2019

Teacher Learning and Continuous Professional Development.

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Recommended Citation

Faulkner, F., Kenny, J., Campbell, C., Crisan, C. (2019). Teacher Learning and Continuous Professional Development. In: Hobbs, L., Törner, G. (eds) Examining the Phenomenon of “Teaching Out-of-field”. Springer, Singapore. DOI: 10.1007/978-981-13-3366-8_11

Chapter 11. Teacher Learning and Continuous Professional Development

Fiona Faulkner, John Kenny, Coral Campbell and Cosette Crisan

Abstract. This chapter discusses teacher learning and professional development of out-of-field teachers from the point of view of the literature. It examines what makes this kind of learning and development effective and explores the ideas surrounding the varying rationale for the introduction of such teacher learning and professional development opportunities. Classical approaches to professional development are discussed in addition to several emerging international models of professional development that are currently being employed in the Republic of Ireland, England and Australia for in-service out-of-field teachers of mathematics predominantly but also a range of other subject disciplines (in the case of South Korea). Details of the structure of each of the models of professional development for in-service teachers are outlined using a country case study approach. Comparisons are made between the techniques employed in each country to upskill out-of-field teachers in specific disciplines. This chapter also proposes an international framework for teacher learning and professional development for out-of-field teachers that encompasses the best aspects of each country's approach.

Keywords. Teacher learning, professional development, continuous, in-service.

11. 1 Introduction: Professional Development and Professional Learning

Before professional development or professional learning can be defined or discussed, one common challenge must be overcome and that is making explicit the difference between these two concepts. Although the terms professional development and professional learning are often used interchangeably, if the literature is examined carefully one can differentiate between them (Mayer & Lloyd, 2011). Professional development has been described as "activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher" in the OECD's extensive study across 23 countries (OECD, 2009, p. 49). Another definition of professional development which is in keeping with that of Mayer and Lloyd (2011) description if that of Knapp (2003, pp.112-113) who describes professional development as "the full range of activities, formal and informal, that engage teachers or administrators in new learning about their professional practice". Knapp

(2003) also compares professional learning to professional development and describes professional learning as being linked to "changes in the thinking, knowledge, skills, and approaches to instruction that form practicing teachers' or administrators' repertoire" (Knapp, 2003, pp.112-113). In their extensive literature review on professional learning Mayer and Lloyd (2011, p.3) therefore deem professional learning to be linked to "one's capacity for practice (i.e., changes in professionally relevant thinking, knowledge, skills, and habits of mind) and/or changes in practice itself (enacting the new knowledge and skills in one's daily work)". Professional learning has also been characterized as learning that is not structured in any systematic way but occurs as a teacher goes about their working day in their classrooms (e.g., Day, 1999; Doecke, Parr & North, 2008). In this chapter the differences between the two concepts are acknowledged and it is a combination of both professional development practices and the resultant professional learning that will be examined.

Much research in the area of professional development highlights that little is known about the effects of engaging in professional development on improvements in teaching or on students' outcomes (Garet, Porter, Desimone, Birman & Yoon, 2001; Luke & McArdle, 2009) however there is in fact literature that has extensively detailed the characteristics of effective professional development (Ingvarson, Meiers & Beavis, 2005; Kriewaldt, 2008; Meiers & Ingvarson, 2005; Timperley, 2008; Timperley, Wilson, Barrar & Fung, 2007; Wilson & Berne, 1999) which will be outlined next.

11.1.1 What makes professional development and professional learning effective?

An extensive examination of literature in the area of effective professional development resulting in professional learning carried out by Mayer and Lloyd (2011, p.4) emphasized the need to focus on "developing subject matter/content knowledge; active learning sustained over time with opportunities to put the learning into practice and with follow-up and support; a focus on student learning and examination of student work; and, collective participation". In addition to this Hawley and Valli (1999) carried out a meta-synthesis of research in the area of effective professional development and outlined the following design features which need to be in place for effective professional development to be rolled out:

Table 11.1 Meta-synthesis of Effective Professional Development Literature (Hawley & Valli, 1999)

1. The content of professional development focuses on what students are to learn and how to address the different problems students may have in learning the material.

2. Professional development should be based on analyses of the differences between actual student performance and goals and standards for student learning.
3. Professional development should involve teachers in the identification of what they need to learn and in the development of the learning experiences in which they will be involved.
4. Professional development should be primarily school-based and built into the day-to-day work of teaching.
5. Professional development should be organised around collaborative problem-solving.
6. Professional development should be continuous and ongoing, involving follow-up and support for further learning—including support from sources external to the school that can provide necessary resources and new perspectives.
7. Professional development should incorporate evaluation of multiple sources of information on learning outcomes for students and the instruction and other processes that are involved in implementing the lessons learned through professional development.
8. Professional development should provide opportunities to gain an understanding of the theory underlying the knowledge and skills being learned.
9. Professional development should be connected to a comprehensive change process focused on improving student learning.

Many of these characteristics of effective professional development are also mentioned in other extensive studies of teacher professional development programmes (Garet, Porter, Desimone, Birman & Yoon, 2001; Luft, Dubois, Nixon & Campbell, 2015). Garet et al. (2001) studied the responses of 1027 teachers and presented a model by which professional development programmes could be compared and evaluated. It explored the characteristics of professional development in terms of *Structural features* and *Core Features*. *Structural features* are concerned with the design of the professional development activities and include the Form, Duration and Degree of Collaboration of the activities, whereas the *Core Features* relate to the substance of the professional development program, including the degree of focus on content knowledge (including pedagogical knowledge), the extent to which it provided opportunities for active learning and the coherence of the activities with other demands, needs, and expectations of teachers (Table 11.2).

Table 11.2 Framework for comparing teacher professional development (Garet et al., 2001)

Structural features	Core features
Form: The type of activities involved: Workshops or conference compared to "reform" activities such as network, study groups and mentoring.	Content: The degree of focus on improving teachers' content knowledge (in mathematics and science) e.g., subject specific or more general teaching topics)
Duration: The number of hours of PL activity and the span of time over which it was conducted	Active learning:

	The degree to which PL offers teachers opportunities to become engaged in the meaningful analysis of teaching and learning (e.g., observe experts, review student work, get feedback on their teaching, give presentations & lead discussions.)
Collective participation: The degree of emphasis on groups of teachers from a school learning together or individual teachers from many schools	Coherence: The degree to which PL fits with broader educational agendas to reform teaching, links to previous PL and encourages continuing professional communication among teachers.

Consistent with the points in Table 11.1, Garet et al. (2001) maintained that PL for teachers is more effective when it is aligned with how they work in their classrooms, the *Duration* of the professional development and the extent of active learning are key factors in its effectiveness, largely because sustained professional development activities promote coherence and teachers are more likely to be able to discuss content and to explore the effectiveness of different teaching strategies in their classrooms and reflect on their practice.

Content knowledge is clearly one area where the needs of out-of-field teachers will differ from colleagues with expertise in a curriculum area. However, the literature is clear that the term refers to more than knowledge of subject matter; it also encompasses knowledge of pedagogical practices that will enable students to develop a deep conceptual understanding of the subject and "sound content and curricular knowledge, an understanding of learners and learning, an ability to enact appropriate instructional strategies, to embed assessment in their practice, to support the learning of all students and to build their professional disposition" (Luft et al., 2015, p. 41).

Luft et al. (2015) looked at studies of teacher PL for beginning teachers, as "Newly Hired Teachers of Science" (NHTS), over the 30-year period from 1982-2012, which included both those with strong science knowledge (secondary teachers) and those with relatively little science expertise (primary teachers) and compared their responses to professional development programs. They argued that the subject matter knowledge alone does not necessarily translate into better teaching practices, especially those related to student-centred and inquiry based practices. They call for development of a clearer understanding of what we mean by the term *content knowledge* as it pertains to teachers. Suggesting that it includes a range of aspects such as: conceptual understanding of the subject area, deep knowledge of the curriculum and connections between topics, an understanding of how students learn, understanding of assessment practices that promote learning. Further, they argue that teachers can develop their expertise in these aspects overtime as they work in classrooms, but their ability to develop is influenced by their beliefs about science and their identity as teachers of science and access to professional learning opportunities.

> Furthermore, a tested model of teacher content and curricular knowledge could identify high-leverage areas that could better assist generalist teachers, such as those teaching elementary grades, and those teaching outside of their specialisation. (Luft et al., 2015, p. 15)

Finally, these studies also indicate the context in which a teacher professional development programme is developed can have a direct affect its structure, purpose and core design and therefore its effectiveness. These aspects of a professional development programme can vary depending on whether it is driven by needs external to the school, such as government policies or political agendas, or by more local needs such a shortage of expertise or a desire for improvement recognised by eachers themselves. Thus systemic issues, local school circumstances and identity issues may all affect how teachers approach being an out-of-field teacher. and the benefits they may gain for participating in professional development opportunities. Drawing on the notion of Boundary Between Fields (Akkerman & Bakker, 2011), Hobbs (2013) also claimed that out-of-field teachers need to re-shape their identity to encompass themselves as teachers of their out-of-field subjects. Along with , Luft et al. (2015), she maintained that so effective PL would need to be based on a clearer understanding of the motivations and needs of the individual teachers involved. So, in addition to a better understanding of the content knowledge needed by out-of-field teachers, effective professional development programmes would also "attend to their beliefs and identity formation as they are in the midst of learning and teaching content and in enacting the curriculum" (Luft et al., 2015, p.12).

This has clear implications for the design of professional development programs. Luft et al. (2015, p.26) suggest that programmes "need to be conceptualised in a manner that encourages the cultivation of professional practice over time." This suggests that effective PL incorporates "broadening experiences, building capacity for the future, support, mentoring" with an "emphasis on peer observation, feedback and sharing" (p. 36). Garet et al. (2001) warned that effective teacher PL is an expensive exercise which is consistent with the case studies discussed below:

> …providing activities with multiple high-quality features is challenging, and requires a substantial amount of lead time and planning, which schools and districts may not always have. Second, providing activities with these high-quality features is expensive. (Garet et al., 2001, p. 935).

Such contextual differences are likely to lead to teacher learning being situated differently in different contexts and countries with the consequence that certain professional development offerings might be more effective than others.

While much of the literature considers teacher professional development in general, there is little mention teaching out-of-field. It is not unreasonable to assume that, in many aspects, the *structural features* of effective professional development for out-of-field teachers would be similar to programmes designed for teachers with expertise in the area, but it is also likely that the *Core features* will differ for out-of-field teachers, particularly the *Content*, in comparison of teachers with disciplinary expertise who typically attend subject-related programs.

In the next section, four different case studies will be analysed against the features of effective professional development as outlined in Table 11.1 (Hawley & Valli, 1999) and Table 11.2 (Garet et al, 2001) to compare and contrast and identify key aspects of effective professional development for out-of-field teachers.

These case studies indicate that internationally, a variety of approaches to the provision of professional development for out-of-field teachers have been implemented, with some approaches specifically designed for out-of-field teachers, while others are inclusive to all teachers. The evaluation of these programmes will inform the development of an emergent model for effective professional development which supports professional learning for out-of-field teachers.

11.2 Existing Professional Development Programmes for out-of-field Teachers: International Case Studies

The following case-studies are recent examples of the response in a number of countries to the professional learning needs of out-of-field teachers. Each case is relevant to the particular context bound and was developed independently of the others described within the chapter. As such, cross-case analysis provides an effective way to interrogate the salient features of each case, to arrive at a set of common parameters for effective professional learning for out-of-field teacher.

11.2.1 The Case of Ireland

In 2008, the Irish government rolled out a revised mathematics curriculum in all post primary (secondary) schools with the aim of addressing issues in the Irish education system relating to students' understanding of mathematical concepts, their ability to problem solve and over reliance on rote learning procedures. All stakeholders in Irish education agreed that such an initiative could not be successfully implemented and these existing issues could not be resolved without significant improvements in the quality of mathematics teaching. Furthermore, the problems which existed with implementation of the new curriculum were intensified by a concentration of 'out-of-field' teachers teaching mathematics at lower secondary school (Junior Cycle) (Ní Ríordáin & Hannigan, 2009). Thus, while changes and improvements in initial teacher education in mathematics will lead to improvements long term, compensatory actions such as continuous professional development and other upskilling opportunities were considered necessary to improve quality and support practicing teachers in the medium term. As such, a continuous professional development programme, entitled 'The Professional Diploma in Mathematics for Teaching' (PDMT), was rolled out in 2012, specifically for out-of-field teaching mathematics teachers in Ireland. The primary stimulus for the development of the

programme was a report published by Ni Riordain and Hannigan in 2009 which highlighted that 48% of in-service post primary (secondary) mathematics teachers in Ireland were not suitably qualified to teach mathematics but rather were qualified secondary school teachers in other subject disciplines (see Chapter 3 for more details on teacher education in Ireland).

Therefore, to tackle this issue the Irish government is in the process of funding four cohorts of 400 out-of-field teaching mathematics teachers (maximum) per year. Initially, over 2 million euro was provided in funding for the programme to cater for these four cohorts. In January 2015, the first cohort of 300 teachers graduated (400 teachers were initially enrolled) while in January 2016, approximately 250 teachers graduated. In January 2017, there are approximately 200 teachers due to graduate with 140 teachers likely to graduate in January 2018. The interest and willingness of eligible teachers to engage with the programme has declined as the years progress. This may be in part due to teachers learning of the heavy work load and commitment that is involved during the programme and/or those teachers teaching out-of-field with a higher relative propensity to mathematics teaching having already enrolled on the course. Details of the structure of the programme will be outlined next.

The Structure of the Professional Diploma in Mathematics for Teaching (PDMT)

The PDMT is a 2 year part-time blended learning programme which is offered free of charge nationwide. The National Centre for STEM Education (EPI•STEM) (formally the National Centre for Excellence in Mathematics and Science Teaching and Learning) at the University of Limerick (UL) leads a national consortium of Higher Education Institutions (HEIs) established for the purposes of delivering this programme. The programme is jointly accredited and run by UL and the National University of Ireland, Galway (NUIG).

The requirements for the structure of the programme were set out by the Minister for Education and Skills, and Teaching Council regulations in Ireland. The Teaching Council regulates the teaching profession in Ireland and outlines criteria which teacher education programmes have to meet if they are to be recognised by the council. As such, it is a 75 ECTS credits [2] level 8 programme[1]. This can be broken down into 60 ECTS credits towards mathematics modules (5 modules per year worth 6 credits each) and 15 ECTS credits towards mathematics pedagogy (2 modules: 1 worth 9 credits and 1 worth 6 credits).

[1]The Bolagna Process, which was developed in 1999 and is now used by 45 countries, is a standardised accreditation process for higher education. It was put in place so that countries had a mechanism to relate national frameworks to each other allowing for international transparency, international recognition of awards and international mobility of learners and graduates. The system consists of 10 levels with

each level being associated with a certain number of ECTS credits depending on the programme demands[1].

The participants complete the pedagogy elements of the programme concurrently with the mathematics modules. Upon completing the first 5 mathematics modules in year 1 of the programme, participants are required to attend a week long summer institute on mathematics pedagogy which is offered in 2 venues in Ireland; University College Dublin and UL.

This summer institute outlines the criteria for much of the pedagogy continuous assessment which must be completed as part of the programme. Participants are also required to attend 5 pedagogy workshops which take place on Saturdays throughout year 1 and 2 of the programme. These workshops are informing the teachers directly on best mathematics pedagogical practices for second level mathematics teaching with a particular focus on the mathematics curriculum in all Irish post primary secondary schools.

The Blended Learning Platform

Participants have the option of attending 9 different lecture venues and 19 different tutorial venues in a variety of higher education institutions around Ireland. The large variety of venues requires a lot of co-ordination, however it maximises accessibility and participation from the out-of-field teachers across the country. The course is designed so that it facilitates teachers who are working during the day as contact hours are in the evenings. The blended learning format allows for participants to attend live lectures for approximately 50% of the mathematics content modules and use an on-line platform to engage with the rest of the material. Google is a partner in the programme and provides the online platform on which it runs.

On the evenings of live lectures, one lecture venue is responsible for delivering the material and this lecture delivery is streamed live to all other venues for participants to watch. At 3 different intervals during the live lectures there is a break in the live streaming for participants to engage in onsite problems related to the content being delivered. Each lecture venue has a qualified mathematics lecturer onsite to facilitate the 3 hour lecture with the onsite lecturer playing a particularly important role when the live streaming breaks for onsite problems to be completed. The onsite lecturer also serves as a fail-safe option to take over the delivery of the lecture should the technology break down for any reason. Participants are required to attend three 2 hour tutorials for each 6 week module and these are all live onsite tutorials.

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[1] [2]The European Credit Transfer and Accumulation System (ECTS) is an academic credit system based on the estimated student workload required to achieve the objectives and learning outcomes of a module or programme of study (Trinity College Dublin, 2016).

Management of the Professional Diploma in Mathematics for Teaching

The programme is managed and coordinated by the National Centre for STEM Education (EPI•STEM) in conjunction with the Department of Mathematics and Statistics and Department of Education and Professional Studies at UL. These parties are responsible for the marketing, recruitment, admissions and academic and student administration, academic standards and the delivery and implementation of the programme. In addition, under the terms of the Department of Education and Skills (DES) contract, a group consisting of DES officials and members of the course team monitor the programme.

The programme has a course director, appointed by EPI•STEM, who chairs the Course Team which contains members of faculty from the 2 lead institutions, UL and NUIG. A full time National Programme Co-ordinator and a Teaching Co-ordinator are responsible for the day-to-day running and organisation of the programme with contributions from mathematics educators in the EPI•STEM centre.

Recruitment Practices and Eligibility for the Professional Diploma in Mathematics for Teaching

As previously mentioned, all advertising and recruitment for the PDMT is carried out through the administration team at UL. Newsletters, detailing the programmes call for teachers to submit applications, are sent to schools along with electronic notification to principals, teachers and school administrators. Many teachers choose to participate for personal and career advancement reasons however others, who may be less intrinsically motivated to participate, come to engage with the programme due to encouragement or instruction from their school management/principal. In the Irish context, there is no written requirement from a government perspective for teachers to be placed in the school subjects which they are qualified to teach. Thus, it is the school principal's role to deploy teachers and organize school timetabling. However, many factors at a school level, such as teacher quotas, subject offerings, location and contractual issues, have led to principals facilitating out-of-field teaching often with no other viable options in order to keep the school timetables functioning. Encouraging / instructing in-service teachers to undertake the PDMT has been seen as one way to try to redress this situation.

Similar to the programme structure the eligibility for the programme is set out by the Minister for Education. Applicants to the PDMT must meet the following criteria in order to be considered for a place on it:

- They must be currently teaching mathematics in a second level school in Ireland.
- They must be a qualified second level teacher in a discipline other than mathematics and be registered with the Teaching Council.
- The above 2 criteria points must be signed off by the principal of the second level school in which the applicant currently teaches.

In terms of academic eligibility there is no specific mathematics requirement for the programme.

Programme Evaluation

A platform for ongoing programme evaluation was a priority from the outset of the PDMT development. This programme evaluation is carried out through real time evaluation in addition to longitudinal research. The real time evaluation includes teacher and lecturer feedback through various programmes and informal mediums. Daily feedback from the lecturers on all sites is monitored and responded to by the Programme Co-ordinator and the Course Director.

In addition to day-to- day evaluations and monitoring of the programme from lecturers and teachers, a series of end of year general programme evaluations have been conducted by the UL Centre for Teaching and Learning (CTL). The CTL have carried out 3 evaluations to date covering cohorts 1, 2 and 3. These evaluations involve teachers completing an online questionnaire which aims to determine teachers' general satisfaction with the programme. Teachers are also asked to give advice to others considering taking on the PDMT. This evaluation also serves as a means of adapting and improving the programme on a yearly basis. To date, the major finding from this form of evaluation was that 33.5% of teachers stated that they were not satisfied or unsure of their satisfaction levels with the programme. Primarily, this was due to teachers feeling stressed as the programme requires a significant amount of work in addition to having a full time teaching job and a family. They also reported dis-satisfaction due to inconsistencies with regard to the teaching conducted across different centers while issues with the technology breaking down from time to time were also highlighted. However, there was a slight majority of participants (52.5%) who agreed with or strongly agreed with the statement that they were satisfied with the programme. This agreement was mainly due to it being effective professional development for career advancement and participants' support for the tutorial structure. More specifically on the tutorial structure, these participants commented on how beneficial and enjoyable it was to engage with the tutors and other participants within this context resulting in improved self-confidence. In the section of the evaluation which asked participants whether they had any advice for others considering enrolling on the course, 3 major themes emerged: 1. Prospective students were advised not to underestimate the level of pre-requisite mathematical knowledge required, 2. The importance of attending tutorials and reading lecture notes prior to lectures commencing was stressed and 3. That it was a programme they would encourage people to do as they felt it was a good career move in spite of the fact that it was not an easy programme to successfully complete.

An additional evaluation is ongoing which is examining teachers' content and pedagogical knowledge before and upon completion of the programme. This study is being conducted by a mathematics education professor in Boston College and mathematics education lecturers in NUIG. Extensive details of the results of this

research can be found in chapter 5. Some of the major findings indicate that teachers' mean cognitive score has increased pre and post completing the course and that teachers' mean conceptual error score has decreased over this same time period. However, neither of these improvements were as significant as the programme team would have anticipated.

Research is also being carried out on the perceived effectiveness of the mathematics specific pedagogy workshops. This research aims to investigate if in-service out-of-field teaching mathematics teachers think that it is necessary for them to engage with mathematics specific pedagogy and whether these perceptions change throughout their engagement with the PDMT. The study also examines whether the teachers' classroom practices change as a result of engaging with the PDMT to align with the intentions of the new mathematics curriculum in second level education in Ireland. Prior to engaging with the pedagogy workshops 71% of participants felt that it was a necessity for them to engage in mathematics specific pedagogy. This figure increased to 82.9% upon completion of the workshops showing that participation in the workshops led to an increase in the value placed on them. The predominant response of the participants on the teaching style they employed prior to undertaking the pedagogy workshops was 'didactic teaching'. Significantly, of the 60.6% of participants who stated they changed their teaching style upon completion of the pedagogy workshops, all, except one, changed to a more student-centred teaching approach as advocated for in the workshops and in the new mathematics curriculum. Overall, this research found a positive response to the mathematics specific pedagogy workshops as indicated by the growth in those considering it necessary upon completion of the workshops.

The final element of programme evaluation that is currently underway is a doctoral study examining teacher identity (re)construction whilst undertaking the course. As this case study research is only in its infancy, there are no substantial findings to report to date. However, once completed, this work should provide extremely useful insights into the journey from out-of-field to infield that a teacher experiences while undertaking an extensive professional development programme specifically for out-of-field teachers of mathematics. The initial findings indicate that the salience of mathematics teaching to the identity of the teachers involved in the study reflects to some extent their intentions for undertaking the course. This suggests that the teacher's identity at the point of departure can impact positively or negatively on how these teachers participate in the programme and engage with the course material. Furthermore, the teachers participating in this research appear to rely heavily on, and believe primarily in, the capacity to learn to teach lower secondary school mathematics through experience. This portrays that these teachers, in terms of lower secondary school mathematics, seem to believe in what Britzman (1986) refers to as 'vocational training' or the 'apprenticeship model of education' (Gordon, 1985) – in effect, learning through repeated practice. Significantly, this is not the case for these teachers with regard to teaching higher secondary school mathematics (Senior Cycle). Instead, these teachers described their fear of teaching

senior cycle mathematics and for some, this was a key contributory factor for undertaking the course. Thus, it remains to be seen, does the professional development programme challenge and alter these teachers' perceptions of learning to teach lower secondary school mathematics and/or alleviate their fear of teaching higher secondary school mathematics, and in doing so, affect identity (re)construction.

Finally, the aforementioned DES Monitoring Group have a responsibility to submit reports on the programme upon carrying out 'spot checks' at centres whilst lectures and tutorials are ongoing. This element of the programme evaluation has produced very positive reports to date. Additionally, the members of the Monitoring Group actively engage with teachers on the programme when they are in their schools. Based on this, they reported (after 3 years of the programme being in operation and 527 teachers qualified from it) that the programme is having a positive impact on mathematics teaching in schools.

The forms of evaluation discussed here will continue to be carried out for the duration of the running of the PDMT. The most effective elements of the programme which have emerged from the evaluation research to date are outlined next.

Effectiveness of the Programme Development Programme

The PDMT programme receives and responds to feedback from lectures and participants in real time. This results in continuous changes being made to the programme to ensure an ever evolving improved service over time. The evaluation of the satisfaction levels of the programme demonstrated the relative effectiveness of the small group tutorial structure which is provided to students during the course of each mathematics module in conjunction with the content lectures. This has been reported to be a forum in which the participants really learn and engage with the mathematics being delivered in lectures. The pedagogy workshops appear to be an element of the programme which supports and encourages teachers to change from a predominantly didactic classroom practices to one which engages in active learning methodologies and focuses on students' understanding of mathematics. A significant proportion of teachers maintained that the pedagogy workshops were the most effective element of the programme in terms of providing them with ideas and strategies to improve their teaching with some stating that they'd prefer a heavier weighting on this aspect compared to content lectures.

11.2.2 The Case of England

The shortage of mathematics teachers in the UK has led to a number of government initiatives aiming to increase the supply of teachers of mathematics. One such initiative concerns up-skilling teachers who are already employed at a school or college in England and who are teaching some mathematics, but who initially

trained to teach in a subject other than mathematics. The **MDPT** initiative (Mathematics Development Programme for Teachers) was specifically commissioned for such serving teachers and it was launched by the Teacher Development Agency (TDA) in 2009. Participation on the MDPT course required that a teacher had completed their Newly Qualified Teacher (NQT) year and was employed in a state school and teaching at least some mathematics to pupils in the secondary age range (11-16 years old) and had no post 18 mathematics or any mathematics teaching qualification (although primary trained teachers were allowed to take the course), had the support of their head teacher and had a school-based mentor to support them. The structure of the course was: 30 days based at the university and 10 based in school with specific pedagogical tasks to complete. The participating teachers were offered a £5000 bursary on completion of the course where 'completion' included having at least 80% attendance and an assessment at a level of a final undergraduate of 40 CATS credits (Credit Accumulation and Transfer Scheme) is used by many universities in the UK to monitor, record and reward passage through a modular degree course and to facilitate movement between courses and institutions; one credit is equivalent to 10 hours of study comprising of contact time and allocation for self-study). Schools could claim for cover on the days where the teachers were in the university for the MDPT course sessions.

Various providers in different regions of England offered these MDPT courses and had the freedom to design their own curriculum. The participants in the MDPT courses were expected to transfer their pedagogical knowledge from their initial specialism into the context of mathematics teaching as a result of developing their mathematical subject knowledge.

The structure of the MDPT course, one of eight similar national courses, as designed by the mathematics education team at the UCL Institute of Education, University College London is reported in this chapter.

The structure of the MDPT programme

The design principle of the in-service mathematics courses for non-specialist teachers of mathematics was that effective secondary mathematics teaching is founded on sound subject knowledge, together with a thorough knowledge of a highly-connected curriculum and a sympathetic understanding of pupils' needs and interests. Thus, the emphasis of our in-service courses was on revisiting and teaching the subject matter (school mathematics), aiming to develop the participating teachers' technical fluency of some of the more challenging topics taught at different levels of school education (Key Stage 3: 11 to 14 year old pupils and Key Stage 4: 14 to 16 year olds).

Even with the full engagement and efforts of the teachers on the course, the aims of the course could not have been achieved if an attempt was made to cover exhaustively all aspects of mathematics in the National Curriculum for Mathematics

in England (NC) at Key Stages 3, 4 and 5. Our course thus made careful design choices about the most appropriate places to focus attention.

The aims of our MDPT course were thus to:

- present mathematics as a coherent and connected living web of meanings,
- encompass the most challenging topics for teachers in the target group to understand,
- involve the teachers in developing technical fluency, and
- provide opportunities to create a range of ideas about mathematics-specific pedagogy.

The various providers in different regions of England who offered these MDPT courses had the freedom to design their own curriculum. The curriculum the mathematics education team at the UCL Institute of Education, University College London was designed to deliberately avoide mathematics National Curriculum classifications; in support of OfSted's observation (OfSted, 2006), the MDPT curriculum covered four broad mathematical content themes: Infinities, Uncertainties, Structures and Spaces.

In all settings, both schools and FE colleges, the most effective teachers understood how the particular aspects of mathematics they were teaching fitted into the wider development of mathematical themes and concepts. They were aware of the progression of mathematical ideas and the rich links across them. This enabled teachers to develop students' secure understanding by making links with previous and forthcoming work on the same topic and by emphasising the recurring mathematical themes and ways of thinking (p. 5).

Theme 1: Infinities

- Gaining an understanding of how procedures and techniques used in school mathematics are underpinned by notions of infinity.
- Understanding some of the history of how rigour needed to be established in order to develop processes such as convergence.

Theme 2: Structures

- Recognising and using similarities and differences across mathematical topic boundaries.
- Understanding how knowledge about one area of mathematics may be applied to support learning and problem solving within another area of mathematics.
- Improving confidence and competence in mathematical reasoning.

Theme 3: Uncertainties

- Gaining an understanding of different probability models, with opportunities to use ICT and simulations to model real world phenomena.
- Contextualising the use of these theories in society's endeavours to conceptualise and measure risk.
- Understanding that a set of data that can be represented in various ways.

Theme 4: Spaces

- Representing and visualising two and three-dimensional situations in a variety of ways
- Euclidean geometry of the plane.
- Modelling in three dimensions, for example, movement or stability of physical structures.

Between them, these four broad connecting themes were not exhaustive of all aspects of the school mathematics curriculum, but they provided a deep appreciation of the connections between those areas of mathematics where we expected a lack of competence and the study skills to enable them to address other areas of mathematics independently.

The selected content areas provided many opportunities for attention to pedagogical issues such as: planning, observing and reviewing lessons; a rich variety of learning approaches and teaching resources, including digital technologies; developing and adapting personal resourcefulness and creativity; developing questioning strategies; developing a range of assessment strategies; developing an awareness of the connectivity of mathematics and its place in a wider societal context; taking advantage of the opportunities provided by communities of practice and professional associations.

Through the teaching of these themes, the intention was to address the learning outcomes of the MDPT course, namely teachers learning about modes of mathematical enquiry, namely: generalisation and abstraction, reasoning and proof, precision in mathematical language, conceptual structures within mathematics and appreciating the potential for mathematics teaching and learning of digital technologies.

Mode of delivery of the MDPT course

The course consisted of three interrelated parts: Face-to-face contact sessions based at university; Directed work arising immediately from the taught contact sessions and School-based work where teachers relate the university-based experiences

to their own practice. Each teacher was allocated a personal tutor from the mathematics education team at the UCL IOE. The personal tutor was to help participating teachers to steer their way through the course, developing the portfolio of evidence in response to the needs analyses. Each teacher's school needed to commit at the outset to the allocation of a mentor within the school. This mentor, usually a senior colleague, possibly the Head of the Mathematics Department ensured that the teacher on the course received continued support for his/her activity, reducing as far as possible the obstacles that might normally intervene on the teacher's study-time. Where possible mentors also provided advice on planning and outcomes of school-based tasks. A Virtual Learning Environment (VLE) was used throughout the course to enable participating teachers to maintain contact with each other and with tutors, enabling the ideas to be embedded in professional practice.

The VLE provided a central delivery system of course documentation, including course structure and assessment. It offered reading and links to other places of support on the World Wide Web and during school-based aspects of the course, the participating teachers were encouraged to maintain contact with their personal tutor by email or through the VLE.

Assessment

Participating teachers benefited from thorough and continuous formative assessment, aimed at ensuring that the course as experienced by any individual was tuned to that individual's needs and progress. Although much of the formative assessment took place in the everyday interactions between tutors and the participating teachers, we were able to identify several specific formal mechanisms that will support the development of the teachers:

- A *needs analysis* was carried out on the first day of the course in order to establish areas in which individuals felt confident, and which were reviewed and modified in the light of interviews and course progress.
- A *portfolio*, in which participating teachers collected information, ideas, relevant materials from teaching and other resources.
- A *Dialogue Notebook* throughout the course where teachers were able to reflect upon issues that concerned or interested them in the face-to-face sessions.
- A *Virtual Dialogue Notebook* on the VLE where the participating teachers shared experiences of directed and school-based work with colleagues and tutors on the course.

There were two elements of summative assessment:

- A *Structured Portfolio* (6000 words) consisting of five sections, one for each of the five powerful connecting themes. In each section, participating teachers were required to provide evidence of their mathematical achievement in relation to a

particular aspect of the theme and to reflect upon their learning processes. The Structured Portfolio was assessed according to H-level criteria (Honours H level)
- An *Essay* (5000 words) where participating teachers chose to write about a pedagogically-oriented focus that cut across or drew upon several of the four themes. The essay was assessed according to M-level criteria.
- At the end of the course the participating teachers were asked to give informal group presentations. These presentations were intended as supporting the summative assessment at M-Level (Masters M level).

Accreditation

Since the aims of the course encompassed both mathematical content and subject pedagogy, the accreditation of the course was divided into two modules. The first module, *Mathematical appreciation, knowledge and technical fluency* was assessed by the Structured Portfolio and accredited at H-level (60 credits), while the second module, *Mathematical pedagogic content knowledge* was assessed by the Essay was accredited at M-level (30 credits). On successful completion of the course, the teachers were considered to "have gained an additional specialism" (TDA, 2009, p.10) in mathematics.

Recruitment Practices

All advertising and recruitment for the MDPT course was carried out through the administration team in the UCL Institute of Education, University College London. We promoted the course through our 500 partnership schools in London as well as through the publications of the London Education Research Unit, which reaches all London schools.

During all of the recruitment and marketing activity, care was taken not to overburden schools, whose focus is on the teaching and learning of their students. Our approach was to ask interested teachers to complete a simple application form. Teachers were also asked for contact information of the principal of their school. At the second filtering stage, principals of schools were asked to confirm:

- that the teacher was expected to continue teaching mathematics in the forthcoming years and that the teacher would teach mathematics in the next year;
- the name of a mentor, who was needed to be a senior colleague whose duties would be set out in the letter to the principal;
- that the school would support the teacher as they worked on the course by allowing the teacher leave for those days in the course where attendance at the university was needed, by guaranteeing time and resources for school based tasks to be completed and for in-school mentoring to take place.

The material advertising the course summarised: the target audience, including qualifying criteria; the three core aims of the course; the content of the course, based around the four powerful connecting mathematical themes; the need to reach levels of fluency that support the development of confidence coming from competence; the methodology of the teaching that will take into account differentiated needs and the level of commitment needed by participating teachers and schools.

Evaluation of the Programme

The course described above was taught to four cohorts of non-specialist mathematics teachers on two different programmes: the 40 day MDPT courses in 2009-10 and 2010-11, the length of the programme being imposed by the government specification. Participant numbers at the beginning of each course were 14 and 16 respectively. The teachers participating in these courses were recruited from the London area and regions from which it was possible to travel into the capital. The QTS specialisms of the teachers enrolled on the course included languages, science and business studies, with the most popular specialisms being primary and Physical Education, while four of the participants were from overseas, one of whom did his training through an Overseas Trained Teacher (OTT) scheme in England and the others used their EU (European Union) qualifications.

Soon after the start of the course, the university tutors for this course realised that in algebra particularly, there was a lack of meaningfulness in the teachers' work that we witnessed through their 'instrumental' application of methods and their displaying defence mechanisms like avoidance, talking or requesting explanations to them personally. Similar topics that brought to surface unexpected emotional responses from the teachers were solving two linear simultaneous equations, factorising a quadratic, working with inverse proportion. This brought up the very practical question: how can these participating teachers develop into mathematics teachers who are fit to teach the secondary age and ability range? We had 30 meetings with them over a school year! This motivated us to collect data more systematically in the second year concerning participating teachers' mathematics teacher journeys. Hence our orientation was to look at a purposive sample of case studies to investigate the transitions towards a mathematics teacher identity, thus research took place alongside the course and was subordinate to the course.

Given the small number of participants on these courses, the evaluation of the course was mainly qualitative. The main element of our course evaluation was our research focus on examining the mathematics teacher identity trajectories of the participating teachers during and after undertaking the course.

The participating teachers embraced the challenges presented to them throughout: learning new mathematics, reflecting on their understanding of the school mathematics, learning from mathematics teacher colleagues' practices, reflecting on their own practices of the in-service course. As the course progressed, we noticed that our participating teachers became more focussed on the learning and doing of

mathematics compared with their focus at the beginning where ‘how do you teach this [mathematical topic]?’ was the central concern (Crisan & Rodd, 2011, 2014a). While some teacher participants resisted changing their conceptions about the teaching of mathematics (‘understanding a topic’ was construed by some as an instrumental facility with a mathematical procedure sufficient to answer standard questions), we witnessed powerful moments when the participating teachers experienced joy and surprise at noticing connections between different topics, starting to see mathematics in a new light, more than just a set body of knowledge and skills (Crisan & Rodd, 2014b; Rodd & Crisan, 2015). During interviews and oral presentations, the participating teachers talked about the interconnectedness of the mathematics topics, use of investigative approaches, group work. Despite the gaps in their knowledge of school mathematics topics and despite their technical mathematical competence still needing further development, the participating teachers gained confidence in themselves as learners of mathematics, which in turn gave them confidence in their mathematics teaching.

As the participating teachers’ confidence in their own mathematical ability increased, we noticed a change on how they talked about themselves as potential mathematics teachers. The teachers became preoccupied with whether and how they will be recognised as mathematics teachers by their colleagues on the course, current school or potential employing schools and mathematics departments. Gaining certification at the end of the course that indicated their new specialism in mathematics teaching was a goal to which many of the teacher participants aspired.

In the research we conducted (Crisan & Rodd, 2014b) we found that towards the end of the course were the participants on such courses, all of whom were aware of limitations in own mathematics subject knowledge at the beginning of the course, were able to articulate a wider view of what mathematics was about. At the end of the course the teachers still lacked fluency with mathematics and were far from having secure subject knowledge. However, the teachers overcame some difficulties they had with mathematics in the past and by immersing themselves in learning mathematics, they felt more secure and confident in their mathematics and teaching of it. These teachers came to appreciate and understand mathematics, and relate to it in a more personal manner. Familiarity with and learning of new mathematics topics on the course increased their confidence in themselves as learners of mathematics.

11.2.3 Two cases from Australia

Across Australia, about 21% of classes in years 7-10 (13-16 year olds) are taught by out-of-field teachers. For STEM subjects the figures are as follows: Mathematics, (21%), Biology (14%), Chemistry (18%), Physics, (23%) and General Science (10%), with the majority being teachers with less than five years experience (Weldon, 2016). Price and Hobbs (2014, p.11) claimed that, in some secondary subjects,

"Australian students are more likely to be enrolled in schools with a lack of mathematics and science teachers than other OECD countries." They also presented data from numerous other reports showing estimates of those teaching out-of-field in Australia ranges from 15-25%, with an alarming 38-50% suggested in mathematics and physics. One of these reports (McConney & Price, 2009) described the situation in Western Australia (WA) where out-of-field teaching was "higher in Catholic and Independent schools and considerably higher in country schools across all sectors" and "teachers teaching out-of-field had over 21 years of experience – calling into question conventional wisdom that it is often new teachers assigned to teach out-of-field".

This section explores the second of the three approaches to dealing with out-of-field teaching (mentioned in the introductory section of this chapter) through the provision of PL programmes for out-of-field teachers in Victoria and Tasmania.

11.2.4 The case of Australia – with a focus on Tasmania

Along with the growing national and international emphasis on the need to improve the student retention and interest in Science, Technology, Engineering and Mathematics (STEM) subjects in schools, due to their perceived links to national prosperity (Marginson et al., 2013; Office of the Chief Scientist, 2014), the Tasmanian Context of the PLI Programme

According to Weldon (2016), the Northern Territory (at 40%) has the highest proportion of teachers in years 7-10 teaching out-of-field in Australia, followed closely by Tasmania at 37%. Of approximately 230 government schools in Tasmania, about 198 (86%) would be classed as rural or regional with many of these considered remote according to the criteria used in the SiMERR[2] Report (Lyons et al., 2006). (Note this does not include private schools).

The University of Tasmania (UTAS) is the only university in the state of Tasmania. The Tasmanian Department of Education approached the University of Tasmania in 2015 to develop a professional learning initiative (PLI) program designed to up-grade the skill and knowledge of secondary teachers currently teaching out-of-field in science and mathematics. This section explores the evolution of the design and effectiveness of the PLI program which was developed and conducted in July-October, 2015.

Structure of the PLI Programme

[2] Science, ICT, and Mathematics Education for Regional and Rural

While the PLI is a relatively small programme compared to the scale of some others discussed in this chapter, it illustrates a practical example of how a professional development programme was conceived, developed, implemented and modified to address a pressing concern about out-of-field teaching. The Department of Education supported the PLI programme financially by releasing the teachers from all teaching duties for the10 weeks of term 3 and covering travel, accommodation costs associated with their participation.

The primary purpose of the PLI programme was to support teachers who were teaching out-of-field in science and/or mathematics in schools at that time, and who had at least five years of teaching experience. Initial discussions with the Faculty of Education about the structure of the PLI programme were held at managerial level, and it was not until later the academics who would be developing and teaching the programme were brought into the discussions. The participants were to be awarded credit towards a post graduate qualification on successful completion of the PLI programme. In the form of two post-graduate units, one in science pedagogy and one in mathematics pedagogy to the selected participants.

Based on the literature concerning good PL practice for teachers, the academics requested a modification to the structure by suggesting that the participants retained access to at least one class during the PLI programme to enable an active learning approach to try out ideas from the programme with their students and reflect on their experiences, with the support of peers and their academic leader in a safe and supportive environment.

As the preparations for the PL progressed through the early part of 2015, a political desire to be seen to address the shortage of specialist teachers led to pressure to change to the scope of the project. The goal was to promote the participants as 'specialist' teachers of mathematics or science, even though they would not meet the qualification requirements of the Registration Board to be categorized as such. In addition, this effectively doubled the workload for both the academic staff, tasked with the development and teaching of the PL programme as well as for the participating teachers. The Faculty was required to proceed with the revised PL programme, despite objections from the academic staff, and to consider how it might be improved in subsequent years.

Recruitment practices for the Professional Learning Initiative (PLI)

The Department of Education called for expressions of interest from teachers who were teaching science or mathematics out-of-field in government schools and who had at least 5 years teaching experience. Those selected were to be enrolled in four units of science (or mathematics) to be completed in two blocks of 5 weeks.

Blended learning

As teacher participants came from schools all around the state, to minimise costs associated with travel to the university and accommodation, the programme was structured as a blended learning mode, with the teachers to attend 3 face to face sessions, interspersed with online learning activities through the universities online learning platform.

Assessment

The units were to designed to consider theory of teaching in science or mathematics, effective teaching strategies and to try these out in their classrooms, with sharing and reflection on their experience to occur in the face to face sessions at the university. Formal reflective summative assessment tasks were required chiefly based around classroom activities where the participants were to plan and try out an idea considered in the class sessions and to try it out with their class between sessions. In the following face to face session, they would present their observations and examples of student work to their peers and the academic staff for discussion and reflection upon their experiences, and consider what they might change in the next phase of their learning.

Evaluation of the PLI Programme

For evaluative purposes, and due to the innovative nature of the program, a research project was established to study the effectiveness of the PLI Programme. This used an emergent methodology and a mixed methods approach to data collection, in the form of pre and post questionnaires (adjusted slightly for participants according to whether they were teaching science or mathematics), pre-post interviews, assessment student artefacts, planning documents, observations and communications (including email) to explore the effectiveness of the programme. Ethical issues associated with conducting research while teaching the program was addressed by ensuring the teachers that their participation was optional and had no bearing on their assessment. In addition, an external evaluator and a research assistant were appointed to administer the research and collect the data during the teaching and assessment phase, so that the names of those teachers participating were unknown to the academic staff teaching into the program.

Summary of findings from the research

A total of 14 of the 23 participants agreed to participate in the research and responded to the pre-survey, but only six responded to the post survey. The key elements of their feedback are discussed below, using the framework and terminology from Garet et al. (2001).

Structural features

Form

There is evidence that changing the structure of the PLI programme had a detrimental effect on its effectiveness. For example, the increased workload put the teachers under a huge workload pressure. This was exacerbated in some cases through poor communication, particularly the school leadership did not have a clear understanding of the demands on these staff while undertaking the PLI programme. As a consequence, in some cases the context for learning was not as expected in the design. Some teachers were expected to maintain some of their non-teaching duties and others reported having been taken off all classes, and so had difficulty accessing to a class in which to explore their new learning. There was a long delay (three weeks) in the teachers gaining access to the university's online learning system and, as there had been no induction for the teachers prior to the PLI starting, this affected the ability of some to participate. The increased requirement to undertake four PG units in ten weeks, with two running concurrently over each of two sequential five week blocks compounded the workload pressure on the teachers and academics due to the need. As a result, there was little engagement with the online activities between classes.

Duration

The participants also reported that the tight and technical issues mentioned above meant there was insufficient time to try out many of the ideas and to help their students to adapt to the new ways of teaching. In terms of coherence, most of the teachers reported that the workload pressures were too great and others found ongoing demands placed on them while in their school to cover absences and perform other duties made it even harder to complete the tasks as expected.

To address these structural concerns there is a need for clearer communication between the stakeholders about the structure and expectations and to identify the needs of the teachers much earlier. Clearly also, as indicated by Garet et al. (2001), a longer *Duration* is needed for the PL to enable the teachers to explore changes to their practice and to alleviate many of the structural around the PL programme. In the next iteration it has been agreed to spread the PL over two terms (terms 3 and 4), with a break of two weeks between the terms, this essentially doubles the time to carry out the assessment activities and provides more tme to complete the assessment activities.

Core features

In terms the active learning aspects of the PL, the teachers found the tight timelines made it difficult to try out the ideas with their class and meant their students had insufficient time to adapt to the new ways of learning. The density of the programme also meant that the academics had difficulty giving feedback on their assignments in a timely manner.

Content

The participants all expressed a desire to gain a deeper understanding of the content of their out-of-field area, be it science or mathematics, however, this term "content" meant more than simply covering subject matter content. While the teachers were able to learn the content for a given lesson, they reported a lack of relational knowledge in the out-of-field discipline. They were looking for a deeper understanding of the curriculum, how the concepts were linked, how to plan for effective teaching. This is consistent with Luft et al. (2015) who stated that subject matter knowledge alone may not necessarily equip teachers to take an inquiry based approach. Clearly, the PLI needs to consider carefully how to support those teachers to build their pedagogical skills.

Active learning

Despite the organisational difficulties alluded to, the teachers valued the highly the on-going active learning aspect of the PL, where they shared with the lecturers and their peers what they were doing in classes and the ideas they picked up about teaching. They appreciated the insights into teaching which were presented and many said they would change their practice as a result.

When interviewed at least six-weeks after the programme, four teachers reported their students as being more engaged, and eight of the nine teachers who responded to the final evaluation reported benefits in terms of the understanding of pedagogy and a willingness to use more student-centred approaches in their teaching.

To improve the learning opportunities, the assessment activities in the PLI need to be more integrated across the four units, although university course regulations may not make this easy to achieve. In addition, as teaching in a class forms a key part of the assessment, the academics designing the course need to ensure how the assessment tasks are designed to be adaptable to different subject matter and year level groups.

Coherence

Coherence would touch on support and context of the learning. Several participants said they experienced a lack of support from their school and some resentment from colleagues not involved in the program suggests that some of these teachers remains on the periphery of the legitimately science-trained teachers. These teachers took on the role of out-of-field teaching for a variety of reasons. Most saw an opportunity to improve their career options others were given little choice but to teach out of their field due to local needs of the school. Three teachers reported that their colleagues were not necessarily supportive of their participation in the PLI.

This indicated that the support for the participants varied considerably from school to school. Research indicates that school-based support is essential for the teachers to gain the most a PL program (Luft et al., 2015). Attention needs to be paid to building teachers' capacity to teach effectively in the out-of-field discipline, and this is affected by the school culture within which the teacher operates. However, limiting support to colleagues in the local school context would not necessarily challenge pre-conceived ideas about the out-of-field discipline area, and may perpetuate didactic teaching approaches and limit exposure to more progressive teaching approaches. In some cases, the progressive ideas promoted within the PLI clashed with the more traditional teaching approaches used by the in-field teachers in some schools. This also points to the need for greater coherence around the selection process and consideration of how the PLI can be designed to benefit other staff within the school, not just the individual who happens to attend. Should there be some requirement to report on or share what is happening with the rest of the science (or mathematics staff)? After all, these staff may be supporting the absence of the participant in some way, especially in rural schools.

Developing a new professional identity as a teacher of science or mathematics is one in which the teachers will need the support of their school administration, the university and ideally their colleagues (Hobbs, 2013; Luft et al., 2015). Unfortunately, the tight timelines associated with the initial iteration of the PLI meant that little attention was paid to the identity issues and this will need to be emphasized more in the next iteration.

The teachers of science reported a lack of science related professional development opportunities, compared to mathematics, which seems to be reflected in the concentration on mathematics in the other case studies. They also commented on the difficulties of coming to terms with the various disciplines within science (e.g., chemistry, physics and biology).

Recommendations

1. The purpose of the PLI programme as offering support to teachers teaching out-of-field needs to be reiterated, and it raises the question of what is meant by the content knowledge they required.

2. The term “Content knowledge” should be understood in the broader sense of incorporating a relational understanding of concepts and an ability to plan and implement student-centred teaching practices, rather than perpetuating didactic content driven approaches.
3. Supplementary programmes would be needed develop these teachers as subject “specialists”, with the full range of qualifications that implies.
4. There is a need for more clarity around, and better communication of, the purpose of the PLI programme and the associated expectations so that all the stakeholders, including the principals understand the expectations and support the outcomes of the PLI programme.
5. The PLI programme needs to be modified to include an induction session to orient the students to the university systems and the expectations and the *Duration* of the PL programme needs to be doubled to at least twenty weeks (or two terms). The blended learning provides an opportunity to build a learning community and overcome the remoteness, but it needs to be more thoroughly incorporated into the programme.
6. The associated administrative and technical issues need to be sorted out early, with some induction provided to the teachers into the expectations and the university systems.
7. In terms of the design of the learning (Core features) the induction mentioned above and the assessment tasks should include sessions where participants consider their identity as teachers and reflection on how the current identity changes to incorporate themselves as teachers of the out-of-field discipline.
8. The assessment tasks across the four units need to be more integrated and should be modified to include some work on developing a professional identity within their chosen subject, as this leads to improved content knowledge.
9. To maintain their on-going professional development, it is likely that the participants would need on-going support in terms of discipline related professional development and mentoring, but this needs further research to explore the longer term gains.

11.2.4 The Case of Australia - with a focus on Victoria

In 2016, Deakin University developed a programme to support out-of-field teachers in STEM pedagogy. Initiated through a funded grant from the Victorian, Department of Education (DET), thirty schools from low socio-economic areas were offered the opportunity for a principal (or leadership member) plus two teachers from year seven and eight to participate in a comprehensive professional learning programme running across two years. The DET funding provides ‘buy out’ time for all teachers to participate as well as provides the teachers’ fees for the academic study for the Graduate Certificate of STEM Education.
The programme operates with five specific features:

- A **guiding vision** that includes innovative pedagogies in the separate STEM disciplines and inter-disciplinary approaches.
- An **induction program** that involves the alignment of teachers' current beliefs and practices with exemplar STEM practices, and exploration of change directions.
- **Principals' workshops** that focus on STEM Education practices and possibilities and how these can be effectively supported. These workshops can provide entry into the Deakin Graduate Certificate of Education Business Leadership
- A purpose-built **Graduate Certificate of STEM Education** that moves teachers from personal knowledge building to leading, and monitoring change in schools. This will be supported by trained STEM mentors, and explicitly linked to the Principals' workshops.
- A **research and monitoring program** whereby school and teacher change processes will be tracked and analysed, and fed back into schools and the units to support ongoing innovation.

With a focus on STEM, many of the teachers undertaking the STEM Catalyst Programme will be teaching out-of-field in one of the areas. With an appreciation of the complexity surrounding out-of-field teaching, such as a teacher's level of experience and their perception of their competence and confidence, a supportive school culture and a sympathetic leadership are essential for fostering teacher learning and maintain teacher well-being. These insights inform all parts of the program, especially the principals' workshops. Through the programme, teachers are supported to examine their own understandings, beliefs and practices and then to explore new and innovative ways of engaging students in STEM practices, collaborating within and across schools. The out-of-field teachers will be supported to adapt their existing expertise to STEM disciplinary cultures and practices. 'Leading change' programs will support teachers and principals to gain insight into exemplar STEM practices and to lead improvement in STEM provision in their schools. The programme is delivered over a two year period to the DET cohort of teachers.

Induction Program

Prior to commencing the Graduate Certificate of STEM Education, the 3-day induction program was initiated. This involved representatives from DET, principals and teachers participating in a 'STEM Vision' framework. DET representatives followed the development of the STEM Vision as schools (teachers and principals) worked together to develop and plan their own STEM vision. Using a workshop environment, participants were introduced to exemplars of successful implementations of STEM visions in schools. Teachers gained insights into and shared their experiences in developing a STEM Practice. They explored how their different roles contribute to their schools' STEM vision. Principals, recognized as the drivers of

change in their schools, were presented with opportunities to reflect on their leadership practice and how to support STEM priorities for their schools.

Induction outline

Day 1: Moving from current practice to a STEM focus

- All participants session
- Catalysts-only breakout session
- Principals-only breakout session

Day 2: Exploring the Possibilities for school-based STEM initiatives

- Inquiry through representation
- Approaches to problem-solving in mathematics
- Design/challenge-based learning

Day 3: Developing a school-based STEM vision

- Resourcing for schools 1: Digital learning environments (Digital technologies in Vic Curriculum)
- Resourcing for schools 2: School industry and community partnerships
- School-based STEM vision development

The DET wanted to ensure that the academic workload associated with undertaking a university unit of work would not be overwhelming for the teachers. The university structured the program to allow a slow progression.

Principals' Workshops

These were run as one day interactive workshops to introduce Principals to STEM Education practices and possibilities and how these can be effectively supported. Principals were given an overview of the requirements of the Graduate Certificate of STEM Education and what their teachers were expected to complete as part of that.

The Graduate Certificate of STEM Education

The Graduate Certificate of STEM Education is specially designed to meet aims of this initiative. It is not designed to teach content knowledge. Units will equip teachers with deep knowledge of the Victorian STEM Curriculum, including Digital Technologies, reflect on their teaching and leadership practice in STEM, learn more about STEM pedagogies that support student engagement and learning, and enact and research these practices in their classrooms and with STEM colleagues. Specifically, for out-of-field teachers, material related to developing themselves as out-of-

field teachers is embedded in each unit and additional support is provided (see below under Research and monitoring programme).

The units are:

- Unit 1: Knowledge, Learning and Learners in STEM
- Unit 2: Designing Contemporary STEM teaching and learning programs
- Unit 3: Researching Your Practice as Teachers and Leaders of STEM
- Unit 4: Supporting and Leading Development of Communities of STEM Practice

Successful completion of the units will provide credit towards a Master of Education at Deakin University.

Unit Delivery

The delivery of each unit is considered 'mixed mode' (blended). Students are enrolled into one unit at a time and this is undertaken both as intensives and through an online environment. There are 5 days allocated to intensive teaching – broken down into a 3 day initial intensive (aligned with the Principals workshop), followed by a 2 day intensive closer to the end of the semester of study. This allows teachers to have significant information about the academic unit and also allows them to 'try for themselves' aspects of their learning from one intensive to the next. Each assessment piece in each unit is designed to fit into a school curriculum, to add value to the teaching, rather than adding unnecessary extra work to the teacher.

Research and Monitoring the Programme

This involves the tracking and analysis of school and teacher change processes, which are fed back into schools and the units to support ongoing innovation. The research component involves the development of case studies of 8 selected schools so that in-depth understanding can be gained about how schools develop their STEM vison and implemented sustainable and successful change to students' STEM outcomes. Due to the innovative nature of this programme, the methods for support are emerging through the monitoring aspects. The monitoring component involves discussion and feedback from teachers and principals through the use of a group Facebook site and through the use of a School Liaison Officer (SLO). The role of the SLO is to keep in touch with schools regularly via email and school visits and to assist with any aspect of school change/curriculum matters. The SLO is a previous teacher of STEM subjects who searches answers to teachers' questions – saving them time and effort. In addition to this, a number of other measure of teacher and school development are undertaken:

- a pre programme survey

- mapping of teacher capabilities using a STEM component mapping tool developed specifically for this purpose.
- collection of teacher artifacts: school vision statements, planning documents, students attitude survey (aggregated results)
- post programme survey

11.2.4.6 Recruitment practices

For this specific initiative, the DET sent out invitations to the 30 schools identified as low 'socio-economic status' (SES) across the state of Victoria. The school had to apply to be part of the program with the recognition of compliance with the defined elements of the participation: principal and teacher participation. Teachers involved in teaching mathematics, science, technology, or STEM, in year seven and eight (children aged 12-14) were offered the opportunity to participate, although it is uncertain how much of the detail of initial information was understood. Often with other professional learning structures, teachers are not expected to 'study' or undertake additional workload to complete the professional development. The expectations of an academic qualification are different

Programme Evaluation

The programme is being evaluated in a number of ways. Through monitoring and research, the programme will be evaluated for components such as teacher development, school change processes and leadership in STEM. Whole-cohort data collection will consist of the collection of artefacts developed by the teachers across time. In parallel with this, in-depth case studies of 8-10 schools, featuring interviews with all stakeholders and artefact collection, will be developed and used in a cross-case analysis. This information will be combined with the individual unit evaluations which occur as part of the university procedure at the end of each unit. The evaluation of each unit considers students' satisfaction with the teaching, materials' quality and provision, aspects enabling student learning.

Initial evaluation findings suggest that the role of the SLO has taken on much greater importance than originally predicted. The feedback from the STEM teachers is that they find the SLO staff crucial for providing on-the-ground support, guidance and materials. Considering that the teachers involved include a mixture of experienced and non-experienced teachers who are meant to support each other in their paired roles, this finding was quite surprising. However, the added element of completing course-work assignments related to their course, has stretched the teachers' capacities to deal with new curriculum developments in STEM without further support.

The first unit of the course was one which required teachers to develop understanding of theoretical perspectives on learning theories. The subsequent unit evaluation indicated some interesting trends. The more experienced teachers did not value the time spent on discussion of theories and wanted specific advice and material to move more quickly in the school environment. However, the younger, less experienced teachers appreciated the slower approach and having the opportunity to apply theory to their practice – to better understand why they were doing it. This information will be fed into the subsequent units so that they can be developed along lines to accommodate both groups of teachers.

Another aspect of evaluation is the appointment, by the Department of Education (Victoria) of an independent evaluation company. Its role will be to make contact with all schools and teachers to undertake a full evaluation of the programme and its components, including the Graduate Certificate of STEM Education.

At the completion of this programme, a detailed report will be written by the provider of the professional development, providing insight into all aspects of the programme. This information will be used to support a revised version of the professional development and the delivery of an ongoing Graduate Certificate of STEM Education, in online mode only and open to all teachers.

11.3 A Cross Case Comparison of the International Case Studies

We applied a cross-case analysis to the international case studies to facilitate a comparison between commonalities and variances in events, processes and activities that inform the evaluation of the cases. As indicated earlier, we considered components of analysis derived from previous literature - the features of effective professional development as outlined in Table 11.1. Normally, cross-case analysis extends understanding beyond the single case to the numerous, allowing for the delineation of a variety of factors that are contributors to the results of a case; to explain why differences and similarities are evident across cases; to understand perplexing or distinctive case findings or; to extend concepts, hypotheses or theoretical positions uncovered or developed from an original case (Khan & Van Wynsberghe, 2008). For this cross-case analysis, we use direct case knowledge generated from the ‘thick description’ of each professional development setting, to support further discourse on the professional development models. It is this form of qualitative, comparative research design that allows the distinctive traits of multiple cases to support reflections on similar or contrasting findings (Bryman 2012) and allows us to develop a framework for effective professional development for out-of-field teachers (see Figure 11.1).

From reviewing each of the international case studies detailed in this chapter thus far it is clear that there are many similarities and indeed differences between the out-of-field professional development programmes in terms of the: context and goals, structure, recruitment practices and the means through which the quality of

the programmes is measured. The following characteristics are present across country case study for each of the parameters being used for comparison:

11.3.1 Context and Goals

- All programmes are government funded and aim to specifically tackle the issues of out-of-field teaching in the area of STEM education in an attempt to improve the current teaching situation within these disciplines due to them being linked to the economic prosperity of a country (Marginson, Tytler, Freeman & Roberts, 2013; Office of the Chief Scientist, 2013).
- All programmes came about due to the incidence of out-of-field teaching being investigated in some formal way in their respective countries.
- Programmes were developed for different purposes. Some aimed to support teachers currently teaching out-of-field (e.g., Australia) to be better teachers, while others aimed to up-skill the out-of-field teachers into specialist subject teachers (e.g., England).
- The case study from Victoria in Australia was unique in that it only offered the up-skilling programme to teachers from lower socio economic schools.

11.3.2 Structure and Design Features

In terms of the structure of the programmes there was a larger variety across countries with some similarities present. The design of the programmes should be aligned with the desired outcome of the PL. In the Tasmanian case, late changes to the design due to political imperatives caused organisational difficulties and affected the quality of the learning.

- Some of the programmes were 2 year part time with a level 8 discipline specific qualification as the outcome for a successful candidate while others involved 40 days of engagement with the programme and resulted in the teacher gaining an additional specialism in a specific discipline.
- All programmes, with the exception of the Irish case, involved having some form of school based discipline specific mentor and also enabled out-of-field teachers engaging with the programmes to get some ‘buy out’ time from school with some additionally supporting the engagement with the programme by providing an addition £5,000 in teachers’ salaries for that year (the case of England).
- All programmes required the support or at least approval from the school principal/management, with the Victorian case study detailing that the programme also included sessions for the principals as well as the out-of-field teachers.

The programmes also have some contrasting elements when it comes to their design features:

- The focus of each other programmes varies considerable. Some programmes specifically detail that that they are not focussed on teaching content knowledge but rather focussed on curriculum, leadership, pedagogy and research (the cases in Australia) and some focus on both mathematics specific content knowledge and discipline specific knowledge (the case in Ireland and England). These variations in design features could be seen to be reflected in the time over which the programmes are run, however variations exists even across programmes which run over the same time frame.
- The blended learning format is common across all programmes often being mentioned in the context of reducing travel time for participating out-of-field teachers.
- The assessment strategies for the programmes vary depending on what the focus of their design features are (i.e. focus on content only or pedagogy and school practices only or both) however all programmes have some assessment which involves out-of-field teachers attempting to bring their learnings to their classroom and reflect on their practice as out-of-field teachers.

11.3.3 Recruitment Practices

In most country case studies the recruitment process began with the government calling for an expression of interest from out-of-field teachers to come forward to engage with the professional development programmes with the exception of the case of Victoria where 30 socio-economically disadvantaged schools were invited to apply to take part. All programmes detailed in the case studies in this chapter insisted that school principals sign off on teachers within their schools who had applied as being out-of-field and in some cases ensuring the support that they and the school would provide the participating teachers while engaged in the programme (the case of the England). In the case of Victoria, the principal had to sign off on the 'whole school' involvement in the program (principals, Catalyst teachers and other teachers as necessary). In no case was the out-of-field teacher obliged to take up a place on a professional development programme however some of those who did volunteer may have underestimated the level of work and commitment which was involved.

11.3.4 Programme Evaluation

There is some variation with respect to the extent and weighting that different professional development programmes currently place on evaluation:

- In the case of Ireland the presence of a full time academic co-ordinator allows for real time feedback about the programme to be reported from nationwide staff and students with the benefit that real time changes can be made to improve practices if needs be.
- Many programmes implement a general programme review where participants can detail their overall satisfaction with different aspects of the programme. This appears to provide general useful information for advancement of the programmes.
- Some evaluations involved interviewing a small number of participants or discussion and feedback from teachers via an online forum.
- The Irish professional development programme evaluation involved a very extension evaluation of pedagogical and content knowledge of out-of-field teachers through pre and post programme completion which is discussed in detail in Chapter 5. There is also an examination of the effectiveness of the mathematics specific pedagogy workshops within this programme and a doctoral thesis currently looking into teacher identity upon programme completion.
- One programme had an external examination of the programme in the form of a monitoring committee which consisted of government members and involved report writing on the programme effectiveness over time (the case of Ireland).

11.3.5 Programme Effectiveness

Several common themes emerged in terms of programme effectiveness from the case studies presented in this chapter:

- A very strong theme was one which found that the discipline specific pedagogy elements of the professional development programmes to have a strong impact on teachers opinion of the importance of and willingness to implement student centred/ inquiry based teaching as opposed to a more didactic traditional approach to teaching STEM subjects. Enquiry learning was deemed as something that was worth the effort as practice in the classroom showed improvements in student engagement to many of the professional development programme participants. Some evaluations demonstrated that participants found the pedagogy aspects of the programme to be the most useful in terms of developing ideas and strategies for the classroom and called for more of this. The research showed that

out-of-field teachers' focus changed from 'how to teach a specific topic' to learning and doing mathematics i.e. the teachers began to see mathematics as more than knowledge and skills.

- Another theme which emerged in terms of programme effectiveness was participants' appreciation for the face to face aspects of their respective programmes i.e. the spaces in which there was room for discussion and sharing of ideas whether it be mathematics content tutorials or sharing pedagogy experiences from the classroom.
- In spite of this appreciation for the face-to-face aspects of the programmes the evaluations also noted that the blended format in which some material is presented on-line was seen as a positive by many as it enable the reduction in travel time.
- Participants across the country cases who successfully completed their respective professional development programmes appear to have reported embracing the significant challenges that all programmes seem to have presented. out-of-field teachers reported growth in their confidence as teachers of a particular discipline, increased inclination to take risks and learn from mistakes and a motivation factor relating to the status of become a specialist teacher.

There were also some common negative aspects of the professional development programmes across country cases:

- Some programmes did not focus on content knowledge and this is something which evaluation showed that out-of-field teachers would have preferred.
- A lack of coherency and support of the teachers engaged in the out-of-field programmes (no 'buy-out' from class time, poor leadership support/knowledge on what the professional development involved) resulted in a more challenging environment and larger stress levels on the teachers involved in the programmes.
- Several evaluations reported a professional development programme with a work load that was too heavy and rushed both in terms of trying to implement pedagogical practices learnt into the classroom and summative assessments. Many participants across programmes felt that a workload that was too heavy with a time frame that was too short was not allowing for success and in some cases students dropped out of programmes for these reasons.
- Problems with the on-line platforms not working from time to time seemed to have caused issues across the board also despite the support for the blended learning style due to its accommodation for those who had to travel long distances to attend class/lectures.

The comparison of the case studies across countries, and in particular the examination of the effectiveness of each of the programmes allows for some concrete ideas to be pulled together to determine what a framework for effective out-of-field professional development programmes might look like based on lessons learnt from existing structures. Such a framework will be discussed and put forward in the section which follows.

11.4 Towards a Framework for Effective Professional Development

As the reporting of the incidence of out-of-field teaching and indeed the development of programmes aimed at upskilling out-of-field teachers is a relatively new phenomenon, the case studies presented in this chapter go some way in trying to determine what aspects of a professional development programme specifically designed for out-of-field teachers work and which do not. The comparison of characteristics and their perceived success of each of the country case studies presented in the previous section allowed for the pulling together of the most effective aspects of all programmes, along with caveats that should be born in mind, and these are presented in figure 1 which follows.

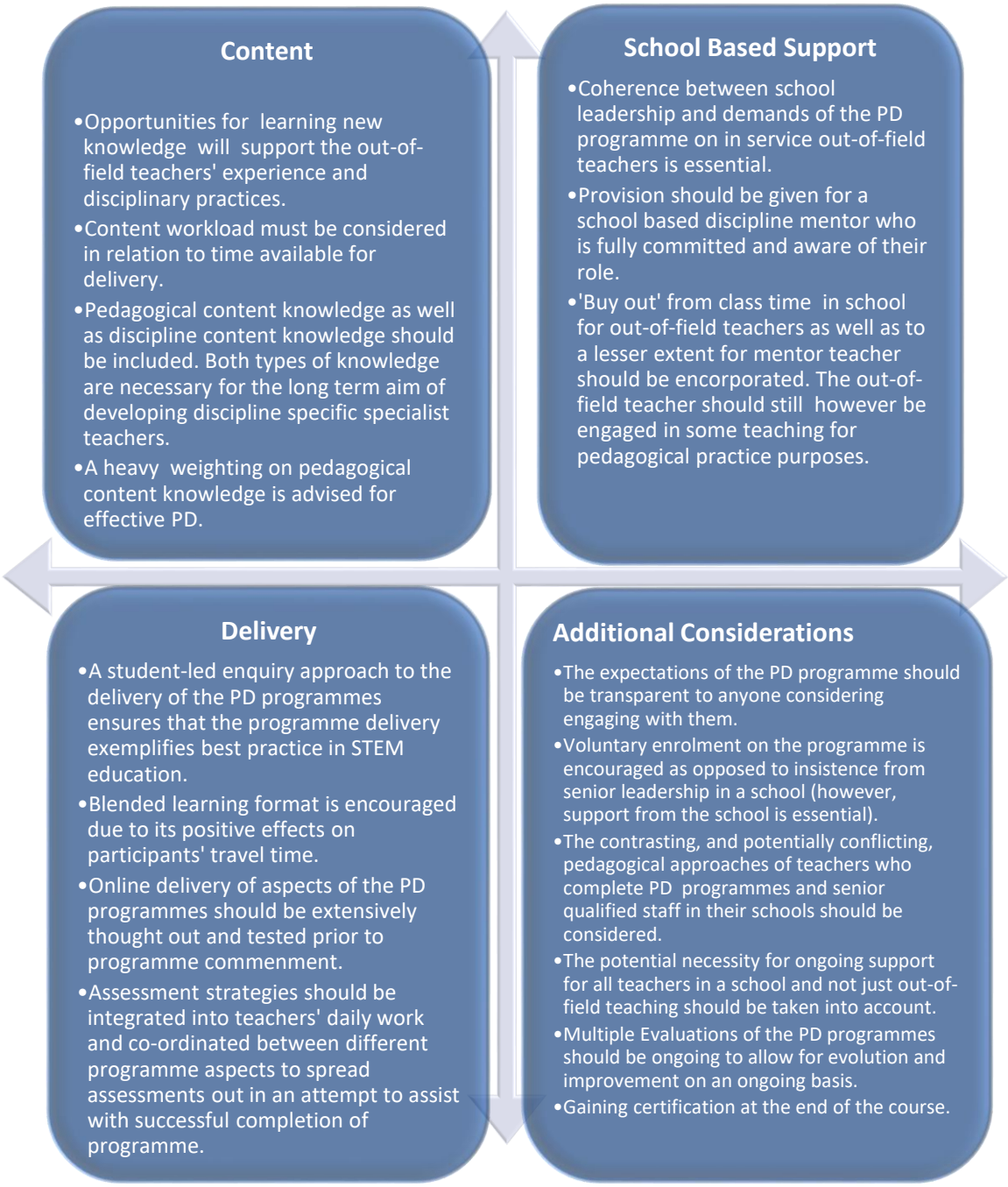
Content
•Opportunities for learning new knowledge will support the out-of-field teachers' experience and disciplinary practices.
•Content workload must be considered in relation to time available for delivery.
•Pedagogical content knowledge as well as discipline content knowledge should be included. Both types of knowledge are necessary for the long term aim of developing discipline specific specialist teachers.
•A heavy weighting on pedagogical content knowledge is advised for effective PD.
School Based Support
•Coherence between school leadership and demands of the PD programme on in service out-of-field teachers is essential.
•Provision should be given for a school based discipline mentor who is fully committed and aware of their role.
•'Buy out' from class time in school for out-of-field teachers as well as to a lesser extent for mentor teacher should be encorporated. The out-of-field teacher should still however be engaged in some teaching for pedagogical practice purposes.
Delivery
•A student-led enquiry approach to the delivery of the PD programmes ensures that the programme delivery exemplifies best practice in STEM education.
•Blended learning format is encouraged due to its positive effects on participants' travel time.
•Online delivery of aspects of the PD programmes should be extensively thought out and tested prior to programme commenment.
•Assessment strategies should be integrated into teachers' daily work and co-ordinated between different programme aspects to spread assessments out in an attempt to assist with successful completion of programme.
Additional Considerations
•The expectations of the PD programme should be transparent to anyone considering engaging with them.
•Voluntary enrolment on the programme is encouraged as opposed to insistence from senior leadership in a school (however, support from the school is essential).
•The contrasting, and potentially conflicting, pedagogical approaches of teachers who complete PD programmes and senior qualified staff in their schools should be considered.
•The potential necessity for ongoing support for all teachers in a school and not just out-of-field teaching should be taken into account.
•Multiple Evaluations of the PD programmes should be ongoing to allow for evolution and improvement on an ongoing basis.
•Gaining certification at the end of the course.

Fig. 11.1 A framework for effective professional development (PD) programmes for out-of-field teachers.

The framework detailed in Figure 11.1 outlines characteristics and elements for consideration for effective professional development programmes for out-of-field teachers; it also takes in the components of the meta-synthesis of effective professional development as outlined by Hawley and Valli (1999). In this meta-synthesis the authors detail a need for the content of professional development to focus on what students learn and addressing students' difficulties. This would be covered in the discipline specific pedagogy aspect of effective professional development for out-of-field teachers. It also calls for professional development to be based on an examination of the gap between students' actual performance and curriculum goals and standards for teaching. The focus on student centered learning and teaching for understanding as outlined in the framework proposed in figure 1 provides a platform for this gap to the closed. Hawley and Valli (1999) call for professional development to be primarily school based and to involve teacher identification of what they need to learn and develop – the framework for professional development programmes for out-of-field teachers calls for out-of-field teachers to still be engaged in their everyday teaching and to have some 'buy out' from class time which allows for these aspects of effective professional development to be fulfilled. All other aspects of Hawley and Valli's (1999) meta-synthesis of effective professional development are possible within the existing proposed framework for the development of effective professional development for out-of-field teachers such as: being organized around collaborative problem-solving (pedagogical aspects of the programmes should involve this), it should be continuous and on-going providing internal and external support (the presence of a school based mentor system and the consideration for ongoing support for all school teachers allows for this), it should involve multiple evaluations (as seen in the Irish case study and incorporated in the framework in Figure 11.1), and finally it should provide an opportunity to gain an understanding behind the theory underlying the knowledge and skills being learnt (pedagogical aspects of the programme would provide a platform for this along with the delivery of the programme using an inquiry approach) .

11.5 Conclusion

This chapter brings together current international developments in the area of the professional development of out-of-field STEM teachers. Using research literature, several models of professional development from the Republic of Ireland, England and Australia (four in total) were interrogated against proposed examples and components of effective professional development for teachers. A cross case analysis was undertaken, searching for themes related to similarities and differences across

the cases. The examination of the models, each of which included results from evaluation studies, detailed key components for effective professional development models for out-of-field teachers. These key components were similar to the features of effective professional development programs highlighted in the literature, but also included aspects that were not as well defined and were particular to the 'out-of-field' teacher. An international framework for effective teacher professional learning for out-of-field teachers was developed using data from the four cases. In the analysis of the four models, key insights and new knowledge were gained in relation to the needs of out-of-field teachers' professional learning. These are summarized below:

- Teacher quality requirements recognise that the teachers assigned to teach subjects other than their own specialist subject need to be targeted and supported with continuing professional learning opportunities. The common finding of the studies presented in this chapter is that this type of professional learning requires substantial support at all levels.
- Subject knowledge and identity-related issues were highlighted to be amongst the factors affecting the professional development and retraining of high-quality out-of-field teachers. There isn't a quick-fix re-training of an out-of-field teacher to become a subject specialist teacher.
- Developing the out-of-field teachers as a subject specialist is linked to re-shaping their identity as teachers of their out-of-field subject. Professional development needs to attend to teacher identity development.
- professional development that promotes engagement with school curriculum content (e.g., mathematics) and alignment with the particular teaching practices (e.g., mathematics) contributes to teacher identity in that area.

For each of the four case professional development programmes studied, the aim was to support teachers to become better teachers in their out-of-field area by building their identity as teachers of the out-of-field discipline as a continuous process (as they teach) and by allowing them to gain content knowledge and pedagogical skills as they grow. This is a distinctly different approach to that where, for specialist teachers, the aim might be to further develop specialist knowledge to meet accreditation standards.

As with any comprehensive research or analysis of practice, findings often point to ways to move forward or recommendations for the future. There are significant implications from the study of the four cases, implications which have impact on both policy and practice. With most professional development being highly reliant on contextual factors that influence its impact and uptake, the programme needs to be both designed around its purpose and be specific to the teachers' needs and situations surrounding the teachers. Developers of professional development need to be clear on what they are trying to achieve and this would require a close examination of the context, and local and institutional policies and practices. From the cross-case comparison and analysis, recommendations were framed as follows:

- At the school and policy levels, provision of high quality in-service professional learning opportunities needs to occur through professional development and funded retraining programs.
- Funding, time and space for out-of-field teachers are needed to allow them to adapt to and understand new teaching approaches to maintain quality teaching. This will assist with the retention of teachers, avoiding the loss of teachers due to stress created from teaching outside their specialism
- School leaders need support to appreciate the demands of out-of-field teaching, and to foster communities that respect and support continuous learning of teachers.

In designing and delivering the training, schools should work with strategic partners (for example Higher Education Institutes, teacher training institutions, and national centres of excellence). All staff directly involved in the development and delivery of training of out-of-field teachers should have a deep understanding of both the specialist subject required for high quality teaching of the subject and of how teachers develop this knowledge. Considering that out-of-field teachers are already working in potentially stressful situations, any programme should offer teachers some form of professional recognition. Such courses could offer professional awards (such as Masters level credits, or a professional award/certification) nationally recognized so that out-of-field teachers could use them as evidence as professional development in their new subject specialism. Professional development offered within a school or through external courses need to offer both discipline and pedagogical knowledge, so that the out-of-field teacher has the opportunity to develop their own pedagogical content knowledge.

Teachers are continually learning and developing in their profession. In particular, out-of-field teachers face this 'learning imperative' in a much more concrete and intense way on a daily basis. Professional development, as outlined in the framework above, offers opportunities to out-of-field teachers to change their thinking, knowledge, skills, and approaches to teaching in an informed and continuous way.

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