiency.

Similarly, all three out-of-field participants enhanced their use of *representations and examples* to portray concepts to students. While both Tony and Alan used these strategies in their pre-CoRe design lessons, they often struggled to portray the desired concept effectively. In his pre-CoRe design class, David rarely used these strategies, and when he did, they appeared unsuccessful at helping students learn. In contrast, in all of their post-CoRe design lessons, all teachers incorporated representations and examples they learned in the CoRe workshop into their teaching and were more confident and effective at using them to support student learning.

Tony and Alan improved their use of instructional strategies to elicit *metacognition.* After taking part in CoRe design, there were many more instances showing where they prompted students to think about their own thinking and to express their ideas. For example, Tony tried to engage students in a whole-class discussion and debate that linked concepts of electrical circuits the students were learning about to the wiring in their homes. In comparison, David underwent little change with regard to this indicator.

10.5 Discussion

It was clear that the out-of-field teachers in this study prior to the CoRe design intervention relied on the list of student learning outcomes provided in the departmental curriculum guidelines to structure and carry out their classroom teaching. As the teachers focused primarily on teaching prescribed concepts, links and transitions between those concepts were overlooked. These findings do not align with rich PCK as described in the literature where many authors argue that identifying important ideas and concepts to teach, making appropriate and accurate links between those ideas and concepts, and being aware of curricular requirements are important considerations underpinning well-developed PCK (e.g., Alonzo et al., 2012; Gardner & Gess-Newsome, 2011; Magnusson et al., 1999; Park & Oliver, 2008). Similarly, when describing their teaching approaches in their pre-workshop interview, the out-of-field participants talked about eliciting student thinking during lessons and trying to accommodate students' learning needs. However, in the classroom, they all appeared to have quite rigid teaching routines, which they were reluctant to adapt or deviate from in the moment. Again, teaching in this way contrasts with the notion of ascertaining and utilising students' ideas, which is a long-established practice for supporting student learning in science (e.g., Scott et al., 2007) and a key consideration of rich PCK (e.g., Gardner & Gess-Newsome, 2011).

Comparing pre- and post-workshop interview and observational findings offered a nuanced view of these teachers' pPCK and ePCK development as a result of collaborative CoRe design. While the changes to their pPCK were unique to each teacher, there were important similarities in how enhancement in one PCK component supported the development of others. For instance, as they refined their CK through collaborative interactions with their in-field physics colleagues, the out-of-field teachers' KI also developed as they became aware of more pedagogically effectual instructional strategies (e.g., representations) during the workshop that they later used in their classroom teaching. With their improved CK, there were also enhancements in the out-of-field teachers' KS, in that they were more responsive to students' learning needs and were able to support their conceptual development by providing students with insightful explanations. These findings align with those from other studies investigating how rich PCK develops (Chan et al., 2019; Park & Chen,

2012) and highlight the importance of providing opportunities for the interplay and integration of PCK components during professional learning experiences.

While the out-of-field teachers all self-reported developments to their KS after the workshop, they articulated fewer examples than for CK and KI. However, findings from the observational data corroborate this development. In their post-CoRe lessons, they sought students' prior knowledge more often and used this information to inform their in-the-moment teaching, unlike their pre-CoRe teaching actions. It appeared that as the out-of-field teachers developed their own conceptual understanding and discussed communicating ideas to students with their in-field colleagues, they became cognisant of student understanding as reflected in their teaching. Thus, comparison of their pre- and post-CoRe design pPCK and ePCK characterisations shows the CoRe design workshop promoting transformations that were more aligned with a sophisticated PCK (i.e., Alonzo et al., 2012; Gardner & Gess-Newsome, 2011; Lee et al., 2007).

As the participants discussed and debated which electricity and magnetism concepts should be taught and addressed the pedagogical prompts, a collaborative environment was generated that stimulated purposeful discussion about teaching and learning, promoted metacognition, and produced a transformative effect on teachers' knowledge (e.g., Desimone, 2009; Nelson, 2005). The out-of-field participants in this study identified both the collaboration with colleagues and the discussions informed by the CoRe framework as key for their own knowledge development. The authentic and professional discussions (Hume & Berry, 2013) that took place in the CoRe workshops contributed to knowledge exchanges, as predicted by the RCM (see Fig. 10.1).

10.6 Conclusion and Implications

The CoRe's combination of big ideas with pedagogical prompts provides a framework that promotes an inquiry stance, allowing teachers to think and reflect on their own practice and to discuss teaching and learning in ways that create a shared contextual cPCK. These in turn help individual teachers to develop their own pPCK and ePCK. For this study, three core components of PCK were identified (i.e., CK, KS, and KI), and each was characterised by quality indicators (see Table 10.1). While having expertise in each of these quality indicators is important for rich PCK, identifying how these components interlink and the extent to which they affect each other in the complex act of teaching are also fundamental in characterising PCK. In this study, the dynamic and iterative nature of the workshop discussions revealed how the big ideas and eight pedagogical prompts of the CoRe initiated and encouraged integration of PCK components (see Fig. 10.2).

The CoRe framework also served as a scaffold to elicit teachers' pedagogical reasoning, promote in-depth discussion, and provoke metacognition through the lens of student learning. By discussing teaching and learning in this way, the conversations shifted from sharing teaching tips and tricks to a collaborative inquiry stance, which is an essential consideration for collaboration to have transformative effects (Nelson, 2005). In responding to the tasks required of collaborative CoRe design, the out-of-field teachers worked with colleagues from their own school to generate a form of cPCK, which in turn produced transformative effects on their own personal knowledge thus confirming the knowledge exchanges predicted in the RCM (see Fig. 10.1). The process also provided opportunities for PCK components to be integrated and ultimately strengthened. Thus, as a means of addressing concerns arising from the increasing number of out-of-field teachers in physics, using CoRe design as an intervention for structuring discussions with in-field teachers within a school seems a useful strategy for promoting the development of out-of-field teachers' pPCK and ePCK to support student learning.

An important implication emerging from this study into supporting collaboration between out-of-field and in-field teachers to promote PCK development was the role a framework embracing content and pedagogy can play in eliciting rich discussion and metacognition about teaching and learning. Establishing the big ideas and addressing pedagogical prompts to create a CoRe enabled the transfer of pPCK from experienced in-field teachers to out-of-field teachers. While previous research has noted the importance of collaboration for teacher professional learning, using the CoRe structure supported the aim of making tacit pPCK explicit and developing contextualised cPCK (as captured in the CoRe). Through this collaborative design process, and using the CoRe generated, the out-of-field teachers' pPCK (and subsequent ePCK) was enhanced.

Appendix A: Pre-CoRe design interview protocol

Guiding questions for semi-structured interview:

1. At the end of teaching the unit, what do you want your students to have achieved?
2. What qualities or skills do you think students need in order to achieve the goal(s) you outlined earlier?
3. What key ideas/concepts do you think students should learn about electricity and magnetism unit during this unit? Why are they important to learn?
4. What prior knowledge for electricity and magnetism are you expecting to see from your students?
5. What alternate conceptions do you think students might have in electricity and magnetism?
6. Tell me about your sequence of lessons for electricity and magnetism.
7. What types of learning opportunities do you provide when teaching electricity and magnetism?
8. How do you accommodate you students' learning needs in electricity and magnetism?
9. How are you going to determine if your students have learnt those ideas/concepts that you have described as being important?

Appendix B: Post-CoRe design interview questions

Guiding questions for semi-structured interview:

1. How worthwhile was developing the CoRe for electricity and magnetism?
2. Did CoRe design change how you might approach the unit or a concept?
3. How did you find working collaboratively?
4. What aspects from the CoRe did you use when you planned your teaching of electricity and magnetism for your second class? (Why?)
5. Did you teach your second class in a different way due to CoRe design? For example, a different approach? (Can you explain why/why not?)
6. Can you give instances where you taught the same concept, but in a different way due to CoRe design?
7. How do you think CoRe design has affected your PCK in Y10 electricity and magnetism? That is:
    a. Has it affected the way you teach certain concepts?
    b. Are you more aware of student alternate conceptions/prior knowledge?
    c. Are there some concepts and/or skills that you would add/drop?
    d. Has it affected the way you monitor or assess student learning?
8. Do you have any final comments about being involved in this CoRe design study?

Appendix C: Rubric for Inferring Teachers' ePCK

PCK indicator	Limited	Basic	Proficient	Advanced
Content Knowledge				
Appropriateness	No alignment of concept(s) in lesson with New Zealand Curriculum—Physical World (Level 5)	Little alignment of concept(s) in lesson with New Zealand Curriculum—Physical World (Level 5)	Adequate alignment of concept(s) in lesson with New Zealand Curriculum—Physical World (Level 5)	Close alignment of concept(s) in lesson with New Zealand Curriculum—Physical World (Level 5)
Accuracy	Explanation(s) were mostly inaccurate, which did not address the concept(s)	Explanation(s) were somewhat inaccurate, which loosely addresses the concept(s)	Explanation(s) were mostly accurate with only small inaccuracies seen, or they were too brief	Explanation(s) were accurate, which addresses the concept with no inaccuracies
Concept links	No possible links and/or connections are made	Few of the possible links are made, but not connected with explanations	Some of the possible links and connections are made	Many of the possible links and connections are made
Knowledge of Students' Understanding and Learning				
Prior knowledge	No recognition or acknowledgement of possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises some possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises and acknowledges some possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises and acknowledges most/all possible student prior knowledge, difficult concepts, and/or misconceptions
Variations	No acknowledgement and/or use of variations in student understanding and learning to guide instruction	Acknowledgement of variations in student understanding or learning, but not used to guide instruction	Some acknowledgement of variations in student understanding or learning are used to guide instruction	Many instances where teacher acknowledged variations in student understanding or learning and used these to guide instruction
Questions	No questions are used to probe or extend student understanding	A few questions are used to probe or extend student understanding	An adequate range of questions are used to probe or extend student understanding	Many and varied questions are used to probe or extend student understanding
Knowledge of Topic Specific Instructional Strategies				
Sequencing	No overall flow between concepts and the sequence confuses students	Some flow between concepts and the sequence allows some concept building to occur	Suitable flow between concepts and the sequence allows satisfactory concept building to occur	Clear flow between concepts and sequence allows effective concept building
Representations	No examples and/or representations used	Examples and/or representations used that do not appear to be pedagogically effective	Examples and/or representations used have some relevance, but appear pedagogically limited	Relevant examples and/or representations used that appear pedagogically effective
Metacognition	No use of strategies that allow for metacognition	Limited use of strategies that allow for metacognition	Adequate use of strategies that allow for metacognition	Much use of strategies that allow for deep levels of metacognition

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Chapter 11
'Teaching Was not in My Head': Narratives from Lateral Entrants of Their Experienced Biographical Transition into the Teaching Profession in Germany

Teresa Beck

Abstract The dissertation project *'SeLe an Grundschulen' (= lateral entrance into the teaching profession in primary schools)* focuses on the collective professionalisation process of teachers who entered the profession through the lateral entrant. To understand their collective orientation of 'the field' in which they are teaching as lateral entrants, I use 15 interviews and additional data from a standardised questionnaire of 4 groups ($n = 114$) from Seiteneinsteiger*innen in a special qualification measure in Saxony. Their narrative-biographical interviews give an insight into the teaching profession with no prior teaching experience as primary teachers (own data). The study focuses on their professional biographies, their transition and career entry, the experiences in teaching practice and their didactic convictions of teaching which all appears in a collective orientation, and is determined by their constructions of being in or out of 'the field'.

Keywords Biographical transition · Documentary method · Lateral entrants · Professionalisation · Transition into teacher profession

11.1 Lateral Entrance into the Teacher profession—In or Out of Field?

> The lateral entrant was just, let's say the last possibility into the primary school direction, just to change sides. (Interview Mrs J, 11/2018)

In the discussion about teaching in- and out-of-field in primary schools in Germany, a special target group has recently become prominent: the lateral entrants. Lateral

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entrants[1] are teachers who usually have a university degree but do not have formal teacher training certification for primary school teaching. They are hired to attend a school without formal qualification or actual preparatory service, but take part in a special qualification program outside the school, at least in most of the Federal States such as in Saxony. In addition to the knowledge learned with their studied university degree subject, the lateral entrants attend this additional training program, which is taught alongside work and can be of different lengths. For the Standing Conference of the Ministers of Education and Cultural Affairs the lateral entrants are hired to maintain the provision of instruction in specific subjects, types of schools and regions with a lack of applicants (KMK, 2019, p. 32; SMK, 2020).

Lateral entrants can work in-, between- and out-of-field in primary schools in Germany, because their studied profession doesn't fit exactly to most of the taught school subjects. In this context 'the field' refers to the different subjects teachers are usually formally qualified for. But even though lateral entrants have a studied subject which is recognised, German primary school teachers have to teach all subjects according to the 'Klassenlehrerprinzip' (KMK, 2015).[2] As a result, teachers often teach a subject in a field in which they do not have a formal teaching qualification. Therefore, primary school teachers can teach sometimes in-field, regarding their studied profession, but regarding the 'class teacher principle' sometimes also out-of-field, and are mostly meandering between these two poles.

As the definition for primary school teachers is quite difficult, whether they teach in- or out-of-field, it is similarly difficult for lateral entrants who teach in primary schools in German. Theoretically, lateral entrants are following formal restrictions to be 'foreigners' in some fields of specialisation and are missing formal qualification to work in the field of the subject, so they do teach out-of-field (cf. Porsch, 2016). Therefore teaching as a lateral entrant is obviously connected to 'out-of-field-teaching', because this occurs when teachers teach a subject for which they are not qualified (cf. Gorrell, 1960; Hobbs, 2013). Looking at the professionalisation process of this group there is something important to add. Even though they are formally teaching out-of-field, they have partially sufficient achievements in a school related subject (Melzer et al., 2014; Puderbach & Gehrmann, 2020). And while entering the profession they participate in a special qualification program of an average length of two years (KMK, 2019 SMK, 2020). They do gain a formal qualification for a studied subject and additional content and pedagogical knowledge (KMK, 2018; Kunter et al., 2011).

[1] This article uses the English term of lateral entrant's equivalent to Seiteneinsteiger*innen in Germany. Since there are several descriptions in the German terminology for lateral entry, the German concept of Seiteneinsteiger*innen is meant (State Ministry of Education and Cultural [SMK], 2020).

[2] The term 'class teacher principle' describes the concept that a school class is taught by the same teacher in almost all subjects, or at least in the main subjects. Additionally, "the class teacher principle as a constituent element of the work in the elementary school is brought into a balanced relationship with the subject matter of the teaching" (KMK, 2015, p. 21).

Research on career changers like lateral entrants entering the teaching profession, which is quite recent overall, provides little evidence to date on what distinguishes career changers. For example, studies show that lateral entrants have a lower understanding of pedagogical knowledge than regularly trained student teachers (cf. Kleickmann & Anders, 2011; Kunina-Habenicht et al., 2013; Oettinghaus et al., 2014). For the subject and the subject didactic knowledge, the findings are inconsistent and vary. 'Some analyses indicate that career changers have a similar level of subject and subject didactic knowledge as teachers with regular training (Kleickmann & Anders, 2011), while other studies found lower subject didactic knowledge among career changers if the studied subject did not correspond to the teaching subject' (Richter et al., 2019, p. 387). Studies on the relationship between the teaching of lateral entrants and students' academic learning success are also scarce in Germany. In addition to these outcomes, I would like to contribute to this discussion the idea of a range of in-field and out-of-field teaching. The term is therefore not divided into two poles, but rather to be understood as a movement that lateral entrants experience, a collective movement that reveals a shared orientation problem and might not be exclusively connected to the taught subject.

This movement into the teaching profession of lateral entrants involves, reconstructed in the material, an orientation or a tension between norm and habitus in the professionalisation process, while the construct of in- and out-of-field teaching shines through (Bohnsack, 2017, 2020). The research data gives an insight into the reconstruction of this transition in the teaching profession while meandering between different aspects of how in- and out-of-field-teaching is reconstructed.

Additionally, the project follows the theoretical construct, that teaching as lateral entrant is a boundary crossing event and marks the development towards a professional identity (Akkerman & Bakker, 2011; Hobbs, 2013). The lateral entrants have not taught before entering the profession, so while starting teaching, they experience boundaries in everyday work life. The individual biographies support the search for the collective movements and the shared orientations. They are not read as individual biographies, but as representatives of common spheres of experiences. In addition, the documentary method can provide another perspective on teaching in- and out-of-field. The orientations reveal the tension already mentioned and how these are negotiated. The question is, how do the lateral entrants process the in-field and out-of-field localisation of their experiences.

To get a deeper understanding of how important lateral entrants became to Germany and the narratives of their experiences, I will outline first some aspects of the current educational situation to explain afterwards the methodological approach and give a first insight in my material, considering that the analysis is still a work in progress.

11.2 A Short Literature Review—Shortage and Lateral Entrants

For several years the shortage of teachers in Germany is continuously rising, primary schools especially do not have adequately trained teachers (Klemm & Zorn, 2018). This shortage forced the Federal States to find rapid and extensive solutions, precisely because the enormous gap cannot be regulated with formal qualified teachers or the shift of teachers from different school forms. The conclusion at the federal level was a paper of the Standing Conference of the Ministers of Education and Cultural Affairs (2013), which provided the basis for a special measure, the so-called Quer- and Seiteneinstieg (= lateral entrant).

Due to the fact that the Federal State Saxony had the highest requirement of all states, I started my research project focusing on lateral entrants in Saxony. This constraint was made due to the fact that most of the 16 Federal States have different notations for lateral entrants (KMK, 2019; Tillmann, 2020), even different regulations. Therefore, the project uses the term 'Seiteneinsteiger*innen'. To be clear in the use of the terminology, these lateral entrants from Saxony are teachers who usually have a higher university degree (Master, Magister or Diploma) but did not study teacher training so they do not have a teaching certification and with this no formal certification for teaching. According to their very different studied subjects and no teaching background, they are employed in schools without preparatory service (for 12 months) and while teaching regularly in schools, they attend an additional pedagogical and didactical qualification program. This program is attended alongside their teaching work and takes place 2–3 days per week. Officially, they are immediately hired to maintain the provision of instruction 'in specific subjects, types of schools and regions with special lack' (cf. Klemm, 2019; KMK, 2019, p. 32), which is usually in the countryside. The KMK released updated public-school hiring figures in March 2019, showing a slight increase from 2018 to 13.3% (4,798 of 36,084 total hires). The numbers of new recruitments via lateral entrant is continuously rising every school year. The federal state of Saxony, as the front runner of all other federal states, covers approx. 50.6% of the vacancies in schools with lateral entrants. This puts Saxony far ahead in a nationwide comparison of the employment rates, followed by Berlin (40.1%), Brandenburg (32.4%) and Hamburg (25.5%) (KMK, 2019, p. 57). Therefore, the concept of lateral entry and of teaching in-, between- and out-of-field in Saxony should become more prominent in school research.

Looking at recent years and knowing that the special measure works as an intermediate solution with long-lasting results, the inducement of the project was to recognise the changing school culture in primary schools. Furthermore, the increasing number of recruited lateral entrants shows that the idea of formal and regular recruited teachers isn't contemporary anymore. Summarising, teaching in-, between- and out-of-field is unavoidable, because we have schools in especially rural areas (e.g. Saxony) where more than 90% of the vacant positions are filled with out-of-field-teaching teachers as lateral entrants. For the project it is therefore important to include this growing target group in the controversial discussion about teaching out-of-field as a lateral entrant and to carryout research efforts from a reconstructive perspective towards the concept of in- and out-of-field-teaching. Therefore, my inducement lies in the biographical stories and career trajectories of the lateral entrants and the reconstruction of their experiences which can show underlying patterns of a collective orientation of how lateral entrants define in- and out-of-field while entering a new profession.

11.3 Methodological Approach

In this chapter, I shed light on the shifting professionalisation process of teachers in a new period—the period of lateral entrants in the school system. Using the qualitative method and methodological approach of the 'Documentary Method' (cf. Bohnsack, 2003, 2017, 2020), I try to gain an insight into the transition of a new professional field and outline the orientation problem as a notoric discrepancy from the new teaching field which defines their interaction in classrooms in the beginning of their professional careers. For that reason, I use the qualitative structure of the Praxeological Sociology of Knowledge (cf. Bohnsack, 2017, 2020) to extend step by step the comparative framework along the different reconstructed narratives. In this article, I outline two specific dimensions which are basically themes or common orientation figures central to lateral entrants' experiences. The first dimension is 'approach into a new profession' and the second dimension is 'teaching out-of-field'. These two dimensions are part of a sense-genetic typology and will be supplemented by others in future. The final goal is to develop a sense-genetic typology in which several dimensions and several types are included.

The 'Documentary Method' is to be understood as a reconstructive methodology as well as a methodical approach, rooted in the tradition of the sociology of knowledge and ethnomethodology. (cf. Bohnsack, 2003, 2017; Mannheim, 1980). In the reconstruction of social reality, which is produced in social practice, the action-guided knowledge of the individual actors is consequently a reflective understanding of action practice. This reconstruction of the action practice 'aims at the habitualized and partly incorporated orientation knowledge underlying this practice, which structures this action relatively independently of the subjectively intended meaning' (Bohnsack et al., 2013, p. 9).

Based on this duplexity of knowledge, it is necessary to differentiate between two forms of knowledge so that can overcome this discrepancy between objectivism and subjectivism (Wagener, 2020, p. 19). On the one hand, there is theoretical knowledge, which structures communicative knowledge and can be clearly explicated by the actors. This form of knowledge exists above all everyday theories and common-sense structures. On the other hand, there is the a-theoretical knowledge that structures the action or underlies it and cannot be explicated by the actors. This conjunctive knowledge is acquired and habitualised in the commonly shared practice of action. That means on the one hand, in everyday life, in every interaction between people, we have an implicit knowledge of mutual and circular knowledge or recursive relation

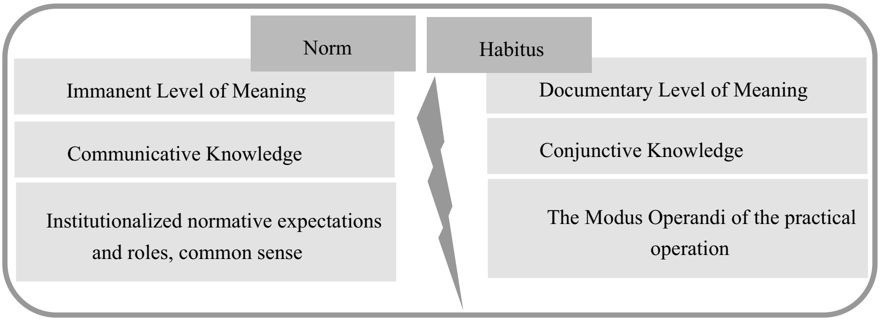

Fig. 11.1 Tension between conjunctive and communicative knowledge. *Source* cf. Bohnsack (2003, 2017), Mannheim (1980)

between an action, utterance or incorporated practice, and on the other an overarching existential social context. For the interpretation of incorporated practices, actions and utterances of the Praxeological Sociology of Knowledge or the Documentary Method, a distinction is made between conjunctive and communicative knowledge, which differentiates between understanding and interpretation (cf. Mannheim, 1980). While we all communicate on an immanent level, the interest lies in the space of conjunctive experiences to understand how people construct their field of experiences and how they gain their processes of understanding. It is about the construction of the collective orientation and the tension between norm and habitus. Figure 11.1 shows an overview of the distinction or tension between conjunctive and communicative knowledge.

The focus is on reconstructing the conjunctive sphere of experience and the possible action-guiding knowledge of the interviewees in this tension between norm and habitus. The interviewees and their stories become representatives of collective spheres of experiences and thus representatives of types who can be formed through the sphere of experience and the shared knowledge. These sphere of experience lie in a field of tension between performative logic and propositional logic, between communicative and conjunctive knowledge (Bohnsack, 2017, p. 103; Wagener, 2020, p. 18 ff.). It is the 'interest of the performative routines of communicative and didactic mediation that form the same framework' (Bohnsack, 2020, p. 10). In this tension, the teacher's orientation meanders between norm and habitus. The proposed logic is one level in which especially constructed normative structures on a social or institutional level are located. The performative logic refers to the 'performative structure of the execution of the practice or the "habitus" as the "actual"' (Wagener, 2020, p. 26).

This is of interest, since the gap between normative-propositional knowledge and practical-performative knowledge marks the professional practice of teachers. Which is an interesting aspect to look at while reconstructing the biographical transition into the teacher profession. This development into an expert in one's own specialist area demands endurance of the tension moving in 'the field' and between communicative knowledge on the one hand and conjunctive knowledge on the other (cf. Bohnsack, 2017; Mannheim, 1980; Wagener, 2020).

To find the ‘typical’ patterns, the collective sphere of experiences can be reconstructed using a first basic-type, which marks the collective orientation figure or the collective ‘problem’ which might be negotiated in a group or peer of society. In this project, the use of a basic-type shall be understood as a conceptual tool (Nentwig-Gesemann, 2013, p. 300). ‘In everyday life, too, we make use of typecast to order the complex and often unclear reality, to put experiences into familiar contexts and to gain orientation for action’ (Nentwig-Gesemann, 2013, p. 295). Therefore, the documentary method (cf. Bohnsack, 2003, 2017, 2020; Bohnsack et al., 2013; Nohl, 2007) uses the reconstruction of collective spheres of experience from people or people’s narrations to get an idea of collective patterns in social interactions of people and their constructed orientations. These conclusions make it possible to justify the different social environments of professional socialisation histories. ‘Only on the basis of an approach to overlapping conjunctive spheres of experience a typology can be generated ultimately that may provide insights into which orientations are related to which spaces of experience, i.e., are “typical” for them’ (Nentwig-Gesemann, 2013, p. 323). In this case, the focus lies in the orientation figure of how in- and out-field is reconstructed and how the lateral entrants experienced their beginning of teaching.

11.4 Empirical Reconstruction—Three Types of Career Approaches

For the research interest and the reconstruction of the lateral entrant’s entry into a new profession and the orientation of how *the field* is reconstructed, several steps were included. In order to identify the orientation figure, it is necessary to work out case-specific characteristics. According to the principle of minimal contrasts, components of a collective orientation are thus worked out (Przyborski & Wolrab-Sahr, 2014, p. 304). These orientations are further abstracted in the basic-type, ‘development-type’, since the approach to professionalisation as a movement is shown in the material. The orientation figure enables an integration of similar as well as very different cases into the interpretation. This collective figure supported the construction of several dimensions in which different themes are negotiated. After this short overview of the methodological approach, I will outline some empirical passages.[3]

Summarising, along these comparative figures, three types could be reconstructed, which will help to generate a further complex typology, including additional dimensions and types. The research interest focuses to gain a holistic construct of a meaning—and sociogenetic typology whereby a multidimensional level construct of types is to emerge. For a first insight into this construction, I would like to show

[3] The passages were transcribed according to the transcription rules TIQ: Talk in Qualitative Research (Bohnsack, 2014). See more in Appendix. Additionally, the passages were slightly smoothed out.

you dimension A and dimension B and the first reconstructed types, to give afterwards some insights into the empirical material.

The two dimensions are:

- dimension A: approach
- dimension B: teaching out-of-field

The three types[4] are:

- 'the resistant'
- 'the analyst'
- 'the independent'

In the following, an attempt is made to outline the orientation figure and to illustrate interpretations regarding how '*the field'* is reconstructed. In addition, it is about the formation of certain action-guiding orientations that lead to a habitualised practice of action. The typologies thus become documents and exemplifications for several typologies within the typology (Nentwig-Gesemann, 2013, p. 297).

Now follows a closer look at the basic-type 'development typic' on the sense-genetic level, which is condensed by case-immanent as well as cross-case comparisons.

The first type **'the resistant'** can be defined as a type whose modus operandi is reconstructed as stable and resilient in his daily professional habitus. The orientation pattern in the interviews reveals a collective negotiation of existing norms and rules of the school. The interviewees do not mention conflicts, situations are described in which their needs are met. The persons do engage in confrontation with colleagues or with the school management. Entry into the school is constructed as very soft, without major problems or barriers. The practice of action is mostly described from the first-person perspective as a teacher, less from that of the students. Differences between norm and habitus do not emerge prominently here; norms of the school are internalised and absorbed without conflict and transferred into the practice of action.

This can be seen, for example, in two small excerpts of a longer narrative to the question of whether Mr. Schwarzdorn feels well supported so far as he teaches and participates in the two day a week qualification measure. Here he negotiates his closeness to the subject and the importance of it. He first refers to how colleagues and the school administration address his needs, including his wish to change things, for example, subjects he should teach or how lessons are carried out. The type is fully respected regarding his new entrance as a lateral entrant and can slowly embark on 'the field'. The second excerpt refers to a change of the textbook and his handling of the fact that conditions such as the use of a textbook can change without the involvement of the teachers.

I: Do you have the impression that you have been well supported so far?
Mr. S: °um° that's the nice thing, if I bring up something and say it doesn't work like that then it's just changes. a::nd if I want it like that then it's just changes

[4] It should be mentioned at this point that the three types are merely templates of what shows up in a common orientation figure, that is, what is typical of the shared experiences.

> like that; it's working like that. because I'm just the person for this subject, for sports. and yes (.) for the other things I can ask anyone, so there have never been any problems. I could always ask questions. was also always considered when it comes to things that one says, um, well, a whole lesson or you are doing science lessons in class today because there is no one there at the moment. (3.) that just never happened. it was just arranged in such a way that I didn't have to do it but that I either sat in with them or supported them but was never just thrown in at the deep end. a:nd I thought that was very good. a:nd that is still the case today. (3.) and they are there, also, that they still slow down. uum yes I then got a little bit involved myself and they also realise okay with this one you can also do something else or have something else done. he will not die from it. (Interview Mr S, 01/2020)
>
> […].
>
> Yes, I don't know why we changed it because, really no idea. I just got it. and then I said well well; let's just continue with that one. (.) and nevertheless, you just work through the pages. Well, I'll put it this way; 'Nussknacker' is for me um so I have to say that many like to work with the 'Nussknacker' and a colleague with whom I have sometimes also worked together; she also liked to orient herself with it. but so that is just I think pretty simple. so at least it is user-friendly for me. where I think it is sometimes not so difficult. The first use of 'Rechenweg' was um. somehow a bit strange. especially because I was used to 'Nussknacker' before, but now 'Nussknacker' is back again; and I don't think it's too bad. (Interview Mr S, 01/2020)

In the next excerpt with Mrs Mispel, another collective orientation can be identified, which is also evident in some other cases. Entering the profession, no barriers are visualised, the person is identified as a teacher. A negotiation that one is not yet a fully fledged teacher as a lateral entrant does not take place here. Being a teacher is internalised, incorporated into the practice and does not trigger any conflicts. One's own role as a teacher is marked as 'in-field'. The persons see themselves as a part of the school, as a part of the college which makes its professional contribution. So, this type is consolidating the professional role, while adapting to the current circumstances. This type could be reconstructed with a satisfied modus operandi, embracing the situation.

One's own role as a new teacher is accepted, internalised and manifests itself in habitualised practice. The subject matter does not always come to the fore; here, too, it is evident that the lateral entrants are able to deal with the unfamiliar in a resistant, typical manner and always develop solution proposals and ideas. The type tries to adapt immediately and uses basic methods and didactical knowledge to give his classes, whether it is in-, between- or out-of-field. The following excerpt from Mrs. Mispel can be located to this type, showing her construct of learning and giving classes. In particular, a modus operandi that standsout through a habitualised practice of action that is not a continuous planning and organising of the daily lessons in detail. Mrs. M pursues a subject didactic approach via active-discovering learning and the opening of lessons. On the communicative level, she outlines a differentiated teaching, challenges are considered part of it. Furthermore, this type embraces knowledge from the qualification program to develop her classes.

I: Ookay. and how would you describe your teaching?

Mrs. M: Yes, it is mostly a very open lesson. I am a friend of open, of um actively discovering learning. if it works; does not always work; um (2) um the teaching is I think (4) very often; I'm someone who does a very detailed planning and structuring //mhm//. but I always give space for the input of the students. that always has space and also um the experiences which depends on the structure of the day. things and to integrate them into the lessons and apart from that I know that my share of speech is still too high because I like to tell anecdotes or I have the feeling that the children will remember them better because I have noticed that is also an effect of the qualification program of course which methods, they lead to the fact that I remember things better and there is a professor who likes to tell anecdotes and we all remembered them. and I probably won't forget them. and that's why I said okay? um that's a good thing I think my classes are actually fun for everyone. the students are all motivated with me, I really rarely have that. of course, sometimes they don't feel like it, but they always show interest in the subject. (Interview Mrs M, 11/2018)

Just as in the previous excerpt from Mrs M, the other two can equally shed light on how the type unfolds. Mr. Sanddorn also responds to the question of what teaching looks like, describing it initially as rather 'frontal'. He sees himself as reflective, trying out new methods that he has learned in training. Here it also becomes clear that at first there is a rather transmissive understanding of teaching, which is not doubted but should be underpinned with new knowledge in the long term. The tension between norm and habitus is very weak here; this type does not come into conflict between everyday practice and newly learned content, but rather adapts new knowledge to existing knowledge. Even if instructional concepts are not up to date, habitualised practice constructs are oriented towards older notions of instruction. Thereby a transmissive understanding of learning is assumed and incorporated. This softens the approach to the teaching profession. Uncertainties are buffered by a status quo of teaching.

I: Well, um, how would you describe your teaching?

Mr. S: Yes, I say it like it is, it's even mo:re frontal. and I try again and again to question myself and the new methods, what I'm already learning here, I'm trying to understand and try to check things out. not everything works right at the beginning but it's getting better. but you still stick a lot to the frontal teaching because you have the <u>workbook</u>, you have the <u>book</u>, you know ok there you can work things out with the students, now the project-oriented is

> rather less, I hope that in the next few years still improves where I can take things. (Interview Mr. S, 01/2019)

In addition, Mrs. Jochelbeer's excerpt shows that a habitual adaptation to her 'field' occurred. Mrs. J describes her everyday practice to the effect that when she is not there, her colleagues keep her up to date and are interested in her situation as well as her needs as a career beginner. News about daily school routine are given to her and she can implement them. Her 'field' is thereby a kind of space of teaching and learning in which she is integrated. This becomes more explicit especially when she is not in school and has to attend her qualification training program. She marks not difficulties according these circumstances, but rather points out that this is quite normal and that as a lateral entrant she simply cannot always be in school. Since she has her qualification measure on Mondays and Tuesdays and is not in there on those two days. Mrs. Jochelbeer states this special status of a lateral entrant in the beginning of her professional entry, in response to the question of what her school day looks like.

I: And does that have an effect on the staff that you are not there on Monday, Tuesday?
Mrs. J: Um no. we plan our service consultation on Wednesdays. that is especially for us, and that is now also not somehow; that one is now excluded just because one is not there on a Monday Tuesday; so that's not the case at all.

I: So you have the feeling that you get all the information?
Mrs. J: Yes. they tell me then u::m immediately on Wednesday what I have missed, or one of my colleagues sends me the changed timetables.

I: Are you also a class teacher?
Mrs. J: Yes um; class teacher of the fourth um; yes I have raised them from the second to the fourth @(.)@ (Interview Mrs. J, 10/2018)

Furthermore, this type is reconstructed as mostly in-field, especially when referring to her studied subject or prior experience in pedagogical fields of work. Only in some cases, the identification can be reconstructed as partly 'out-of-field' with a huge support mechanism to bring her into 'the field' or make her feel being part of the system as a fully accepted and qualified teacher. This is shown when the interviewees explain their support strategies, e.g. help from colleagues with missing information or changing plans to support them in the beginning. The field is reconstructed as a sphere of the school structure, while this type assumes 'the field' without negotiation. The expertise of the lateral entrants is reconstructed as recognised in the teaching team and is seen as respectful, due to the fact that no negotiations are mentioned but support as part of the professional development. Even if small prejudices existed at the beginning, these were directly eliminated and did not play a major role in the start of their career. The typical approach of this orientation figure is to reconstruct no significant conflicts in their entry into teaching and to act in the habitualised practice of a fully fledged teacher. This can be reconstructed in the case of Mrs. J and the structure that she immediately got her 'own class' and taught them from the second to the fourth level, a short narration where she outlines the process of being part of 'the field'.

The second reconstructed type is defined as **'the analyst'**. This type tries to deal with problems and difficulties in the beginning of the teaching profession as a lateral entrant. The professional role is not at all times stable in the modus operandi, uncertainties in methods and didactical implementations are reconstructed in the habitualised practice. Naming these problems, this type can mark difficulties without having immediately proposed solutions in her habitualised professional interaction in the classroom, but in a theoretical way. Everyday practice is constructed as something that is not determined by a clear certainty or constancy in action. The actors deal less with the institutionalised norm and their habitualised practice, but rather with the social norm of how a teacher should be or do things (Bohnsack, 2020). This shows the double side of existing norms in which teachers often move. At the same time, societal norms of the teaching profession are also very effective. This construct shows that especially lateral entrants do not only deal with existing norms and needed knowledge, but rather the construction of their entered 'field' of profession.

The constituent framing of the organisation school and what exactly frames 'the field' is less negotiated in this type. However, the collective orientation figure points to the tension which is negotiated in some situations, precisely at the points where the actors reach limits and problems in the execution of their actions. This is because they do not know exactly what is expected and how they can meet the correct expectations or norms, but have a vague analytical approach and know that they need more information. Thereby, exactly these ambiguities are named, partly brought to an individual level, but not further negotiated in the tension. This is illustrated by the excerpt of Mrs. Mispel, when asked how she copes with the preparation of the lessons, she answers the following.

I: That means you would say, the preparation time and follow-up time for studying takes even more time than the preparation for teaching?

Mrs. M: Yes, yes in any case; if you take it seriously. and if you also say okay? I haven't quite understood that yet or I would like to get more information. because maybe the problem also affects me at school. I need the theoretical basics to be able to deal with it responsibly. I can of course say I'm doing it intuitively somehow. but I think that I really quickly reach a point where it's not quite right because I have the responsibility.

[…]

and then I also told my students that it is not easy for Mrs. M to describe how she did it here at the front? and that's how I am then, and my students also know now that I am not yet very experienced in mathematics lessons. (Interview Mrs. M, 11/2018)

Furthermore, this type reconstructs itself as mainly 'new-in-field' with difficulties on one hand but simple approaches for teaching on the other hand. The field is reconstructed as the subject and the didactical and method knowledge. Nevertheless, didactic considerations in this type are not finalised. Often pedagogical to general approaches are offered. However, the demarcation from teaching concepts that do not want to be pursued in this way always becomes clear. As, for example, in the case of Mrs. Kiwi, who wants to distinguish herself from old teachers in her didactic approach. She does not want to follow the small-step approach, but at the same time does not present any concrete ideas of how exactly she wants to do it differently.

This is embedded in the conjunctive experience sphere in which students have co-determination rights in the classroom. To involve their ideas and opinions and not to put a hierarchical gate-structured teaching over it.

Mrs. K.: Well, in any case, the children should enjoy learning. I have (.) sometimes I think maybe I'm too; well how should I put it; well cheeky ('flappsich'"), so (.) if you look at the very old teachers they do so; um step by step ('dippel dappel dur') and so and so um those have a different approach to the students I think than maybe someone who so; I do not know if it's because of whether you enter from the side entrance, or whether it's just because of the kind of person

[…]

I think one is not so dogged maybe, so partially, so on the discipline so eagerly, always quite straight sit there and so; maybe one sees the differently; nowadays maybe yes; (2) so no longer quite so strict breeding and order, and strictness, but that one um sometimes laughs with the children, and so […] maybe I am also too; (2) too na too fun also not, (.) but too; (2) I just do not can't really think of a word for it. (Interview Mrs. K, 03/2019)

Due to the status of being 'new-in-field', respectively, new in the subject content, the lateral entrants also have the chance to help shape certain structures along the school norm and clearly distinguish themselves from old structures. This can be seen in some cases, where newcomers are seen as profitable, bringing along new ideas or new didactic suggestions from their qualification programs at university. Especially in the differentiation to other mainly older colleagues, the orientation shows itself as 'new-in-field', while 'the field' emerges as being part of the professional team. The lateral entrants are 'new-in-field' and understand their role as adding value and do not have to deal with any fundamental conflicts.

Seen in the next excerpt, the counter horizon 'older colleagues' is shown to be even very positive. They can be asked at any time and do not form an imaginary border to one's own values and ideas of teaching. On the contrary, they can even be asked out of retirement. When asked how many teachers are at the school, Mrs. Hollunder describes on a more explicit level her experienced start to school.

I: And how many teachers are there?

Mrs. H.: We are um I think eleven. eleven; now we have a newcomer in music, um; no, so also very so I can't say that the director, she has a very good feeling for all. that fits; so she didn't reject us now, there are two of us, three of us were three of us; one of us has applied for a transfer; and now we have a new new music lateral entrant has joined us.

I: That means you were also very warmly welcomed?

Mrs. H.: Very, very warmly; and I had also the quarter year entrance, um; and I had also a mentor; that one did sit in class there with; theoretically thus or practically one should not teach yet; but if worst came to worst I hold classes; and that; I think they were also grateful, and the colleagues always help you; also with materials or if you have questions, now some are already retired; I can always call and ask again. (Interview Mrs. H, 03/2019)

As can be clearly seen in the example of Mrs. H, the second type shows a positive view of the development as a new teacher. Challenges become clear, but there is still no concrete perspective or goal guidance. Everyday practice is shaped based on simple structures of subject knowledge and pedagogical knowledge. By describing the entry and support structures, the role becomes clearer and shows how 'the field' is constructed. Becoming part of the team can be slowly achieved if regulations are followed and time goes by. In the case of Mrs. H., the concrete time can't be identified, as she mentions a mentor and the regulation that she usually shouldn't teach immediately. Additionally, concrete knowledge of how teaching or being in 'the field' can be realised is not available. This orientation figure of having strategies to overcome obstacles and find solutions for problems is the main difference between this type of identification and the third type.

The third type has some different typical modus operandi, especially in dealing with hurdles, problems and tasks that cannot be clearly assigned. Here, the third type makes concrete attempts to explore its options for action. The type **'the independent'** wants to make variances and is willing to stand up to inevitable confrontations. The professional role is stable and difficulties can be solved with the right tools. Typically for this type, support systems are gladly accepted and are part of the problem-solving strategy in case uncertainties with methods and didactical implementations occur. Changes are individually identified and are steered in the right or better-fitting direction. When asked how Mrs. J understands her teaching, she responds as follows. It becomes especially clear how the teaching access has changed over time and due to the qualification measures strategies have been formed.

I: And when you think about the lessons you have done so far at school, how would you describe them?

Mrs. J.: So the (.) um as feedback from the students. I actually only get positive confirmation, tha:t um so I see that also so as develop-ment that the students have taken. that it is a positive development and (.) my whole colleagues, who have now observed me. of course I made mistakes in the beginning, didactic mistakes; but I don't make them anymore, because we learned a lot in the program. that really brings something; and uhm (3) yes, so you get better and better the more often you teach; so I am much more satisfied with myself now than in the beginning. (Interview Mrs. J, 10/2018)

This type is also characterised as someone who does not conform to some normative structures of the institution as well as the formal framing of lateral entry. At numerous points in the interviews, an orientation became clear. The stubborn working off of formal requirements of the state or the university regarding the content of the qualification measure. In the following excerpt, Mrs. Traube addresses the fact that there was an additional 3-month preparatory service at the beginning of the teaching position, and she was told that it was just as unnecessary as the qualification program at the university. As she was in the first group of the new program, they didn't participate in this preparatory service.

Mrs. T: That was just as pointless as maybe our Thursdays; but yes that's what I think it is. that it was just pure theory or that you just sat in there in the classes and looked and looked I'm clear you take a bit of that with you but if you cannot try it yourself, try out; then all this is of no use. (Interview Mrs. T, 11/2018)

At these points, the tension between habitualised practice, the daily experience of what is considered necessary and the normative programmatic specifications become apparent. Organisational conditions are understood here as non-action orientations. The programs contain theoretical foundations that are not needed in practice. Rather, the type seeks structures that guide actions. The self-positioning as often left alone, strengthens the role of independently taking care of necessities. The type **independent** is at the same time an active-becoming one, who does not remain stuck in the status quo, but wants to develop further. On the basis of Mrs. Mirabell's narration, this is clearly highlighted and supports the type.

Mrs. M: I had for example, last year, when it was the end of the school year, there was a colleague who had to leave her room and clean out the cupboards. and I said wow so much self-made stuff? and I said, can I have a look? maybe we can use something or some-thing or we put it together in the one room where is still space, so that we can all access it. and then the school administration came in and said that this is not required here; (Interview Mrs. M, 05/2019)

Interaction in the school is understood here as partly contradictory. The teachers help each other, while the school management is seen as less helpful. Opposing understandings are divided into two levels i.e. between teachers and school management. In this orientation figure, these levels become clearer than in the other two. Normative guidelines are rejected, own action alternatives are worked out 'in secret'. Thus, Mrs. M finds a way to collect material without the help of the school administration and builds up her own support system with the help of a pedagogical teaching aid. This case indicates that the third type is more likely to experience conflicts in the search for a belonging. 'The field' is not accessible from the beginning.

11.5 A First (In-Between) Conclusion

As a first in-between conclusion, this shows the reconstruction of 'the field' from a different perspective, thus it is not completed yet. The three constructed types are a conceptual tool which show the complex challenge of entering the profession as a teacher and how each type evolved their own idea of 'the field' in which they want to be incorporated and move while entering the profession. On one side, 'the field' is the subject itself in its complexity. On the other hand, the excerpts have also shown that 'the field' is the approach to the profession itself. Approaching knowledge and teaching also means approaching the construct of the school with all its facets, a challenge that is experienced by newcomers to the profession as well as lateral entrants. It becomes clear, how strongly the access to the professionalised milieu depends on a professional assignment. Identifying one's teaching orientation plays a central role for lateral entrants. All types have made attempts to differentiate where they stand; this becomes clear in the reconstruction of numerous habitualised practices in the narrative excerpts. In this first overview, the dimensions are pulled together whenever orientation figures and their contrast figures are seen. In this process, jointly processed orientations can be made visible and accountable. The following figure should clarify further work on the development of the typology, including several themes as dimensions and the advancement and concentration of the three types. Depending on the perspective, all components can be contrasted with another aspect of the construct. The small points are examples of single cases to make clear, that the interviews are not immediately transferrable into types, generating the types occurred through the orientation figures and the contrasting case work (Fig. 11.2).

Additionally, in further work process, it will be necessary to subject the elaborated specified types to case-internal comparisons. The aim is to show that the typical patterns can not only be assigned to individual cases but represent a superordinate

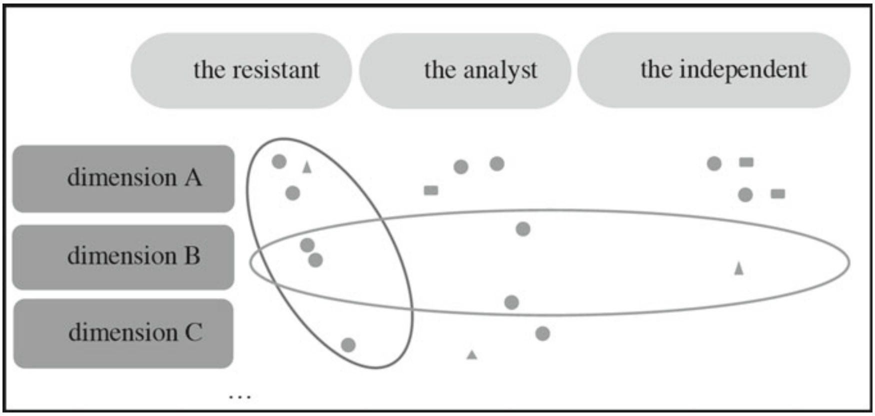

Fig. 11.2 Multidimensional level construct of types

framework. Thereby an overall typology can be approached. This is beginning to subsume sense-genetic types and to reconstruct the tension between habitus and norm. An attempt was made to look at the concept of 'the field' from a broader perspective using a reconstructive qualitative method. In the next step, sociogenetic type formation will be approached.

11.6 Conclusion

For further research, reconstructing the discrepancies of out-of-field-teaching and the constituent framing, numerous elements of common-sense theory, motive theory and epistemology need to be considered (cf. Bohnsack, 2017, 2020; Helsper, 2011; Hericks, 2006; Schütz, 1974; Weber, 1968). This includes the consideration of subject matter, which emerges in instructional negotiation. The framing of the specific milieu 'school' and its professional negotiation must be integrated. Within the project, the relevance of the reconstruction of the habitual practice of action on the level of performative logic will also be elaborated. Furthermore, it is central for the empirical analysis that within the collective experience spheres, that not the individually made experiences come into focus and that their narratives or reconstruction are useful, but rather 'the experience of structurally similar experiences leads to the common stratification of experience that characterizes a conjunctive experience sphere' (Bohnsack et al., 2013, p. 113).

Based on the biographical approach as well as the inclusion of the concept of habitus or incorporated habitus patterns, the methodological-theoretical procedure of the research work is founded and it is shown how lateral entrants incorporate these performative routines of habitualised practice and reconstruct them in tension with their educational-biographical ruptures. This happens on the level of propositional logic and individual narratives while entering 'the field'. Consequently, it is a question of how teachers who do not teach a specific subject have experienced their professional biographical breaks, how they reconstruct their teaching and their teaching practice in 'the field' and which conclusions can be drawn from a comparative analysis.

The aim is to shed light on an area that is still less researched in order to generate concepts that can be applied to teachers in Germany who are not teaching a specific subject and meander between in-, between- and out-of-field-teaching. Research has been undertaken for several years in the field of subject didactics and Educational Science, but the special view on lateral entrants is still less prominent.

Moreover, the concept of lateral entry upsets canonised teacher education. This is also reflected in the strong debate among German experts in the educational landscape (cf. Gehrmann, 2020; Koch et al., 2017; Puderbach & Gehrmann, 2020). The previously divided training program into phases, which extends over 5 years to the state examination, receives strong competition in the direct employment of lateral entrants. The discourse of de-professionalisation is steadily increasing. At this point, the research also attempts to contribute to this complex discourse. After all, the teaching shortage has to be covered and quality losses do not necessarily have to be foreseen. In this context, I would like to share first ideas, initial proposals and suggestions regarding the biographical transitions from new teachers with an alternative approach into the teaching profession. Therefore, it seems to be very important:

- That **education policy** promotes the integration of teachers into the school via alternative approaches and supports them accordingly.
- It is also connected to seeing and understanding the **coherence between support systems and school development**.
- It is necessary to see that the high relevance of the school entrance phase of the teachers is considered, therefore **special support** is needed. As shown in the material, career starters need **mentoring** and **targeted support structures**.
- Additionally, **subject-specific training** should be provided; this becomes apparent, for example, when the new teachers recognise a need but are not yet able to work out their own options for action, but can expand on them with, e.g. a mentor.
- And finally, **collegial structures** should be provided, supported, expanded and established as a basic premise for teachers.

Appendix: Transcription guidelines (TiQ: Talk in Qualitative Research)[5]

(.)	short break, about 1 second
(3)	seconds that a break lasts
no	emphasised
no	loud (in relation to the speaker's usual volume)
°no°	very quit (in relation to the speaker's usual volume)
	strongly dropping intonation
;	Weakly dropping intonation
?	strongly rising intonation
,	weakly rising intonation
mayb-	interruption of a word
wou::ld	Extension of a word, the frequency of: corresponds to the length of the extension
( )	word(s) not understood, according to length
(well)	uncertain in transcription
((moans))	Vents beyond language
@(.)@	laughing

(continued)

[5] For a more detailed description see Bohnsack, Ralf. (2014). *Rekonstruktive Sozialforschung. Einführung in qualitative Methoden.* Verlag Barbara Budrich.

(continued)

//mhm//	for biographical interviews: listener signal of the interviewer if the "mhm" is not overlapping
└	Overlapping of speech acts

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Chapter 12
Eliminating the Fear of Getting 'Caught Out': An Examination of the Development of Out-of-Field Mathematics Teachers' Professional Self-Understanding

Máire Ní Ríordáin, Merrilyn Goos, Fiona Faulkner, Stephen Quirke, Ciara Lane, and Niamh O'Meara

Abstract Research has demonstrated that teacher identity matters in mathematics education. This is of heightened concern when we consider those teaching mathematics out-of-field, a phenomenon prevalent at the post-primary level in the Irish context. A national program (PDMT) to upskill out-of-field teachers was established and current research is appraising graduates' experiences. In this chapter, we bring together out-of-field teachers' knowledge and identities, using Kelchtermans' (2009) concept of *professional self-understanding*, which is an essential part of a teacher's personal interpretive framework and acts as a lens through which teachers view their job, give meaning to it and act in it. We report on aspects of an online, primarily quantitative, survey administered to graduates of the PDMT examining their professional self-understandings on completion of the programme. The findings contribute to our understanding of important considerations relating to the development of professional learning programmes for upskilling out-of-field mathematics teachers.

Keywords Commitment · Job satisfaction · Mathematics · Professional self-understanding · Self-efficacy

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12.1 Introduction

There is a rich research literature examining the professional learning needs of teachers of mathematics at all levels of education. However, examination of the distinctive needs and experiences of those who teach mathematics out-of-field—without formal qualifications in the subject content or pedagogy—is still an emerging field of research. Out-of-field teaching of mathematics is prevalent in post-primary education in the Irish context and occurs when teachers are assigned to teach mathematics without meeting the Teaching Council of Ireland's subject registration criteria for mathematics (Teaching Council, 2013). Criteria currently consist of a degree-level qualification, a third of which must consist of studies in mathematics, with specific credit requirements in analysis, algebra, geometry, probability and statistics and some additional optional topics. A national professional development (PD) programme to upskill out-of-field teachers was established and current research is appraising graduates' experiences.

The Professional Diploma in Mathematics for Teaching (PDMT) is a two-year, part-time, nationally delivered programme, which is fully funded by the Department of Education and Skills. A key aim of the programme is to develop out-of-field mathematics teachers' knowledge of content (60 ECTs of programme credits) and pedagogical approaches (15 ECTs of the programme credits) (Ní Ríordáin et al., 2017), as well as teacher reflection, beliefs and practices, as aligned with mathematics subject specifications at post-primary education in Ireland (Goos, O'Donoghue, et al., 2020*;* Lane & Ní Ríordáin, 2020). However, research examining the effectiveness of such PD programmes for out-of-field teachers is scant (Faulkner et al., 2019). Accordingly, the aim of this chapter is to add to the current literature on PD relating to out-of-field mathematics teachers and to build on existing research examining the PDMT and its impact.

Typically, professional development programmes for out-of-field teachers of mathematics focus on developing subject matter knowledge and pedagogical content knowledge—two kinds of knowledge that Ball et al. (2008) combined into the single concept of Mathematical Knowledge for Teaching (MKT). However, teaching out-of-field involves more than mastering the content to be taught; it also entails developing a new professional identity, giving a sense of alignment with the community of mathematics teachers. Although the concepts of teacher knowledge and teacher identity are informed by different theoretical perspectives, knowledge and identity need to be intertwined when considering the development of out-of-field teachers (Goos, Bennison, et al., 2020).

Our research into the PDMT brings together out-of-field teachers' knowledge and identities, using Kelchtermans' (2009) concept of *professional self-understanding*. Self-understanding is both a product, that is one's view of one's self at a particular moment in time, and an ongoing process of sense-making through which one interprets one's experiences. Professional self-understanding is an essential part of a teacher's personal interpretive framework—a set of cognitions and mental representations that act as a lens through which teachers view their job, give meaning to it and act in it. In this chapter, we report on aspects of an online, primarily quantitative, survey administered to graduates of the PDMT to address the following research question: *What professional self-understandings are held by formerly out-of-field teachers of mathematics who have completed an upskilling programme that confers in-field status?*

The dimensions of identity of interest to us in this study are job satisfaction (Caprara et al., 2003), commitment to mathematics teaching (Meyer et al., 1993) and self-efficacy regarding teaching mathematics (Tschannen-Moran & Woolfolk Hoy, 2001). In addition, in the first phase of examining the impact of the PDMT, it was found that out-of-field teachers displayed low levels of proficiency with curriculum-aligned mathematical content and high rates of conceptual errors, which can accordingly impact on practices in the classroom and student learning (Ní Ríordáin et al., 2017). Given the major focus of the PDMT on developing teachers' mathematical knowledge for teaching, we are interested in evaluating participants' perceptions of the extent to which the programme prepared them to effectively teach the mathematical content of the post-primary mathematics curriculum, which in turn can impact on their self-efficacy (Carney et al., 2016).

12.2 Literature Review

Teacher identity is a viable analytic tool for educational research given that it serves to represent teachers' psychological experiences and social behaviours (Sfard & Prusak, 2005). It is particularly suited to the study of teacher development as identity is situated at the nexus of learning and the socio-cultural context. However, the notion of identity is complex and keenly contested due to the great variety of perspectives on the concept. In educational research, studies on identity have drawn on conceptions from the fields of psychology, sociology, cultural studies and anthropology (Sfard & Prusak, 2005). Each of these fields of study provides their own understanding of what identity is and how it should be researched.

Graven and Lerman (2014) argue that mathematics education researchers should be explicit about their use of the term 'identity,' the sources that have shaped their perspectives on identity, and the pertinence of their work with identity with regard to the teaching and learning of mathematics. This would avoid the problem, identified by Darragh (2016), of researchers collecting inappropriate data and drawing conclusions that are inconsistent with the view of identity they have espoused.

In this study, our perspective on identity follows the theorisation of Holland et al. (1998) on identities and the processes of identification. Building on the work of Mikhail Bakhtin and Lev S. Vygotsky, identities are self-understandings produced by and from the experiences of living in, through and around cultural forms practiced in social life (Ibid.). Mathematics teaching is an example of one such cultural form practised in social life. Therefore, in this study, we are interested in researching the self-understandings of former out-of-field teachers of mathematics who have successfully completed the PDMT programme.

To more firmly anchor our analysis in the context of out-of-field teaching, we draw on the theoretical model of teacher identity development proposed by Hobbs (2013). She argues that out-of-field teachers must negotiate a boundary between their in-field and out-of-field practices and experiences. Successfully negotiating this boundary provides opportunities for identity development, leading to increased knowledge and appreciation of the subject outside their primary area of expertise. Hobbs' Boundary Between Fields theoretical model aims to account for factors that influence these teachers' identity construction. The model has three groups of factors: context, support mechanisms and personal resources. Contextual factors include a school's geographical location, size and design, governance structures, practices and policies. Support mechanisms could be provided by a school or sought out by out-of-field teachers to help them adapt to teaching an unfamiliar subject. Personal resources that teachers can bring to the out-of-field experience include adaptive expertise, knowledge and dispositions such as confidence and commitment. In terms of the Boundary Between Fields model, we suggest that the PDMT represented a support mechanism sought by out-of-field teachers to strengthen their personal resources.

There are clear parallels between Hobbs' notion of personal resources, which are specific to out-of-field teachers, and Kelchtermans' (2009) more general concept of professional self-understanding as a personal interpretive framework for making sense of one's job. Kelchtermans identified five components of self-understanding: self-image, self-esteem, job motivation, task perception and future perspective. Canrinus et al. (2012) utilised these components as teacher identity indicators in their study of 1,214 Dutch teachers working in secondary education. According to Canrinus et al., the components of self-image and self-esteem are akin to teachers' self-efficacy. For Kelchtermans, the job motivation component refers to the teacher's motives for choosing to become a teacher along with their reasons for staying in teaching or giving it up to pursue a different career. Canrinus et al. couple this component with occupational commitment in their study on the basis that an increase in the teacher's motivation is related to an increase in commitment to the job while a decrease in the teacher's motivation is associated with a decrease in their level of commitment to teaching. In addition, these researchers espouse that the teacher's job satisfaction contributes to occupational commitment. Therefore, for Canrinus et al., job satisfaction, commitment and self-efficacy collectively provide a tacit representation of the complex concept of teacher identity. Hence, the measures of job satisfaction, commitment to mathematics teaching and self-efficacy were employed in this study to obtain insights into teachers' identities. The existing quantitative identity research supports the use of these dimensions as effective measures (Hanna et al., 2019).

Although many educational research studies have highlighted the importance of teacher identity, few have used quantitative methods to investigate the concept, with no quantitative study undertaken with out-of-field teachers of mathematics. Hanna et al. (2019) suggest that this gap may not be attributable to any conflict between quantitative approaches and epistemological viewpoints on teacher identity, but rather could be explained by the absence of an instrument for measuring teacher identity. In the present study, we do not claim to have used an instrument to measure teacher identity; instead we have operationalised the notion of self-understandings in order to obtain insights into the identities of out-of-field teachers of mathematics.

We have argued that identity is intertwined with knowledge in out-of-field teacher development, and the Boundary Between Fields model of Hobbs (2013) acknowledges the key role of knowledge as a personal resource that shapes out-of-field teachers' identity formation. It is therefore necessary to consider the role of knowledge for teaching mathematics and its significance for the development of out-of-field teachers' professional self-understanding.

Ball et al. (2008) ascertain that MKT is necessary in order for teachers to present mathematics as a coherent, interconnected and logical body of knowledge but also has been found to have a strong influence on how effectively students learn in the mathematics classroom. Accordingly, this has implications for out-of-field teachers of mathematics (Ní Ríordáin et al., 2019). Hobbs (2013) highlighted the negative effective of a lack of SMK on out-of-field teachers' identity due to their inability to engage with more advanced mathematical content in the classroom. This significant challenge has been found to result in more experienced out-of-field teachers relying heavily on PCK to scaffold their limited SMK (Sanders et al., 1993). Ní Ríordáin et al. (2019) outline the need for out-of-field teachers to engage in relevant professional development in order to obtain the necessary PCK and SMK for effective mathematics teaching, a key design characteristic of the PDMT.

When considering the necessity for high levels of MKT we must also think about the quality of instructional design in relation to effective teaching (O'Meara & Faulkner, 2021). Characteristics of effective instructional design, and therefore effective preparation for teaching, include: student engagement in the learning process; providing a platform for students to attempt non-routine tasks; including real-world problem solving into lesson plans; encouraging students to explore connections between different topic areas within mathematics; and using appropriate manipulatives to enhance teaching where appropriate (O'Meara & Faulkner, 2021, p. 3). While each of these characteristics has been shown to contribute to effective mathematics teaching, of interest to us is research indicating that each is underpinned by a teacher's self-efficacy, thus highlighting the important role that self-efficacy plays in effective mathematics teaching (Bates et al., 2011; Enochs et al., 2000).

Enochs et al. (2000) defined mathematics teaching self-efficacy as teachers' belief in their ability to teach mathematics effectively. Many studies indicate that there is a direct correlation between teacher self-efficacy and many aspects of teacher effectiveness. Bates et al. (2011) specifically discuss a relationship between teachers' self-efficacy and levels of teacher knowledge, while Czerniak and Schriver (1994) conclude that teachers with low levels of self-efficacy are inclined to use less effective, teacher-led teaching strategies such as reading directly from a textbook. Enochs et al. claim that inquiry and student-centred approaches are favoured by highly efficacious teachers. Similarly, Darling-Hammond et al. (2002) ascertained that teachers' self-efficacy 'increases when they receive learning opportunities that provide them with additional skills' (p. 297) and concluded that a relationship existed between teacher preparation and teacher effectiveness. Research in the area of out-of-field mathematics teachers' self-efficacy is limited. One recently published study in this area sets out to examine the self-efficacy of out-of-field teachers of mathematics and their self-reported teaching style before and after engaging in mathematics-specific pedagogy workshops (O'Meara & Faulkner, 2021). These workshops were one component of the PDMT being examined in this chapter. Analysis of survey responses from this group of out-of-field teachers showed statistically significant improvements in teachers' self-efficacy after completion of the pedagogy workshops. Additionally, participants reported a shift in their teaching style from more teacher-led approaches to more student-centred approaches focusing on student understanding. Therefore, PD programmes which are seeking to improve the teaching and learning of mathematics must be cognisant of the role that teacher self-efficacy can play in this regard and provide opportunities for teachers to enhance their own self-efficacy.

In summary, the design of out-of-field mathematics teacher PD is of immense importance when considering the value of the professional self-understanding concepts of job satisfaction, commitment and self-efficacy and a strong MKT base, in terms of preparing effective teachers. Countries such as Australia, Germany, Ireland, the United Kingdom, the USA and Indonesia have begun the process of trying to address the needs of out-of-field teachers by providing in-service training specifically for them in their out-of-field discipline area (Price et al., 2019). These PD programmes have been found to vary in size and delivery approaches, however they have many commonalities in terms of what they deem necessary for effective preparation of out-of-field teachers. Faulkner et al. (2019) compiled a framework for effective PD programmes for out-of-field teachers based on the learnings from these programmes. This framework highlights four major components which include content weighted towards PCK; a student-led enquiry approach and a blended learning delivery platform; school-based support; and clear programme expectations being set out and voluntary enrolment. Accordingly, out-of-field mathematics teachers cannot be expected to develop personal resources (Hobbs, 2013) or characteristics relating to professional self-understanding (Kelchtermans, 2009) independently or in isolation; teacher preparation has a significant role to play. We aim to examine this further in relation to the PDMT by examining the professional self-understandings held by graduates of the programme.

12.3 Methodology

The findings reported in this chapter relate to an anonymous online survey administered to graduates of the PDMT from 2014, 2015, 2016 and 2017. In total, 822 graduates were emailed in November 2018. However, 26 of these emails were void, perhaps due to changing school working context, so the survey was delivered to 796 graduates of the programme. There were 218 valid response received, giving an overall response rate of 27%. The sample 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 6–15 years teaching experience, and 70% had 10 years or less experience of teaching mathematics. The focus of the online survey was to examine the perceptions and experiences of graduates on completion of the programme. It contained several key sections, namely, personal and professional background, preparedness for teaching mathematics, beliefs and identity as teachers of mathematics, pedagogical approaches and effectiveness of the PDMT. Generally, the survey was quantitative in nature, with opportunity built in for further explanation/comment at key points which provided qualitative data.

The focus of our analysis is on the development of teacher professional self-understanding. Survey items examined teachers' levels of job satisfaction (Caprara et al., 2003), commitment to mathematics teaching (Meyer et al., 1993), self-efficacy with regard to teaching mathematics (Tschannen-Moran & Woolfolk Hoy, 2001) and self-reported preparedness to teach mathematics. Job satisfaction consisted of 5 items and used a six-point scale: strongly disagree (SD), disagree (D), somewhat disagree (SWD), somewhat agree (SWA), agree (A) and strongly agree (SA). The commitment scale consisted of 12 items (6 affective and 6 normative) and used a six-point scale: strongly disagree (SD), disagree (D), somewhat disagree (SWD), somewhat agree (SWA), agree (A) and strongly agree (SA). The self-efficacy scale contained 12 items (4 instructional strategies, 4 classroom management and 4 student engagement) and responses were given on a five-point scale: not at all, a little, a moderate amount, a lot and a great deal. Teachers self-reported preparedness in relation to teaching curriculum-aligned content and used a three-point scale (very well prepared (1), somewhat prepared (2), not well prepared (3)). The curriculum-aligned content was identified from the mathematics subject specification for Junior Certificate (JC) (DES, 2017) and Leaving Certificate (LC) (DES, 2015) in Ireland. In addition, qualitative responses to open-ended questions relating to overall programme experiences were examined.

Analysis was undertaken by examining frequencies of responses to the job satisfaction, commitment and self-efficacy items. The mean and SD are reported in relation to graduates' responses to preparedness for each strand of the mathematics curriculum at JC and LC. Thematic analysis was conducted on the open-ended responses in order to identify and describe patterns within the data (Braun & Clarke, 2006).

12.4 Key Findings

12.4.1 Professional Self-Understanding as Teacher Identity

Table 12.1 shows responses to the Job Satisfaction and Commitment items included in the survey administered to graduates of the PDMT. Shading is utilised to illustrate the most common responses chosen by participants. The response rate for these items is 73–78%, that is, not every teacher responded to each item. It is evident

Table 12.1 Percentage distribution of PDMT graduates' responses to job satisfaction and commitment statements

Statement	SD	D	SWD	SWA	A	SA
Job Satisfaction						
I am satisfied with what I achieve when teaching mathematics	1.2	0.6	3.6	14.8	55	24.9
I feel good teaching mathematics	0.6	1.2	1.8	11.8	45.6	39.1
I am happy with the way my colleagues who teach mathematics treat me	0.6	2.4	2.4	8.3	40.2	46.2
I am happy with the way my superiors treat me	2.4	3.0	4.7	14.8	37.3	37.9
I am fully satisfied with my job	4.1	2.4	5.9	22.5	36.7	28.4
Commitment – Affective						
Teaching mathematics is important to my self-image	4.7	8.9	4.7	29.0	31.4	21.3
I regret having entered the mathematics teaching profession	62.7	27.8	1.8	4.1	2.4	1.2
I am proud to be in the mathematics teaching profession	1.2	1.8	0.6	12.4	36.7	47.3
I dislike being a mathematics teacher	68.6	22.5	3.6	5.3	0.0	0.0
I do not identify with the mathematics teaching profession	54.4	30.2	7.1	4.7	1.8	1.8
I am enthusiastic about mathematics teaching	0.0	0.0	1.8	11.2	46.2	40.8
Commitment – Normative						
I believe people who have been trained as mathematics teachers have a responsibility to stay teaching mathematics for a reasonable period of time	11.2	14.8	11.2	22.5	26.0	14.2

(continued)

Table 12.1 (continued)

I do not feel any obligation to remain teaching mathematics	17.8	20.1	11.2	20.1	20.1	10.7
I feel a responsibility to the mathematics teaching profession to continue in it	15.4	17.2	15.4	18.9	21.9	11.2
Even if it were to my advantage, I do not feel that it would be right to leave mathematics teaching now	17.8	30.2	13.0	14.8	16.6	7.7
I would feel guilty if I left mathematics teaching	26.6	24.9	13.0	15.4	16.0	4.1
I am in mathematics teaching because of a sense of loyalty to it	30.8	26.0	18.9	10.1	11.2	3.0

that most respondents feel strong satisfaction in terms of teaching mathematics and in relation to who they are working with. This is a very positive outcome given that these teachers would have been teaching mathematics out-of-field. We suggest that engaging in a professional development opportunity (i.e. the PDMT) may have supported the teachers in achieving, or at a minimum maintaining, a sense of job satisfaction relating to teaching mathematics. This is important in terms of contributing to a well-functioning school and committing to the profession (Caprara et al., 2003). However, it is worth noting that over one in three respondents somewhat agree or disagree (at various levels) with the statement 'I am fully satisfied with my job,' suggesting that although they are satisfied with teaching mathematics and working with colleagues, they do not feel complete job satisfaction. This may in part be attributed to what some referred to in their comments at the end of the survey as the lack of opportunity to teach higher level and senior-cycle mathematics and the desire for their qualification to be recognised at a school level. After investing such a significant amount of personal time and commitment into completing the PDMT, Kate conveys some respondents' views in that it '…stretched me. I am proud of my achievement and grateful for the opportunity. I just wish I was teaching LC maths.' Some also referred to the continued out-of-field practices in their schools, even on completion of the PDMT: 'Disappointed that many schools still engaging in appointing unqualified maths teachers to teach maths with qualified maths teachers appointed to teach other random subjects' (Dave).

In terms of examining commitment, our study focused on affective commitment to the mathematics teaching profession and as an obligation to remain in the teaching profession (normative commitment) in order to help us to understand PDMT graduates' relationship with the mathematics teaching profession (Meyer et al., 1993). Overall, from Table 12.1, it is clear that respondents have a strong desire to remain in the mathematics teaching profession. They possess a strong affective commitment which generally develops when involvement in the profession is a satisfying experience. We suggest that participating in the PDMT has contributed to these teachers' experiences and in building their sense of affective commitment. For example, John noted in his comments that 'Am delighted I was given the opportunity to qualify to teach maths to all second level students. It has opened up new opportunities for me and I can honestly say that I love my work.' Given that teachers were provided with the opportunity to develop valuable knowledge and skills, it is arguable that the PDMT has supported them in their practice.

Taking into consideration that teachers completing the PDMT were afforded the opportunity to upskill in a core post-primary subject area and to gain an additional subject for registration with the Teaching Council, we expected normative commitment to develop as a consequence of the resources invested in these teachers. Similarly, the teachers invested a large amount of their own personal resources and time to complete this demanding programme. Given the commitment to upskill, we expected they would develop a sense of obligation to remain in the teaching profession. Participants' responses to the normative commitment items in Table 12.1 demonstrate somewhat of a commitment to the profession but not an overall sense of obligation to remain in the mathematics teaching profession. This is an interesting insight and may be connected to their out-of-field background. Teachers completing the PDMT are registered teachers in other subject areas and mathematics is not a 'first love' in terms of subjects for many of the participants. Some pursue the course for job security purposes and due to pressure from leadership within their schools. As surmised by Annie 'It got me what I needed. The piece of paper saying I am a qualified maths teacher. For that I am eternally grateful.' This finding suggests a need to examine how we might develop a sense of normative commitment to the mathematics teaching profession within our PDMT programme given the importance of the construct in terms of, for example, remaining up-to-date with pedagogical developments and approaches in the classroom (Meyer et al., 1993).

Table 12.2 shows PDMT graduates' responses to the self-efficacy items included in the survey. Once again, shading is utilised to illustrate the most common responses chosen by participants. The response rate for these items is 56–64%—these items were further on in the survey and it is expected that participants' interest dwindled as they completed the online survey. Responses to these items reflect teachers' beliefs about their ability to cope with tasks and any difficulties that arise in their mathematics teaching context (Tschannen-Moran & Woolfolk Hoy, 2001). Generally, PDMT graduates demonstrate strong self-efficacy in relation to instructional strategies, classroom management and student engagement. In particular, responses to classroom management items demonstrate at least 75% of teachers selecting 'A lot' or 'A great' deal in relation to the relevant statements. Given that these out-of-field teachers have significant teaching experience on entering the PDMT, this may be a factor in their responses to the items, as opposed to it being an outcome of participation in the PDMT.

However, greater knowledge and confidence in their ability to teach mathematics may be a factor in this also. Similarly, participants commonly self-report 'A moderate

Table 12.2 Percentage distribution of PDMT graduates' responses to self-efficacy statements

Statement	Not at all	A little	A moderate amount	A lot	A great deal
Self-Efficacy - Instructional Strategies					
To what extent can you use a variety of assessment strategies in your mathematics teaching?	0.0	20.0	40.0	31.7	8.3
To what extent can you provide an alternative explanation or example when students are confused in your mathematics class?	0.0	4.2	28.3	41.7	25.8
To what extent can you craft good questions for your students in your mathematics class?	0.0	11.7	42.5	32.5	13.3
To what extent can you implement alternative strategies in your mathematics classroom?	0.0	11.7	39.2	39.2	10
Self-Efficacy – Classroom Management					
How much can you do to control disruptive behaviour in your mathematics classroom?	0.0	3.3	11.7	40.0	45.0
How much can you do to get students to follow the rules in your mathematics classroom?	0.0	0.0	10.8	51.7	37.5
How much can you do to calm a student who is disruptive or noisy in your mathematics classroom?	0.0	0.8	13.3	54.2	31.7
To what extent can you establish a mathematics classroom management system with each group of students?	3.3	1.7	17.5	45.8	31.7

(continued)

Table 12.2 (continued)

Self-Efficacy – Student Engagement					
How much can you do to get students to believe they can do well in their mathematics schoolwork?	0.0	2.5	31.7	41.7	24.2
How much can you do to help your students value learning mathematics?	0.0	4.2	28.3	46.7	20.8
How much can you do to motivate students who show low interest in their mathematics schoolwork?	0.0	7.5	35.8	40.0	16.7
How much can you assist families in helping their children do well in mathematics in school?	5.8	30.0	34.2	20.0	10.0

amount' or 'A lot' to statements relating to instructional strategies in mathematics and student engagement. These findings suggest that the PDMT graduates' self-efficacy is robust on completion of the programme—'I now know when standing in front of students that I am capable of answering their questions. Previously I was nervous that I may be "caught out"' (Emma). However, it is worth noting that one in five respondents report 'A little' in relation to use of a variety of assessment strategies in mathematics teaching and over one in three feel that they could not or only assist families a little in helping their children do well in mathematics at school. There is also room for improvement in developing self-efficacy in relation to instructional strategies—the majority of graduates chose 'A moderate amount' in relation to the statements. As Liam suggests 'I found it really improved my maths base and my general maths ability, but it could have been a lot better in terms of maths teaching strategies for the classroom.' Other teachers referred to the need for better connection to the 'content that we teach in school'. Such insights into graduates' beliefs are valuable in terms of considering how we prepare out-of-field mathematics teachers and how the PDMT might need to be modified.

12.4.2 Professional Self-Understanding as Preparedness for Teaching Mathematical Content

As part of the online survey, graduates were asked to respond to how well prepared (very well prepared = 1, somewhat prepared = 2, not well prepared = 3) they felt in relation to teaching post-primary mathematics curricular strands and associated

Table 12.3 Mean and SD of PDMT graduates' responses to preparedness to teach mathematical strands (1 = well prepared, 2 = somewhat prepared, 3 = not well prepared)

Strand	Mean	SD
JC Statistics & Probability	1.5	0.6
JC Geometry & Trigonometry	1.5	0.6
JC Number	1.5	0.7
JC Algebra & Functions	1.4	0.6
JC Unifying Strand	1.8	0.7
LC Statistics & Probability	1.5	0.6
LC Geometry & Trigonometry	1.6	0.6
LC Number	1.5	0.7
LC Algebra	1.5	0.6
LC Functions & Calculus	1.5	0.6

topics. The response rate to these items was from 85–88% (these items appeared earlier in the survey). Table 12.3 provides the mean and SD in relation to graduates' responses for each strand of the mathematics curriculum at Junior (JC) and Leaving Certificate (LC). Overall, respondents feel very well prepared to somewhat prepared to teach mathematics at both Junior and Senior Cycle post-primary education in Ireland—'I feel the biggest impact on my teaching of maths is researching it, reacting to student needs and guiding them to achieve in mathematics' (Niamh). This is a positive outcome of the PDMT given its focus on qualifying these teachers to teach mathematics at post-primary level.

Within strand analysis of topics provides some very useful insights in terms of improving the PDMT. There were several topics that some graduates felt not well prepared to teach, and interestingly this was very much at JC level (where most out-of-field teachers teach). In particular, at least one in four respondents did not feel well prepared to teach topics relating to the JC Unifying Strand—Building Blocks (23%), Representation (22%), Connections (22%), Generalisation and Proof (24%), and Communication (20%). This strand permeates the other four strands at JC and is important for development of students' mathematical thinking and practices. With respect to mathematical content topics, some respondents report being not well prepared to teach JC Geometrical Proof (20%), JC Transformations (16%), LC Complex Numbers (17%), and LC Transformation Geometry and Enlargements (16%). Given the structure of the PDMT and a focus on traditional mathematical content modules, there may be a need to revisit the focus of these modules and how best to support teachers' preparedness to teach across all strands.

12.5 Discussion

In this section, we discuss our findings in relation to relevant literature in order to address our research question: What professional self-understandings are held by formerly out-of-field teachers of mathematics who have completed an upskilling programme that confers in-field status? We operationalised professional self-understanding in terms of teacher identity and knowledge, creating survey items that referred to job satisfaction, commitment to mathematics teaching, self-efficacy with regard to teaching mathematics and self-reported preparedness to teach mathematical content.

Firstly, in relation to upskilled mathematics teachers' job satisfaction, our research found strong satisfaction among participants in relation to teaching mathematics and with regards to their school colleagues. This positive finding could be attributed (at least partially) to these former out-of-field mathematics teachers' successful completion of the PDMT and hence their enhanced preparedness to teach mathematics which has been highlighted as important to teachers' self-efficacy (Darling-Hammond et al., 2002). In turn, research has shown that teachers' self-efficacy directly impacts their job satisfaction (Caprara et al., 2003) which provides a reasonable argument for the contribution of the PDMT to graduates' high levels of job satisfaction.

In addition, our findings also highlight that a significant minority—approximately a third of respondents—were not fully satisfied with their job, which would appear to be connected to some PDMT graduates' perceived lack of opportunity to teach advanced mathematics classes despite their significant investment in upskilling. This perceived lack of recognition of their mathematics teaching qualification coupled with some school principals' continued deployment of out-of-field teachers to teach mathematics could be indicative of a mismatch between these upskilled teachers' goals and values and those of the school and principal. This is supported by Caprara et al.'s (2003) research which found that teachers' job satisfaction is influenced significantly by their perceptions of the principal's behaviour as well as their collective efficacy–the teachers' perceptions as to whether the school can effectively deal with difficulties or issues. Unfortunately, the issue of out-of-field mathematics teaching is an ongoing issue which has not been resolved in some schools, potentially leading to lower levels of job satisfaction for some of the PDMT graduates despite their satisfaction with teaching mathematics. In this way, we argue that the lack of recognition of upskilled mathematics teachers and the ongoing appointment of out-of-field teachers will negatively impact on these former out-of-field teachers' identities as mathematics teachers in terms of their *professional self-understanding* (Kelchtermans, 2009) by diminishing the *meaning* of their qualification and their position in the school.

Secondly, in relation to commitment to the mathematics teaching profession, PDMT graduates reported high levels of *affective* commitment which has been linked in the literature to job satisfaction (Canrinus et al., 2012; Meyer et al., 1993). This was also the case in our study as teachers indicated strong satisfaction with teaching mathematics as well as a strong desire to remain in the mathematics teaching profession with reasonable supposition that participation in the PDMT contributed to both. On the other hand, the PDMT graduates' responses to our survey were more moderate in terms of *normative* commitment to the mathematics teaching profession with no real sense of obligation to the profession. We suggest two possible reasons for these findings. One possibility is that these former out-of-field teachers were already qualified to teach in a chosen subject(s) and as such, mathematics is not the subject they originally entered the teaching profession to teach. Potentially, this could mean some teachers feel a stronger obligation to their original subject, although this was not measured in our study. In addition, for some teachers, participation in the PDMT was 'a means to an end' in terms of obtaining a permanent teaching position as having the additional qualification to teach mathematics was desirable to school leaders and therefore a means of obtaining job security. The second possible reason for the lower normative commitment is that, as discussed, a considerable number of teachers in our study were not fully satisfied with their current jobs due to a perceived lack of opportunity to teach advanced mathematics and ongoing appointments of out-of-field mathematics teachers. Weiner (1992) suggested that normative commitment develops through socialisation experiences that emphasise a sense of obligation to one's employer and/or through receiving benefits (as cited in Meyer et al., 1993). It is logical that the lack of opportunity and ongoing out-of-field appointments may play some role in the lower levels of normative commitment, particularly as research suggests that normative commitment tends to be more entwined with the short-term (Meyer et al., 1993) than affective commitment. Thus, while the majority of respondents in our study expressed a desire to continue teaching mathematics, they may not necessarily have developed a sense of obligation to do so in their current context. It is unclear what, if any, impact this might have on the teachers' long-term identity as mathematics teachers, as *professional self-understanding* as examined in our study can be highly contextualised to a particular moment in time (Kelchtermans, 2009), although both affective and normative commitment have been found to correlate positively with desirable professional behaviours and behavioural intentions (Meyer et al., 1993).

Thirdly, PDMT graduates generally reported strong self-efficacy in relation to teaching mathematics, with highest levels of self-efficacy demonstrated in relation to classroom management and lowest levels of self-efficacy expressed with regards to assessment strategies and providing familial assistance. The high levels of classroom management self-efficacy are likely linked to the fact that most PDMT participants have considerable teaching experience. Yet, self-efficacy has been described as context-specific (Tschannen-Moran & Woolfolk Hoy, 2001) which means that a teacher could be very confident in managing a science class, for example, but may not be as confident managing a mathematics class. As such, the high self-efficacy reported by the PDMT graduates in this regard could also be influenced to by their enhanced preparedness to teach mathematics. Moreover, the PDMT graduates reported moderate to high self-efficacy with regards to instructional strategies and student engagement which can justifiably be attributed to some extent to their completion of the PDMT. For example, Bates et al. (2011) highlight the relationship between teachers' self-efficacy and levels of teacher knowledge while the positive impact of teacher preparation on teachers' self-efficacy has also been discussed by Darling-Hammond et al. (2002). That is not to say that there is no room for improvement. In particular, some PDMT graduates believed there needed to be greater emphasis on mathematics teaching strategies and a more patent connection between the mathematics content modules of the PDMT and the school curriculum. In addition, self-efficacy was relatively low among some respondents in relation to employing a variety of assessment strategies when teaching mathematics and in providing assistance to families in helping their children to do well in mathematics, so enhancing teachers' self-efficacy with regards to these should also be considered in designing future professional development programmes for out-of-field teachers of mathematics.

Finally, our findings show that PDMT graduates felt generally well prepared to teach mathematics at post-primary level in Ireland. Responses did highlight some differences in the level of preparedness for different topics, especially at Junior Cycle level with at least one in four respondents not feeling well prepared to teach topics relating to the Unifying Strand. One possible reason for this is that recent changes to the mathematics 'specification' at Junior Cycle level, including the introduction of the Unifying Strand, only occurred in the final stages of the PDMT and therefore programme materials would not have referred specifically to this strand. While topics such as representation, connections, generalisation and proof permeated the programme materials, as discussed previously, the PDMT participants do not necessarily recognise connections to the mathematics curriculum (or in this case the 'specification') unless explicitly made. This need for enhanced connection between mathematics content modules and school curriculum content may also explain lower levels of preparedness perceived in some other school topics. Given the links between teacher preparation, teacher self-efficacy and effective teaching (Darling-Hammond et al., 2002), it is essential that out-of-field teachers of mathematics are fully prepared to teach effectively across all strands in future upskilling programmes. This may require revisiting the focus of mathematical content modules, creating enhanced connections between this content and the school curriculum and/or ultimately enabling these teachers to recognise the connections between university and school mathematics content themselves.

12.6 Conclusion and Recommendations

Many out-of-field teachers have been found to experience significant anxiety, stress and feelings of inadequacy arising from their perceived lack of subject matter and pedagogical content knowledge in their out-of-field subject. Professional isolation is therefore a significant concern for out-of-field teachers if they do not have support from school leaders, and especially if those in leadership positions fail to recognise or understand the impact of an out-of-field assignment on teachers' sense of professional 'self.' For teachers, including those teaching out-of-field, 'who I am' is intertwined with 'what I know' and 'what I do,' both in the classroom and in the school community more broadly.

The findings from our survey of PDMT graduates, when considered in the light of previous research into teacher professional self-understanding (Kelchtermans,

2009) and out-of-field teachers' identity formation (Hobbs, 2013), give rise to three recommendations for consideration by school leaders:

1. Give careful attention to the rationale behind selecting and assigning teachers to classes, prioritising teachers' subject-specific qualifications wherever possible to maximise the number of students who are taught by fully qualified teachers.
2. Encourage teachers who are given out-of-field assignments to participate in professional development aimed at developing subject matter and pedagogical content knowledge in their out-of-field subject.
3. Create a professional environment in which all teachers can learn with and from their colleagues, for example, through peer observation, collaborative planning or assigning mentors to less experienced teachers.

While there is evidence that upskilling programmes such as the PDMT are effective in improving (formerly) out-of-field teachers' subject and pedagogical knowledge, job satisfaction, commitment and self-efficacy, professional development cannot provide all the support needed by teachers who are crossing boundaries between subject disciplines. School leaders have a vital role to play in establishing practices, policies and support mechanisms that nurture the personal resources that teachers bring to their out-of-field experience.

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Chapter 13
Transitioning into the Profession with an Out-of-Field Teaching Load

Susan Caldis

Abstract In Australian secondary schools, reports show there is a high incidence of geography being taught by an out-of-field teacher. It is also reported that there are a high proportion of specialist geography teachers who are not teaching geography. This chapter reports on findings from a recent longitudinal, qualitative study of five pre-service teachers (PSTs) as they transition into the profession. Participants enter the profession and their early career years with an expectation of being able to teach geography as their specialist subject. However, not only did their timetable include an out-of-field teaching load, they were also called upon to support out-of-field colleagues to teach geography. Reflexivity theory and the professional standards for teaching geography are used to analyse data. Results show a sustained and explicit process of theory–practice reflection enabled the PSTs to discern, deliberate and act upon the strength of their personal values and beliefs about teaching overall and about teaching geography to overcome the constraint of out-of-field teaching.

Keywords Geography education · Initial teacher education · Out-of-field · Reflexivity · Transition

13.1 Introduction

Transitioning into the teaching profession is internationally regarded as a challenging, uncertain, and complex career phase without a well-defined path which can contribute to teacher attrition (Abrandt-Dahlgren et al., 2014; Heikkinen et al., 2018). Evidence shows the experiences encountered by pre-service teachers (PSTs) during an initial teacher education program (ITEP), the professional relationships they develop, and the support structures available in schools are important for assisting their transition into the profession (Heikkinen et al., 2018; Mason & Poyatos Matas, 2015). Precarious or casual and short-term contractual employment (Millar, 2017; Mindzak, 2019) together with an overwhelming workload and level of responsibility (Fantilli &

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McDougall, 2009; Miles & Knipe, 2018) arise in the literature as common challenges or 'shocks' (Farrell, 2016) experienced by PSTs as they transition into the teaching profession. Out-of-field teaching is a common workload feature during a time of transition which presents many challenges to teacher practice and can be a contributing factor in decisions to leave the profession from those in their early career years (Du Plessis & Sunde, 2017; Gallant & Riley, 2017; Mason & Poyatos Matas, 2015).

Within initial teacher education, the gap between theory and practice is often noted in the practice of PSTs, particularly during professional experience (Stenberg et al., 2016). In response to this circumstance, Stenberg et al. (2016) suggest a purposefully designed professional experience around theory–practice reflection is helpful for enabling PSTs to have agency in transforming their pedagogical practice. Eckersley et al. (2017) and Strangeways and Papatraianou (2016) assert that when PSTs make their own connections between theoretical understanding and practical knowledge, they develop capacity to think and act like a teacher and identify with the role. This enhances their 'classroom readiness' and development as a teacher (TEMAG, 2015). If theory–practice reflection occurs in a subject-specific context, then critical engagement with subject knowledge occurs, which allows the practitioner to analyse their pedagogical and professional practice in terms of policy recommendations, curriculum documents, existing context, and reflexive problem-solving capabilities (Butt, 2018). For PSTs and early-career teachers (ECTs) to effectively navigate an out-of-field teaching context, questions are raised about the role of initial teacher education programs (ITEPs) in preparing teachers for such an experience. Results from an Australian study reveal a focus on developing teacher identity in ITEPs, such as through generating a teaching philosophy and deepening understanding is beneficial for helping PSTs to respond and adapt to the experience of out-of-field teaching (Campbell et al., 2019). Reflection is understood to act as a bridge between the incorporation of theory into practice, and specific theory–practice reflection activities can help PSTs to meaningfully understand the reasons why they teach as they do (Stenberg et al., 2016) within an in-field or out-of-field context.

This chapter reports on results about out-of-field teaching arising from a recent longitudinal, qualitative Australian study that investigates how the experience of transitioning into the teaching profession influences pedagogical practice in a secondary geography education context. The study sought to explore the following research question: How does transitioning into the teaching profession influence the transformation of pedagogical practice in the secondary geography classroom?' The aim of the study was to understand the experience of transition from the view of pre-service teachers (PSTs) together with how the experience of transitioning into the teaching profession influenced pedagogical practice. Another aim of the study was to investigate the relevance of the professional teaching standards for geography as a reflective tool in a PST and early career teacher (ECT) context because the standards arose from the practice of experienced geography teachers. Whilst it was determined that the teaching standards for geography are relevant to the reflective and pedagogical practice of PSTs and ECTs, findings from the study reveal that out-of-field teaching is part of the transition experience for each participant. Findings also show that a sustained and explicit emphasis on theory–practice reflection enables the participant to respond to the initially identified constraint of out-of-field teaching.

In the study, the journeys of five secondary geography PSTs are qualitatively examined for 18 months, from the middle of their final year in an ITEP, to the end of their first year of teaching. Whilst the purpose of the research was not to explicitly investigate out-of-field teaching, this phenomenon clearly arose as being part of the experience of transition into the profession. The purpose of reporting findings about out-of-field teaching is to support the work of Du Plessis (2016) and Campbell et al. (2019) about ways in which practitioners can mitigate and manage the challenge of teaching out-of-field.

13.1.1 Geography Education in Australia

In 2018, the National Committee for Geographical Sciences (NCGS) launched a strategic plan for the discipline called Geography: Shaping Australia's Future (NCGS, 2018). The purpose of the strategic plan was to explain the contribution made by the discipline of geography to the economic, social, and environmental wellbeing of Australia. The plan provides a series of recommendations for future directions to advance the visibility of the discipline, including geography education in Australian schools. This strategic plan is drawn upon here in conjunction with theoretical examinations to provide an overview of the Australian context for geography and geography education.

In a recent review of the discipline, Head and Rutherfurd (2021) reported that whilst geography grew steadily in Australian universities between 1951 and 1981 with the appointment of eight to more than 200 full-time geography academics, in recent times the growth of the discipline has plateaued. Such plateauing is attributable to 14 out of 37 universities not including 'geography' in the school or department name because geography is incorporated into areas such as geosciences (Head & Rutherfurd, 2021; NCGS, 2018).

Geography education in Australian schools also faces challenges with identity because of curriculum positioning and the high proportion of out-of-field teaching compared with other subjects (NCGS, 2018; Weldon, 2016). For example, in curriculum development and school subject department structures, the interdisciplinary nature of geography is not recognised. For example, geography is known to straddle the sciences and social sciences (Baerwald, 2010) yet in Australian schools, geography is positioned in the Humanities and Social Sciences (HASS) key learning area (KLA) (Gerber, 1990). This diminishes the opportunities for exploration and representation of geography's interdisciplinary nature and has contributed to the recent call for the professional teacher associations to lobby Ministers of Education about recognising geography in policy and practice as a subject of science, technology, engineering, and mathematics (STEM) education (NCGS, 2018).

The *Australian Curriculum: Geography* was endorsed in October 2013 and available for implementation in Australian schools pending decisions by state and territory curriculum authorities (ACARA, 2013). So, despite the introduction of a national curriculum for geography, its implementation varies around the country. In New South Wales (NSW), where research for the present study occurs, geography is core learning between Kindergarten up to Year 10 (age 16). In other states and territories, such as South Australia and the Northern Territory, geography is core learning from Kindergarten up to Year 8 (age 14). The discrepancy in core learning for geography across Australia affects visibility of the subject and perceptions of its relevance for further study and career pathways.

13.1.2 Out-of-Field Teaching in Geography

In this chapter, out-of-field teaching is defined in the context of subject specialisation and stage qualification (Du Plessis, 2015). Out-of-field teaching is also defined through self-identification which aligns with the work of Hobbs (2013) who asserts that out-of-field teaching can be determined from the way a practitioner identifies themselves and their practice.

It is known that out-of-field teaching is a common experience encountered by PSTs and ECTs as part of their transition experience into the teaching profession (Du Plessis & Sunde, 2017; Weldon, 2016), and that it presents constraints to teacher practice. For example, a study by Du Plessis (2019) with 48 teachers across seven schools in Australia and South Africa found that classroom management issues are more likely to occur when practitioners are trying to master content knowledge and content delivery in an out-of-field teaching context. Out-of-field teaching can also be a contributing factor in decisions made by PSTs and ECTS to leave the profession (Avalos & Valenzuela, 2016; Du Plessis & Sunde, 2017; Gallant & Riley, 2017; Mason & Poyatos Matas, 2015).

The extent of out-of-field teaching occurring in Australian secondary schools for geography is empirically under-researched and the reported existence of out-of-field teaching in geography presents a challenge for developing rigour and maintaining relevance of the subject. According to a report by Weldon (2016), 40% of teachers across Years 7–10 who teach geography are out-of-field because they did not complete a geography major and geography methodology as part of their teacher preparation. Further, the report by Weldon (2016) also states the proportion of teachers who are specialised in geography but do not teach it is greater than the proportion of teachers who teach geography out-of-field. As such there are implications from the high incidence of out-of-field teaching in geography for the development of subject-specialist teacher identity; teacher acquisition of discipline, subject and pedagogical knowledge in geography; and the incidence of increased levels of student misconceptions arising about geographical processes (NCGS, 2018).

In part, the high incidence of out-of-field teaching in geography is attributable to only 19 out of 37 universities offering geography methodology units in ITEPs which then affects the number of teachers who can graduate and identify as specialist geography teachers (NCGS, 2018). Geography: Shaping Australia's Future states the number of geography methodology units available in Australia is insufficient for preparation of effective geography teaching and recommends that professional teacher associations should address provision of geography methodology units in ITE and the urgency of out-of-field teaching in geography with Ministers of Education (NCGS, 2018).

Recent Australian scholarship identified discussion about the 'degree' or 'scale' to which teaching occurs 'out-of-field' (Hobbs & Törner, 2019) and reflects systemic requirements or a need to respond to individual school contexts such as policy determinants for timetable loads and an allocated number of permanent teachers per school based on student enrolments (Price et al., 2019). However, the degree or scale of out-of-field teaching can also be connected to teaching within a Key Learning Area (KLA) where multiple subjects are offered. For example, Weldon (2016) states that teachers employed in the science KLA are in-field if they teach biology, chemistry, physics, earth and environmental science, and/or general science even if they meet the methodology or minor or major criteria for only one or two of those subjects. The same situation applies for teachers employed in the HASS KLA which includes geography and commerce in the secondary years of schooling up to Year 10 (age 16).

Results from a study conducted in the US by Nixon et al. (2017) confirmed the multi-subject offerings in KLAs and the scale of out-of-field teaching identified by Hobbs and Törner (2019). Nixon and colleagues followed 74 PSTs in secondary science for five years, starting from their entry into the profession. Out-of-field teaching amongst some participants appeared, in part, to be related to being assigned to teach within a KLA where the major or minor subject was a component of the subject offerings. For example, a PST may have a major in biology and a minor in earth and environmental science yet must teach general science because certification structures determine that they are qualified to teach in the KLA of science, and school organisation structures tend to be broader than one subject (Nixon et al., 2017). To address concerns about managing out-of-field teaching, Nixon et al. (2017) suggest the development of subject-specific induction programs aligned with professional standards. For example, the Next Generation Science Standards can help to develop teacher capacity in subject knowledge and pedagogical understanding.

Strategies exist to help PSTs and early career teachers (ECTs) manage the challenge of out-of-field teaching in their timetabled workload and develop their practice. These strategies include the provision of mentoring (Burger et al., 2021; Du Plessis, 2016; Fantilli & McDougall, 2009) and having access to support from school leadership teams (Buchanan et al., 2013; Du Plessis, 2016). Both strategies are known to build resilience amongst those who are teaching out-of-field to help them manage the challenge of this phenomenon (Du Plessis, 2016). Additional important support structures for beginning teachers include formal and informal engagement with Communities of Practice such as professional associations and having access to relevant and timely professional learning (Gallant & Riley, 2017; Rajendran et al., 2020).

13.2 Literature Review

In a thematic content analysis, Mason and Poyatos Matas (2015) identify three themes known to affect the transition experience of pre-service teachers (PSTs) from an initial teacher education program (ITEP) into the teaching profession: quality and nature of ITEP; collegiality and quality of relationships in a school setting; and presence of support structures overall. Each theme relates to the capacity of PSTs and early career teachers (ECTs) to respond to the challenges of transitioning into the profession, including the challenge of out-of-field teaching. Initial teacher education programs emphasise regular engagement with reflection and reflective practice facilitates the transformation of PSTs into effective, contemplative teachers who can connect theory with practice (Loughran, 1996). Engagement with reflection and reflective practice within ITEPs also helps PSTs to understand, analyse, adapt, and respond to context, including ethical dilemmas (Dimova & Loughran, 2009).

One area of reflection and reflective practice known to help PSTs transform their practice and adapt to challenging situations such as out-of-field teaching relates to the development of personal values and beliefs about teaching (Campbell et al., 2019). In geography education, reflection and reflective practice is known to focus on beliefs about teaching geography as a specialist subject. Opportunities for PSTs to explore their geographical subject identity arise during geography methodology units which helps them to understand their values, beliefs, and perspectives about geography teaching and develop their connection with the discipline itself (Brooks, 2016, 2017, 2021; Mitchell, 2017; Seow, 2016). A strong teacher–subject identity shapes a teacher's practice (Brooks, 2016, 2017). In a longitudinal investigation over 14 years with 10 geography teachers in England examined how teachers used their subject knowledge of geography to help guide the 'why' of their pedagogical practice and deal with challenges faced in their teaching of the subject (Brooks, 2016, 2017). Set questions were regularly posed to participants, such as: Why is geography important to them? Why is teaching geography worthwhile? And why do they prioritise some pedagogical approaches over others? (Brooks, 2016, 2017). Participant responses revealed that a disciplinary way of thinking (geographical thinking) with a focus on key concepts, such as place, was important in their decision-making processes about which pedagogical strategies to employ (Brooks, 2016, 2017). Further, a strongly held teacher–subject identity helped them to navigate their pedagogical practice because they knew what was important and distinctive about geography, so they could develop a 'subject story' that resonated with students (Brooks, 2017).

Depth of thinking about one's practice and resultant actions can be measured or assessed through the development of reflective frameworks or models that are suitable for use with a range of practitioners, including PSTs (Ryan & Ryan, 2013, 2015). Such frameworks or models can assist with determining how a practitioner activates their theory–practice knowledge to solve a problem arising in the classroom (Hennissen et al., 2017).

The study reported on in this chapter was conceptualised around reflection and pedagogy. The theoretical framework used was Archer's theory of reflexivity (Archer, 1982, 2010a, 2012). The Professional Standards for the Accomplished Teaching of School Geography (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010), also known as the GEOGStandards formed the pedagogical conceptual framework. Reflexivity theory and the GEOGStandards were used in data analysis and were drawn on for sustained and explicit theory–practice reflection activities with participants to assist them in working through the problem of transitioning into the teaching profession, such as managing a timetabled load of out-of-field teaching. The Teaching and Assessing for Reflective Learning (TARL) model (Ryan & Ryan, 2013, 2015), was the conceptual framework used to understand the depth of reflection over time, however, this framework was used for data analysis and not in theory–practice reflection activities with participants.

13.2.1 Reflexivity Theory

Reflexivity theory addresses a structure-agent problem in education, in this instance, transition into the profession and the transformation of pedagogical practice. In reflexivity theory, Archer makes evident the relationships between structure, agency, and culture as transformative causal mechanisms, known as emergent properties (Archer, 1979, 1982, 1988). Reflexivity is defined as the 'bending back' of thought to stimulate inner conversation and create distance between self, circumstance, and the phenomenon requiring thought and action (Archer, 2010a). The inner dialogue or internal conversation is not observable in most instances; however, it is self-monitoring, self-aware, and changes over time. The inner dialogue is also contextualised by three emerging properties—structural, agential/personal, and cultural—to help one determine the most appropriate action for future practice (Archer, 2010a). Therefore, Archer's (1979, 1982, 1988) reflexivity theory can be understood as iteratively progressive cycles of identification, contemplation, and action whereby internal conversation allows clarification, evaluation, and re-evaluation of decisions so that resultant action will elicit impactful transformative practice (Archer, 2012).

Each emergent property can provide a separate understanding of its influence on ontologies and epistemologies in cycles of change (morphogenesis) or stability (morphostasis). Cycles of time are necessary to understand how emergent properties interplay with each other to generate morphogenetic or morphostatic cycles (Archer, 1995, 2010b; Archer & Morgan, 2020) and explore how practitioners manage change, choice, and decision-making processes in a variety of contexts (Archer, 2010a, 2010b; Archer & Morgan, 2020; Ryan & Carmichael, 2016). The level of influence occurring from each emergent property and actions taken may change over time as PSTs transition into the teaching profession and are exposed to different school contexts. Furthermore, emergent properties are not hierarchical or conflatable; the effect of their presence and interplay will differ over time to cause change or stability in response to a given situation and context (Archer, 2020; Archer & Morgan, 2020). Therefore, it is crucial for educators, particularly PSTs, to continuously reflect on their own pedagogical practice and weigh up possibilities according to influence and context to then take appropriate action (Ryan & Carmichael, 2016).

Structural Emergent Properties (SEPs) include empirical evidence, rules, procedures, policies, and other structures to provide consistency and guidance to the conduct of activities (Archer, 2010b, 2017). Agential or personal emergent properties (PEPs) refer to personal values and beliefs; they are powerful influences because plans for action occur in response to the strength of their feelings or belief systems (Archer, 2010b, 2017). Cultural Emergent Properties (CEPs) refer to behaviour and practice associated with place, time, and people (Archer, 2010b, 2017).

Reflexivity theory emphasises internal dialogue as part of a 3D process about the influence of emergent properties: discernment, deliberation, and dedication (action). Reflexivity occurs when the inner dialogue focuses subjectively on one's reality by assessing concerns and practice and, in doing so, arrives at an action that allows one to play their desired role in the given context and shape change (Archer, 2003). Reflexivity theory was useful in analysing the out-of-field teaching experience of participants because it revealed the most influential emergent property in the cause, effect, and action taken.

Participants consider a recurring question: 'What makes your geography lesson geographical?' and respond according to what they discern and deliberate as influences of enablement or constraint on their practice. Their responses are explored in response to additional questions such as 'Why?', 'At what time?', 'Where?', 'Who?', and 'With what outcome or consequence?' which assists participants to reach a decision about how to act upon the influence which either maximises the enabler or mitigates the constraint (Archer & Morgan, 2020).

13.2.2 The GEOGStandards

The *Professional Standards for the Accomplished Teaching of School Geography* (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010), otherwise known as the GEOGStandards, are the outcome of an Australian empirical research project managed by the University of Melbourne titled Strengthening Standards of Teaching through Linking Standards and Teacher Learning: The Development of Professional Standards for Teaching School Geography, 2007–2010.

The GEOGStandards were developed over three years, in collaboration with experienced specialist teachers of geography across Australia. The purpose of the standards is to provide a tool for teachers' self-reflection about their pedagogical practice in geography, and to initiate collaborative discussion and reflection as part of their professional learning (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010). A strength in having a set of standards specific to the teaching of geography is that it provides value and an identity to the subject at a time when public perception about the discipline and the profile of geography education in schools and at universities is diminishing (NCGS, 2018).

Table 13.1 identifies nine evidence-based GEOGStandards as demonstrated

Table 13.1 Professional Standards for the Accomplished Teaching of School Geography (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010)

Standard	Overview
1. Knowing geography and the geography curriculum	As the teacher: understand the discipline, including concepts and skills; understand the curriculum; understand that geography draws from the social sciences, physical sciences, and humanities; and make connections with other curricula and learning areas
2. Fostering geographical inquiry and fieldwork	Allow students to carry out: a range of structured and open-ended inquiries; and undertake inquiry in the field, selecting and using geographical tools
3. Developing geographical thinking and communication	Encourage and support students' understanding of spatial reasoning; conceptual interdependencies, interconnections, and assemblages; real-world contexts at a range of scales; and lived experience as a personal geography
4. Understanding students and their communities	Use local community contexts and personal geographies to connect, enhance, and enrich conceptual and perspective-focused learning
5. Establishing a safe, supportive, and intellectually challenging learning environment	Facilitate students becoming active participants in their learning by creating a need to know and creating conditions for students to question complex geographical ideas
6. Understanding geography teaching—pedagogical practices	Teachers: have extensive understanding of pedagogical content knowledge; encourage students to gather information from a variety of sources; use fieldwork; and introduce a range of tools to students
7. Planning, assessing, and reporting	Plan, monitor, and assess geographical learning through a range of formal and informal methods; recognise achievement and provide direction for improvement; and use diagnostic assessment to inform teaching practice
8. Progressing professional growth and development	Engage with professional learning communities and recognise that geography is an evolving subject that requires regular updating of content knowledge
9. Learning and working collegially	Actively engage with the professional community; share expertise; build a culture of professional improvement; and promote geographical education

by specialist, experienced geography teachers from schools across NSW, South Australia, and Victoria (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010).

As participants consider the recurring question: 'What makes your geography lesson geographical?' they identify their practice with an appropriate GEOGStandard(s) and then connect this with their influences of enablement or constraint. Further questioning assists participants to incorporate the GEOGStandards as part of their pedagogical plan for action in responding to the most influential emergent properties of enablement or constraint on their practice (Archer & Morgan, 2020).

13.2.3 The Teaching and Assessing for Reflective Learning Model

The Teaching and Assessing for Reflective Learning (TARL) model (Ryan & Ryan, 2013, 2015) is a multidimensional framework used to indicate the depth of reflective thinking and action over time. In the TARL model, there two dimensions: categorical (cognition) and development. Within each dimension, there are customisable scales.

In the present study, the categorical (cognition) dimension was represented by the '4Rs Model of Reflective Thinking' (Ryan & Ryan, 2013, 2015). The 4Rs are reporting and responding, relating, reasoning, and reconstructing; they identify hierarchical levels used to guide reflective thinking as shown in Table 13.2.

The developmental dimension, also referred to as experience or course phase, shows the focus or subject matter of reflections over time. There are three levels to experience or course phase in the TARL model: foundation, theory, and professional practice. The current study was conducted in three phases (see Sect. 13.3). During

Table 13.2 The 4Rs Model of Reflective Thinking (Ryan & Ryan, 2013, 2015)

The 4R reflective scale	Description
Reporting and responding	An observation, opinion or brief report about an event or issue (e.g., a lesson or the act of reflection)
Relating	A connection is made between the event or issue (e.g., a lesson or the act of reflection) and the practitioner's own skills or experience or discipline knowledge to provide an understanding of purpose or importance (e.g., to improve)
Reasoning	An explanation of significant factors (e.g., lack of student engagement or pedagogical approaches) and a range of perspectives (e.g., a student or supervising teacher) in relation to the event or issue (e.g., a lesson or the act of reflection)
Reconstructing	A change in response to theory and practice is developed so the event or issue (e.g., an activity from a lesson) has become reframed or reconstructed, ready for the practitioner to deal with in the future. It is clearly stated what this change of understanding or practice looks like

Phase 1: Preparation, all participants were positioned at professional practice because they were coming towards the end of their studies in an ITEP. During Phase 2: Profession entry, and Phase 3: Positioned in schools, participants were positioned at foundation because they had just entered and were transitioning into the profession.

13.3 Methodology

The aims of the study were to understand the experience of transitioning into the teaching profession and how this experience influences or transforms pedagogical practice in the secondary geography classroom. To understand the processes of transition and transformation, it is necessary to have a timeframe divided into cycles so potential developments in pedagogical decisions and enactment, together with developments in reflective capacities, can be monitored. A longitudinal, qualitative, reflexive design enabled a deep understanding to be gained about context-specific transformative influences on pedagogical practice over time.

Key protocols of longitudinal research informed the research design, such as the conduct of repeated research activities over time with multiple data-generation instruments and making comparisons over a prolonged period of time with the same participant group (Johnson & Christensen, 2017; Neale, 2019). An invitation was extended to participants for them to 'member-check' the interpretation of data (Korstjens & Moser, 2018).

There were five purposefully sampled participants from a geography methodology class at the same large metropolitan university in Australia: Anna, Emily, Grace, Karen, and Matt. The research period for data-generation spanned 18 months and contained three phases:

- Phase 1: Preparation (June–August 2019) occurred in the month before, and during the time participants completed professional experience (each at a different school).
- Phase 2: Profession entry (September–November 2019) immediately followed from Phase 1. Each of the participants were still completing the final weeks of the ITEP, and had received provisional accreditation to teach.
- Phase 3: Positioned in schools (March–September 2020, extended to December 2020 due to COVID-19-related disruption): A short gap exists between the end of Phase 2 and the commencement of Phase 3 because, in Australia, the school year ends in December and the summer break occurs during January. The school year commences at the end of January.

Data-generation instruments reported on in this chapter are the social labs. Each social ab brought together the whole participant group. The focus of each social lab is in Table 13.3. Social labs are a space for discussing complex challenges (McKenzie, 2015). Dialogue, active listening, and the interchange of ideas are key features and demands of participating in a social lab. The purpose of social labs in the present

Table 13.3 Phase of the study and focus of the social lab

Phase	Month conducted	Focus of the social lab
Phase 1: Preparation	June 2019	Social lab 1 was conducted prior to commencing professional experience. Focus was on understanding the distinctive nature of geography and geography teaching
Phase 2: Profession entry	November 2019	Social lab 2 was conducted when participants completed ITEP requirements, were accredited to teach and were entering the profession. Focus was on examining influences on and choices about pedagogical practice
Phase 3: Positioned in schools	December 2020	Social lab 3 was conducted at the end of the school year and concluded data generation for the doctoral study. Focus was on examining the experience of transition and the influences on teaching practice

study was to identify features of transformative practice through explicit theory–practice reflection and the posing of teaching problems and provocations related to geography (McKenzie, 2015; Ryan et al., 2019).

Preliminary data analysis occurred using memos to make meaning of the data or make a 'first stab' at interpreting the data (Cope, 2021) in connection with the theoretical and conceptual frameworks—for example, 'enabling', 'personal belief', 'inquiry', or 'reporting'. Memos were a quick, informal note-taking process to help organise, explore, and reflect on the possible connections between and groupings of participants' experiences (Cope, 2021). Initial memo's were then organised into themes such as 'wellbeing', 'challenges', 'identity', 'pedagogy', 'personal beliefs'. Deductive data analysis drawn directly from the theoretical framework (Archer, 1982, 2010a, 2010b, 2012) and the two conceptual frameworks (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010; Ryan & Ryan, 2013, 2015) which confirmed the themes from the initial memo's. Deductive codes such as 'Structural Emergent Property, timetable' and 'constraint' were derived from reflexivity theory; codes such as 'concepts' and 'inquiry' were derived from the GEOGStandards.

13.4 Findings

This chapter shares findings about out-of-field teaching as reported in the social labs conducted during each phase of the doctoral study.

13.4.1 Phase 1: Preparation

Social Lab 1 was held in early June 2019 at the beginning of Phase 1. Each participant was about to commence or had just commenced their final placement for professional experience. Anna was the only participant to report concerns about out-of-field teaching because as a history major, she self-identified as being out-of-field for geography.

Anna reported 'personal bias towards history' as a personal emergent property (PEP) that constrained her pedagogical practice. Anna was a history major, which meant that her exposure to geographical learning was limited to the core geography discipline units during her first year of study; a one-semester unit in her second year of study called 'Human Society and Its Environment', which focused on Australia-centric content knowledge about history, geography, civics, and citizenship; and the geography methodology units in her fourth year of study. Anna mentioned a pedagogical constraint being her 'lack of training in geography is more apparent [compared with teaching history] and I feel less trained in terms of "thinking geographically"'.

During a deliberation process, Anna reflected at the level of relating because she connected her personal beliefs about geography to her previous experience:

> I see geography as a subject that pilfers from other subjects, it pilfers from history, science, maths, philosophy … I don't always have complete confidence that I know the material and skills well enough to teach someone else.

Anna then pinpointed her enabling PEP as a 'belief in relationships with students' and being able to use inquiry-focused pedagogies to help build relationships. Anna connected her beliefs to a purpose or desired outcome, which demonstrated her ability to reflect at the level of relating: 'inquiry-based learning, and project-based learning helps my practice because it helps me get to know the kids which is really important to me'.

During the social lab, Anna identified the following GEOGStandards as being a distinctive feature of a geography lesson: knowing geography and the geography curriculum (GS1) and understanding students and their communities (GS4). For her goals during professional experience, Anna identified knowing geography and the geography curriculum (GS1) and geographical thinking and communication (GS3) as areas to work on in her teaching of geography.

13.4.2 Phase 2: Profession Entry

Social Lab 2 was held in late November 2019, at the end of Phase 2. Each participant had concluded their formal study in the ITEP and was either seeking work or were precariously employed at one or more schools. Anna, Emily, Grace, Karen, and Matt discerned, deliberated, and dedicated action about key features of their transition journey into the teaching profession; also about the nature and effect of influences on their pedagogical practice within and beyond the geography classroom.

Participants found the experience of transitioning into the profession to be a structural constraint on their practice. Structures discussed included timetabling decisions related to out-of-field teaching or teaching beyond their specialist subject area, and policy-related responsibilities of employment as a classroom teacher related to classroom management, marking final assessments, and report writing.

Out-of-field teaching was raised by Anna, Karen, and Matt as a constraint. Whilst Anna was a history major with geography as a minor area of study, Karen and Matt both had geography as their major area of study.

In the process of Anna 'writing up my CV' and 'looking for history jobs', Emily questioned Anna about whether she wanted to teach geography. Anna replied that she would 'teach geography but would not necessarily elect to teach it'. Anna spoke about a recent interview she had for full-time employment at a 'rural school in Queensland', where the focus of the discussion turned towards a range of subjects that she would be expected to teach if recruited to the role:

> …the more they talked to me, the more they were like 'you can teach legal studies and commerce', and I was like 'this does not sound great', and the more they were talking about me teaching other subjects [to history], I realised they are probably a lower-resourced school … I wasn't sure how comfortable I was going to be in that space, especially because I was going to be away from my support networks, so I ended up saying no. I've been applying at more local schools now. (Anna)

Anna's response demonstrated an ability to reflect at the level of reconstruction because she acted on the given circumstance. During her discernment and deliberation process, she reported a problem (teaching other subjects), related the situation to a possible reason why it occurred (lower-resourced school), and then reasoned why it would not be an ideal situation for her circumstances (away from her support networks). Anna then decided on and enacted a course of action (say no, apply for local schools).

Karen experienced out-of-field teaching during most of the time she was entering the profession. Karen related her current 'focus on classroom management skills' to teaching outside her specialist subject area. Her deliberations showed a reasoned approach towards reflection because implications for practice were revealed (classroom management):

> …casual teaching in two schools and I ended up teaching multiple subjects: art, geography, commerce, legal studies, future learning. I'm only trained in one of those, so it was definitely a new thing learning about different subjects, their content, and then learn about the students, the school, and the faculty … and that leads into classroom management, so I've been focusing on my classroom management skills.

Matt felt constrained by 'teaching commerce', and his reflection revealed an ability to relate his experience to prior learning: 'I've never been prepared for that, so there you go … it comes with a level of stress and expectation so that reduces my excitement [about teaching]'.

During the social lab, Anna, Karen and Matt identified the GEOGStandards they felt were distinctive to their teaching of geography. These GEOGstandards were also the ones they could use and apply to help them manage the experience of teaching out-of-field. For Anna and Karen, it was knowing geography and the geography curriculum (GS1), fostering inquiry and fieldwork (GS2), and developing geographical thinking and communication (GS3). For Matt, the important GEOGStandards to him were GS2 and GS3 together with understanding students and their communities (GS4). Overall, participants reported the recurring question 'What makes a geography lesson geographical?' and the GEOGStandards to be an enabling evidence structure against which they could confirm in theory and practice, and further reflect on what becomes distinctive about teaching and learning in a geography lesson. Participants then substituted the out-of-field subject name, such as 'commerce', with 'geography' to provide them with a strategy for finding out how to teach out-of-field and discover distinctive features of the given subject. Such discernment and deliberation were reported as a helpful process they could apply to teaching subjects with which they were not familiar.

13.4.3 Phase 3: Positioned in Schools

Social Lab 3 was held at the end of Phase 3 in mid-December 2020. By now there were four participants in the study: Anna, Emily, Karen, and Grace. At the beginning of Phase 3, Matt decided to withdraw from the study because his entire teaching load for 2020 was out-of-field despite being recruited as a geography teacher. During Social Lab 3, participants discerned and deliberated the influences of transition on their pedagogical practice, including their achievements, challenges faced, and strategies for mitigating constraints or maximising enablers. Overall, participants were invited to think about their experience of transition as a 'year in review' to consider the context of change, stability or same-ness, and future aspirations or next steps.

Anna was teaching at a Kindergarten to Year 10 School in regional New South Wales and identified teaching out-of-field as indicative of her 'year in review'. Through the process of reflecting on her experiences, Anna no longer identified as an out-of-field teacher for geography because she was 'responsible for co-ordinating geography' during 2020, she defined herself as a geography teacher. However, Anna did identify as an 'out-of-field teacher' for 'teaching Stage 3, technology … but in another twist, teaching languages in 2021'. Anna outlined her experience of transitioning into the profession as having 'survived under pressure, so that is a success'.

Faculty organisation and timetabling structures resulted in some concern for Emily and Grace. Emily is a career-change teacher who is driven by a determination to develop herself as a specialist geography teacher. She noted that the school leadership team was supportive of her 'desire to teach geography only'; however, she reported being met with a difference of opinion with colleagues, for example, some of them 'thought I should teach commerce'. Grace reflected that teaching commerce and business studies was a constraint initially, although she found plenty of resources available through social media, 'the resources gained from Facebook groups is unbelievable'.

Anna and Grace identified the GEOGStandards they felt were distinctive to their teaching of geography. For Anna it was fostering inquiry and fieldwork (GS2), understanding students and their communities (GS4), and understanding geography teaching (GS6). For Grace it was knowing geography and the geography curriculum (GS1), fostering inquiry and fieldwork (GS2), and understanding geography teaching (GS6). Again, when deliberating about an out-of-field teaching context, participants reported the GEOGStandards to be most helpful to apply to the given out-of-field subject and direct them towards finding out what how to teach a subject with which they were not familiar. For example, in response to managing out-of-field teaching, Anna and Grace applied their understanding about, and practice developed from GS2; Grace also applied learning from GS1 to 'teach herself' the commerce and business studies courses through reading the syllabus and working closely with in-field teachers.

13.5 Discussion

The use of a recurring question: 'What makes your geography lesson geographical?' purposefully set against the GEOGStandards (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010) was reported as an enabling evidence structure against which participants could confirm and further reflect on, in theory and practice, what becomes distinctive about teaching and learning in a geography lesson. The recurring question helped participants to explicitly use the standards to identify and reflect on their pedagogical choices in their geography lessons. The use of reflexivity theory (Archer, 1982, 2010a, 2012) encouraged the participants to interpret the broader context that influenced their decisions about pedagogical practice. Participants reported this theory–practice reflection process as being helpful, and one they could apply to teaching subjects with which they were not familiar.

Anna, Grace, Karen, and Matt spoke about out-of-field teaching being indicative of their transition into teaching profession during research phases, and Emily spoke about resisting suggestions from her colleagues to teach a subject other than geography. Such findings align with research (Gallant & Riley, 2017; Nixon et al., 2017) and policy (DET, 2018; Weldon, 2016) that ECTs are most likely to teach out-of-field. Findings about out-of-field teaching are discussed in three areas: identification and incidence of out-of-field teaching, mitigating the challenges of out-of-field teaching, and concerns about out-of-field teaching in geography.

13.5.1 *Identity and Incidence*

In Phases 2 and 3 of the present study, most participants taught part of their timetable out-of-field and identified themselves as out-of-field teachers for business studies (Grace), commerce (Grace, Matt), and sport, technology and in the primary school

(Anna). Anna commenced the study as a self-identified out-of-field teacher for geography but by the end of the study self-identified as a specialist geography teacher. Hobbs (2013) believed that identification of self and practice as an out-of-field teacher is important for a practitioner to engage with the process of seeking strategies for support. Du Plessis et al. (2015) suggested that out-of-field teaching occurs in response to subject specialisation and stage qualification.

Participants in the present study were geography teachers employed to teach in the Human Society and Its Environment (HSIE) KLA. Commerce and business studies are subjects of the HSIE KLA, and two participants were expected to teach these subjects during Phase 2, even though these subjects were not part of their specific subject training in the ITEP. This finding relates to discussion about 'degrees' or 'scales' of being 'out-of-field' (Hobbs & Törner, 2019), whereby an assignment to teach within a KLA occurs because a major or minor teaching subject is part of multiple subject offerings. However, certification structures determine the practitioner as qualified to teach within the KLA, and school organisation structures tend to be broader than one subject (Nixon et al., 2017). Therefore, participants' experience of out-of-field teaching in HSIE reflects systemic requirements and a need to respond to individual school contexts–for example, due to policy determinants for timetable loads and an allocated number of permanent teachers per school based on student enrolments (Price et al., 2019).

During Phase 3, Anna relocated to regional NSW for a 12-month contract at a Kindergarten to Year 12 School. She taught geography and history as her in-field subjects, and also taught extensively out-of-field in subject and stage: technology, sport, and in the primary years. At the end of 2020, Anna's contract was renewed for another 12 months and she knew her timetable would include teaching languages to students in Year 7 and 8 (ages 12–14). Anna's self-identification as an out-of-field teacher for subject and stage is consistent with the definition of out-of-field teaching used in the present study from the work of Du Plessis et al. (2015) and Hobbs (2013). Her experience correlates with a study by Sharplin (2014), which revealed that teacher shortages in regional and rural communities contribute to an increased likelihood of teaching out-of-field. Anna's experience is also an inevitable outcome of policy that requires a teacher to be positioned in every classroom yet exacerbates the incidence of out-of-field teaching in regional Australia because teacher distribution is concentrated in metropolitan areas (Hobbs & Törner, 2019).

13.5.2 Mitigating the Challenges

Two main challenges were identified in by participants about out-of-field teaching. Participants felt underprepared from the ITEP to teach subjects out-of-field and they also felt overwhelmed with having to learn content and find ways to teach a subject they were not specifically trained to teach. Miles and Knipe (2018) confirmed that feelings of under-preparedness are a common experience for PSTs as they transition into the teaching profession from an ITEP. A study by Du Plessis (2019) acknowledged that a connection does exist for ECTs between the incidence of classroom management issues arising when practitioners are trying to master content knowledge and content delivery in an out-of-field teaching context. This was confirmed by two participants who believed classroom management issues were more noticeable when teaching out-of-field compared to when they were teaching geography.

Although participants in the present study reported out-of-field teaching as a constraint to their pedagogical practice in that given context because they felt underprepared, they each found a way to mitigate the challenge. A sustained emphasis on theory–practice reflection with a recurring question, where they explicitly used reflexivity theory and the GEOGStandards to interpret and take action upon their teaching beliefs and decisions meant they could apply the process of theory–practice reflection to understand how to approach teaching the out-of-field subject. By drawing on their beliefs about teaching and about teaching geography, and applying ideas from the GEOGStandards, such as knowing geography and the curriculum (GS1) and understanding students and their communities (GS4), participants used structural enablers such as reaching out to networks either in person or via social media groups, which they found helpful for gaining advice about suitable resources and strategies for teaching other subjects. These strategies support Gallant and Riley's (2017) finding that constraints associated with out-of-field teaching are best managed when practitioners purposefully engage with CoPs and have access to professional learning. In addition, Anna and Grace spoke about a personal desire to learn and 'teach themselves' the subject, thereby demonstrating their commitment to delivering high-quality teaching and learning regardless of the subject (Hobbs & Törner, 2019). Emily drew on her teacher–subject identity and shared with her colleagues evidence from Hobbs and Törner (2019) and NCGS (2018) about out-of-field teaching being prevalent in subjects such as geography and science to justify her refusal of an out-of-field teaching load in commerce during Phase 3.

Participants also spoke about their participation in the doctoral study as being like a mentoring program which helped them to interpret their teaching context and crystallise their beliefs about teaching and teaching geography which helped them to manage the experience of out-of-field teaching. Participants also mentioned the development of trusting relationships with members of the school leadership team or colleagues in their department helped them to respond to the constraint of teaching out-of-field. These coping strategies for out-of-field teaching connect to advice from Du Plessis (2016) about mentoring and support from school leadership teams and trusted others as being important for building resilience, developing teacher capacity, and reducing negative outcomes associated with out-of-field teaching.

13.5.3 Concerns About Out-of-Field Teaching in Geography

Participants in the present study all qualified as geography teachers, yet they taught out-of-field in addition to teaching in-field during entry and transition into the teaching profession. Participants also reported being either the only specialist geography teacher or one of two geography teachers in their school. Whilst they taught in-field for geography, they also taught subjects outside their specialisation, despite the likely scope within their school context to have a full teaching load of geography, or at least a combination of their specialist teaching subjects. Participant experience corresponds with statistics in a national report about the out-of-field teaching phenomenon in Australian secondary schools (Weldon, 2016). The report showed that the proportion of teachers who are specialised in geography but do not teach it is greater than the proportion of teachers who teach geography out-of-field (Weldon, 2016). Out-of-field teaching presents many challenges to those entering and transitioning into the profession, and it contributes to attrition (Du Plessis & Sunde, 2017). Whilst each participant in the study chose to remain in the profession, the pressure of a predominantly out-of-field teaching load for 2020 was cited by Matt as his reason for leaving the study.

It is a concern that specialist geography teachers are not timetabled to teach a full load of geography when there is in-school scope to do so, especially when there are small numbers of graduating specialist geography teachers in Australia due to a small number of methodology courses offered in Australian ITEPs as evidenced in *Geography: Shaping Australia's Future* (NCGS, 2018).

13.6 Conclusion

Out-of-field teaching was encountered by each participant as they entered and transitioned into the teaching profession. The strength of their personal values and beliefs about teaching and teaching geography was influential in enabling each participant to manage the initially identified constraint of teaching out-of-field. To make sense of the transition experience and to determine what enabled or constrained pedagogical practice, each participant reflected on teaching context in response to a recurring question. To answer the recurring question, participants needed to explicitly consider the GEOGStandards (Hutchinson & Kriewaldt, 2010; Kriewaldt & Mulcahy, 2010) and reflexivity theory (Archer, 1982, 2010a, 2012).

Overall, in response to results about the constraint of out-of-field teaching, participant experience showed personal emergent properties were a dominant enabler of pedagogical practice together with the structural emergent property of applying a process of theory–practice reflection about geography to help manage teaching out-of-field subjects. Once the participants identified what enabled or constrained their practice they drew on their enabling influences to take action.

Out-of-field teaching was experienced during Phase 2: Profession-entry and Phase 3: Positioned in schools within a HASS context. Whilst participants remained in the profession for the current study, it is known that out-of-field teaching contributes to teacher attrition. To minimise future rates of attrition and reduce rates of out-of-field teaching for those entering and transitioning into the profession, it is recommended for accrediting institutions to deem proficient status as conditional upon meeting the professional standards from a fully in-field teaching context.

Future studies could seek to understand the views about out-of-field teaching from a larger cohort of PSTs and ECTs. These studies could focus on how the participants respond to out-of-field teaching to inform unit development within ITEPs and design support structures, either within schools or as part of school-university partnerships. Results from such future studies could also provide an evidence base to understand the extent of out-of-field teaching occurring in a secondary geography education context because empirical evidence about the extent, reactions to, and reasons why out-of-field teaching occurs in geography is limited, both in Australia and internationally this would help to respond to recommendations in Geography: Shaping Australia's Future (NCGS, 2018) about how to address the out-of-field teaching phenomenon for geography in Australian schools but could also be appropriate in other countries.

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Chapter 14
Neither Fully 'In', Nor Completely 'Out' of the Field: The Case of Teaching Mathematics as a Second Subject in Poland

Barbara Barańska and Małgorzata Zambrowska

Abstract In this chapter, we present a Polish perspective on the phenomenon of out-of-field teaching. The group that we refer to are teachers with expertise in teaching different school subjects who have decided to start teaching mathematics as a second subject. In Poland, these teachers typically are required to complete pedagogical qualifying non-degree postgraduate studies, which currently last for at least three semesters. We report data collected among a group of 160 teachers who have completed such studies. The goal of our study was to determine the motivating factors standing behind teachers' choices. We wanted to know both why they have decided to complete pedagogical qualifying postgraduate studies and why they have chosen mathematics as the discipline. While research on teachers' motivation shows the prevalence of intrinsic motivation in teachers entering the profession, we found that for teachers who begin teaching a second subject, the contribution of extrinsic motivation is significant.

Keywords Postgraduate studies · Teachers' qualifications · Teaching mathematics as a second subject

14.1 Introduction

Teaching out-of-field means teaching a subject without necessary training and qualifications (Hobbs & Törner, 2019). Due to its wide spread, this phenomenon has already been researched in several countries, for instance: Germany (Törner & Törner, 2012), Ireland (Ríordáin & Hannigan, 2011), UK (Fitzmaurice et al., 2019), USA (Ingersoll, 1999, 2001; Shah et al., 2019) and Australia (Hobbs, 2013). The literature on this

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topic provides many examples that help us to better understand what teaching out-of-field is. For instance, Bosse and Törner (2015) write about a person formally qualified for teaching theology and sports, who has been teaching mathematics for 30 years and thinks he/she has natural capabilities for such profession. Ingersoll (1998) shares his own teaching experience. Although his field of expertise was social studies, as a teacher in the USA he has been assigned to teach other subjects, such as mathematics, special education and English. On the other hand, Hobbs (2013) highlights the fact that in Australia, a teacher with a degree in one area of science, e.g. physics, would not fall into the category of out-of-field teachers when teaching mathematics.

Out-of-field teaching stems mostly, but not exclusively, from the shortages of qualified teachers (e.g. Ingersoll, 1998, 1999). When standard procedures for the replacement of missing teachers or the recruitment of new teachers fail, school principals may use some emergency measures, such as redeployment of staff whose training does not fit to their new teaching assignments. The emergency recruitment of new teachers allows for the hiring of those who are not qualified to teach a particular subject or to work with students at a particular educational level, or who have not completed their teacher training yet. However, as stated in the Eurydice report (2002), such moves do:

> …not reduce teacher shortages but simply provide temporary solutions until appropriately qualified staff can be found. They convert an overt teacher shortage into a hidden one. (p. 51)

14.1.1 Who Can Teach Mathematics in Poland?

Due to the last reform (see Eurydice, 2020), the structure of Polish schooling has changed (implementation period 2017/18–2022/23). The new structure includes an 8-year primary school at the primary level. This single structure covers grades 1–3[1] of early school education and grades 4–8 with teaching by subject. At the post-primary level, the students choose between:

- 4-year general upper secondary school,
- 5-year technical upper secondary school,
- stage I 3-year sectoral vocational school and stage II 2-year sectoral vocational school.

Preparation for the teaching profession in Poland is regulated by two documents: the Regulation of the Minister of National Education from 1 August, 2017 (Journal of Laws, item 1571) on specific qualifications required from teachers[2] and the Regulation of the Minister of Science and Higher Education of 25 July 2019 on the standard of education preparing for the teaching profession (Journal of Laws 2019,

[1] Children aged 7–9 years.

[2] Journal of Laws of 2020, item 1289 provides the consolidated text of this Regulation of the Minister of National Education on detailed qualifications required from teachers.

item 1450; for brevity: Standards).[3] According to the first document, the qualifications for the position of a teacher at the post-primary level are granted to a person who has completed:

- second-cycle studies or long-cycle studies in the field consistent with the subject taught and has a pedagogical preparation, or
- second-cycle or long-cycle studies in a field of study where the learning outcomes in terms of knowledge and skills cover the curricular contents of the subject taught at this level and who has a pedagogical preparation, or
- second-cycle studies or long-cycle studies in a field of study other than the above-mentioned and postgraduate studies in the subject taught and has a pedagogical preparation (Journal of Laws, 2020.1289, § 3.1).

Although the qualifications specified above allow for teaching in grades 4–8 as well, in order to take a position of a teacher at that level it is sufficient that a person has completed:

- first-cycle studies in a field consistent with the subject taught and has a pedagogical preparation, or
- first-cycle studies in a field of study where the learning outcomes in terms of knowledge and skills cover the curricular contents of the subject taught at this level, and has a pedagogical background, or
- first-cycle studies in a field of study other than mentioned above, and non-degree postgraduate studies in the subject taught, and has a pedagogical preparation (Journal of Laws, 2020.1289, § 4.1).

The provisions of the educational law provide for exceptional situations in which persons who do not meet the qualification requirements may be employed. In special cases the principals may employ teachers/non-teachers who do not have the qualifications required for the position. Such an employment must be, however, well justified by the principal and the permission from a relevant regional school superintendent is required. The principal has to prove that there is no possibility to employ a teacher with the required qualifications and that there is a need resulting from the organisation of teaching. The only case when it is not necessary to apply for the school superintendent approval is when a recruited teacher does not have pedagogical preparation. In such a situation, the school principal has the right to decide to employ this person him or herself, and the newly hired teacher is obliged to complete the pedagogical preparation within a certain period of time.

In the Eurydice report (2002), Poland was mentioned as a country where the OOT phenomenon had little occurrence in math and science, even though such practices were generally accepted under certain restrictions. At that time, Poland even had the lowest number of out-of-field teachers among TALIS countries (Zhou, 2012). As for the current state, however, there is no data showing the scale of OOT in Polish schools. The Central Statistical Office in Poland does not collect data that would

[3] This replaced previously applicable Regulation of the Minister of Science and Higher Education from 17 January 2012 on teachers' training standards.

make it possible to determine the number of teachers who teach mathematics on the basis of different qualifications (first or second-cycle studies in mathematics, first or second-cycle studies in other disciplines supplemented with pedagogical qualifying postgraduate studies in mathematics). Also, the Educational Information System (SIO) database which is a central collection of data maintained by the minister for education, which includes data on teachers, does not provide such information. It is however very probable that the share of teachers who are not fully or appropriately qualified in subject matter remains negligible in Poland due to the popularity and accessibility of postgraduate studies which allow obtaining relevant qualifications in a relatively short period of time.

14.1.2 Pedagogical Postgraduate Studies Qualifying for Teaching Mathematics as a Second Subject

Non-degree postgraduate studies are defined as a form of education other than university and doctoral studies, intended for people with higher education. They may for instance be taken by persons who want to supplement their already held degrees in given subjects with pedagogical preparation for teaching (pedagogical studies), or teacher-practitioners who want to obtain qualifications to teach another subject (pedagogical qualifying studies). We will focus on the latter case. Obtaining qualifications to teach another subject is carried out in accordance with the Standards. This document states that postgraduate education preparing for the teaching profession may be provided in the area of substantive, psychological, pedagogical and didactic preparation. It is now being offered to the graduates of first- and second-cycle studies in fields of study whose programmes specified learning outcomes including knowledge and skills corresponding to the general requirements of the core curriculum for the subject to be taught. The Standards also define the time span of postgraduate qualifying studies preparing for the teaching profession as being no shorter than 3 semesters. Previous regulations on that matter allowed teachers to obtain qualifications to teach another subject, even if it was very distinct from their primary discipline, e.g. a physical education teacher could have become a mathematics teacher. This has given rise to serious concerns regarding the quality of teachers' professional preparation. Some researchers (e.g. Krause et al., 2017) called postgraduate studies 'the Pandora's box' and postulated the liquidation of harmful regulations allowing such a careless approach towards the vocational preparation of the teachers which could ultimately become detrimental to the educational process. Perhaps it has been their voice that provoked some changes.

The postulate of lifelong learning, encourages people for continuous development and acquiring new skills, and there are many professions where completing appropriately narrow postgraduate studies may give an employee skills and competences for taking multiple tasks. However:

> Few would require cardiologists to deliver babies, real estate lawyers to defend criminal cases, chemical engineers to design bridges, or sociology professors to teach English. The commonly held assumption is that such traditional professions require a great deal of skill and training and that, hence, specialization is necessary. In contrast, the commonly held assumption is that teaching in elementary and secondary schools requires far less skill, training, and expertise. (Ingersoll, 1998, p. 776)

So far, the phenomenon of becoming a math teacher after completing postgraduate studies has not received much attention from Polish researchers. The fact that postgraduate programmes are available as part of educational offerings has its pros and cons. On the one hand, these studies seem to solve the problem of shortages of school teachers, since teachers may obtain qualifications for teaching new subjects in a short period of time. For many teachers the opportunity to teach a second subject is a shield protecting them from losing their jobs, missing hours to full-time employment or having to seek additional hours at other schools. On the other hand, however, it is not easy to acquire knowledge and skills in a new discipline, especially when committed teachers may have a genuine desire to become experts in each of the subjects they teach (Barańska & Zambrowska, in press). Full-time studies distribute the material of a curriculum each weekday for over five years. This gives the students enough time to work through each of the topics they learn, in a discipline that they study both broadly and deeply. Postgraduate studies do not give the same chance to the teachers who attend them. Before the new regulations came into force, postgraduate studies had to last at least two semesters. Currently, such studies are supposed to last not less than three semesters, but still they may be completed within one calendar year, when e.g. the summer holidays period becomes the so-called third semester. In such cases, the teachers are expected to gain sufficient mastery in a discipline that may be quite new to them, within a single year. Although it is claimed that the educational outcomes of postgraduate studies match those of full-time studies, it is practically impossible to prepare a teacher for the profession in one year to a similar extent that can be achieved over five years. Since in most cases the teachers graduating from studies qualifying them to teach mathematics as a second subject simply do not have the adequate time and conditions to learn mathematics in depth but they studied it for a year and, having graduated, became qualified to teach it in school, we consider them as being neither fully ‘in’, nor completely ‘out’ of the field of mathematics.

14.2 Literature Review

Postgraduate studies are considered one of the forms of realisation of the postulate of lifelong learning (Commission of the European Communities, 2001), understood as an ongoing, self-motivated pursuit of knowledge for either personal or professional reasons, enhancing personal development, self-sustainability, competitiveness and employability. Having completed some studies, attendees of postgraduate courses are considered people who make conscious choices, and due to the experiences they already have they know how to study effectively and what elements of the offered courses they should pay attention to (e.g. Bakonyi, 2013). Postgraduates are also expected to manage their own time and reconcile studies with work and family responsibilities better than undergraduates.

Postgraduate studies are said to address **the needs** of two groups of people (Marcinkiewicz, 2012): those who want to supplement their knowledge in a field other than the one they studied (or simply refresh, extend or update their knowledge in a certain field); and those who for some reasons want to gain education in new fields and specialties, and retrain to take up employment in a field not related to their previously learned professions, without having to go through the first- or/and second-cycle studies. It seems that in the case of teachers undertaking postgraduate studies qualifying for teaching another subject, both of these sets of needs play an important role. In the case of postgraduate pedagogical qualifying studies, applying for the status of a certified teacher of a certain subject seems to be the most obvious motivation to take them, but perhaps the choice of a particular subject is based on individual preferences. This point needs to be explored further, especially since the issue of motivation in itself, and teacher motivation in particular, is very complex.

Professional development of teachers, including activities undertaken as part of lifelong learning, can be motivated by a variety of factors. Teacher participation in professional activities is motivated by different reasons or goals. Self-determination theory (SDT) (Ryan & Deci, 2000a, 2000b) provides a framework that may help to address these phenomena.

According to SDT, human motivation can be seen on a continuum spanning from *amotivation*, leading through various types of *extrinsic motivation*, to the most autonomous and self-determined *intrinsic motivation*. We speak about amotivation when a person has no intention to take any actions. It might be due to the lack of interest, seeing no value or purpose in one's activity or predicting no positive outcomes from possible efforts. People are said to be extrinsically motivated when they are driven by the desire to obtain some external outcomes. These, in turn, may have a correspondence to internal factors, ranging from a lack of relevance to a strong connection. The source of motivation can be solely *external*—for instance a reward or punishment, *introjected*, i.e. partially external—such as the desire to avoid some unpleasant emotions, *identified*, which means being somewhat internal—like personal importance of taken actions, or even *integrated*, which happens when the external reasons are congruent with one's volition. In case of intrinsic motivation, the driving force is the satisfaction that stems from the activity itself or the sense of fulfilment one has when doing something. Here the interest, pleasure or even joy and excitement found within the activity steer the person's actions.

A number of studies on teachers' motivation have adopted SDT (e.g. Colares et al., 2019; Harvey et al., 2005). The research shows that amotivated teachers are less engaged, tend to perform their duties automatically and more often suffer from burn-out syndrome (Abós et al., 2018). Extrinsically, motivated teachers may work with the feeling that they are doing it because they have to, or simply because they want to get a salary, or they are afraid of losing their job (Pelletier & Rocchi, 2016). Such teachers may show little commitment and creativity. On the other hand, intrinsically motivated teachers are passionate, creative, have a sense of mission and find a deeper meaning in their work (e.g. Fischman et al., 2006). Teacher motivation is significantly related to their job satisfaction (Davis & Wilson, 2000; Fokkens-Bruinsma & Canrinus, 2012) and self-fulfilment. Moreover, teachers' intrinsic motivation was found to be the most important predictor of primary school students' engagement and a factor contributing to the development of students' motivation of the same kind (Demir, 2011).

Another important contribution was made by Williams and Burden (1997) who distinguished two different kinds of motivation. One was the *initiating motivation* that pushes a person to take an action, and the other was the *sustaining motivation* that makes a person continue a commitment once made. While the former will be undoubtedly present in a person entering the teaching profession, the latter plays a significant role in subsequent years. However, for teachers who begin teaching a new subject at some stage in their career, again initiating motivation comes into play.

According to Harvey and colleagues (2005), teachers vary from other professionals in their attitudes and perceptions towards professional development. The specific nature of teachers' work and the challenges they face every day also affect the specific nature of their work motivation. Subject-related interests play an important role in the decision to become a teacher (Glutsch & König, 2019; Roness, 2011). If this interest does not change over time, then beginning teachers happen to be very enthusiastic for the subject they teach or generally for teaching (Kunter et al., 2011). They have been found to follow intrinsic motivation, driven by a desire to learn more, teach effectively and become professionals in their fields. Teachers who make the decision to begin teaching a second subject are novice in a certain field, but not in the teaching profession. They cannot be amotivated, since they make a considerable effort related to studying. However, it is interesting what kind of motivating factors stand behind their decision and whether they are extrinsic or intrinsic in nature.

In the life of a teacher, it is possible to discern certain stages characterised by different types and intensity of motivation, varying interests and consequently by different levels of professional activity of the teacher (see Table 14.1). Huberman and colleagues (1997) distinguished and described five such stages of a teacher's life cycle. In Table 14.1, we follow the authors in presenting the key experiences of each stage.

The authors notice that teachers' commitment and interest in professional development decline over the years. Teachers who undertake postgraduate studies choose to do so at different stages of their teaching life cycles. At different stages, there might be different motivating factors standing behind their decisions. Also, we wonder, and perhaps this is an interesting topic for future research, whether in the case of teachers teaching two or more subjects, we could discern a separate life cycle for teaching each subject. Is it that in the professional life cycle of a teacher, different experiences come along, including, for example, teaching more subjects, but the cycle is one? Or is it that teaching different subjects sets separate, though interfering cycles? For now, we assume the first of these possibilities, but we see here an interesting field for further inquiry.

In the light of the above considerations, it is important to note that the situation of practising teachers who begin teaching a second or subsequent subject is markedly

Table 14.1 Teacher's life cycle (according to Huberman et al., 1997)

	Phase	Years of teaching	Experiences
1	Career entry: Survival and discovery	1–3	Survival: • reality shock, clash of ideals and reality • dealing with initial complexity and uncertainty of the classroom environment • trial and error • the difficulty of combining instruction and classroom management • the vacillation between intimacy and hostility towards the pupils • inadequate teaching materials Discovery: • enthusiasm of the beginner • the 'headiness' of assuming a position of responsibility or of seeing oneself as a colleague within a guild of professionals
2	Stabilisation	4–6	• the choice of a professional identity • professional commitment • becoming more assertive towards more experienced colleagues • pedagogical mastery, increased confidence, greater flexibility in day-to-day classroom management • finding one's own personal style of teaching • setting longer-term objectives
3	Experimentation/activism or reassessment/self-doubts	7–18	Experimentation/activism: • attempts to increase one's impact in the classroom • diversifying instructional materials, methods of evaluation, modes of grouping the students or instructional sequences • searching new challenges Reassessment/self-doubts: • the sense of routine emerges gradually without passing through any particularly 'innovative' period • 'the number of alternative career options retract, and classroom teachers can assume that the next 20 years of their life will not bring spectacular changes' (p. 47)

(continued)

Table 14.1 (continued)

	Phase	Years of teaching	Experiences
4	Serenity/relational distance or conservatism	19–30	Serenity/relational distance • a state of mind among teachers around 45 to 55 years of age experienced after enduring a phase of uncertainty or reassessment • being less vulnerable to the opinions of others • feelings of greater confidence • less investment in preparatory work and greater tolerance and spontaneity in the classroom • relational distance experienced between older teachers and their younger pupils Conservatism: • complaining about the changes in pupils, attitudes of younger teachers, public attitude towards education, educational policies and reforms • increased rigidity and dogmatism, greater prudence • more resistance to innovations • more pronounced nostalgia for the past
5	Disengagement: Serene/bitter	31–40	• gradual withdrawal and 'interiorisation' near the end of the professional career • detaching oneself progressively, with or without regrets, from professional commitments • channelling energy elsewhere, taking more time for: oneself, activities outside work • greater 'focusing' on preferred classes, tasks, aspects of the academic programme

different than that of teachers who continue their practice in one subject. Questions about the choice of profession, which are often asked in the context of teachers, do not apply to this group. The question about the choice of a discipline is of a slightly different nature—after all, teachers have already made their major choice at the beginning of their career. What is intriguing, however, is the reasons why teachers, at various stages of their professional experience, make the decision to enter postgraduate studies and, in particular why, when willing to teach another subject, they choose mathematics.

14.3 Methodology

14.3.1 Research Objectives and Questions

The objective of the present study was to identify and analyse motivational factors that lead Polish teachers of various school subjects to enrol in non-degree postgraduate studies that provide qualifications for teaching mathematics as a second subject. Hence our two research questions are: Q1: Why do the Polish teachers decide to take part in non-degree postgraduate qualifying studies? and Q2: What motivates the choice of mathematics as the second subject they would like to teach?

14.3.2 Instrument

This study was conducted with the use of an electronic questionnaire form, the link to which was made available to teachers. The link was sent to the principals of all primary and secondary schools across Poland (email addresses of almost 24,000 schools have been retrieved from the website: https://rspo.men.gov.pl/). We also tried to contact the teachers of mathematics via the Polish Association of Mathematics Teachers, two publishers of Polish school textbooks on mathematics, and teachers' groups on social media. Answering the questionnaire was voluntary and the participants were neither obliged nor did they receive any benefits for taking part in the study. The data was collected within the period of 8 weeks (February–April 2020).

Our research instrument consisted of: 8 metric questions, 7 questions strictly related to the postgraduate studies, 3 questions on the experience of teaching mathematics after completing postgraduate studies and 2 supplementary questions. Two out of twenty questions were related to our research questions given above:

1. What was your motivation for pursuing postgraduate studies (in general)?
2. What was your motivation for pursuing teacher postgraduate studies qualifying for teaching MATHEMATICS as a second or another subject?

Unlike in many other studies, where instruments for motivation measurement were created or adapted, we chose to ask the respondents open-ended questions. Open questions allow for capturing the full range of possible responses, which is important, especially when conducting research on a previously unexplored problem. Instead of forcing them to choose among the pre-imposed answers, such questions give the respondents freedom to answer with their own words (Singer & Couper, 2017). This, in turn, allows identifying response categories for possible close-ended questions that may be used in the future. After coding the raw data, we extracted motivating factors occurring in teachers’ responses and assigned them to several categories.

14.3.3 Participants

The group of teachers participating in the study consisted of 160 respondents who declared that they had completed postgraduate studies qualifying them to teach mathematics as another subject. The vast majority (87.5%) of the participants were women, which is not surprising since in Poland the teaching profession is more often chosen by women (Eurostat, 2016). Table 14.2 outlines the age groups of the respondents:

Among the study group, age-mature teachers in the range of 41–50 years, were the most represented. Teachers under the age of thirty together with those around retirement age formed about 11% of the study group.

We asked respondents to provide information on what their previous field of academic study was. Seven people gave only the name of the university they graduated from, which did not clearly indicate the discipline. On the other hand, some people declared having graduated from more than one department. A total of 156 answers were given and we grouped them into categories shown in Fig. 14.1.

In the study group, the teaching of mathematics as a second subject was overwhelmingly undertaken by those who graduated in science, technology or economics-related subjects. However, the two most represented groups were science and social studies/humanities subjects. Science graduates were the largest group (about 44%), and there were twice as many of them as graduates of subjects from the social sciences/humanities group. We have included in science the following disciplines: chemistry (30), physics (24), biology or biology with chemistry (6), geography (6) and informatics (5) teachers. The social studies/humanities category includes

Table 14.2 Participants age groups ($N = 160$)

Age (years)	Percentage of the group (%)
25–30	7
31–40	19
41–50	42
51–60	28
Above 60	4

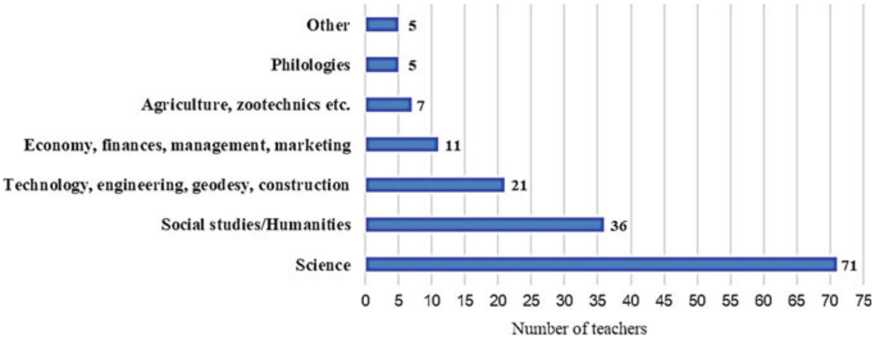

Fig. 14.1 Areas of university studies completed by the respondents before taking up postgraduate studies ($N = 160$)

graduates in pedagogy (33), history (1), psycho-pedagogical counselling (1) and revalidation (1). Interestingly, there were 3 physical education teachers in the study group.

We asked the respondents to also provide the year of their graduation, the year of completion of postgraduate studies, the number of years of service as teachers and the number of years they have worked as mathematics teachers. Unfortunately, 30 teachers did not tell us the year of their graduation. Among the remaining 130, only 37 teachers began teaching right after obtaining their degree and have been working continuously to this day. The discrepancy between the number of years since graduation and the number of years in the profession, which we found in many cases, shows that, as in other professions, there is no guarantee of continuity in the teaching profession either. The lack of continuity may be among others due to the lack of employment in the profession or the fact that the surveyed group was dominated by women, who after graduation could devote several years to maternity care. By comparing in this group of 130 people the number of years since graduation with the number of years spent on working as a teacher, we also found that 27 people began teaching before they completed their higher education. Perhaps these teachers became certified to teach in elementary school after their undergraduate studies and, while already employed, continued their education until they attained a master's degree. But it could also be that they were hired while they were still students when emergency measures were used due to the lack of qualified teachers. In both cases, the year of graduation would not surprisingly be later than the year of entering the workforce. Our data, however, do not provide sufficient details on that matter, since it was not the goal of our study to determine the scope of the out-of-field phenomenon.

At the time when this study was conducted, more than a half of the surveyed teachers had 19 or more years of teaching experience. Detailed data on the number of years of service are presented in Fig. 14.2.

If we decide to assume that a teacher's life circle is determined by the years of service in the profession, regardless of any possible discontinuities, then the most represented group in our study were teachers who, according to the phases proposed

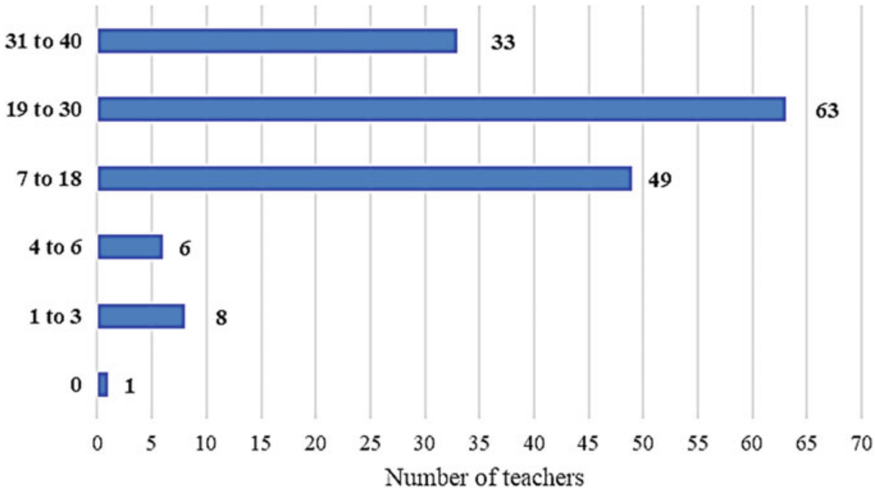

Fig. 14.2 Number of years in the teaching profession ($N = 160$)

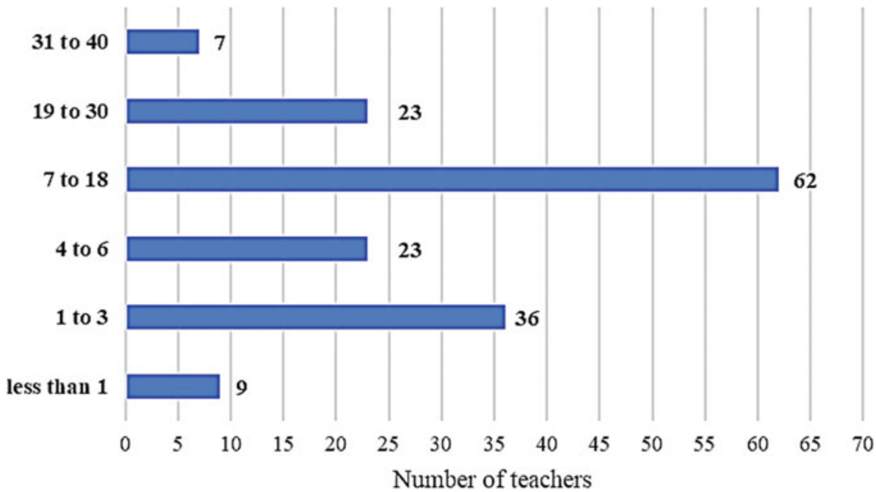

Fig. 14.3 Number of years of teaching mathematics ($N = 160$)

by Huberman and colleagues (1997) were in the fourth phase (serenity/relational distance or conservatism).

We also asked teachers how many years they have been teaching mathematics. The answers they gave are presented in Fig. 14.3.

Unfortunately, our data do not allow us to determine after how many years of being in the teaching profession an individual began teaching mathematics. However, based on the data we have, we can determine how the number of years of working as a mathematics teacher relates to the number of years of being qualified to teach mathematics. It turns out that in the study group, 39 people have been teaching mathematics for a longer period of time than it has been since they completed their postgraduate studies. In this group, the youngest person was 26, the oldest was 63, the mean age was 50, and the standard deviation was 9. It is possible that during the period when the respondents were working as mathematics teachers, educational reforms were carried out, introducing new regulations which e.g. reduced the number of teaching hours of particular subjects. Such a change meant that teachers suddenly lost full-time positions and had to become qualified to teach another subject in order to keep a full-time position while teaching in two fields. Also, some changes could have made the existing teachers' qualifications insufficient. For instance, the Regulation of the Minister of National Education of 12 March 2009 on detailed qualifications required from middle high school teachers abolished the possibility of employing teachers on the basis of completing a field of study similar to the subject. Teachers who previously worked under the so-called acknowledgement of qualifications had to complete postgraduate studies.

In order to gain a better understanding of the specific characteristics of the study group, we also checked the number of years that have passed from the time the respondents graduated from their degree studies to the time they completed their postgraduate programmes. We were only able to do this for 130 individuals who provided their graduation year (Fig. 14.4).

Here, we decided to use the ranges proposed by Huberman and colleagues (1997) again to be able to relate teachers' activity associated with entering and completing postgraduate studies to the to the time that has elapsed since the respondents' graduation from university, which is when their teacher identity may have begun to take shape. We can see that this activity was by far greatest in the 7 to 18 years following

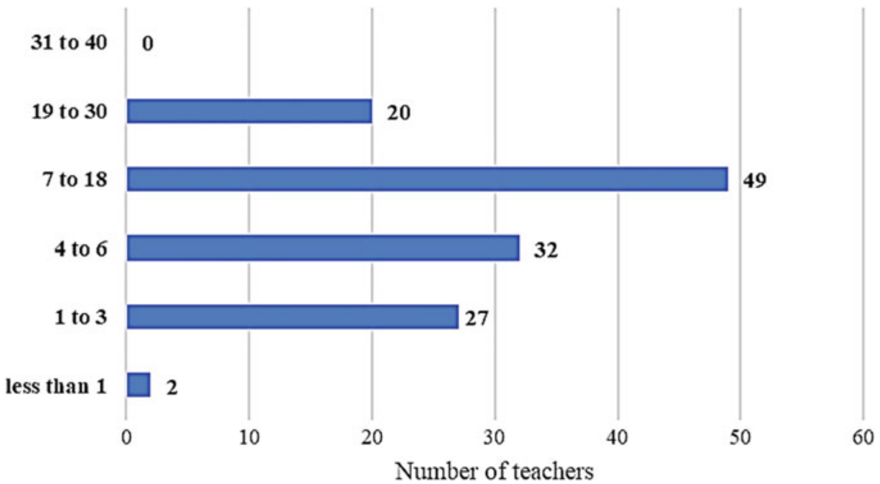

Fig. 14.4 Number of years between graduation and completion of postgraduate studies ($N = 130$)

graduation. However, it should be noted that nearly half of the group completed their postgraduate studies within the first six years after graduation.

14.4 Findings

14.4.1 Why Do the Polish Teachers Decide to Take Part in Non-degree Postgraduate Qualifying Studies?

When responding to the first question, each teacher gave at least one factor that had influenced his or her decision to pursue postgraduate studies. A total of 192 such indications were collected. The most numerous category of responses (43) was that in which teachers said they wanted to either obtain or confirm qualifications and competencies. The second most frequently addressed issue (34 indications) was that the teachers wanted to maintain full-time positions and fill in the missing hours. Third on the list of reasons expressed by the teachers was the desire to be able to maintain or gain employment and to have more opportunities to secure a job in the future. All categories along with the number of responses of each type are shown in Table 14.3.

More than half of all indications, from the categories A1, B1, C1, H1 and I1, were related to economic or institutional reasons. The top two categories of given responses were associated with indications of just this type. These indications imply that teachers' motivation to pursue postgraduate studies was largely determined by external factors.

Table 14.3 Teachers' reasons for taking postgraduate studies

A1	Obtaining or confirming qualifications and competences	43
B1	Maintaining, completing a full-time position	34
C1	Maintaining or gaining possibility of employment	19
D1	Realisation of interests, passions	16
E1	Acquiring knowledge, learning mathematics	15
F1	Willingness to teach mathematics	11
G1	A general will to develop	9
H1	Reform and its consequences	9
I1	Principals' expectations, the need of the school	8
J1	Professional advancement and development	7
K1	General willingness to teach	5
L1	Satisfaction gained from teaching	2
M1	Other	14
	Total	192

The desire to **gain qualifications** may have had different meanings for the respondents. Some people's responses suggest that they wanted to gain qualifications just in case, as a 'backup', for the future, because they might be useful. Such motivation may be illustrated as follows:

> Ability to teach a second subject if physics hours were lacking. (T28)

Some teachers specifically indicated that completing the postgraduate programme was to give them formal validation to teach mathematics, which they were already doing anyway:

> Receiving formal credentials and working not having only acknowledged qualifications. (T28)

> So that no one questions my eligibility to teach math. (T34)

> At various times at work, I had to prove that after completing technical studies I could not only teach vocational subjects, but also physics, computer science or mathematics. As soon as there appeared the possibility of obtaining a clear qualification to teach these subjects by completing postgraduate studies, I decided to obtain such a qualification, so that there would no longer be any doubts as to whether I could be a teacher of these subjects. (T54)

Teachers who were prompted to pursue postgraduate studies by the **fear of losing a full-time position** indicated that they were short of hours as teachers of chemistry, physics, biology or elementary education. A teacher wrote:

> If it wasn't for the other subject, I would have had to work part time. I recall that physics was heavily reduced in middle schools back then (by 1/3 over elementary school) and I couldn't teach another subject in middle school without credentials. (T116)

One person wrote that despite teaching three subjects: computer science, technology and physics, she still had too few hours in school. One comment pointed to the decreasing number of class divisions in the school. Several respondents emphasised that the opportunity to obtain additional teaching hours allowed them to avoid having to work in several different schools at the same time.

Teachers who referred to **maintaining or gaining employment** tended to give very short answers. They indicated three types of motivation: a desire to keep a job that was in threat; a desire to take a job that one did not have or to take advantage of a job offer for a teacher who also teaches mathematics; and a desire to have a buffer just in case for the future.

A relatively small number of teachers admitted that their decision to study was based on the **needs of the school** ('there was a teacher shortage', 'there was a need for a math teacher') or the demand of the school principal ('principal's request', 'principal's requirement' and 'coercion').

Some teachers indicated the reform, changing regulations and the related uncertainty:

> I started my studies before the reform, it was not known what the new education system would look like. (T15)

Individuals who were motivated to pursue postgraduate studies by their interests wrote about their love of mathematics (‘I love math’, ‘I love counting’), the fulfilment of an everlasting dream or the continuation of their interests related to their prior completion of a mathematics profile class in high school.

Several respondents emphasised that they really had a strong desire to work as teachers. Thus, postgraduate studies were a kind of opportunity for them to anchor themselves in the teaching profession. A group of teachers wrote about their desire to teach mathematics. Certainly, at least some of the respondents from this group undertook postgraduate studies only because of mathematics and the desire to become qualified to teach that particular subject. Two teachers emphasised that they had experience of teaching math and received positive feedback from students. This reinforced their belief that they could do it well. One teacher wrote:

> I taught grades 4–6 on a replacement schedule and I taught grades 1–3. I achieved very good results in teaching mathematics. The students liked the subject very much and said it was because of me. (T58)

Another person wrote:

> I graduated from Poznan University of Technology. In the last year of my studies, I started postgraduate pedagogical studies thinking that I would like to become a teacher. I started my work in education 35 years ago as a physics teacher. At various times I had to prove that after completing technical studies I could not only teach vocational subjects, but also physics, computer science or mathematics. As soon as there appeared the possibility of obtaining an official qualification to teach these subjects by completing postgraduate studies, I decided to obtain such a qualification so that there would no longer be any doubts as to whether I could be a teacher of these subjects. I really wanted to pursue the teaching profession, I had the feedback that I could teach well. (T54)

In the ‘Other’ category, there were indications such as: having other, different hours at school, wanting to try something new, new challenges, ambition, finishing something that was once started, wishing to work with children, wanting to change the nature of work or changing jobs. There were also individual, somewhat absurd, responses such as ‘I collect diplomas’ or ‘very good’ in response to the question ‘What was your motivation…?’

14.4.2 What Motivates the Choice of Mathematics as the Second Subject They Would Like to Teach?

When responding to the question regarding their choice of mathematics as a field of study, the teachers gave a total of 215 indications. The group of responses pointing to teachers’ own interests related to mathematics was the most numerous. It would seem that the desire to teach mathematics should be one of the main and obvious reasons for choosing it as a field of study. However, such indications constituted only about 11% of the total. The categories of maintaining or gaining possibility of employment and obtaining formal qualifications came next, with a similar number of indications. Table 14.4 provides further details.

Nearly half of the indications (102 altogether; categories A2, B2, F2, I2 and K2) were related to factors such as personal interests, preferences or sense of competence. The top two response categories, encompassing a total of 74 indications, were also of this nature. Some teachers who wanted to teach mathematics emphasised that they had already dreamed of doing so long before they enrolled in postgraduate studies:

> I always wanted to teach this subject only the educational path did not go as planned. (T106)

> I always wanted to teach mathematics, finances decided that I chose to study physical education. (T137)

We obtained several statements highlighting aspects of mathematics that respondents wanted to show their future students:

Table 14.4 Teachers' reasons for choosing postgraduate studies in mathematics

A2	Interests (I enjoyed math)	50
B2	Willingness to teach the subject, become a math teacher	24
C2	Maintaining or gaining possibility of employment	22
D2	Obtaining formal qualifications	22
E2	Maintaining, completing a full-time position	19
F2	Sense of competence, knowledge of mathematics	16
G2	Mathematics is a subject related to the one being already taught	15
H2	Principal's expectation, the need of the school	11
I2	Willingness to gain knowledge in this area	8
J2	A large number of hours of mathematics	7
K2	General willingness to develop	4
L2	Reform, educational law	2
M2	Other	14
N2	Answer not clear	1
O2	*No answer*	1
	Total	215

> Being able to show students the beauty of science. (T99)

> To convey knowledge in a simple way and encourage children and young people to see their surroundings from that perspective. (T124)

> The desire to share my passion with students and show that mathematics would be their way of life in the future. (T139)

Among the responses, we identified a group of indications related to the sense of one’s competence and aptitude in teaching mathematics. Sixteen respondents mentioned that they found it easy to solve tasks, assessed their knowledge of the subject as good, understood mathematics, felt confident in this area or had the conviction that they could teach others mathematics. A teacher wrote:

> I have never struggled with mathematics and, despite my lack of a subject qualifications, I have been helping students in my family to prepare for secondary school exams. (T110)

Someone else emphasised:

> I felt that I could do it well, students gave me feedback that I could explain it well to them. (T54)

Fifteen individuals’ responses emphasised the closeness of mathematics to the field of their previously completed studies or the subject already taught (‘related to chemistry’, ‘closest subject to physics’, ‘I studied a discipline where there were many hours of mathematics’).

Respondents who indicated a desire to obtain qualifications commented on them in different ways. While some wrote simply about wanting to have the qualifications, others indicated that obtaining them was a necessity, e.g. so that they could continue to teach mathematics. In the statements of some respondents, one can find a desire to prove that they had the basis for teaching the subject. One teacher formulated her motivation as follows:

> Getting officially qualified rather than working under the acknowledgement of qualifications. (T28)

Someone else had completed postgraduate studies in mathematics with the following motivation:

> So that no one would question my eligibility to teach mathematics. (T34)

A total of 41 teachers referred to completing or maintaining a full-time position, maintaining or getting a job. However, a relatively small number of teachers wrote that their choice of mathematics as a field of postgraduate studies was dictated at least in part by the fact that teachers of this subject were guaranteed a high number of hours in their assignments.

There were eleven respondents who indicated that taking postgraduate studies in mathematics was due to staff shortages and thus school needs or a request from the principal. We compared these responses with the analogous statements made for the first question. Only three people gave this type of argument in response to both questions. A total of sixteen people wrote about the needs of the school or the expectations of the school management.

In the 'Other' category, there were indications like: these studies were the cheapest or free; math is an important subject—it matters; wanting to try something new; wanting to have more time for family; wanting to work with children; believing that these studies will be useful someday. As before, here too there were individual unusual responses such as 'I just finished my fourth postgraduate course and had time' or 'My motivation was very good'.

14.5 Discussion

Whereas studies on pre-service teachers' motivation for becoming a teacher have typically revealed the intrinsic nature of their motivation (e.g. Glutsch & König, 2019; König & Rothland, 2012; Watt & Richardson, 2008), many of the reasons given by the respondents in our study had external origins. They were closely related to (a) the desire to retain or gain employment, (b) the desire to fill in the missing hours in order to keep a full-time position, (c) reforms (which reduced the number of teaching hours for some subjects and put teachers at risk of losing their full-time positions or changed the qualifications required from teachers), (d) the problem of staff shortages at school and (e) the expectation or recommendation of the principal. Many of the responses gave the impression that, even if teachers' life situation forced them to obtain new qualifications, they tended to at least partially assimilate these new external goals. Our study did not address this issue, but the analysis of the respondents' answers leads us to the conclusion that in further research it would be worthwhile to ask teachers whether, if not for external circumstances, they would decide to undertake postgraduate studies all by themselves.

In the study group, teachers who completed their postgraduate studies 7–18 years after graduation were the most represented. According to the phases of a teacher's life cycle (Huberman et al., 1997) applied to the teachers' post-graduation identity development, this period corresponds to the experimentation/activism or reassessment/self-doubt phase. But experimentation and activism can be rewarding if undertaken in freedom. Also, reassessment and self-doubt can be very valuable and productive in teachers' lives—again, as long as the teachers are free to decide how they want to remodel their lives. In the group of 20 teachers who undertook postgraduate studies 19 or more years after graduation, there were two people who decided to make their earlier dreams come true, two other people who declared that they wanted to increase their qualifications and one person who claimed she had been collecting diplomas from various universities. The remaining 15 people indicated external circumstances, which meant that undertaking postgraduate studies was not a free choice, but rather a determined necessity.

The need for qualified teachers is definitely a significant problem and a major challenge. However, it is even more important and crucial to have a competent teaching staff that is well prepared and equipped with relevant knowledge and skills, but this takes time and effort. The availability of postgraduate studies has probably solved the problem of out-of-field teaching in Poland effectively, however, the solution seems to be only superficial. Without going into the definitions of out-of-field teaching (Ingersoll, 2019), it is worth noting that whether teachers have qualifications or not is a matter of meeting certain formal requirements rather than having actual competences. Teachers who feel that they have an aptitude for teaching mathematics, who like and know the subject well and want to teach it, can easily and quickly obtain the appropriate qualifications. However, just as easily and quickly a qualification can be obtained by someone who does not have similar aptitude and competence. Since postgraduate studies are undertaken by people who have different motivations, more attention should be paid to the quality of education of prospective mathematics teachers in these studies. A teacher who is motivated and interested in the subject may have more robust knowledge at the beginning already and more skills than a teacher who enters the studies because of the fear of losing his/her job or due to an order from the school principal. One and the other will get the same qualifications, and yet the gap between them may be enormous. What they have in common, however, is that both will be neither fully 'in, nor completely 'out' of the field of mathematics.

14.6 Conclusion and Recommendations

One could say it is disrespectful to the teachers to let them obtain their credentials within a single year. It may seem to be unfair both to those who have spent five years to gain the same qualifications and to the teachers completing postgraduate studies who believe that they would gain sufficient preparation within a year.

Teachers who choose to teach mathematics as a second or further subject need additional support, especially in the first years of their new career path. Due to the fact that postgraduate studies qualifying to teach further subjects last only three semesters, universities and centres conducting such studies could offer their graduates additional courses and training. We suggest that consultation points be organised at universities for teachers who are struggling with problems of teaching practice. Also, it might be beneficial to hold regular meetings of postgraduates where they could exchange their experiences and help each other under the supervision of a faculty member. Such 'support groups' would provide not only substantive assistance, but also emotional support in the first, most difficult period of work.

The out-of-field teaching phenomenon is not just a school problem. We believe that it is worth drawing attention to the occurrence of this phenomenon also among university teachers in various disciplines. This issue includes, in particular, integrating newly hired staff into teaching, providing mentoring support from more senior staff and assigning responsibilities to academic teachers according to their experience and competence.

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Part IV
Teaching Practice Contexts

Chapter 15
Investigating the Self-Efficacy Beliefs and Classroom Practices of Out-of-Field, In-Field, and Upskilled Mathematics Teachers

Merrilyn Goos and Aoife Guerin

Abstract The study that we report in this chapter contributes to our broader research agenda for evaluating the impact of a national professional development programme that upskills out-of-field post-primary mathematics teachers in Ireland. The aim of the study was to compare the self-efficacy beliefs, perceived and observed classroom practices of six post-primary mathematics teachers (three groups of 2) who were either out-of-field, upskilled via the professional development programme, or in-field. The teachers completed surveys of their self-efficacy beliefs and approaches to teaching mathematics. Video recordings of three mathematics lessons taught by each teacher were analysed using the Productive Pedagogies classroom observation framework. The findings showed that there were similarities and differences between the three groups of teachers; however, the upskilled teachers were developing self-efficacy beliefs and pedagogical practices that are similar to those of in-field teachers of mathematics.

Keywords Mathematics classroom practice · Out-of-field · Productive pedagogies · Upskilled

15.1 Introduction

'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 mathematics. Out-of-field teachers of mathematics generally possess a teaching qualification that is not mathematics-specific, and so they typically lack the necessary mathematics content knowledge and pedagogical content knowledge that are required for developing students' mathematical understanding (Baumert et al., 2010). Out-of-field teachers may also have low confidence levels, especially in relation to the subject content

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they are teaching, and this can impact their classroom practice and hinder their development of a professional identity in their out-of-field subject (Du Plessis, 2016).

There is growing recognition of the need for professional development programmes that meet the needs of out-of-field teachers (Du Plessis et al., 2015). While programmes are being developed in some countries, little research has so far been conducted on their effectiveness (Faulkner et al., 2019). In addition, there have been calls for research into the teaching practices of out-of-field teachers (Ní Ríordáin et al., 2017). This chapter aims to address these identified research gaps. We report on aspects of a larger study that is evaluating the impact of a long-term, large-scale, government-funded, nationally consistent and university-accredited programme offered to out-of-field teachers of mathematics in Ireland—the Professional Diploma in Mathematics for Teaching (PDMT).

15.2 Background and Context

In Ireland, growing concerns about the underperformance of post-primary school students in mathematics at the beginning of the twenty-first century, coupled with the low uptake of Higher Level mathematics in the senior post-primary years, led to an overhaul of the post-primary school mathematics curriculum. This new curriculum, known locally as ‘Project Maths’, was introduced in 2010 and shifted the emphasis away from memorisation and procedures towards understanding and problem-solving (National Council for Curriculum & Assessment, 2005). A national survey of mathematics teachers, conducted by Ní Ríordáin and Hannigan (2009) around the same time as the introduction of Project Maths, revealed that 48% of respondents were teaching mathematics without recognised subject-specific qualifications. Such a high incidence of out-of-field teaching may be due to the small size of many schools in Ireland and the autonomy accorded to school principals in the recruitment and assignment of teachers to subjects and classes. Ní Ríordáin and Hannigan’s finding was perceived by education policy makers as a potential threat to the successful implementation of the new mathematics curriculum. In response to this survey, the Department of Education and Skills (DES) funded a national programme (PDMT) to develop out-of-field teachers’ content and pedagogical content knowledge in mathematics to meet the required level as specified by the Irish Teaching Council (2013). The Teaching Council requires that in mathematics, fully qualified teachers must have a degree qualification with the specific study of mathematics comprising at least one-third of the degree. There are also minimum credit requirements in algebra, analysis, geometry, and probability and statistics with additional credits to be obtained in a variety of optional topics.

The PDMT is a two-year part-time postgraduate programme with teachers’ tuition fees fully funded by the DES. Delivery of the programme is led by the University of Limerick in conjunction with a national consortium of 13 higher education institutions in Ireland. The PDMT programme comprises ten mathematics modules, each of which is presented over a six-week intensive session, with additional face-to-face and online support. Two year-long mathematics pedagogy modules are delivered face-to-face over weekend workshops and a one-week summer school. The pedagogy modules place an emphasis on classroom practices that foster problem-solving and develop conceptual understanding. One of these pedagogy modules requires participants to complete a supervised action research project on their mathematics classroom practice. Participants of the PDMT programme are usually teaching full-time in schools and are not released from regular duties to undertake the programme. Six cohorts comprising 1078 teachers participated in the PDMT from 2012–2020.

One of the main aims of the PDMT is to develop out-of-field teachers' knowledge of mathematics content and pedagogy. The programme is also aimed at supporting teachers in developing pedagogical practices that are in alignment with the goals of Project Maths, and this is the focus of the present chapter. We analysed video-recorded mathematics lessons taught by teachers who are currently out-of-field, upskilled (as a result of having completed the PDMT) and in-field, as well as survey responses of these three groups of teachers with respect to their self-efficacy and perceptions of classroom practices. The research question that we investigate is: *What insights can be gained from comparing the self-efficacy beliefs, perceived and observed classroom practices of out-of-field, upskilled and in-field teachers of mathematics?*

In the following sections, we present a discussion of relevant literature on teacher professional development, self-efficacy beliefs and classroom practices, followed by a summary of our study's methodology. We then present key findings from analysis of quantitative and qualitative data collected from the teacher participants and reflect on insights into similarities and differences between those who were out-of-field, upskilled and in-field with respect to mathematics.

15.3 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 emphasised the importance of choosing data collection methods to align with research questions. Adler and colleagues (2005) also point out that due to having a personal investment in teaching, it is difficult for teacher educators to take a critical stance towards the research we do with teachers. They suggest the development of strong theoretical languages in order to distance ourselves from what we are looking at. In the present study, as we 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 conceptual framework for studying teacher professional development.

Desimone's (2009) framework consists of two components. The first component classifies the critical features that define effective professional development in terms of increasing teacher knowledge and skills and improving 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 may 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 programme (Step 1 in Desimone's model; see Goos et al., 2020) and its effect on the teachers who participated in the programme (Steps 2 and 3; see Lane & Ní Ríordáin, 2019; Ní Ríordáin et al., 2017; O'Meara & Faulkner, 2021). In this chapter, we further examine the impact of the PDMT on teachers' *self-efficacy beliefs* (Step 2) and their *classroom practices* (Step 3) as key elements in Desimone's model of teacher change.

15.4 Teacher Self-Efficacy Beliefs and Classroom Practice

Teacher self-efficacy beliefs refer to the beliefs held by individual teachers about their abilities to perform specific teaching tasks (Dellinger et al., 2008; Enochs et al., 2000). Self-efficacy beliefs are specific to a task and situation, rather than fixed traits of individuals; thus, measures of this construct should assess teacher self-efficacy beliefs in the context in which they are formed (Dellinger et al., 2008). Of relevance to our research on professional development for out-of-field teachers of mathematics is existing evidence that shows teachers with low levels of self-efficacy tend to favour teacher-centred approaches such as reading from a textbook (Czerniak & Schriver, 1994), while highly efficacious teachers are more likely to use student-centred or inquiry approaches (Enochs et al., 2000). Although there has been little research on out-of-field teachers' self-efficacy beliefs, Ingersoll (1999) proposed that the incorrect assignment of out-of-field teachers to classes and subjects they were not qualified to teach was likely to have a negative impact on their sense of self-efficacy. More recently, O'Meara and Faulkner (2021) surveyed participants in the PDMT to examine their self-efficacy beliefs before and after completing the mathematics pedagogy workshop component of the programme. They found statistically significant improvements in self-efficacy as well as a shift in the teachers' self-reported classroom practices from teacher-led to student-centred approaches focusing on developing mathematical understanding. This body of research aligns with Desimone's (2009) conceptual framework, as it suggests that participation in professional development may improve out-of-field teachers' self-efficacy beliefs and subsequently lead to changes in their classroom practices.

The Productive Pedagogies framework was chosen as the classroom observation instrument for this study as it has been theoretically and statistically validated in Australian research in primary and secondary school classroom across all subject areas (Lingard et al., 2001; Mills et al., 2009). The Productive Pedagogies framework, although not specifically designed for mathematics classrooms, has been used in longitudinal studies of mathematics teaching and is particularly useful for evaluating the intellectual and social environment of the classroom (Maker, 2011). The framework consists of four dimensions. Two of the dimensions, namely Intellectual Quality and Connectedness (shown in the top row of Fig. 15.1), are concerned with

Intellectual Quality 1. Higher order thinking (HOT) 2. Deep knowledge (DK) 3. Deep understanding (DU) 4. Substantive conversation (SC) 5. Problematic knowledge (PK) 6. Meta-language (ML)	*Connectedness* 7. Knowledge integration (KI) 8. Background knowledge (BK) 9. Problem-based curriculum (PBC) 10. Connectedness beyond the classroom (CBC)
Supportive Classroom Environment 11. Student direction (SD) 12. Social support (SS) 13. Academic engagement (AE) 14. Explicit quality performance criteria (EC) 15. Student self-regulation (SS)	*Recognition of Difference* 16. Cultural knowledge (CK) 17. Inclusivity (I) 18. Narrative (N) 19. Group identities (GI) 20. Active citizenship (AC)

Fig. 15.1 Productive Pedagogies dimensions and components

the academic outcomes of schooling; the remaining two dimensions of Supportive Classroom Environment and Recognition of Difference are concerned with the social outcomes.

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. In the Supportive Classroom Environment dimension, the focus is on relationships and giving students a voice in the classroom, while Recognition of Difference notes the degree to which students are facilitated to participate 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 of the twenty components across the four dimensions (Fig. 15.1).

Desimone's (2009) conceptual framework provides a useful heuristic for studying the impact of teacher professional development. However, it would be an oversimplification to regard the framework as a model of how teachers learn, since it could be interpreted as proposing a linear pathway that does not take account of the complexities of teachers' professional contexts and histories. Nevertheless, the framework does draw attention to key 'ingredients' that need to be considered when seeking to understand teacher change. This is our aim in investigating the possible impacts of the PDMT on teachers' beliefs about their ability to teach mathematics effectively and their classroom practices as perceived by the teachers themselves and systematically recorded by an independent observer.

15.5 Methodology

Our research team's earlier analysis of PDMT participants' action research reports indicated that teachers perceived a shift over time in their pedagogical practices towards more student-centred approaches that emphasised conceptual understanding and problem-solving (Lane & Ní Ríordáin, 2019). A related study of PDMT participants' self-efficacy beliefs found statistically significant improvements after completion of the programme's pedagogy workshops (O'Meara & Faulkner, 2021). A corresponding pre-post research design for investigating the impact of the PDMT on participants' classroom teaching approaches would require observation of lessons taught before and after the teachers experienced the programme. However, this was not possible due to resource constraints and the demands of delivering a large, complex programme involving 13 higher education institutions. Instead, we designed an instrumental multiple-case study (Stake, 2003) to gain insight into 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 ($n = 2$).

The six mathematics teachers participating in the study worked in six different post-primary schools. They were recruited from the 344 teachers who responded to a national survey (adapted from Goos et al., 2019) that examined their perceptions and experiences of teaching mathematics. Those who were interested in participating in a subsequent classroom-based study gave their contact details by completing the final question in the survey. Altogether, 37 of the surveyed teachers indicated initial interest, of whom 30 were in-field, five out-of-field and two upskilled. Upon follow-up, only two of the five out-of-field teachers were willing to participate in this component of the study. It was no surprise to us that teachers were so reluctant to volunteer for research involving classroom observation, since there has been no tradition of teacher observation, peer coaching or mentoring in Ireland (OECD, 2007). Instead, the practice of teaching in Ireland is characterised by 'pedagogical solitude' with few opportunities to 'see, understand and develop pedagogy' (Conway et al., 2011, p. 90). This culture of professional isolation creates challenges for engaging teachers in classroom-based research.

Selection of the six participants was guided by the replication logic underpinning multiple-case studies, which differs from the sampling logic that applies to surveys (Yin, 2003). Sampling logic requires a statistical procedure to ensure selection of a representative subset of an identified population, whereas cases are instead selected to predict either similar results (literal replication) or contrasting results for predictable reasons (theoretical replication). Both types of replication were built into the design of our study. The participants were six teachers who had contrasting backgrounds in their preparation for mathematics teaching. They comprised the two out-of-field and two upskilled teachers who had indicated willingness to be involved, and two in-field teachers who were selected so as to achieve the best match with the demographic characteristics of the other participants (gender, years of experience of teaching mathematics and teaching assignments in terms of class year level).

The research study was designed to generate rich insights into teacher experience across multiple sites, using both quantitative and qualitative data collection and analysis. The data sources were teacher surveys, pre- and post-lesson interviews and structured classroom observations. To address our research question, only selected survey and observation data are reported in this chapter.

The Teacher PDMT Survey (adapted from an instrument designed by Goos et al., 2019) sought demographic data and included items investigating teachers' perceptions of their classroom practice. The latter items came from Question 14 in the Trends in International Mathematics and Science Study (TIMSS) Grade 8 Teacher Questionnaire Mathematics (International Association for the Evaluation of Educational Achievement, 2014) and asked respondents to indicate how often they used the listed strategies while teaching their mathematics class: in every/almost every lesson, in about half the lessons, in some lessons or never.

The 31-item Teachers' Efficacy Beliefs System-Self (TEBS-Self) Survey developed by Dellinger et al. (2008) was also completed by the six teachers. In this chapter, the focus is on three of the survey's six sub-scales, concerning communicating/clarification, accommodating individual differences and higher order thinking skills. Responses were given on a 4-point scale, indicating whether the teachers' beliefs in their capabilities were weak, moderate, strong or very strong. All survey data were analysed using the Statistical Package for the Social Sciences (SPSS), with frequencies and means reported where relevant.

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. In this chapter, we present analyses of three consecutive lessons for each teacher. Before observing and video-recording lessons, 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.

15.6 Key Findings

15.6.1 Teacher Demographic Characteristics

Table 15.1 summarises the gender, years of mathematics teaching experience and grouping (out-of-field, upskilled, in-field) of the six participating teachers. The school year in which upskilled and in-field teachers gained their mathematics teaching qualification through the PDMT or initial teacher education programme respectively is also shown in Table 15.1, in addition to the school type (mixed gender, female

Table 15.1 Teacher demographic characteristics

	Teacher					
Characteristic	T1	T2	T3	T4	T5	T6
Gender/ group	M US	M IF	F OOF	M US	F OOF	M IF
Years teaching mathematics (year qualified)	16–20 (2018)	11–15 (1999)	< 5 (n/a)	< 5 (2018)	6–10 (n/a)	6–10 (2010)
School Type	Mixed	Girls	Girls	Mixed	Mixed	Mixed
Class Year (level and size)	Third	Second	First	Second	First	Second
	(H-21)	(H-23)	(C-21)	(O-7)	(C-19)	(H-27)

Note OOF = out-of-field; US = upskilled; IF = in-field; H-21 = Higher-level, 21 students; C-21 = Common-level, 21 students; O-7 = Ordinary-level, 7 students. Students in the first year of post-primary school study mathematics at common-level; they are streamed in second year when they study mathematics at either foundation, ordinary or higher level or male) and class year, mathematics level and class size taught (first-third year; common, foundation, ordinary or higher level mathematics; number of students in class) for each of the six participating teachers.

15.6.2 Teacher Self-Efficacy Beliefs

Responses of the six teachers to the relevant items of the Teacher Efficacy Beliefs Survey are recorded in Table 15.2. Looking across the rows of Table 15.2 enables comparison between the three groups of teachers on each self-efficacy item. In general, for each item, the strength of the teacher's belief in their capabilities increases from out-of-field to upskilled to in-field teachers. The upskilled and in-field teachers reported either strong or very strong beliefs in their capabilities to perform every teaching task listed in the survey: these two groups did not differ greatly in their self-efficacy beliefs. On the other hand, the out-of-field teachers reported only weak or moderate beliefs in their capabilities for most survey items, with one of these teachers indicating stronger self-efficacy beliefs for some items.

Differences in self-efficacy beliefs of the three groups of teachers were most pronounced for the following three items (shaded in Table 15.2), referring to the teachers' beliefs in their capabilities to:

- actively involve students in developing concepts;
- actively involve students in critical thinking and/or problem-solving;
- provide opportunities for students to learn at more than one cognitive level.

Out-of-field teachers reported weak or moderate belief in their capabilities to provide learning environments described by these three items, whereas upskilled and in-field teachers reported strong or very strong beliefs for the same items.

15.6.3 Teacher Perceptions of Classroom Practices

Table 15.3 presents the six teachers' responses to the TIMSS Grade 8 Teacher Questionnaire Mathematics, indicating how often they claimed to use the listed approaches when teaching their mathematics class. For five of the seven items, the reported frequencies increased from out-of-field to upskilled to in-field teachers, with upskilled and in-field teachers reporting similar frequencies for most approaches.

The most frequent approaches, endorsed by all three groups, involved:

- linking new content to students' prior knowledge;
- asking students to explain their answers.

The least frequent approaches (shaded in Table 15.3), which also revealed the greatest differences between the perceptions of out-of-field and upskilled/in-field teachers, referred to:

Table 15.2 Teacher self-efficacy beliefs

	Out-of-Field		Upskilled		In-Field	
Right now in my present teaching situation, the strength of my personal beliefs in my capabilities to:	T3	T5	T1	T4	T2	T6
Communicate content knowledge that is accurate and logical to students	2	3	3	3	3	4
Clarify students' misunderstandings or difficulties in learning	2	3	3	3	3	4
Actively involve students in developing concepts	1	2	3	3	3	4
Solicit a variety of questions throughout that enable higher order thinking	1	3	3	3	3	4
Actively involve students in critical thinking and/or problem solving	1	2	3	3	3	3
Involve students in developing higher order thinking	1	3	3	3	3	4
Provide opportunities for students to learn at more than one cognitive and/or performance level	1	2	3	3	3	3
Improve the academic performance of all students including those with special needs	1	3	3	3	3	3

Note A 4-point rating scale was used: 1 = weak belief, 2 = moderate belief, 3 = strong belief, 4 = very strong belief

Table 15.3 Teacher's perceived engagement in classroom practices

	Out-of-Field		Upskilled		In-Field	
Approach	T3	T5	T1	T4	T2	T6
Relate the lesson to students' daily lives	3	1	2	2	3	1
Ask students to explain their answers	3	3	1	3	2	3
Ask students to complete challenging exercises that require them to go beyond the instruction	1	1	2	2	2	2
Encourage classroom discussions among students	1	0	2	2	2	3
Link new content to students' prior knowledge	3	2	3	3	3	3
Ask students to decide their own problem solving procedures	0	0	2	2	2	3
Encourage students to express their ideas in class	2	1	2	3	2	3

Note A 4-point rating scale was used: 0 = never, 1 = some classes, 2 = about half the classes, 3 = almost every class

- asking students to complete challenging exercises that require them to go beyond the instruction;
- encouraging classroom discussions among students;
- asking students to decide their own problem-solving procedures.

Out-of-field teachers reported that they either never used these approaches or only used these approaches in some classes. The upskilled and in-field teachers reported that they used these approaches for about half of the classes or in almost every class.

15.6.4 Observations of Classroom Practice

The mean scores on the Productive Pedagogies dimension for each group of teachers over the three lessons for which they were observed are shown in Table 15.4. Each mean score is calculated from six observations (2 teachers × 3 lessons). Looking down the columns of Table 15.4 reveals some similarities between the three groups of teachers: each group scored highest on the dimension of Supportive 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.

Looking across the rows of Table 15.4 allows a comparison to be made between each of the three groups of teachers for each dimension of the Productive Pedagogies framework. In-field teachers were the group that achieved the highest mean score for the dimensions of Intellectual Quality and Supportive Classroom Environment. Upskilled teachers recorded the highest mean score for the dimension of Connectedness, with the mean score of the in-field teachers being very similar. Out-of-field teachers achieved the highest mean score for the Recognition of Difference dimension, largely due to significantly higher scores on the Inclusivity component of this dimension. This may be because they were the only teachers with mixed-ability, rather than ability-streamed, mathematics classes. It was observed that the out-of-field teachers placed particular emphasis on the element of Inclusivity within the dimension of Recognition of Difference by encouraging the participation of weaker students. Out-of-field T5 also paid particular attention to questioning and encouraging responses from female students, as in this class there was a tendency for male students to dominate the answering of questions.

Because the PDMT is mainly concerned with teaching mathematics for academic outcomes, its effects are most likely to be observed in teachers' pedagogical practices corresponding to the academic dimensions of Intellectual Quality and Connectedness. Table 15.5 presents each teacher's score totals for the three observed classes for each component of the dimension of Intellectual Quality. The maximum possible score total for each teacher is 15 (3 lessons × 5 points). Score totals instead of mean scores are presented for each component within the dimension for ease of comparison across the teachers and components.

Table 15.4 Productive pedagogies mean scores

	Teacher Group		
Dimension	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

Table 15.5 Intellectual quality score totals

	Out-of-Field		Upskilled		In-Field	
Component	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

The greatest differences between the groups of teachers within the dimension of Intellectual Quality occurred in Higher Order Thinking, Deep Knowledge and Problematic Knowledge (shaded in Table 15.5). The differences in the score totals between individual teachers for these components was at least 6 points across the three lessons or an average of 2 points per lesson on the 5-point observation scale. In general, the score totals increase from out-of-field to upskilled to in-field teachers.

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, which occurs when students combine facts and ideas in order to synthesise, generalise, explain, hypothesise or arrive at some conclusion or interpretation. Brief excerpts from lessons taught by T5 (out-of-field), T4 (upskilled) and T6 (in-field) are presented below to illustrate differences with respect to the quality of their questioning to necessitate student engagement in Higher Order Thinking. The excerpts represent typical practice of each teacher.

T5 (out-of-field) had used the analogy of a balance scale to show the method of solving an equation by 'doing the same to both sides' and thus maintaining the balance on both sides:

T5: Now what happens if it is scales and I take 8 away from 12 on the right-hand side? What happens to the scales?

$$\begin{array}{r} \Delta + 8 = 12 \\ -8 \\ \hline \Delta = 4 \end{array}$$

T5: I'll be left with 4. That side (points to right-hand side of equals sign) is now lighter than this side (points to left-hand side). This side (RHS) has only 4 on it and this side (LHS) has something plus 8. Remember both sides have to be equal. So whatever you do to one side of the scales you must do to the other side. So if I take 8 away from here as well (on LHS), we've cancelled them out so that means you've only your triangle left. So the triangle equals 4.

$$\begin{array}{r} \Delta + 8 = 12 \\ -8 = -8 \\ \hline \Delta = 4 \end{array}$$

T5 then set the students to work individually on textbook exercises, and reconvened the whole class to check on their progress on solving the following equation:

$$\square - 5 = 4$$

T5:	How much is the square worth.
Student:	9
T5:	Is she right, is the square worth 9?
Many students:	Yes.
T5:	**What did she do to both sides of the equation?**

The final question asked by T5 only requires students to reproduce previously learned mathematical procedures and therefore does not elicit higher order thinking.

T4 (upskilled) was teaching students how to solve linear simultaneous equations. Student A had begun to solve a pair of equations as shown below:

$$\begin{array}{l} x + 2y = 7 \\ \underline{2x + y = 8} \\ 3x - y = 15 \end{array}$$

A typical first step in solving simultaneous equations is to decide on a strategy for eliminating one of the variables. This is done by either adding or subtracting the equations (or a multiple of either or both equations that will give equal coefficients of either x or y). However, in this case, the student appears to have added x and $2x$, but then subtracted y from $2y$, and added 7 and 8. The following excerpt shows how T4 tried to find out what the student had done:

T4:	Student A we'll start with you.
Student A:	So I plused the xs.
T4:	So $3x$, I'm confused about what you did with the ys. **Can you explain to me what you did?**
Student A:	So I plused the x and the $2x$ and I got $3x$ and then y-$2y$ is $-y$.
T4:	(continues with questions to guide Student A towards the correct procedure)

T4's question (in **bold** type) asked Student A to explain, which is an instance of higher order thinking that manipulates rather than only reproduces information, as occurred in the previous example.

T6 (in-field) was also teaching students how to solve simultaneous equations. In the introductory lesson for this topic, he provided students with the following list of equations and asked:

T6: **Which of these equations do you think is the hardest to solve? Why?**

(1) $95x^2 - 2x + 105 = 0$
(2) $3x + 2y = 8$
(3) $9x^4 - 39x^3 + 9x^2 - 90x + 3035 = 0$
(4) $\sqrt[4]{9x^4} - \frac{9}{2}x^3 - 4^{5x} - 87x = 0$

Through further questioning of individual students, T6 elicited the conclusion that Eq. (2) is the most difficult to solve because it has two variables and, in fact, this equation has an infinite number of solutions. However, it is possible to find values of x and y that satisfy *two* equations of this type *simultaneously*. T4's question requires a high level of higher order thinking on the part of students, because they must synthesise several pieces of prior knowledge about what it means to solve an equation in order to arrive at and justify a conclusion.

To summarise, higher order thinking is necessary to answer the question posed by T6 and is required to some extent to answer the question posed by T4; however, the questions posed by T5 mainly require the students to rehearse mathematical procedures.

The differences between teacher groups were considerably less for the dimension of Connectedness (Table 15.6); this may be due to the lower score totals obtained by all three groups. The main difference in this dimension occurred for the component of Problem-Based Curriculum (shaded in Table 15.6), with the difference being equivalent to at least 3 points across the three lessons, or a mean of 1 point per lesson on the 5-point observation scale. The Problem-Based Curriculum component refers to the

Table 15.6 Connectedness score totals

	Out-of-Field		Upskilled		In-Field	
Component	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 extent to which students are presented with real, practical or hypothesised problems to solve, including the recognition of the connection between classroom knowledge and situations outside the classroom with the exploration of these connections to create significance for the knowledge.

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). The following brief excerpts from lessons taught by T3 (out-of-field), T1 (upskilled) and T2 (in-field) illustrate differences in how these teachers engaged students in a problem-based curriculum. The excerpts were chosen because they represent typical practice of each teacher.

T3 (out-of-field) was teaching the class how to perform the algebraic manipulations of expanding and simplifying. She began with a numerical example and showed two solution methods, the second of which involved use of the distributive law, the algebraic procedure she wished the students to learn:

$4(3+2)$

Two methods: $4(5) = 20$ and
$4(3) + 4(2) = 12 + 8 = 20$

She then asked students to expand $4(x+2)$. As students were expected to mimic the solution method that had been demonstrated by the teacher, this task is not classified as a problem and so there is no evidence of a problem-based curriculum in this excerpt.

T1 (upskilled) was introducing the topic of patterns and relationships as part of the study of algebra. He posed the following task:

T1:	If I gave you this pattern here: x, y, z, x, y, z, x, y, z, … What letter is in the 63^{rd} position?
Student A:	z
T1:	Why z?
Student A:	Because 3 goes into 63 evenly.

This was a fairly straightforward, but nevertheless unfamiliar, task for which the students needed to construct a solution method based on the recurring *x*, *y*, *z* pattern.

T2 (in-field) was introducing Pythagoras' Theorem, which specifies the relationship between the side lengths of any right-angled triangle: the area of the square on the hypotenuse (the longest side) is equal to the sum of the areas of the squares on the other two sides. This relationship can be written algebraically as $a^2 + b^2 = c^2$, where c represents the length of the hypotenuse and a and b the lengths of the other two sides. Instead of just giving the students this formula, T2 had the students construct a right-angled triangle with side lengths of 6, 8 and 10 units and draw the squares on all three sides (see Fig. 15.2). Because the triangle was drawn on graph paper, it was easy to count the small 'boxes' in the squares on the two shorter sides to arrive

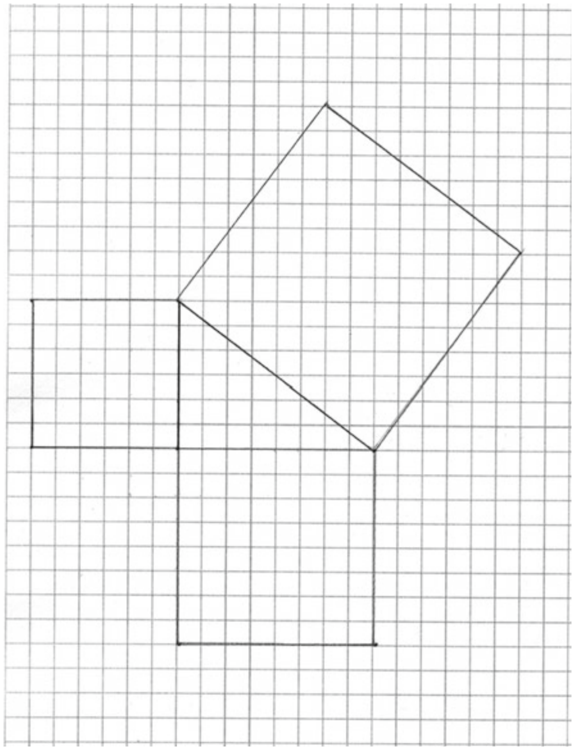

Fig. 15.2 Investigating Pythagoras' theorem

at a measure of their areas. However, because of the orientation of the square on the hypotenuse, this counting of 'boxes' was not straightforward, so the teacher and students negotiated an estimation strategy that involved counting all the 'full boxes' and then combining 'half boxes' to complete the count. This was a genuine problem for which several alternative solution methods were possible.

Thus, there is some evidence that the kind of knowledge construction that characterises a problem-based curriculum is called for in the tasks offered by T2 and T1, while the task set by T3 instead requires using well-defined algorithms for algebraic manipulation.

15.7 Discussion

This study contributes to our larger research agenda for investigating the impact of the Professional Diploma in Mathematics for Teaching, a large-scale professional development programme for out-of-field teachers of mathematics. To date, our research has relied on teacher self-reports (Goos et al., 2019; O'Meara & Faulkner, 2021), assessments of teacher knowledge (Ní Ríordáin et al., 2017) or analyses of teachers' action research reports (Lane & Ní Ríordáin, 2019) to gather evidence of the programme's impact. Some of these studies collected data on self-reported beliefs and classroom practices before and after teachers experienced components of the PDMT (e.g. pedagogy workshops, action research), while others interpreted the self-reported beliefs and classroom practices of PDMT graduates in the light of international mathematics education research literature. In this chapter, for the first time, we report on direct observation of the classroom practices of PDMT graduates.

While we would have liked to observe lessons taught before and after participating teachers had completed the PDMT in order to make stronger claims about the programme's impact, logistical constraints make it very challenging to implement such research designs. Instead, we adopted a multiple-case study design to seek insights into 'a contemporary phenomenon within its real-life context' (Yin, 2003, p. 13): the classroom practices of these upskilled teachers, teachers who were still teaching mathematics out-of-field and qualified teachers of mathematics who had always been in-field. We focused on three aspects of practice: teacher beliefs about their capability to perform specific teaching tasks (self-efficacy beliefs), teacher perceptions about their classroom practices (perceived practices) and structured independent observations of teachers' actual classroom practices (observed practices).

15.7.1 Insights into Self-Efficacy Beliefs and Classroom Practices of Out-of-Field, Upskilled and In-Field Teachers of Mathematics

There were clear differences between the self-efficacy beliefs of the out-of-field teachers, on the one hand, and the upskilled and in-field teachers, on the other hand. Upskilled and in-field teachers resembled each other in reporting stronger self-efficacy beliefs than out-of-field teachers in relation to their capabilities of actively involving students in developing concepts, engaging in critical thinking and/or problem-solving and in providing opportunities for students to learn at more than one cognitive/performance level. The upskilled and in-field teachers, more so than the out-of-field teachers, also perceived that they made more frequent use of teaching practices that ask students to complete challenging tasks, engage students in discussion and encourage students to decide their own problem-solving procedures. These perceptions of classroom practice may indicate that out-of-field teachers are less comfortable using teaching approaches that invite students to go beyond the limits of the teachers' own content knowledge. All teachers claimed that they linked new content to students' prior knowledge in at least half the lessons they taught; however, evidence from the lessons that were observed suggests that connections were made to students' school knowledge of the topic rather than to any out-of-school experiences that might enhance their understanding of the new material.

With respect to the classroom observations, the groups of teachers were similar in that they all scored highest on Supportive Classroom Environment and lowest on Connectedness, a finding that aligns with previous research into mathematics teaching using the Productive Pedagogies framework (Makar, 2011). Some of the differences between the groups suggested that the upskilled teachers (graduates of the PDMT programme) may be adopting pedagogical practices that are more like those of in-field teachers than those who are still teaching mathematics out-of-field, especially in relation to the provision of intellectual quality and connectedness.

15.7.2 Insights into Evidencing the Impact of Professional Development

Desimone's (2009) conceptual framework for studying teacher professional development provided a useful heuristic for planning our research into the impact of the PDMT. She wrote that classroom observation and teacher self-reports are commonly used methods for measuring the effects of professional development. She further argued that both methods can provide valid data if the same observer uses a well-constructed protocol for all classroom observations and the teacher self-report protocol focuses on what teachers did rather than how well they did it. In our study, a single observer used the Productive Pedagogies observation protocol to ensure a consistent approach to gathering and analysing data on teachers' classroom practices. The teacher self-report instruments asked teachers about the strength of their self-efficacy beliefs and the frequency of implementing the nominated teaching approaches, thus avoiding evaluative judgments as recommended by Desimone.

A challenge for research into teacher change is the possibility of social desirability bias, which 'can occur in any form of data collection' (Desimone, 2009, pp. 189–190), whether this involves surveys, interviews or observations. Such biases can be avoided by using well-constructed instruments that are aligned with a study's research questions and administered appropriately. We suggest that, additionally, data collection instruments that combine teacher self-report with independent observation need to be aligned so that they tap into the same, or similar, underlying constructs. For example, many of the items that were used in the Teacher Efficacy Beliefs Survey (see Table 15.2) refer to teacher beliefs in their abilities to engage students in developing concepts, higher order thinking, critical thinking and problem-solving—all of which strengthen the intellectual quality of a lesson as defined by the Productive Pedagogies protocol. Similarly, the TIMSS Grade 8 Teacher Questionnaire Mathematics elicits teacher perceptions of the frequency of classroom practices such as encouraging student discussion, offering challenging tasks (both of which align with intellectual quality) and relating lessons to students' prior knowledge and daily lives (aligned with connectedness, another of the Productive Pedagogies dimensions). It would be beneficial for future research into the impact of the PDMT to conduct a more detailed mapping of alignment between the data collection instruments used in the present study.

15.8 Conclusion and Recommendations

The conclusions that we draw from this study can only be tentative, given the small sample and case study design. A case is not a sample from which one can generalise to a population; however, case study findings permit analytic generalisation in order to expand the theories upon which the study was based (Yin, 2003). Our findings suggest that the structured lesson observation provided by the Productive Pedagogies framework may be useful in supplementing the upskilled teachers' self-reported changes in their pedagogical practices arising from participation in a professional development programme. In addition, such structured observations may usefully inform the design of programmes aimed at developing 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).

Two recommendations arise from the findings of the present study, and the broader research programme that is investigating the impact of the PDMT. Firstly, research into the effectiveness of professional development programmes for out-of-field teachers should be guided by a conceptual framework that operationalises how such programmes influence teacher learning and, ultimately, the improvements to student learning that are claimed to result. We used Desimone's (2009) path model, but other frameworks exist (e.g. see Clarke & Hollingsworth, 2002; Guskey, 2000). The second recommendation is directed at education policy makers who may fund professional development programmes for out-of-field teachers. While such investment in teacher development is welcome, significant funding is also needed to gather evidence of the impact of these programmes, and especially in terms of changes to teachers' classroom practices. Large-scale classroom observation studies are rare and costly (see, Lingard et al., 2001, for an example), but can reveal trends that support further policy and practice initiatives. Our own study, while involving only a small number of participants, offers insights into the knowledge that can be gained from classroom-based research with newly upskilled teachers of mathematics.

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Chapter 16
Elementary School-Appropriate and Algebraic Solutions of Out-of-Field Teachers and Pre-service Teachers in Comparison

Lara Huethorst

Abstract Fostering process-related goals—such as problem-solving or reasoning mathematically—poses challenges for German elementary school mathematics teachers. Among others, there is the challenge of understanding the mathematics within substantial learning environments as well as the challenge of knowing how to encourage learners to make mathematical discoveries. A five-part in-service course focusing on substantial learning environments has been conducted and evaluated. The focus of the accompanying research was on gaining insights into how elementary school teachers who teach mathematics out-of-field solve problems themselves. Problems were solved by the participating teachers before and after the course. Elementary teacher students in their final course after having studied mathematics education (and other subjects) for five years to become elementary school teachers solved the same problems in comparison. Similarities and differences concerning argumentative and algebraic solutions of teachers and teacher students will be presented from the two different angles of reasoning and early algebra.

Keywords Algebraic thinking · Out-of-field elementary school teachers · Pre-service teachers · Reasoning · Teaching mathematics out-of-field

16.1 Introduction

In the German context, teaching mathematics out-of-field in elementary school frequently occurs but is not considered unquestionable as can be concluded from the increasing works around that topic (e.g. Eichholz, 2018; Porsch, 2016). Due to highly diverse conditions in studying and teacher training in the different federal states, out-of-field teaching in elementary school can be found to different extents (Richter et al., 2012). Some pre-service elementary school teachers take courses in two different subjects while others study four different subjects; in some federal states mathematics (education) is obligatory. Hence, elementary school teachers are

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educated to be specialists as well as generalists (Hobbs & Törner, 2019; Porsch, 2017). Common ground in all federal states is the two-parted education with an initial phase of studying at a university or teacher training college and a second phase of being a pre-service teacher at school while being accompanied by teachers and teacher educators (for a detailed account of the teacher education system see Campbell et al., 2019).

"Out-of-field teachers are teachers who teach subjects or year levels that do not match their specializations" (Du Plessis et al., 2019, p. 218). For the German context, this definition is taken up by the German Centre for Mathematics Teacher Education (DZLM), according to which all teachers who do not fulfil both criteria—studying mathematics (education) at university *and* a guided pre-service teacher period in mathematics education—are considered to be out-of-field (DZLM, 2015). Nonetheless, the teachers who are part of the present study were educated to become elementary school teachers for grade one to four—but not in the field of mathematics (education). The teacher training course in which the later presented data was collected was advertised for out-of-field elementary school teachers or those who felt out-of-field (Porsch, 2016).

In the following chapter, differences between elementary school appropriate and algebraic reasoning of out-of-field elementary school teachers with training to teach elementary school but without training in mathematics who participated in a teacher training course on the one hand, and pre-service teachers in their final master's course of studying to become elementary school teachers of mathematics for five years on the other hand, are presented. The focus of this chapter is on the argumentative and algebraic solutions of teachers; the teacher training course is not presented. For a more detailed insight into the teacher training course, see Huethorst and Selter (2020).

After the brief localisation in the research area of out-of-field teachers has been made, it is explained why (1) out-of-field in-service teachers are compared to in-field pre-service teachers without longer practical experience. The two different and yet connected angles of (2) algebraic thinking and (3) reasoning in German elementary schools are presented. As the fourth part (4) the research design is presented. After this, (5) some exemplary results are given to illustrate both adopted perspectives—reasoning as well as algebraic thinking. The chapter is supplemented with a conclusion and a discussion.

16.2 Out-of-Field In-Service and In-Field Pre-service Teachers

Not only in the context of German research, contrasting results emerge with regard to lessons taught by out-of-field teachers. While some research postulates (significant) differences in students' performance (Laczko-Kerr & Berliner, 2003; Richter et al., 2012), others state the opposite (Rjosk et al., 2017; Ziegler & Richter, 2017). Most experts agree that there are multiple possible reasons for those opposing results—most often, different conceptualisations of out-of-field are cited as a possible cause (Porsch & Whannell, 2019). This chapter focuses on a comparison between in-service trained elementary school teachers who teach mathematics out-of-field and pre-service in-field elementary school teachers of mathematics.

As early as the 1980s, Shulman defined the general pedagogical knowledge, content knowledge and pedagogical content knowledge as some of the main categories of teacher professional knowledge (Shulman, 1987). Many contemporary studies of teacher professional knowledge are based on the theoretical considerations of Shulman and have expanded on them to include additional facets. The extent to which the two groups considered here differ in this respect will be examined.

However, teachers can be differentiated not only on the basis of their former training. "Other characteristics that can be looked at in terms of teachers' learning opportunities include, for example, teaching experience (occasionally operationalized as teachers' age) and professional development" (Porsch & Whannell, 2019, p. 180). The phase after their—mainly theoretical—studies at a university is considered highly important: "The transition from teacher training into the teaching profession is seen to be key in the biography of a teacher" (Blömeke et al., 2014, p. 510).

"Teacher knowledge is complex […] and borne from experience before and during teaching" (Du Plessis et al., 2019, p. 238). A German follow up study to TEDS-M where teachers in the second phase of German teacher education were surveyed—TEDS-FU, which asked the same teachers four years later—postulates as one of their interpretations of the results that practical experience might be a source for acquiring a higher mathematical pedagogical content knowledge (MPCK) (Blömeke et al., 2014). "Finally, practical experiences seem to be of utmost importance for the development of GPK [general pedagogical knowledge]. The acquisition of this knowledge facet does not end with finishing teacher education but continues during the first years in the profession" (Blömeke et al., 2015, p. 303). The ranking concerning mathematical content knowledge (MCK) has not changed over time—those participants who achieved a higher MCK in the original study had higher sources in the test four years later as well (Blömeke et al., 2014). However, "the great majority of both PCK and CK is acquired at university" (Krauss et al., 2008, p. 887).

"An argument can be made that a teacher's SMK [subject matter knowledge] develops with experience in the classroom and over a long period of time" (Ríordáin et al., 2019, p. 132). In order to limit the possible learning opportunities, for the present study, pre-service teachers of elementary school mathematics are compared to those teachers already in the classroom and teaching mathematics outside of the subject area.

Now, for a deeper understanding of the mathematical context of the study, the relevance of algebraic learning and reasoning is highlighted below.

16.3 Algebraic Thinking in German Elementary Schools

"To move algebra-as-most-of-us-were-taught-it to elementary school is a recipe for disaster" (Carraher et al., 2008, p. 3). Since focusing on pattern and structures in elementary school is a new(er) topic in German contexts, new demands are placed on teachers. "There is no doubt that teaching algebra and algebraic thinking is both complex and dynamic" (Ferrucci, 2004, p. 131). Few teachers are able to detect potentials of tasks to foster algebraic thinking (Steinweg et al., 2018)—this holds true also for teachers specialised in elementary school mathematics, and all the more, out-of-field teachers should be supported. That content knowledge as well as pedagogical content knowledge of a teacher are considered to be of great importance is shown by various research (e.g. Krauss et al., 2008; Shulman, 1986).

"There may be many reasons for viewing algebra as more advanced than arithmetic and therefore placing it after arithmetic in the mathematics curriculum. But there are more compelling reasons for introducing algebra as an integral part of early mathematics" (Carraher et al., 2006, p. 110). Not only should algebraic thinking be considered in the early years and therefore in elementary school already, but the two sub-disciplines mesh excellently with each other. "Early algebra is about teaching arithmetic more deeply" (Carraher et al., 2000, p. 18). Here, insights into patterns and structures of mathematics play the central role to use insight gained in arithmetic contexts, too. "In order to learn arithmetic, it is necessary to think algebraically, although not necessarily using symbols" (Mason, 2018, p. 329).

Many recently formulated objectives of German elementary school mathematics focus on patterns and structures (Akinwunmi, 2017). The "Standing Conference of Ministers of Education and Cultural Affairs" names the *examination of patterns and structures* as one of five important topics in German elementary school mathematics, which includes predicting, describing and presenting patterns as well as functional relations (KMK, 2014). Several researchers criticise the autonomy of this topic and see patterns and structures rather as a transverse issue which needs to be highlighted and discussed in every topic—including arithmetic (e.g. Krauthausen, 2018; Wittmann & Müller, 2011). Early algebra, however, cannot be found in German curricula (e.g. MSW NRW, 2008) but one "can identify many characteristics that offer opportunities to support algebraic thinking" (Steinweg et al., 2018, p. 284).

Not only should teachers—regardless of being in- or out-of-field—be able to solve tasks, have the pedagogical content knowledge and adequately apply their certain knowledge, but they need to see the potential for fostering early algebraic thinking. In the PD course (see Huethorst & Selter, 2020 for course details) the participating elementary school teachers were asked to solve tasks elementary school-appropriately and algebraically. "Solving and analyzing tasks and predicting student responses during professional development offers teachers the opportunity to develop pedagogical and specialized content knowledge required for teaching" (Hunter et al., 2018, p. 382).

One way of capturing different facets of algebraic thinking are the seven features of algebraic habits of mind of building rules to represent functions: (1) Organising Information, (2) Predicting Patterns, (3) Chunking Information, (4) Different Representation, (5) Describing a Rule, (6) Describing Change and (7) Justifying a Rule. Magiera and colleagues adapted these from Driscoll and used the features for analysing pre-service teachers' solutions to algebraic tasks (Magiera et al., 2013, 2017).

When describing a rule or change, even more when justifying a rule—and thereby following the paradigms of (early) algebra thinking—generalisations are key to tasks and their solutions. This is why the topic of reasoning becomes important and, therefore, is presented in the next paragraph.

16.4 Reasoning in German Elementary Schools

"It has often been stated that generalizing should be the heart of mathematical activity in school" (Küchemann, 2010, p. 233) and occasions in which students could generalise are abundant—especially when teaching with a focus on early algebra. Why a generalisation can be made and why a certain statement holds true for several or for all numbers leads to the field of reasoning.

Proving is one of the—if not *the*—most prominent concepts of mathematics (e.g. Brunner, 2014; Tall, 2002). In an elementary school environment, strictly deductive proofs cannot be expected. However, in order to introduce learners to evidential proving, justifications for relationships and reasoning should be demanded from the very beginning of mathematics school education. The advantages of reasoning, such as gaining insights into mathematical relationships, patterns and structures, are outlined from several perspectives, for example in the NCTM standards (NCTM, 2000) as well as in the German standards for elementary schools (KMK, 2004) or by different experts (Brunner, 2014; Krauthausen, 2018). The German standards name five so-called process-related competencies, one of which is (1) reasoning. This includes (2) checking mathematical statements for correctness, (3) recognising relations and (4) conjecture about reasons and (5) comprehending as well as searching for reasons (KMK, 2004; MSW NRW, 2008). These expectations towards elementary school pupils show that they are not required to perform a theoretical proof but to reason at their level of competence and to focus on patterns and structures and explore those relationships.

Bezold (2012) includes in her conceptualisation of reasoning in the elementary school environment three elements: (1) describing discoveries, (2) questioning discoveries and (3) justifying discoveries. This implies that the interconnection of discovering and justifying is strong in the contexts of reasoning. For Bezold, this leads to different levels of reasoning—on the one hand the justification can be differentiated on different levels, on the other hand the complexity of the number relations can differ. But the more complex the number relation described and explained is, the higher the demands regarding the reasoning process become.

"Creating a classroom culture that focuses on justification and generalization is not an easy task for a number of reasons" (Hunter et al., 2018, p. 380). This is especially true since this is "a new territory for students and teachers" (Bezold, 2012, p. 99, author's translation). This in turn holds particularly true for non-specialist teachers; out-of-field teachers might need support with early algebra and reasoning, which can, for example, be realised in form of teacher training courses.

16.5 Methodology

The presented data is taken from different dates and settings. Firstly, the participants and data collection are presented. Secondly, the problems that the teachers have worked on are presented. As a third part of the methodology, it is presented how the solutions were categorised and analysed.

16.5.1 Participants

The solutions of the out-of-field teachers were collected within two different in-service teacher training courses for out-of-field elementary school mathematics teachers. Before and after conducting the teacher training course the teachers were asked to solve two different elementary school tasks. Forty-seven teachers participated in the first survey (before starting the course) and are included in further analysis. For the comparison of teachers' solutions before and after the course, see Huethorst (in prep). To contrast the solutions of out-of-field teachers, 50 pre-service teachers in their final course in mathematics education did the same survey. They had studied mathematics education for (at least) nine semesters and were preparing for their final oral exam in the course in which they were asked to participate in the survey.

16.5.2 Design of the Study

The participants completed a survey that includes two elementary school-appropriate tasks, which can be found in similar form in German elementary school mathematic school books. One of the two tasks is focused on in what follows below; for results on the other task see Huethorst (in prep). Both tasks were designed following the so-called operative principle, which Wittmann (2021) explains as follows:

> To understand *objects* means to explore how they are *constructed* and how they *behave* if they are subjected to operations (transformations, actions, ...).

Therefore students must be stimulated in a systematic way:

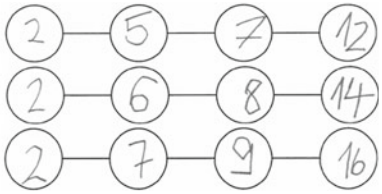

Fig. 16.1 Number chains with operative changes

(1) to explore which *operations* can be performed and how they are related with one another,
(2) to find out which *properties* and relationships are imprinted into the objects through construction,
(3) to observe which effects properties and relationships are brought about by the operations according to the guiding question "What happens with ..., if ...?" (p. 153)

Tasks that are designed according to the operative principle are particularly suitable for addressing both algebraic thinking and argumentation.

The task presented here consists of the number chains, which are built following the Fibonacci sequence: there are two freely selectable starting natural numbers, which have to be added to get the third number. The second and third numbers are added to obtain the target number in a four-part number chain.

When the numbers are operatively changed, as in the example (Fig. 16.1) the second starting number is increased by one from number chain to number chain, the target number is increased by two. This needs to be explained *why* and therefore is a suitable task when trying to foster algebraic thinking as well as reasoning.

The participants were asked to continue this pattern at first. Then they were asked to explain what changes. Afterwards, the teachers were asked to provide an *elementary school-appropriate* reasoning as well as an *algebraic* reasoning for the change of the target number. The later justification should be provided with an explanation.

16.5.3 Analytical Tool—Categories for Elementary School-Appropriate Reasoning

In order to cluster the solutions of the different participants and to be able to better compare them, a deductive-inductive category system was developed. According to Bezold (2012), it can be differentiated between the complexity of the number relations and the level of justification. The elementary school-appropriate reasoning regarding the changes of the target number of the presented number chains are therefore be categorised in Table 16.1.

The categories are sorted from one to five—in such a way that the most desirable category is the first one.

Table 16.1 Categories for elementary school-appropriate reasoning

	… of all changed numbers	… of selected numbers
Justifying the change…	(1) It is justified that the 3rd number increases by 1 when the 2nd starting number is increased by 1. Since the addition of the two affects the target number, the target number is increased by 2. It becomes clear that the increase of the 3rd number results from the increase of the 2nd starting number	(2) It is justified that the 2nd starting number is included in the target number twice and therefore the increase is doubled. No reference is made to the change of the 3rd number
Describing the change…	(3) It is described that the target number increases by 2 when the 2nd starting number is increased by 1 Or it is described that the 2nd starting number and the 3rd number each increase by 1 and the target number by 2 without making clear that the increase of the 3rd number results from the increase of the 2nd starting number. Since this is a description of all changed numbers, there is no need to mention the first starting number	(4) It is described that the target number increases by 2. There can be cases where the condition “if the 2nd starting number is increased by 1” is included, but also those where only the target number is focused on. The 3rd number remains unmentioned. All in all, it does not become clear which numbers change, how nor why
	(5) Wrong answers fall into the fifth category	

16.5.4 *Analytical Tool—Categories for Algebraic Reasoning*

The task of justifying the operative changes in number chains (see Table 16.2) focuses on two different parts of the change. The three important elements which can be addressed are: (1) how the target number is generated, (2) the increase of the target number by two and (3) an explanation.

Here again, the first number indicates the best category.

Table 16.2 Categories for algebraic reasoning

(1) Building rule and change and sufficient explanation	(2) Building rule with change without sufficient explanation	(3) Building rule without change without sufficient explanation	(4) Non-targeted formulaic description
Building rule ✓ + 2 ✓ Explanation ✓	Building rule ✓ + 2 ✓ Explanation x	Building rule ✓ + 2 x Explanation x	Building rule x + 2 x Explanation x
(5) Wrong answers			

16.5.5 Analytical Tool—Features of Algebraic Habits of Mind to Represent Functions

Magiera and colleagues (2013) adapted the seven features of algebraic habits of mind to represent functions. When trying to analyse the given number chains including the operative changes, the features need to be adapted once again, so both foci can be taken into account (Fig. 16.2).

Since the participants' solutions are in written form, it is difficult to tell whether they are able to *organise* and *chunk the information* or *predict the pattern.* Still, if they could describe a rule, it is assumed that they were able to do so for themselves. This is why these three features will not be further considered. The described rules can either stay local—which means that they only hold true for the given numbers in the exemplary chain—or be general. Both foci need to be combined to describe the common change, which can only be reached when considering the building rules as well as the operative changes. This rule needs to be justified. Thus, a certain order is assumed here that is not intended in the habits of mind according to Magiera and colleagues (2017). The representations, however, can vary individually for either the building rules or the operative changes.

When the text is in bold, the solution addresses this feature. When the text is in italics, it is stated in the solution that this should be done but is not actually done; for example, when teachers only state that it would be a good idea to change the representation for the elementary school-appropriate reasoning but they do not provide any particular representation. When the text is in bold and in italics, this feature is addressed indirectly. This model can be used to classify both the elementary school-appropriate and the algebraic solutions.

16.6 Key Findings

The key findings focus on the differences between the elementary school-appropriate as well as algebraic reasoning of out-of-field in-service teachers and in-field pre-service teachers with two different angles of analysis—a category system with a focus on reasoning and algebraic habits of mind with a focus on algebraic thinking.

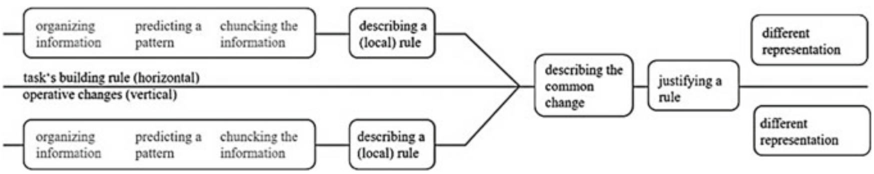

Fig. 16.2 Habits of mind for tasks based on the operative principle

Table 16.3 Elementary school-appropriate reasoning

	Out-of-field in-service teachers	In-field pre-service teachers
Category 1	6	18
Category 2	1	4
Category 3	24	15
Category 4	8	5
Category 5	0	2
No answer	8	6

16.6.1 Categories for Elementary School-Appropriate Reasoning

The solutions of the participating groups were—as expected—quite different. As Table 16.3 illustrates, six participants of the out-of-field teachers were able to reach a justification for the change of the target number. More than two thirds of them remained at a descriptive level. While none of the out-of-field teachers gave a wrong answer, eight participants did not answer at all. Two in-field pre-service teachers, however, gave mathematically wrong answers. But almost half of pre-service teachers were—at least partly—able to justify the rules in an elementary school-appropriate way. This is about three times as much as the participating out-of-filed teachers.

The Wilcoxon test is used to test for significance of the differences of the two groups (Bortz et al., 2008). The results show that these differences are significant with a $p < 0.05$. The effect size (Cohen's d) is in medium range with a value of 0.52.

16.6.2 Categories for Algebraic Reasoning

A similar result can be observed when focusing on algebraic reasoning of those two groups. While almost two thirds of the out-of-field teachers were able to describe the building rule with variables, nearly 90% of the in-field teachers were able to do so. Only four out of 47 out-of-field teachers were able to explain the difference of the target number algebraically (categories 1 and 2). Almost every second in-field pre-service teacher was able to express the change algebraically and every fifth could additionally explain these findings in writing (Table 16.4).

The results of the comparison of the algebraic solutions of the two different groups are significant as well ($p < 0.01$). The effect size is strong with $d = 0.86$.

Both sets of solutions were categorised by two unaffiliated raters, who agreed on a value afterwards. The interrater reliability is—according to Landis and Koch (1977)—"Almost Perfect" (165) with values of 0.87 for the elementary school-appropriate categories and 0.84 for the categories of algebraic reasoning.

Table 16.4 Algebraic reasoning

	Out-of-field in-service teachers	In-field pre-service teachers
Category 1	1	10
Category 2	3	13
Category 3	27	21
Category 4	11	2
Category 5	1	2
No answer	4	2

After the presentation of the statistical overview and demonstration of the significance of the differences in both groups, a few examples of both groups are closer looked at with regard to their features of algebraic habits of mind.

The work of one of the participating out-of-field in-service teachers (ANN) is an example for a description of the change of the target number in which the reason for the change cannot be located (Fig. 16.3).

The rule which is described stays on a local level, since it does not become clear whether the teacher knows if this rule has general validity. The task's building rule is not mentioned. Hence, the common change cannot be described (Fig. 16.4).

This is a representative example for the group of the out-of-field teachers who participated in the teacher training course before they took the course. Results of the surveys after the teachers took the teacher training course are discussed in Huethorst (in prep) and are not included here to better compare the out-of-field teachers of mathematics with the pre-service teachers of mathematics. Since the rule is only described partially on an elementary school-appropriate level, it might be the case that the mathematical connections and justifications cannot be adequately addressed and implemented in the classroom. But since this study did not gain insights into the classrooms of the teacher nor the pupils' answers, this remains speculative.

The algebraic solution of ANN might support the thesis that the mathematical connections were not recognised. Although ANN is able to express the building rule algebraically, she cannot interpret it meaningfully. The change of the target number is attributed to the first starting number two and not to the increase of the second starting number by one (Fig. 16.5).

Hence, both rules are described—even though the rule for the operative change stays local and is not mathematically correct; the target number always increases by two when the second starting number is increased by one, regardless of the

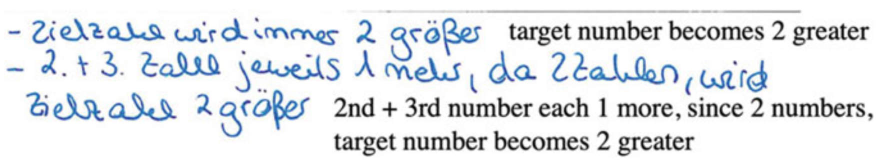

Fig. 16.3 Elementary school-appropriate solution ANN

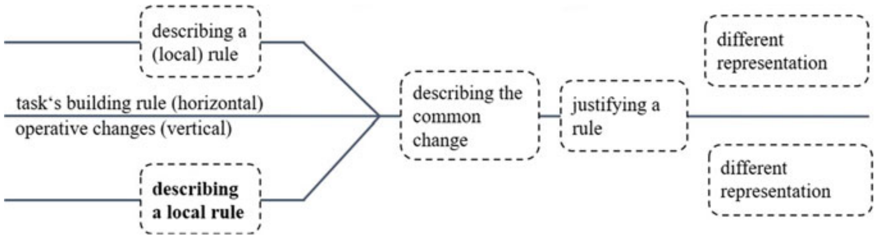

Fig. 16.4 Elementary school-appropriate habits of mind ANN

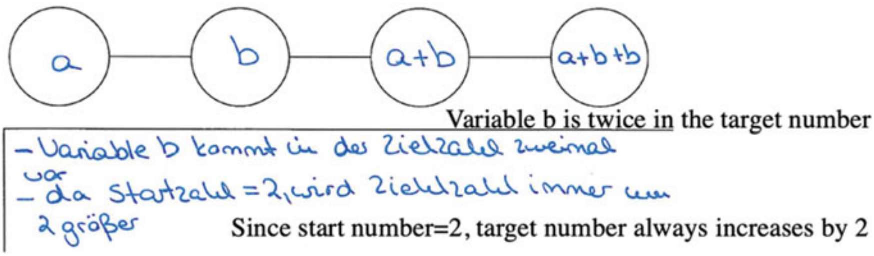

Fig. 16.5 Algebraic solution ANN

first starting number. The representation of the task's building rule is changed from number to variables. The other facets of the algebraic habits of mind are not addressed.

This solution of ANN shows that even if teachers are able to set up the algebraic solution, it cannot always be filled with meaning. Thus, a mere application of the algebraic language is not sufficient to be able to explain the mathematical relationships with it (Fig. 16.5 and 16.6).

In contrast to those solutions—which were common to many out-of-field teachers—the solutions of BETH were among the best of the group. BETH abstracts the representations of numbers and focuses the pupils' attention to the change of the second starting number as well as all the changes which derive from it. Both rules—the building rule of the number chains and the rule of the operative change—can be

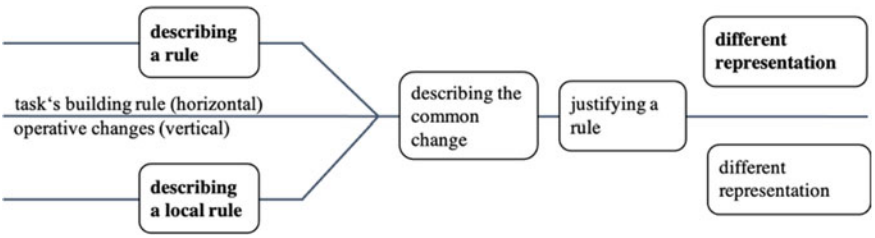

Fig. 16.6 Algebraic habits of mind ANN

observed in BETH's solution. The justification stays implicit; however, this might be because she regards this as obvious, the " +2 is evident" (Fig. 16.7).

The algebraic solution of BETH supports the assumption that the change is understood and perceived as obvious. The two separate +1 are underlined, which might express to her a complete justification (Fig. 16.7 and 16.8).

This means that the justification stays implicit in the algebraic solution as well. The representations are varied for the task's building rule but stay on a numerical level for the operative changes. Nonetheless, most of the algebraic habits of mind are activated in BETH's solution (Fig.16.9 and 16.10).

Overall, BETH's solutions—both the elementary school-appropriate one and the algebraic one—are very advanced for the group of out-of-field in-service teachers who participated in the teacher training course. However, one solution of an in-field pre-service teacher (IRA) illustrates that there are still differences perceptible (Fig. 16.10).

Although one does not want to imply that BETH (Fig. 16.7 and 16.9) finds it difficult to verbalise the discoveries, IRA's solution (Fig. 16.11) expresses the elementary school-appropriate justification more clearly. Additionally, the representation of the operative change is varied as well (Fig. 16.12).

Hence, all of the algebraic habits of mind can be observed in IRA's solution.

A similar picture is observable for the algebraic solution. IRA illustrates the change by contrasting the *original* and the *changed* number chain. She draws a second number chain—at this point it should be mentioned that the presence of only one chain can definitely be seen as a weak point of the questionnaires—to illustrate

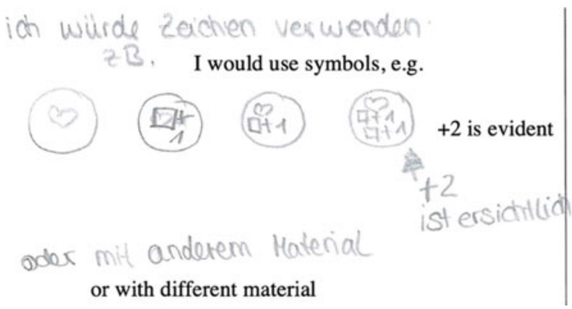

Fig. 16.7 Elementary school-appropriate solution BETH

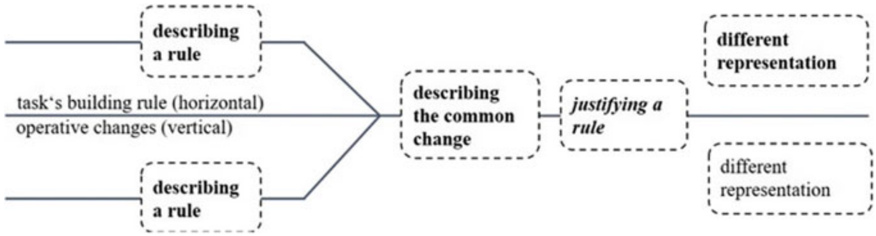

Fig. 16.8 Elementary school-appropriate habits of mind BETH

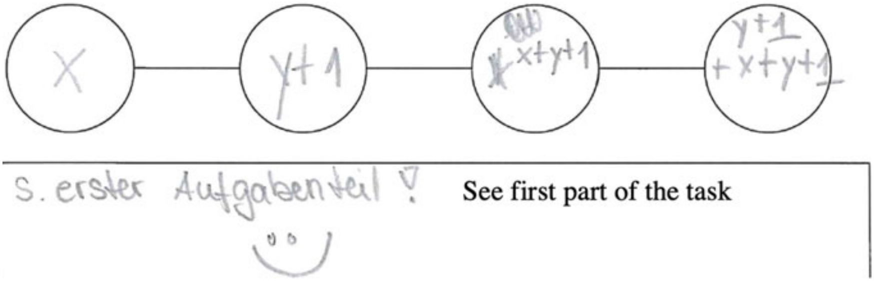

Fig. 16.9 Algebraic solution BETH

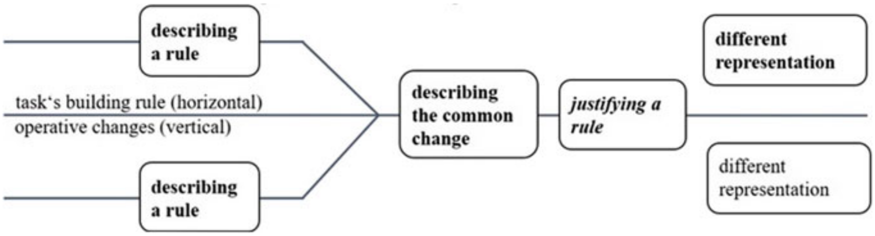

Fig. 16.10 Algebraic habits of mind BETH

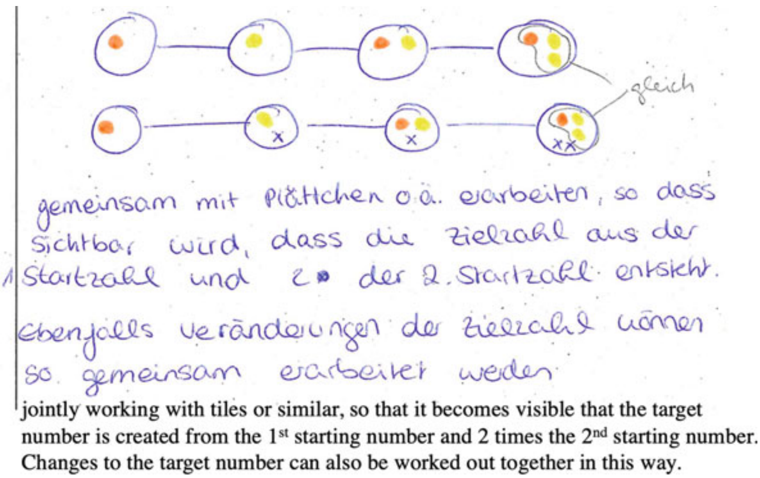

Fig. 16.11 Elementary school-appropriate solution IRA

this comparison. With the usage of arrows and circles, IRA tries to demonstrate the difference between the original and the changed number chain. Furthermore, she adds the calculation to determine the difference (Fig. 16.13).

The task's building rule is demonstrated and the operative change is addressed. The common change is shown by the direct comparison of all elements of the number chains. The rule is justified with verbal language use, but with means of algebraic representations (Fig. 16.14).

In conclusion, the results show that there are statistically significant differences between the groups of out-of-field in-service teachers and in-field pre-service teachers. Additionally, differences in the activation of the algebraic habits of minds can be observed. Even compared to the best of the group of out-of-field teachers, the pre-service teachers who studied mathematics education make use of more features in the elementary school-appropriate as well as algebraic solutions.

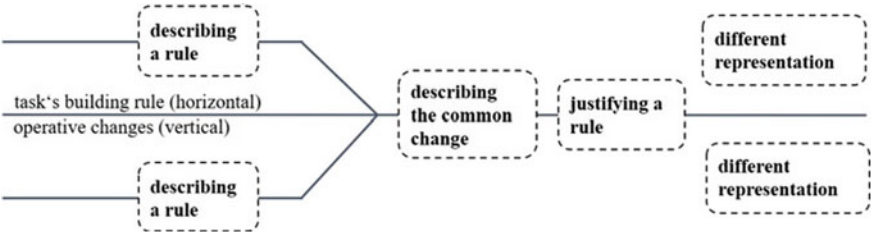

Fig. 16.12 Elementary school-appropriate habits of mind IRA

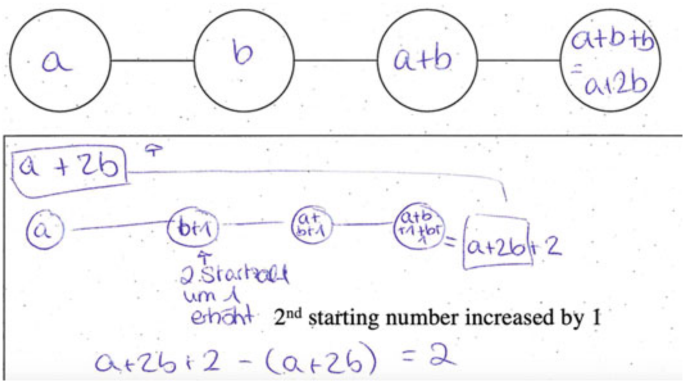

Fig. 16.13 Algebraic solution IRA

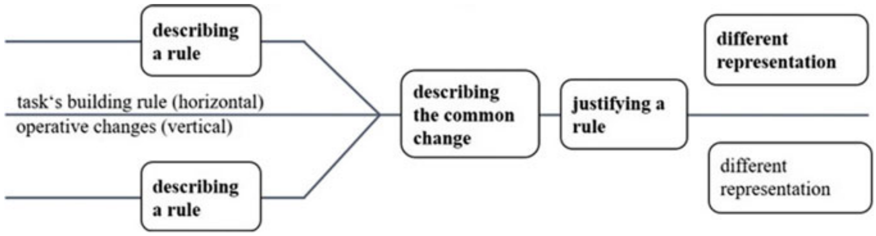

Fig. 16.14 Algebraic habits of mind IRA

16.7 Discussion

The presented data for the two groups of out-of-field mathematics in-service elementary teachers on the one hand, and pre-service teachers trained in the field of mathematics education on the other, show a significant difference in elementary school-appropriate as well as algebraic reasoning for an operative change in the number chains problem.

The results match those of the mathematical content knowledge (MCK) of TEDS-M, in which future elementary school teachers could be divided into three groups of highest, average and lowest competence levels (Kaiser et al., 2017). The "teachers at the highest competence level can be characterized by strong structural mathematical knowledge […] and they possess skills in argumentation and logical reasoning" (ibid., p. 170). This is true for both groups—in- and out-of-field—in the presented study. However, teachers at the average level might "experience problems with the argumentative usage of mathematics" (ibid.) and those at lowest level have difficulties seeing mathematical structures (ibid.).

While only seven participants of the participating out-of-field teachers are able to justify the change of the target number elementary school-appropriately, 22 of the in-field ones give a justification. All other solutions remain on a descriptive level rather than giving a justification. Even more differences can be observed for the algebraic solution; only four participants of the out-of-field teachers were able to illustrate the change, almost half of the in-field teachers justify the change of the target number.

When focusing on the different algebraic habits of mind to represent functions, the results show that a representative solution of the elementary school-appropriate reasoning of an out-of-field mathematics teacher does not combine both rules—the building rule and the rule for the operative change—therefore, the mathematical justification cannot be considered to be complete or generally valid. The comparison with pre-service in-field elementary school teachers of mathematics shows that the participating teachers who studied mathematics education were able to include the task's building rule as well as the operative changes in their justifications.

As the results of the present study indicate, there might be a need for professionalisation of out-of-field elementary school mathematics teachers related to algebraic thinking and reasoning in the elementary school context. "There is broad consensus that teachers' domain-specific knowledge is an essential ingredient of high-quality instruction, particularly in the mathematics classroom" (Krauss et al., 2008, p. 873). The presented study cannot offer insights into classroom practices or pupils' results. However, first insights into the capability to reason algebraically and to use this knowledge to justify changes on an elementary school-appropriate level of in- and out-of-field teachers underline the need of support for the out-of-field teachers.

To sum up, in certain areas, as presented here for reasoning and algebraic thinking, teaching experience might not be an equal substitute for studying mathematics or mathematics education.

16.8 Conclusion and Recommendations

New demands in curricula, like focusing on mathematical patterns and structures, pose new challenges to teachers—regardless of whether they are trained to teach mathematics in elementary schools or not. Even though the sample size of participating teachers is comparably small, the presented study gives reasons to assume that there might be a need for professional development for out-of-field teachers with a focus on both algebraic thinking (and therefore MCK) and reasoning (on MCK and MPCK level). This does not only apply for secondary schools, but holds probably true for elementary school teachers as well.

Further focus could be placed on *how* teacher training courses should be designed and which facets are perceived as most vital by teachers in practice as well as by teacher educators. The learning processes of out-of-field teachers might provide (further) insights into what is important to fulfil the required mathematical tasks. This is true for elementary school level as well, since it cannot be taken for granted that all out-of-field teachers recognise the mathematical patterns and structures by themselves. Without this knowledge, however, it is hardly possible to see the potentials in a task—neither for fostering algebraic thinking nor for fostering reasoning—and therefore, give the pupils a chance to gain these insights.

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Chapter 17
Teaching Mathematics Out-of-Field: What Knowledge Matters?

Kim Beswick and Dennis Alonzo

Abstract In this chapter, we draw upon a project involving teachers of upper primary and secondary school mathematics who were teaching out-of-field to varying extents, and who were variously aware of the knowledge needed to teach mathematics in their context. Rasch analysis of the responses of the 62 middle school teachers to a teacher knowledge profile provided insights into teachers' mathematics qualifications and their knowledge for teaching mathematics. We conceptualised teacher knowledge as a rich construct incorporating each of Shulman's seven knowledge types as well as confidence in relation to everyday mathematics and teaching mathematics, along with aspects of teachers' beliefs about mathematics teaching and learning. Focusing on 10 of the teachers demonstrated that qualifications in mathematics do not guarantee adequate knowledge for teaching mathematics and pointed to ways in which teachers of mathematics with differing knowledge profiles and discipline qualifications might be supported to more effectively teach the subject.

Keywords Mathematics teacher knowledge · Out-of-field mathematics teaching · Professional development

17.1 Introduction

Weldon (2016) defined teaching out-of-field for secondary school teachers as teaching a subject without having studied that subject for at least one semester at second year university level or not having studied curriculum and pedagogy relevant to that subject. He reported that, according to this definition, 38% of Australian mathematics teachers could be considered to be teaching the subject out-of-field. This figure was comprised of 20% of all mathematics teachers with neither second year university mathematics nor curriculum and pedagogy study, 10% who had studied curriculum and pedagogy but not second university year mathematics, and 8% who had studied mathematics to second year university level but had not studied relevant

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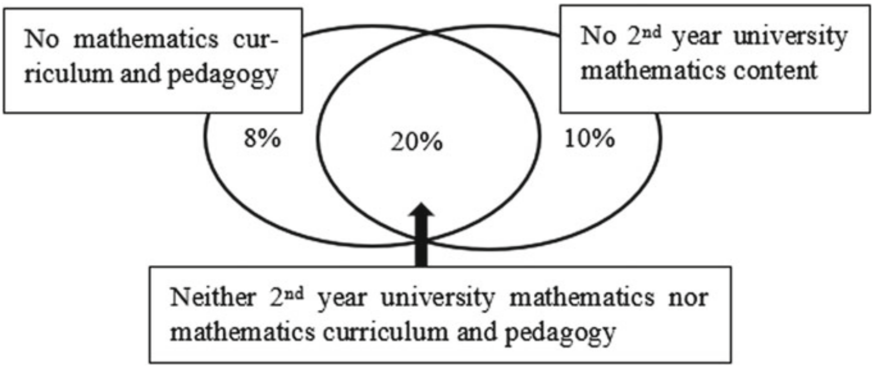

Fig. 17.1 Out-of-field teaching of mathematics in Australia according to Weldon (2016)

curriculum and pedagogy. Thirty per cent of all Australian secondary mathematics teachers had not studied the discipline to at least second year university level and 28% had not studied relevant curriculum and pedagogy. The situation is summarised in Fig. 17.1.

The consensus in the literature, including that cited by Weldon (2016), is that teachers need both knowledge of the discipline that they teach that is well beyond the level at which they will teach it, and knowledge of the relevant curriculum and pedagogy. Weldon's discussion illustrates that definitions of out-of-field teaching typically do not account for aspects of knowledge that are not amenable to assessment by proxies such as courses studied at university even though the limitations of these proxies are recognised (Mewborn, 2001).

We were interested in how a comprehensive measure of the knowledge required to teach mathematics, that included but was not limited to knowledge of discipline content and knowledge of curriculum and pedagogy, varied according to whether teachers of mathematics were out-of-field as defined by the formal study they had undertaken. We addressed the following research questions:

1. What are the characteristics of teachers with high and low levels of knowledge for teaching mathematics?
2. To what extent is being out-of-field in relation to teaching mathematics associated with the knowledge needed to teach the subject?

The study that forms the basis of this chapter was conducted in the context of significant shortages of secondary mathematics teachers particularly in rural areas and in schools serving low socio-economic status communities. The shortages were such that it was common for primary school qualified teachers to be employed to teach mathematics in the lower secondary school years. The study was conducted in the Australian state of Tasmania and involved teachers of middle school mathematics (i.e. Years 5–8, 10–14-year-olds). Of the 62 teachers in the study, 18 (29%) indicated that they had taught only primary year levels whereas most (39, 63%) indicated that they had experience of teaching both primary and secondary classes. It was, therefore, reasonable to assume that more than 70% had taught secondary mathematics even if their teaching qualification was primary. We examine ten of the 62 teachers in detail to provide insight into the characteristics of teachers that are associated with being more, or less knowledgeable in terms of teaching mathematics.

We categorised teachers in this study as in-field for teaching mathematics if they indicated that they had a science degree with a major in mathematics or that they had studied mathematics or statistics to at least second year level as part of a Science, Applied Science, Business, or Economics degree. According to these criteria primary qualified teachers in our sample were classified as teaching mathematics out-of-field even though tertiary study of mathematics content is not a usual requirement for primary teachers. Teachers qualified to teach primary school are certainly out-of-field with respect to secondary school mathematics. We were aware that many of the primary qualified teachers in the study had taught or were teaching mathematics at secondary school level.

In our definition of out-of-field, we did not take account of whether any study of mathematics curriculum and pedagogy has been completed even though this is included in many definitions of out-of-field teaching (Weldon, 2016). This was because it was reasonable, based on the significant overlap between the out-of-field categories described by Weldon (2016) and illustrated in Fig. 17.1, to assume that teachers who had undertaken a bachelor's degree and then an initial teacher education qualification (e.g. Dip Ed, BTech, MTech) would have undertaken curriculum and pedagogy studies aligned with their initial degree and hence their classification as out-of-field would not have been altered by that consideration. Furthermore, the 11 teachers who had undertaken a Bachelor of Education degree indicated either being prepared to teach primary school or a non-mathematics secondary teaching area. The primary qualified teachers in this group could be assumed to have studied curriculum and pedagogy for teaching primary, but not secondary school mathematics and so could be considered out-of-field in relation to secondary school mathematics, while those with non-mathematics secondary BEds could be assumed to have studied curriculum and pedagogy aligned with their specialisation. Three other teachers indicated that they had Bachelors of Human Movement, which would have been unlikely to include mathematics curriculum and pedagogy, and a further three teachers did not indicate that they had an education qualification but listed having studied a mathematics degree, business/economics, and a degree plus four Certificate IV's.

17.2 Literature Review

Employing out-of-field teachers has been heavily critiqued from the perspectives of out-of-field teachers themselves, their colleagues, and the students in their classes. Out-of-field teachers have been shown to lack confidence as a consequence of their lack of content and pedagogical content knowledge (Hobbs, 2013). Teachers dislike teaching out-of-field (Jerald & Ingersoll, 2002), have lower self-efficacy, and leave the profession at higher rates (Sharplin, 2014). In addition, having out-of-field colleagues creates more work for school administrators and those in charge of the relevant subject (Hobbs, 2013). Students in low socio-economic status (SES) or rural and regional areas are more likely to have out-of-field teachers than are their metropolitan peers (McConney & Price, 2009), and those deemed low achieving are also more likely to have an out-of-field teacher (Hill & Dalton, 2013). Given that having a well-qualified teacher is associated with more positive student academic outcomes (Steyn & Du Plessis, 2007), having an out-of-field teacher has been identified as a serious threat to equity in terms of educational opportunities (Darling-Hammond, 2000). In addition, the use of out-of-field teachers can hide the severity of teacher shortages (McConney & Price, 2009) which are a major driver of out-of-field teaching (Zhou, 2014).

Support for out-of-field teachers typically relies on professional learning that can be designed to support the development of out-of-field teachers' professional identity in relation to the subject that they teach out-of-field (Hobbs, 2013), as well as developing their relevant subject expertise (Du Plessis, 2018). Professional learning often takes place in communities of practice (Hobbs, 2013) or the use of coaches or mentors (Vale, 2010). Professional learning programmes typically are aimed at increasing content and pedagogical knowledge (Lane & Ní Ríordáin, 2020). Effective professional learning programmes, such as that described by Vale (2010) for out-of-field teachers of mathematics are typically relatively long term (conducted over a full school year) and involve a combination of seminars as well as school-based self-directed learning and mentoring support. Vale (2010) reported increases in participants' confidence that led to less reliance on textbooks, increased capacity to design or adapt tasks, and to differentiate learning for their students.

Whereas content knowledge and pedagogical content knowledge are widely accepted as necessary for effective teaching of mathematics (Vale, 2010) and can be measured crudely by definitions of out-of-field teaching based on number and level of content and pedagogical courses studied, it is widely accepted that the knowledge needed by teachers is considerably broader. For example, Shulman (1987) suggested seven categories of teacher knowledge that included these two along with: knowledge of; how students learn, the curriculum, general pedagogy, educational contexts, and the values and purposes of education. Pedagogical content knowledge has been enthusiastically embraced by mathematics educators. Ball and colleagues (e.g. Ball & Bass, 2000; Ball et al., 2008), for example, have elaborated on content and pedagogical content knowledge in the context of mathematics teaching in their Mathematical Knowledge for Teaching model, while Watson (2001) and Watson et al. (2006) developed a teacher profiling instrument designed to assess all seven of Shulman's knowledge types in relation to teaching statistics. Based on Watson's profiling instrument, Beswick et al. (2012), in the study that is the basis of this chapter, used a mathematics teacher knowledge profile that encompassed all seven of Shulman's knowledge types, including Ball's elaborations, along with teachers' confidence and relevant beliefs. They argued that such a holistic consideration of teacher knowledge reveals important insights that may not be evident from detailed analytic dissections of the concept.

The teacher profile instrument used by Beswick et al. (2012) comprised eight categories as shown in Table 17.1. The use of "mathematics and numeracy" in relation to several of the profile sections reflects a shift in language from mathematics to

Table 17.1 Teacher knowledge profile

Section	Section title and description/item example
1	*Significant factors for teaching mathematics and numeracy in the middle years.* Teachers responded to 2 prompts: 1. How would you go about improving students' numeracy and mathematical understandings in the middle years? 2. Describe some of the ways you use mathematics to enhance student learning in key learning areas other than mathematics
2	*Preparing to teach a concept in mathematics or numeracy.* Teachers were asked to describe how they would teach a unit on a topic of their choosing. They were asked to nominate the concept and understanding goals for the unit, and describe how they would introduce the concept, specify the amount of class time they would spend on the concept, describe the teaching methods and groupings, assessment methods they would use, indicate whether they had taught this concept before, did they enjoy teaching, describe how students generally respond to it, and suggest how other work across the curriculum could contribute to the develop of the concept
3	*Confidence.* Teachers rated their confidence (on a continuous scale from low to high): to teach of fractions, decimals, per cent, ratio and proportion, measurement, space, pattern and algebra, chance and data, mental computation; in connecting mathematics to other learning areas; in connecting mathematics to the new state curriculum framework; to teach critical numeracy in media; and in assessment against the new curriculum standards
4	*Mathematics and numeracy in everyday life.* Teachers rated the extent of their agreement (on a continuous scale from strongly disagree to strongly agree) with 11 statements about the importance of numeracy to effective citizenship, their own ability to use mathematics to do such things as carpeting a room, their ability to use mathematics to make everyday decisions, the use of mathematics in the media, and their ability to interpret tables, plans, and graphs
5	*Mathematics and numeracy in the classroom.* Teachers rated the extent of their agreement (on a continuous scale from strongly disagree to strongly agree) with 14 statements about the nature of mathematics, mathematics teaching, and mathematics learning
6	*Student survey items.* Teachers were presented with three items that had been used in a survey of middle school students' mathematics knowledge and asked for each item to: 1. Write down responses that they would expect from their students being sure to include both appropriate and inappropriate responses, and 2. Describe how they might use the item in the classroom, for example by choosing an inappropriate response they had suggested and explaining how they would intervene
7	*Teacher background.* Teachers were asked about the number of years for which they had been teaching, the year levels they had taught and were currently teaching, the classes they were currently teaching (not just mathematics), the highest year level at which they had taught mathematics, their preferred teaching area, tertiary qualifications, the level and extent of mathematics studied

(continued)

Table 17.1 (continued)

Section	Section title and description/item example
8	*Professional learning.* Teachers were asked to indicate in relation to 10 commonly used mathematics curriculum documents and resources whether they had not seen, seen, read, or used each, and asked to list any other resources that they regularly used for mathematics teaching. They were then asked whether they had attended professional learning related to mathematics in the past 5 years and if they had, to provide details including the title of the professional learning, the organising body, participants, and number and length of sessions

numeracy that was in process at the time of the study during which a new curriculum was being implemented.

Beswick et al. (2012) used Rasch modelling to identify four levels of their rich conceptualisation of teacher knowledge encapsulated in Table 17.1, based on the responses of the same sample of 62 middle school teachers of mathematics. The four levels, in order of increasing sophistication, and described in terms of the demands of the item steps at each, were:

Level 1: *Personal numeracy.* At this level, very low levels of general pedagogical or pedagogical content knowledge were required, but confidence in their ability to use mathematics in everyday life was required. Item steps indicative of recognition of the importance of mathematical topics related to proportional reasoning (fractions, decimals, per cent, ratio) or algebra were not evident at this level, but agreement with the belief that much of the mathematics taught in their classes was irrelevant to students did appear.

Level 2: *Pedagogical awareness.* This level required high levels of confidence in relation to the everyday use of mathematics, along with more positive views than at level 1 of the importance of struggle to students' mathematics learning, the relevance of school mathematics, and the importance of teachers being fascinated with students' mathematical thinking. Pedagogical content knowledge was required, but at low levels, along with recognition that specific tasks could be used to uncover student thinking and help them to learn. Agreement with almost all items concerning mathematics in everyday life was required along with high confidence in relation to all mathematics topics except for ratio and proportion, and pattern and algebra. Item steps indicative of ambivalence about a range of contemporary teaching practices such as the use of ability grouping, textbooks, and the extent to which mathematics is synonymous with computation also featured. Very limited evidence of pedagogical content knowledge and general pedagogical knowledge appeared at this level.

Level 3: *Pedagogical content knowledge emergence.* At this level, items required very high levels of confidence in relation to both every day and classroom mathematics, along with agreement with a range of belief statements typically aligned with a student-oriented approach to teaching. At the same time item steps indicative of a more traditional view (e.g., agreement that mathematics is best presented in an expository style) were also at this level. Teachers needed, at this level, to suggest both appropriate and inappropriate student responses to each of three items along with limited and not necessarily connected ideas about the classroom use of these items.

Level 4: *Pedagogical content knowledge consolidation.* The highest levels of confidence in relation to teaching mathematics topics were required at this level along with the ability to identify and connect multiple pedagogical uses of the student items. Agreement or strong agreement with student-oriented teaching approaches was demanded at this level along with strong disagreement with the mathematics they taught being irrelevant to their students' lives. High levels of general pedagogical knowledge were also demanded at this level. Item steps indicative of agreement that mathematics would be difficult to teach without a textbook also appeared at this level along with ambivalence, agreement or strong agreement that telling students answers is an efficient means of facilitating their learning.

17.3 Methodology

In this chapter, we draw upon the results of the study reported by Beswick et al. (2012) to examine the extent of relationships between teachers' knowledge for teaching mathematics and their demographic characteristics including the extent to which they could be considered out-of-field with respect to that subject.

17.3.1 Participants

The study participants were 62 middle school (Years 5–8, ages 10–14 years) teachers (of whom only 4 reported having majors in mathematics). They taught in 10 primary (Year K–6), district (Years K–10), and high (Years 7–10) schools in rural areas of the Australian state of Tasmania. The teachers were employed by the Tasmanian Department of Education and were participants in one or more years of a 3-year professional learning programme aimed to support teachers in schools selected by the Department of Education to facilitate their students' development of the numeracy required for active citizenship, and the mathematics knowledge needed for studying mathematics at senior secondary and post-school levels.

For this chapter, we focus on ten participants whose ability as measured by the teacher knowledge profile was highest (5 teachers) or lowest (5 teachers). Their characteristics are presented in Tables 17.2 and 17.3. All were qualified to teach some secondary school subject except for Teacher H3 who was a qualified primary school teacher.

Table 17.2 Five highest ability teachers

Teacher code	Qualifications	Out-of-field status	Teaching experience (years)	Sex	Preferred teaching area	Highest maths taught
H1	BSc, BTech	In-field	5–14	M	Maths, Robotics	10
H2	BEc, BTech	In-field	<5	F	Maths	9/10
H3	BEd, Grad Dip Ed (Special Ed), M Ed (Counselling & Development)	Out-of-field	5–15	F	NA	6
H4	Bachelor, several Cert. IVs	Out-of-field	≥15	M	MDT, ICT, Adult Literacy	10
H5	BEd (Hons), BA (Hons)	Out-of-field	5–14	F	Literacy	8

Table 17.3 Five lowest ability teachers

Teacher code	Qualifications	Out-of-field status	Teaching experience (years)	Sex	Preferred teaching area	Highest maths taught
L1	BHumMovement	Out-of-field	5–14	M	NA	10
L2	DipTeach, BEd	Out-of-field	≥15	F	English, History	9
L3	BEd	Out-of-field	5–14	M	Primary	8
L4	BCom, DipEd	In-field	≥15	F	Maths	10
L5	BSc (Hons)	In-field	<5	F	Don't care	12

17.3.2 Data Collection and Analysis

Data were collected using an eight-section profile (described in Table 17.1). Beswick et al. (2012) used the generalised partial credit model (Masters, 1982) to analyse the teacher knowledge profile data. This model assumes that each of the adjacent categories is dichotomous by nature where the higher performing individual has greater probability of scoring the higher category than its counterpart and assumes that the discrimination indices are not necessarily the same for all items. The Rasch analysis showed that all items are loading significantly to the construct. A variable map, illustrated in Fig. 17.1, provides a visual representation of the distribution of items and persons on the same scale. The unit of measure, logits, is the natural logarithm of the odds of success. In Fig. 17.1, the components of a variable map for 40 persons (represented by Xs) and 20 items are shown for illustrative purposes. The higher up the scale, the greater the ability of persons (in terms of the odds of them successfully

Fig. 17.2 Components of a variable map

Logit	Persons	Items
	X	It18
2.0		It7
	XXX	It19
	X	It12
1.0	XX	It10 It14 It6
		It11 It17
	XXXX	It9 It15
0.0	XXXXXXX	It5
	\XXXXXXXX	
		It8 It13
-1.0	XXXXX	
	XXXX	It4 It20
	XX	It1 It3
-2.0		
	XXX	It2

responding to items), and the greater difficulty of items. A person at the same scale position as an item has a 50% chance of responding correctly to that item. The distribution of items describes the progression of the level of sophistication of knowledge, skills, beliefs, and confidence. Further details of profile coding procedures and model fit statistics were provided by Beswick et al. (2012) (Fig. 17.2).

In this chapter, we consider more closely the five teachers who appeared at the top of the variable map provided by Beswick et al. (2012) for the 62 teachers, and the five teachers who appeared at the lower end of that distribution at the *Pedagogical awareness* (Level 2) level. No teachers appeared at the *Personal numeracy* level (Level 1).

17.4 Results

In this section, we discuss the characteristics of the two groups of five teachers in turn.

Of the five most able teachers, three had abilities that placed them at Level 4, *Pedagogical Content Knowledge Consolidation*. The remaining two had abilities corresponding to Level 3, *Pedagogical Content Knowledge Awareness*. Relevant demographic characteristics are shown in Table 17.2. Three of these teachers were, according to our definition based on mathematics qualifications, teaching mathematics out-of-field. This categorisation would have been the same had we based it on preferred teaching area since only the two in-field teachers listed mathematics as a preferred teaching area. All but one, Teacher H3, were currently teaching mathematics at secondary level, although only Teacher H1 had taught exclusively secondary school mathematics. Teacher H3 was teaching a composite Year 5/6 class and had never taught secondary school mathematics. None of the out-of-field teachers in this group had taught for fewer than 5 years although one of the in-field teachers had. There were several item steps in the General Pedagogical Knowledge and Pedagogical Content Knowledge categories that appeared above the ability level of these teachers. That is, these teachers had a less than 50% probability of correctly responding to these item steps, which are shown in Table 17.4.

The five lowest ability teachers were identified, exclusive of any who had taught only primary school mathematics. They all appeared at the level of *Pedagogical Awareness*, Level 2. As for the five highest ability teachers, three of the five lowest ability teachers were teaching mathematics out-of-field according to their mathematics qualifications. All but one had been teaching for more than 5 years with the least experienced, Teacher L5, being classified as in-field. Had the classification of out-of-field status been based on expressing a preference for teaching mathematics then all but one teacher, Teacher L4, would have been categorised as out-of-field. Despite having an honours degree in science that reportedly included applied mathematics, Teacher L5 indicated that she had no preference in relation to the subject that she taught.

Table 17.4 Item steps that the highest ability teachers were less than 50% likely to achieve

Knowledge category	Level of endorsement/response	Code	Item
General pedagogical content knowledge	Multi-structural response: understanding goals clearly link to teaching, learning and assessment, time frame appropriate, evidence of evaluation of student understanding within plan	P2c.3	Teaching and assessment methods and grouping for the chosen topic
		P2b.3	Class time to spend on the chosen topic
		P2a.3	How to introduce the chosen topic
Pedagogical Content Knowledge	Relational response: Discussion including reference to percentages and wholes with specific examples	PC2b.4	How would you use in the classroom a pie chart showing retail grocery market shares with per cents not adding to 100?
		PC1b.4	What responses, appropriate and inappropriate, to the pie chart question would you expect from students?

Four of the five highest ability teachers reported having attended mathematics related professional learning in the past 5 years, the fifth did not respond to this question. Two of these were the in-field teachers of which one, Teacher H2 reportedly having attended various spaced multi-day professional learning programmes offered by the Department of Education and the other, Teacher H1, having participated in many multi-day programmes, some with residential components, and had also contributed to curriculum writing for the Department of Education. One of the out-of-field teachers in the highest ability group, Teacher H5 also reported attending mathematics conferences and several Education Department professional learning programmes. Out-of-field Teacher H4 had participated in several short duration school-based professional learning activities.

Only two of the lowest ability teachers responded to this question with Teacher L2 (out-of-field) reporting having engaged in approximately 80 h of such activity and Teacher L5 (in-field) reporting having attended mathematics conferences, other statewide numeracy programmes, and having run "many courses" on graphical calculators and their use in exploring mathematical ideas.

17.5 Discussion

The absence of any of the 62 teachers from the larger study (Beswick et al., 2012) at the lowest level, Level 1, suggests that personal numeracy was not an issue for any of these teachers. The very small number of teachers at the highest level (Level 4) also suggests that pedagogical content knowledge was not well established for these teachers. Rather, most of the teachers were at Levels 2 and 3, *Pedagogical awareness*, and *Pedagogical content knowledge emergence*. This is also indicative of imperfect matching of the item difficulties and person abilities with the least demanding items-steps being readily achievable by all of the teachers, and arguably insufficient discrimination around the item steps that defined Levels 2 and 3 (Beswick et al., 2012).

Based on mathematics qualifications, all but 11 of the 62 participants were out-of-field in relation to mathematics. The inclusion of a larger number of such teachers may have made distinctions between the in-field and out-of-field groups clearer and perhaps would have yielded more person abilities towards the top of the scale. It is also noteworthy that for the five highest and lowest ability teachers, using preferred teaching area as the basis for categorising them as out-of-field or in-field in relation to mathematics would have made very little difference. This resonates with Hobb's (2013) observation that some out-of-field teachers resist adapting to their out-of-field and non-preferred subject, seeing the role as a temporary inconvenience. Nevertheless, the fact that H4 and H5 were among the most knowledgeable for teaching mathematics despite being out-of-field and preferring to teach other subjects demonstrates that it is possible for out-of-field mathematics teachers to develop the requisite knowledge for teaching the subject without abandoning their preference for another subject.

Nevertheless, the fact that many of the in-field teachers also had abilities corresponding to Levels 2 and 3 might suggest being out-of-field for teaching mathematics is not a problem. There were both out-of-field and in-field teachers in the highest and lowest ability groups. Being adequately qualified evidently does not guarantee adequate pedagogical knowledge, pedagogical content knowledge, or helpful beliefs about mathematics as a discipline and how it is best taught, nor does being out-of-field in relation to mathematics teaching necessarily mean that one's knowledge will be lower than that of in-field colleagues. Years of teaching experience also did not appear related to knowledge for teaching mathematics for these teachers, but participation in mathematics specific professional learning, particularly multi-day spaced Department of Education programmes was more common among higher ability teachers regardless of their out-of-field status. The out-of-field in this group may have benefitted from effective professional learning such as that described by Vale (2010) as well as that provided as part of the study in which they were participating.

In addition, three of the four in-field teachers across these two groups identified mathematics as their preferred teaching area. The one in-field teacher who did not do so was in the lowest ability group. Together these findings point to the importance of identifying as mathematics teachers regardless of mathematics qualifications. Professional learning aimed at supporting identification with the subject in relation to which a teacher is out-of-field, which has been a focus of professional learning for out-of-field teachers (Hobbs, 2013) might be worthwhile also for at least some in-field teachers. Nevertheless, the results reported here suggest that professional learning aimed at developing the knowledge needed to teach mathematics is less likely to be attended by the teachers who arguably would benefit most, perhaps precisely because they do not identify as mathematics teachers. Subject knowledge also needs to be a focus of professional learning (Du Plessis, 2018) regardless of out-of-field status. For the 10 teachers examined closely in this chapter, the nomination of mathematics as preferred teaching area, which could be seen as indicative of identifying with the subject, matched their qualifications based out-of-field status closely, but not their ability in terms of knowledge to teach the subject.

17.6 Conclusion and Recommendations

The findings reported here underline the importance of using multiple and nuanced indicators of whether and the extent to which a teacher can be out-of-field in relation to teaching mathematics. Neither university mathematics qualifications nor nomination of mathematics as a preferred teaching area predicted the knowledge needed to teach the subject. We posit that what matters for teaching mathematics well is knowledge defined broadly to encompass all seven of Shulman's (1987) knowledge types and encompassing relevant beliefs as well as confidence, and operationalised in the profile used in this study.

The profile and the four knowledge levels derived from it by Beswick et al. (2012) need testing with larger groups of teachers including in particular more mathematically well-qualified teachers and more teachers from metropolitan contexts that would likely contribute to its refinement. Refinements may include the addition of item steps to better distinguish teachers at Levels 2 and 3, and more difficult item steps to accommodate more knowledgeable mathematics teachers. It may be possible also to include a measure of the identification with mathematics.

The profile could be used as the basis for self-assessment of mathematics knowledge in school-based learning communities in which contextual responses could be the basis of discussion and learning rather than measurement. Our findings suggest that mathematics professional learning of this kind, as well as centralised programmes, that focus on both identification with the discipline and general pedagogical and pedagogical content knowledge, broadly defined, should be available to, and perhaps required for all teachers of mathematics regardless of out-of-field status and experience. System provided professional learning for mathematics teachers would benefit from being informed by the results of a knowledge profile like that used here so that actual needs could be identified rather than assumed on the basis of out-of-field status however defined.

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Chapter 18
Researching the Phenomenon of 'Teaching Out-of-Field': Synthesis and Future Directions

Linda Hobbs and Raphaela Porsch

Abstract This final chapter presents a synthesis of the research and proposes a model of the dimensions of the out-of-field teaching phenomenon and a roadmap for future research into the challenges and practices associated with the teaching out-of-field phenomenon. The model captures the range of contexts, research foci, methodological considerations and research outcomes represented in the book and draws together generative research directions for future research proposed by the authors.

Keywords Policy · Practice · Recommendations · Research agenda · Teaching out-of-field

18.1 Introduction

In 2014, the participants of the inaugural symposium of the TAS Collective composed an agenda for research, policy and practice based on what they knew then about the research questions needed, practical considerations for teachers, school leaders and schools and possible policy drivers (Hobbs & Törner, 2014). Five years later in 2019, the synthesis of our first book identified priority actions and an agenda for research and policy (Hobbs & Törner, 2019). Seven years later, this book represents the outcomes of research that are more informed, more debated and more nuanced. This final chapter provides a synthesis of this research and proposes a model of the dimensions of the out-of-field teaching phenomenon and a roadmap for future research. The details of the model were emergent and capture the range of contexts, research foci and research outcomes represented in this book. To begin the conversation about a model for future research into out-of-field teaching, Fig. 18.1 identifies

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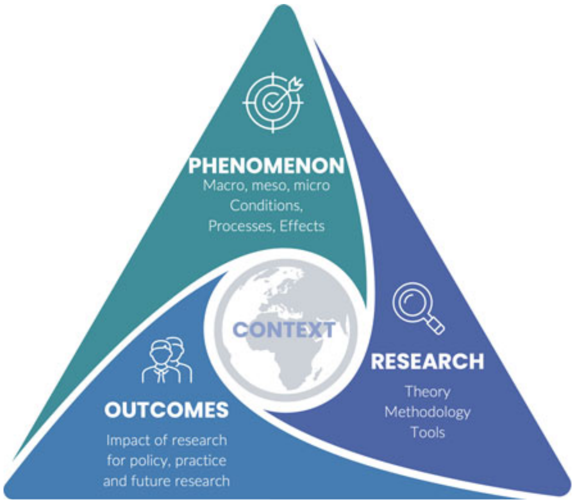

Fig. 18.1 A model for researching out-of-field teaching

four parts of a possible model: Context, Phenomenon, Research and Outcomes, and each of the chapters in this book speak to these in different ways.

As a synopsis for this book, this chapter uses this model to synthesise the following: (1) the contexts of policy, teaching practice, professional learning and the personal contexts, as well as the scale and scope of the research; (2) the phenomenon of out-of-field teaching as being classified at the macro, meso and micro levels; (3) the research methodologies and key learning arising from the out-of-field teaching phenomenon; and (4) a synthesis of research outcomes and recommendation for future research, in particular possible directions for transnational research.

18.2 Context

Context is represented in this book as policy, personal, professional learning and practice contexts (Fig. 18.2). Each of these contexts can be discussed at different scales: at the local (including personal), national or state level (which could focus on particular jurisdictions), or at the international level (where there are international comparisons). All of the studies presented here have either a local or national/state focus. International comparisons are less common and could be a fruitful focus for further research. The chapters introduce the context of their studies and show that despite different labels—'out-of-field', 'teaching across specialisations' or its translated terms (e.g. in German 'fachfremd')—a number of commonalities exist. For example, a number of authors from different countries refer to the same reasons such as a lack of teachers (in particular, in some subjects such as STEM-related subjects), the organisation of teacher education or the certification system in their region/country. A number of studies provide findings from professional development

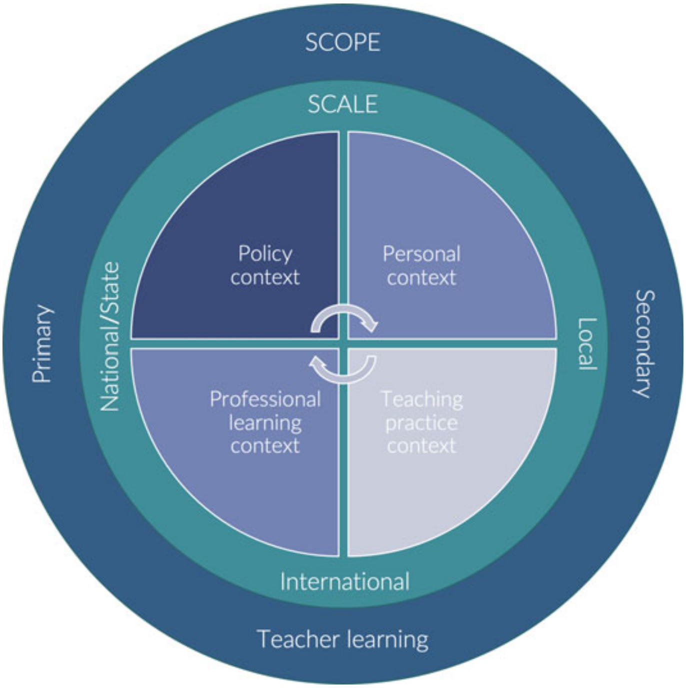

Fig. 18.2 Contexts for researching out-of-field teaching

programmes. Faulkner et al. (2019) provided a framework for effective professional development. In the face of further results presented in the book and developments, such as the need for blended learning formats, a comparison across countries seems promising.

Also relevant for context is the scope of what is meant by 'out-of-field'. More commonly, and as shown in most of the chapters in the book, out-of-field teaching tends to be associated with secondary or high school levels where teaching and curriculum structures are generally subject-specific. This is distinct from the more generalist approach to primary or elementary teaching in many countries, where teachers are trained as generalists and therefore not considered technically out-of-field in the same way that secondary teachers might be. However, there are a number of chapters in this book that focus explicitly on issues of out-of-field teaching in primary schools, either because the non-specialist training during initial teacher education is considered inadequate for particular subjects, or because there are some specialist classes at this primary level where in-field teachers with specialist training are considered more appropriate (e.g. Porsch & Wilden). Researching out-of-field teaching during the primary years is an emergent area, but the context needs to be clearly explained so that the argument for a teacher to be deemed out-of-field is clear.

The scope of out-of-field can also refer to situations where teachers are learning something new, like a teacher learning to use new technology (e.g. Rochette). These teachers experience the same need for learning and feelings of inadequacy that any out-of-field teacher will experience. This is a more general way of thinking about who or what is considered out-of-field in terms of alignment between expertise and role. Bearing in mind that teaching is a learning profession due to, for example, constant changes in curriculum and regular teacher transitioning to new year levels and therefore content, there does need to be careful consideration of why the out-of-field label is in-scope for such research. New developments that became apparent in a number of countries during the COVID-19 pandemic, such as the need to integrate digital tools into the classroom (e.g. Blume, 2020), force teachers to be constant learners. Accordingly, one can argue that the term 'field' may not be reduced to teaching a formerly unknown subject but be widened if referring to any new area that requires teachers to acquire new skills and knowledge.

While these contexts are at the centre of the model in Fig. 18.2, it is useful to tease out the implications that these contexts have for how we think about the phenomenon, the research approaches, the outcomes and recommendations they propose.

18.3 Phenomenon

The phenomenon of out-of-field teaching is complex. Porsch (2017) proposed a classification scheme for the out-of-field phenomenon that can contribute to understand its complexity but can also help to identify research gaps. Figure 18.3 uses a matrix categorisation of the phenomenon using Micro, Meso and Macro levels, along with the three characteristics of Conditions, Processes and Effects. This type of classification scheme can be useful for laying out the various elements of a complex the phenomenon, as well as to identify the concentration of research conducted in a field so far and therefore the gaps in analysis of the phenomenon. In this book, chapters can be placed at all three levels, with some focusing on the macro policy level, some

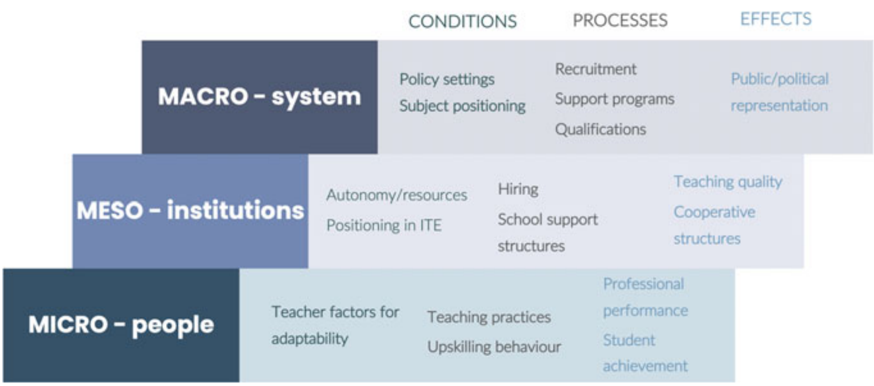

Fig. 18.3 The phenomenon of teaching out-of-field

focusing on what is occurring in schools, while the majority of chapters focus on the micro individual level and mainly on the teacher.

While most of the research on teaching out-of-field in the past focused on the effects, in particular on the students’ proficiency (Porsch & Whannell, 2019), the classification shows nine subfields of possible research on the phenomenon. This framework also shows that taking action is needed at all three levels. Taking action is not the responsibility of the teacher alone but also of school principals, teacher educators and policy makers. The majority of chapters in this book can be assigned to ‘Processes’ on the micro level looking at teachers as learners (e.g. Ní Ríordáin et al.). However, as studies often explore a number of themes, within this framework often the assignment to more than one ‘cell’ is possible—admittingly, a limitation of the proposed classification. Nonetheless, if the chapters are assigned, the framework suggests that research on the meso and macro level is needed. Possible questions for research on these levels are: Which support structures are provided by schools? Which structures are needed and are effective? What is the perspective on the phenomenon by political representatives? How is the phenomenon represented in the media? What policies create the conditions for needing out-of-field teaching, and how can these be changed?

18.4 Research

The 17 chapters of this book present a significant cross-section of research currently occurring in the field. It is useful to look across the chapters in each of the four context categories to understand what research is occurring, predominant methods used to investigate the research problems, and then to identify key learnings about the phenomenon of out-of-field teaching.

Beginning with the chapters focused on **political contexts,** we see research conducted with medium to large data sets (state, national and international data sets) with predominantly quantitative analyses focused on the effects of out-of-field teaching on student achievement (Van Overshelde), or identification of factors on out-of-field teacher distribution (Shah et al.). Also evident are critiques of systems that focus on policy settings within local jurisdictions, implications of this for schools, teachers and students, including how policy influences the distribution of out-of-field teaching (Van Overschelde). Document analysis is used to focus on policy or understand the broader research landscape (Hobbs et al.), as well as interviews with representatives from across the education landscape (Vale et al.). As is often the case with policy focused analyses, critical theories are used to provide a framework for critique (e.g. problem representation by Bacchi, 2012).

The outcomes of this research have highlighted the following:

- The possible negative effects of out-of-field teaching assignments, in particular the detrimental effects of out-of-field teaching assignments in maths at some year levels are apparent.

- Some jurisdictions have quite clear definitions of what out-of-field teaching is due to certification requirements, while in other jurisdictions teacher registration processes exist that do not allow subject-specialisation to be acknowledged or monitored (easily).
- The value of having a tool to identify a multi-faceted definition of out-of-field teaching, that is based on criteria relating to alignment between teacher's qualification and teaching assignments, workload intensity and changeability, and teacher capability. It also highlights the need to pay attention to the multi-disciplinary subjects that, by their design, automatically lead to teachers being out-of-field according to specialisation.
- Challenges to the assumption that out-of-field teaching occurs because of inadequate supply of teachers rather than the supply becoming unequally distributed, with equity issues.
- Incidences of teaching out-of-field strongly depends on the school's situation, in particular, better funded schools, mostly those in the private sector, less often assign teachers to teach out-of-field.
- The out-of-field phenomenon is represented differently by different members within the education system, and this representation depends on the specific demands, assumptions and vested interests of each group, sometimes with the purpose of diverting attention away from out-of-field teaching towards other issues: teacher shortfall, hard to staff schools, less qualified teachers, teacher quality.

For the **personal contexts** represented in this book, the focus shifts to the experiences of teachers and how they negotiate the demands of teaching out-of-field. The analyses include a range of methodologies. Qualitative interviews and questionnaires with teachers and sometimes their principals, and autobiographical self-focused methods are used to elaborate on aspects of the teacher experience and examine motivations, positioning, and teacher growth and change over time (Rochette et al.; Lagies; Yarldey). Large scale datasets generated by national or state-based surveys provide analyses of teacher factors (Porsch & Wilden), and how teacher factors relate to amount of workload (Donista-Schmidt et al.). Across the chapters, teacher factors include: instructional quality; affective factors such as teacher confidence, enthusiasm, commitment, passion and satisfaction; proficiencies, competencies and knowledge; and the relationship of these factors on teacher identity and the identity work that teachers do as they develop and grow as a teacher of, or who teaches, the out-of-field subject.

In addition, a variety of teacher contexts were examined, including the teacher in school (Rochette et al.), the teacher during initial teacher education, transitioning from pre-service teacher to in-service teacher (Donista-Schmidt et al.) and being in-field yet facing new demands that can make them feel out-of-field (Rochette et al.). Also the teacher contexts are represented across the phases of education, including primary (Porsch & Wilden; Lagies), secondary (Rochette et al.; Yardley; Donista-Schmidt et al.) and tertiary level teaching (Yardley). By synthesising research into teachers in different contexts you begin to see that the demands on teachers differ depending on the context.

Some key research outcomes of this section are as follows:

- A questioning of what out-of-field teaching does or can mean arises as a result of the label of out-of-field teaching being applied to the range of contexts and situations where teachers lack confidence in knowing what and how to teach.
- The potential for de-professionalisation of the teaching profession is raised, especially where alternative pathways (lateral entrants, career changers) into teaching are established as policy for addressing teacher shortages in a country. In these contexts teachers are negotiating boundaries between non-teacher to teacher, and this is complicated further when they are required to teach subjects that do not align with their background.
- Further confirming evidence that the school context and support provided is central to the success of teaching in out-of-field contexts.
- The out-of-field teacher is positioned as needing to be a learner, with differences in orientations to learning recognised through typologies or categories.
- There is value for research, teachers and school administrators to acknowledge the strengths that a teacher brings from their in-field teaching, plus their general strengths as a teacher. Such strengths are not a replacement for what might need to be learned when teaching an out-of-field subject, but reflecting on how existing knowledge and skills and attitudes can be applied within the new context may help with the transition. This perspective on out-of-field teaching moves away from the deficit language more typically associated with out-of-field teaching, i.e. starting with what do they bring and how do we build on that rather than focusing only on what are they are missing.
- Regardless of what might be common for all teaching, there are subject-specific differences in teacher knowledge and pedagogy, which goes deeper than just what a teacher knows and can do.

Professional learning contexts focus on how teacher transition and development or change: over time in terms of professional self and identity; often before and after an intervention; at different points of career entry and the transition into teaching; when becoming more in-field and less-out-of-field ('in-betweeners' from Beck), or neither 'in' nor 'out' (Barańska & Zambrowska) through improved knowledge (Carpendale & Hume) and entering the teaching profession through lateral entrance or alternative pathways (Beck). Teacher motivations for undertaking professional development and additional qualifications are a common focus as it speaks to their commitment to learning and the potential for impacting change, although the relationships between these two factors need further research. Interventions in the chapters referred to: in-context reflection activities, such as a 'social lab' (Caldis) or collaborative discussion with peers (Beswick & Alonzo) or mentors (Carpendale & Hume); external formal professional development programs (Ní Riordáin et al.); and analysis of the effectiveness of these interventions on teacher development, the features of the intervention that bring about these changes; or the tools that can be used to support teacher development and applied more generally. Some important insights from this research are:

- Introduction of the language of workload as full, partial and not out-of-field, which will be useful for differentiating between types of out-of-field and monitoring the relative cumulative effects of out-of-field for the teacher.
- Teacher change is facilitated by teacher reflection, teacher collaboration, external input from others and school support structures.
- The transition from pre-service to in-service teachers can be supported with tools to promote reflection. Such tools are particularly pertinent as pre-service teachers realise that part of their general teaching role will include teaching specialisations different to their background.
- There is a tension between teachers needing professional development or qualification upgrade in the out-of-field subject to improve knowledge, practice and teacher identity, and the reality that such professional development does not necessarily make them in-field. The notion of in-betweeners, a sliding scale between out-of-field and in-field, and the idea of becoming 'less' out-of-field in these contexts, acknowledges that being a specialist is more than a qualification or certification, but refers also to teaching quality, depth and teaching commitments.

When looking at **teaching practice contexts,** the focus shifts to factors relating to: teacher moves that are subject-specific; pedagogy, teacher knowledge, confidence and self-efficacy beliefs in relation to practice; and the ongoing nature of teacher learning, in particular, different orientations to on-the-job learning. There are comparisons between upskilled versus in-field teachers (Goos et al.), out-of-field versus in-field (Beswick & Alonzo), and PST in-field and out-of-field in-service teachers (Huethorst). Judgements about teaching quality are made through research tools such as through self-report questionnaires, objective observation and exams and tests.

Gaining objective measures of teaching practice is fraught and complex due to the variability of teaching practices across teachers, even in-field teachers. However, establishing such measures will be important for the research field to determine in what way having a qualification in a subject plays out in the classroom, compared to when this is lacking, so that research is less reliant on judgements as self-report by teachers or the imprecise measure of student achievement. Research approaches that are longitudinal are perhaps more instructive than single-point-in-time measures—following the teacher to see change over time, or following students to see the cumulative effects of teacher-related factors. Many compounding factors, however, would need to be managed in order to gain any precise measure or representation of the effects of out-of-field teaching on teaching practice and then the effects of this practice for students.

Some key research outcomes are as follows:

- There are different typologies for teacher orientation to learning.
- Up-skilled mathematics teachers are shown to have similar self-efficacy beliefs and espoused pedagogical practices as in-field teachers.

- Differences between out-of-field and in-field teachers are seen to be more profoundly focused on their commitment to doing professional development in the subject (that is, out-of-field mathematics teachers were less likely to undertake maths-related professional development).

As we have seen, on a micro level, **context matters** for the out-of-field teacher with regard to the personal contexts, the teaching practice contexts and the professional learning contexts. Taken together, the demands (or pressures) on teachers across different contexts are summarised in Fig. 18.4. The figure illustrates that in general and specifically in the out-of-field context the transition to school teaching can be challenging, either as teacher education students (Caldis), teachers as career changers (Beck), teachers at the beginning of their careers (Donitsa-Schmidt et al.), or teachers transitioning into initial teacher education in the tertiary sector (Yardley). Teaching at primary, secondary or tertiary levels requires specific competencies and provides specific challenges for the out-of-field teacher. For example, on the primary and lower secondary level, it is important that teachers take special care of the teacher–student relationship (Lagies). At any level, a feeling of being an imposter and then needing to rewrite one's identity takes time and resilience (Yardley). Nevertheless, teaching in primary years, as well as at higher level, demands sufficient content knowledge, thus there continues to be a need for professional learning when teaching in an out-of-field situation (Huethorst).

In addition, across the chapters of this book, a number of **tools** were used as part of the research process or developed as a result of the research:

- Multi-faceted definition (Hobbs et al.)
- Teacher Profile Instrument (mathematics) (Beswick & Alonzo)

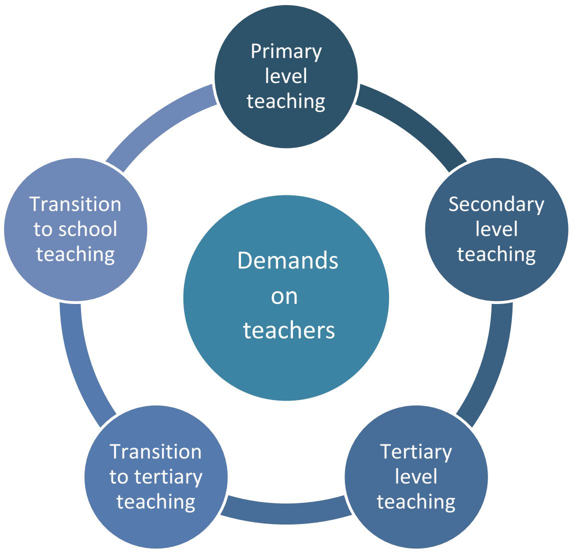

Fig. 18.4 Demands on teachers differ across contexts

- Productive pedagogies structured lesson (Goos & Guerin)
- Content Representation (CoRe) focusing on Pedagogical Content Knowledge (Carpendale & Hume)
- Subject-related teaching standards, e.g. the Professional Standards for the Accomplished Teaching of School Geography (Caldis)
- Reflexivity tool informed by Archer and Morgan (2020) (Caldis)

These tools were used to understand the phenomenon or to help teachers navigate the boundaries between different fields. They also serve as useful heuristics during research to promote teacher reflection or support measurement of out-of-field teaching. While surveys/questionnaires and interview transcripts are common methods, tools can support the generation of data that can then be used for varying purposes: assessing the needs of out-of-field teachers, informing professional development programs and courses designed for upgrading qualifications, facilitating objective observation of lessons, and as teacher self-assessment or reflection for school-based learning communities (Beswick & Alonzo).

18.5 Outcomes to New Research

Drawing from the research summaries above, summaries of the outcomes and recommendations are provided, along with elucidation of some directions for future research, including research generally and possibilities for transnational research.

18.5.1 Outcomes

The potential outcomes that can arise from this research into out-of-field teachers are summarised in Fig. 18.5.

We identified seven types of outcomes. **Types** or any other classifications or categories help to understand the phenomenon of out-of-field or teachers that differ in their prerequisites (Beswick & Alonzo; Hobbs et al.). **Degrees** refer to studies that quantify the distribution of out-of-field teaching or the degree of teachers' characteristics such as their satisfaction (Donitsa-Schmidt et al.) or enthusiasm (Porsch & Wilden) depending on the formal qualification, or show the effects on the teachers or students (Van Overschelde; Shah et al.). **Judgments** are made on what teachers know and can do, the teachers' adaptability, or other characteristics that differ in their professional qualification (Beck) or their professional development (Rochette et al.; Ní Riordáin et al.). Some studies provide extensive **descriptions** of the teachers' experiences (e.g. Lagies; Yardley) or theoretical approaches that show the multiple theoretical lenses applied when trying to understand and research the phenomenon (Caldis). **Effects** of interventions such as professional learning (Ní Riordáin et al.; Goos & Guerin) contribute to our understanding of what out-of-field teachers need

Fig. 18.5 Types of outcomes that are represented in this book

and how professional learning should be organised. A number of **tools** are presented (see above) that could be used in further (transnational) research and can serve as research tools but also as instruments used in teaching as an encouragement for reflection. And finally, a majority of studies compiled in this book express their **critique** on the policies that lead to out-of-field teaching (Van Overschelde) or the less than suitable support to teachers that are required to teach out-of-field (Donitsa-Schmidt).

18.5.2 Recommendations

A range of recommendations are also raised across the chapters. For **policy**, there are calls for sharper and more explicit policies and structures that deal with the out-of-field issue, calls to outlaw out-of-field teaching and to introduce measures to attend to the unequal distribution of out-of-field teaching and not just supply problems. Working with governments to generate data where data does not yet exist, will be important in some jurisdictions.

For **practices that are defined by policy settings**, recommendations are made to address problems with initial teacher education that fail to prepare teachers for the real-world of teaching, with critique falling on the generalist approach to primary teaching in situations where primary teachers are exposed to few specialisations. The case of the class teacher principal in Germany is raised in a number of chapters, and the reality that most teachers need to undertake in-service professional development to become familiar with subjects not covered in their Initial Teacher Education. The treatment of novice, graduate or newly qualified teachers is also critiqued, suggesting that there is a need to reconsider this practice all together, and that clear policies are needed as well as training for school principals and administration to ensure out-of-field teaching assignments are diverted away from teachers already struggling to survive their first years of teaching. Similarly, the practices associated with alternative entry pathways is critiqued, particularly where relatively unprepared teachers are also given out-of-field teaching assignments. The multiple boundary crossings for teachers can have cumulative negative effects with consequences for teachers' capacity to cope with their transition into teaching. Also, there is a need to reconsider how multi-disciplinary subjects are dealt with in Initial Teacher Education.

In relation to **practices**, calling for professional development of out-of-field teachers seems an obvious recommendation, but the research in this book identifies the need to acknowledge the varying motivations for teachers to upskill, and to then consider the adequacy of short courses for creating 'in-field'—or 'less out-of-field'—teachers. Also important to consider are the school factors that can influence the outcomes for teachers who undertake professional development or gain additional qualifications. Another point is the need for more in-school attention to assess teacher needs—this will undoubtedly disclose the different types of teacher responses to teaching out-of-field, and thus the need for different responses in terms of support, but more nuanced research is needed to capture this variation. In addition, there is a need to be aware of the personal resources and biographies of teachers, including their existing skillsets. A call for adequate (and systematic) support structures is a common recommendation, with the need for subject-specific support through, for example, mentoring and collegial collaboration. Such support structures enable teachers to engage in identity work as they grapple with the day-to-day issues while also reflecting on themselves as teachers of the new subject.

18.5.3 Future Research

There is no doubt that research into out-of-field teaching is multiplying, expanding and diversifying. Research begets research—that is, as we open up a phenomenon through research, we can begin to see more clearly the things that we do not yet know. As we move forward in our research, it is important to identify the gaps in what we know as a field—this may be new ways at looking at what we already know or through exploring as yet unchartered aspects of the phenomenon. Based on the avenues for research opened up by the research in this book, future research into out-of-field teaching can use heuristic tools in different contexts to ascertain rich data and support teacher capacity building and reflective communities of practice in schools. More longitudinal studies are needed to examine change over time and the enduring effects of out-of-field teaching, both in relation to transitions into teaching, as teachers learn on-the-job, and when teachers undertake formal professional development programmes or courses. Also needed are more large-scale datasets with more nuanced parameters that can differentiate between different types of teacher workloads, motivations, identities and commitments to teacher learning. Attending to issues of self-report, risk bias and representative sampling (Donista-Schmidt et al.), and social desirability bias (Goos & Guerin) will be important when examining teacher practices. The cumulative effects for different stakeholders including teachers (considering different types), students (achievement, cultural variation), subjects and colleagues (in varied roles) will be important. Potentially related to these cumulative effects are the cultural effects on the expectations and actions (motivations) of teachers, and how the effects of out-of-field teaching might vary depending on the socio-cultural resources of students, that is, the effects of socio-economic status, parental views on education, and school resourcing on whether/how students experience an out-of-field teacher. At an epistemological and ontological level, the delineation of subject-specific differences of being out-of-field in terms of what a teacher must know, how they teach, and attitudes and identities might help to guide teachers in negotiating different subject boundaries. Finally, an undercurrent of critique based on further elaboration of the ethical dimension of out-of-field teaching, and the potential de-professionalisation of teaching should underpin all of our work.

As a research community we might consider how we can work together to gain insight into the out-of-field teaching phenomenon and create change. Potential areas for transnational research were discussed at the 2021 OOF-TAS Collective Symposium and included questions relating to policy, supports, definitions and representing change (see Fig. 18.6).

18.6 Conclusion

In conclusion, this book represents a cross-section of research from around the world exploring the out-of-field teaching phenomenon. The future of this field of research will continue to rely on programmes of research that go deeper than measuring prevalence. Often, the way researchers devise their research questions is idiosyncratic, sometimes strategic, and often driven by immediate concerns within their context. It is important to capture these contexts and concerns. Research collaborations can help us to learn from each other, see the possibilities and locate the tools and insights that can create a supportive milieu for teachers, as well as provide more nuanced representations of the out-of-field phenomenon.

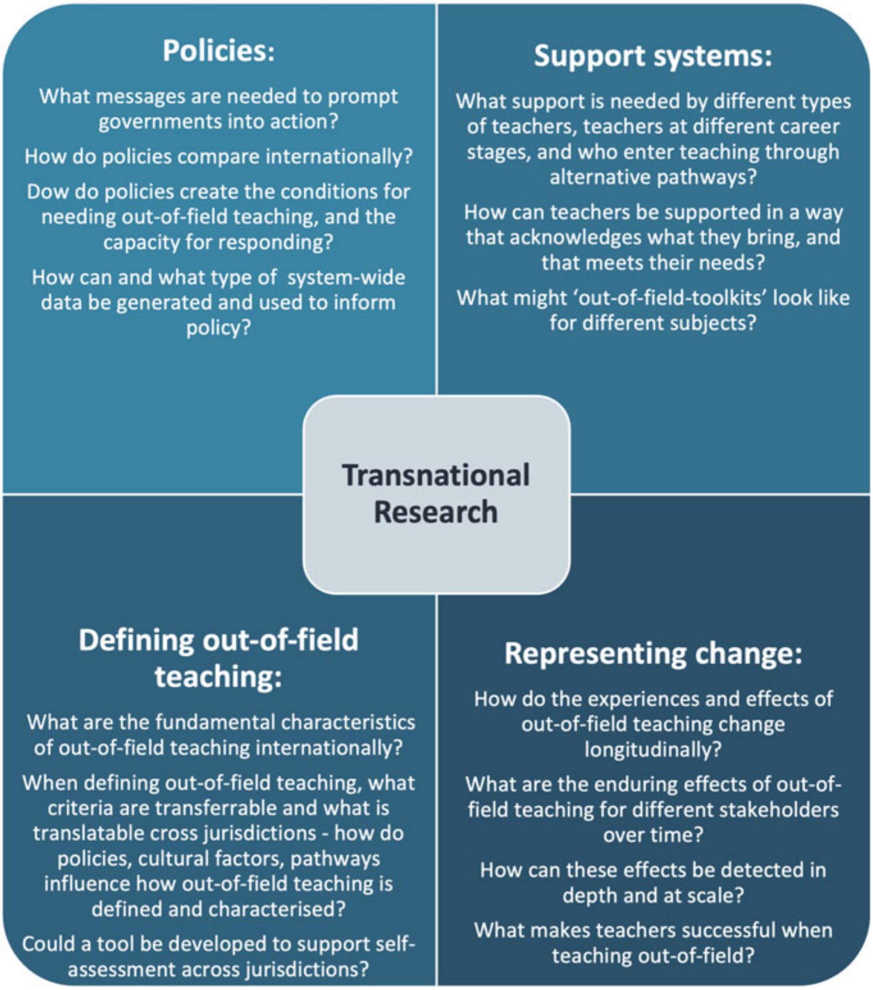

Fig. 18.6 Areas for transnational research arising from the 2021 OOF-TAS Collective symposium

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Correction to: 'Out-of-Field' Teaching in Mathematics: Australian Evidence from PISA 2015

Chandra Shah, Paul W. Richardson, Helen M. G. Watt, and Suzanne Rice

Correction to: Chapter 4 in: L. Hobbs and R. Porsch (eds.), *Out-of-Field Teaching Across Teaching Disciplines and Contexts*, https://doi.org/10.1007/978-981-16-9328-1_4

The original version of this chapter was submitted with corrections. The chapter has been updated with the changes.

The updated version of this chapter can be found at
https://doi.org/10.1007/978-981-16-9328-1_4

L. Hobbs and R. Porsch (eds.), *Out-of-Field Teaching Across Teaching Disciplines and Contexts*, https://doi.org/10.1007/978-981-16-9328-1_19