What characteristics of secondary mathematics professional development courses do teachers find effective?

being a Thesis submitted for the Degree of MEd by research

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by

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Acknowledgements

Abstract

Declaration and word count

Contents

0. Key findings for those who design and deliver professional development for mathematics teachers 10

1. Introduction: professional development for mathematics teachers 11
   1.1. Wider context of secondary mathematics education 11
       1.1.1. The current situation of secondary mathematics education in England 11
       1.1.2. A period of rapid curriculum and qualification change 13
   1.2. Professional development for teachers 14
       1.2.1. Importance of professional development for teachers 14
       1.2.2. Perspectives on the purpose of professional development 15
       1.2.3. Current landscape of teacher professional development 15
       1.2.4. Recruitment and retention of mathematics teachers 16
   1.3. MEI as the context for my research 17
       1.3.1. My role at MEI 19
   1.4. Other influences throughout the course of my research 20
   1.5. Positionality 21
       1.5.1. Background of the researcher 21
       1.5.2. Values and beliefs of the researcher 22
   1.6. Expectations 23
   1.7. Research aims and questions 23
       1.7.1. What aspects of professional development sessions do teachers find effective and why? 24
       1.7.2. Are there common themes for different groups of teachers? 24
   1.8. Definitions of key terms used in this research 25
   1.9. Outline of thesis 25

2. Literature review 26
2.1. Professional development within the other professions in England
2.2. Statutory requirements of professional development for teachers
2.3. Subject associations and advisory bodies
2.4. Quality assurance of standards for mathematics teacher professional development
  2.4.1. Principles document from the Advisory Committee on Mathematics Education
  2.4.2. The CPD standard
2.5. Professional development for teachers: an emerging body of knowledge
  2.5.1. *What Makes Professional Development Effective? Results from a National Sample of Teachers* (Garet et al., 2001)
  2.5.2. *An Enquiry Into Continuing Professional Development for Teachers* (Gray, 2005)
  2.5.3. *Teacher Professional Learning and Development. Best Evidence Synthesis Iteration (BES)* (Timperley et al, 2007)
  2.5.4. “*Researching Effective CPD in Mathematics Education (RECME)*” report (Back et al., 2009b)
2.6. The nature of professional development
2.7. Characteristics of effective professional development
  2.7.1. Sustained duration
  2.7.2. Content
  2.7.3. Active
  2.7.4. Embedded in practice
  2.7.5. Use of research
  2.7.6. Opportunities for reflection
  2.7.7. Collaborative
  2.7.8. Nature of delivery
2.8. How the effectiveness of professional development is measured in the literature
2.9. Conclusion of the literature review

3. Methodology
3.1. Philosophy and methodology
3.2. Research approach and methods

3.3. Strategy and research instruments

3.3.1. Research instrument: Participant general information questionnaire

3.3.2. Research instrument: Participant questionnaire on effective professional development

3.4. Professional development lead questionnaire

3.5. Data collection: questionnaires

3.5.1. Planned professional development courses

3.5.2. Planned timeline of data collection

3.5.3. Treatment of questionnaire responses

3.5.4. Categories for a grounded theory approach

3.6. Data collection: interviews

3.6.1. Rationale for including interviews

3.6.2. Interview process

3.6.3. Interview questioning

3.6.4. Treatment of interview responses

3.6.5. Dual role in the final interview

3.7. Validity, reliability and generalisability

3.8. Ethical considerations

3.8.1. Teacher participants’ permission

3.8.2. Privacy

3.9. Summary

4. Findings

4.1. Profile of the teacher participants

4.1.1. Gender

4.1.2. Age

4.1.3. Length of career (teaching)

4.1.4. Length of career (teaching mathematics)

4.1.5. Teaching role

4.1.6. Mathematics qualification

4.1.7. Teaching qualification

4.1.8. Age of students taught
Table 4.1 Summary of Teacher participants’ general demography and professional background

4.2. Teacher participant responses to the questionnaire
4.2.1. Categories emerging from the questionnaires
4.2.2. Ineffective aspects emerging from the questionnaires

4.3. Detailed findings
4.3.1. Participants on GCSE-level mathematics course versus those on the Advanced level mathematics course
4.3.2. Female versus male response
4.3.3. Age of teacher participants
4.3.4. Length of time teaching
4.3.5. Length of time teaching mathematics
4.3.6. Identity as a mathematics teacher
4.3.7. Mathematics qualification
4.3.8. Teaching qualification
4.3.9. Age of students taught

4.4. Findings from the interviews
4.4.1. Treatment as actually happened (vs that to as described in methodology)
4.4.2. Interview 1
4.4.3. Interview 2
4.4.4. Interview 3
4.4.5. Themes emerging from the interviews

4.5. Comparison with established findings from the literature
4.5.1. A focus on the use of digital technologies as constituting an aspect of effective professional development

5. Conclusion
5.1. What do teacher participants find effective?
5.1.1. Doing mathematics
5.1.2. Receiving resources
5.1.3. Opportunities for discussion
5.1.4. Opportunities for reflection
5.1.5. Pedagogic approach is valued
5.1.6. Mathematics approach is valued
5.1.7. Characteristics of the Professional Development lead
5.1.8. Creating a safe learning environment
5.1.9. Potential aspects of the professional development that should be minimised

5.2. What aspects should be considered for different groups of teacher participants?
5.3. A dilemma for the professional development lead
5.4. Implications for my future work
5.5. Limitations of this research
5.6. Opportunities for further research

6. Bibliography

7. Appendices
Appendix A: Permission to research from Chief Executive of MEI
Appendix B: Participant general information questionnaire
Appendix C: Participant questionnaire on effective professional development
Appendix D: Interview record
Appendix E: Image of the raw data spreadsheet

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Abstract

In this study, I investigate what characteristics mathematics teachers find effective in their professional development. The literature review reveals the significance of teacher professional development and its impact on quality of teaching and student experience. It also describes and offers a critique of an emerging body of knowledge of professional development for mathematics teachers.

I explore and analyse the experience of teacher participants, each engaged in one of three professional development courses for teachers of mathematics. The courses were managed by my employers, Mathematics in Education and Industry (ME). Two were led by my colleagues and one was led by myself. Three forms of data collection were carried out: a paper questionnaire of demographic and background details of the teacher participants; a paper survey of their views of effective (and ineffective) professional development activities experienced during the above courses; and, semi-structured interviews with small focus groups of self-selecting participants.

A classification system is developed to categorise and assess teacher participants’ qualitative responses. This system permits themes to emerge, to be identified and then analysed. The data collection reveals that the individuals forming the community of mathematics teachers on these courses varied widely in terms of professional background and career stage.

Significantly, the findings suggest that a number of aspects contribute to the effectiveness of professional development for mathematics teachers, as identified by the teachers themselves. Furthermore, some groupings of teacher participants on professional development courses present commonalities in terms of which aspects are most significant.

Finally, the thesis presents a number of implications for future practice in the design and delivery of professional development for mathematics teachers, and suggests a number of possible areas for further research in the future.
“That’s one of the things that I’ve definitely noticed … it’s all going back to feeling inspired and me getting excited about maths and that’s coming across in my lessons”.

“Jack”, mature trainee teacher.
Recommendations for those who design and deliver professional development for mathematics teachers

Include sessions on pedagogy
This is the most significant aspect and examples include learning about the pedagogy of teaching problem-solving; how to “be less helpful” when supporting students; managing group work; making connections between different areas of mathematics; and, questioning techniques.

Include opportunities and expectations that participants will do some mathematics
Use a variety of mathematical activities that engage participants at their own level of challenge and that value a rigorous mathematical approach.

Share resources
Include resources (including mathematical software) that are easy for participants to transfer to their own classroom and that are likely to be new to them. Teachers currently value resources that involve a real-life context or that involve the use of different mathematical representations.

Provide opportunities for discussion between participants
Allow time for discussions that arise as a natural result of the other activities. Also, facilitate participants working with different people throughout a training day. (Avoid lengthy or informal periods of “networking”).

Provide opportunities for reflection
This should include considering how an activity would need to be adapted for their own classrooms or time to create similar activities for other topics. Reflection should be structured. For example, beginning with an agreed timeline of a mathematics session was seen as helpful.

Delivery style
Lead Professional Development in a way that encourages critique and aim to have access to the latest information on changes to the curriculum, qualification and assessment.

Create a safe learning environment
Participants appreciate a training environment that encourages the sharing of ideas and risk-taking in order to bring about change in their beliefs and practice.
1 Introduction: professional development for mathematics teachers

In this section I introduce the context and purpose, of my Masters research and what factors may influence how I carry out the research.

I first describe the context of the school and education system within which this research is set, and discover that, in terms of both curriculum and qualifications, it is currently in a state of wide-ranging and rapid change. In section 1.2 I describe the significance of teacher professional development in terms of the important role it plays in outcomes for children and young people. I then detail the specific context of this research, my employers Mathematics in Education and Industry (MEI).

Following, there is a discussion of my positionality. I describe my teaching background, the wider context of my employment and the subsequent influence that these have on my thinking, my motivation to carry out this research and the structure and process of my research. I describe the aims of my research and detail my research questions. Finally, I outline the rest of my thesis and thus this section sets the scene for the review of the literature that follows in section two.

1.1 Wider context of secondary mathematics education

Here I provide an overview of the context in which this research is undertaken. I start with a broad description of the current situation of secondary mathematics education in England, including detail on the age of students, the content of what they are taught and the qualifications they study towards.

1.1.1 The current situation of secondary mathematics education in England

This research is set predominantly within the context of secondary mathematics education for students aged 11 to 18 years old or, alternatively, school year groups 7 to 13. (Alternative contexts for mathematics education is not constrained to secondary schools, for example mathematics teaching and learning also occurs in Pupil Referral Units (PRUs) and the research that follows will involve one person not teaching, or training to teach, in a secondary school. This person, referred to later as Keith, works in adult education within a
prison. Therefore, all but one of the teacher participants involved in this research declared themselves to be working with students aged 18 years of age or younger.

The school year groups of year 7 to year 11 is populated by students aged 11 to 16 years. For example, the first year group of secondary education is year 7 and students will be 11 and 12 years old, the next is year 8 and students will be 12 and 13 years old, and so on. The year groups 7 to 11 are split in to two key stages. Key stage 3 will typically cover years 7 to 9 (commonly referred to as a “three-year key stage 3”) or just the years 7 to 8 (a “a two-year key stage 3”). Key stage 4 is composed of the older students, either year groups 9 to 11 or only year groups 10 and 11 (depending upon the organisation of key stage 3). The decision of whether to split the length of key stages 3 and 4 in to a 2:3 ratio or 3:2 ratio is made by an individual school or perhaps, in the case of multi-academy trusts, the group of schools as a whole.

Key stage 3 students study the National Curriculum for Mathematics as described in the *Mathematics programmes of study: key stage 3 National curriculum in England* (Department for Education, 2013a). At the time of writing there is no formal assessment of key stage 3 mathematics, although there has been in the past.

Key stage 4 students also study the National Curriculum for Mathematics, as described in the *Mathematics programmes of study: key stage 4 National curriculum in England* (Department for Education, 2013b). These students are typically assessed by a General Certificate of Secondary Education in Mathematics (GCSE Mathematics) although other common qualifications at the age of 16 include Entry Level Qualifications for students with lower prior attainment and Additional Mathematics, aimed at catering for higher prior attaining students, “who have a thorough knowledge of the content of the Higher Tier of the National Curriculum for Mathematics” (Oxford Cambridge and RSA, 2016; 6). Due to the importance of these qualifications, the exam specifications may perhaps be viewed as being as influential as the requirements of the National Curriculum.

Key stage 5 is composed of school years 12 to 13 and students are 16 to 18 years old. Students in key stage 5 may also be studying for GCSE Mathematics, most likely as a “re-sit” to improve upon their attainment at the end of year 11 in key stage 4. Other students aged 16 to 18 years old may sit post-16 qualifications such as Core Maths, Advanced Level Mathematics or Advanced Level Further Mathematics (“A level” qualifications).
The National Curriculum states the purpose of mathematics education at secondary level, mentioning the historical development of the subject, as a requirement of being able to function in everyday life and its necessary application in other areas of human endeavour such as finance and technology. The purpose of mathematics education is also stated as involving the opportunities for students to engage in reasoning, creativity and enjoyment (Department for Education, 2014b). This wide-ranging definition reflects the ongoing discussion within the mathematics pedagogic community about the exact purpose of mathematics education (Johnston-Wilder et al, 1999).

1.1.2 A period of rapid curriculum and qualification change

In recent years, mathematics education in England has undergone significant changes in terms of curriculum content, assessment and qualifications. In September 2013, a new primary curriculum, including mathematics, was introduced to key stages 1 and 2, and a new curriculum for key stage 3 was introduced in September 2015. Also from September 2015, students in key stage 4 started studying content for the new General Certificate of Secondary Education (GCSE) in Mathematics specification. A new Core Mathematics course for post-16 students was available to “early adopters” from September 2014 and the new content for Advanced levels in Mathematics and Further Mathematics has been announced as a statutory requirement for teaching from September 2017 (Office of Qualifications and Examinations Regulation (Ofqual), 2017).

In terms of qualifications by student year group, new key stage 2 assessments were introduced at the end of primary school in summer 2016, the new GCSE specification in mathematics was sat by students from the summer of 2017 and the new, optional, Core Mathematics qualification for some post-16 students will be the first to count towards level 3 maths performance measure also from summer 2017. The new Advanced level Mathematics and Further Mathematics examinations will be sat from summer 2018 (Mathematics in Education and Industry, 2017).

In addition to these changes, the assessment procedure of key stage 2 mathematics changed from national curriculum levels 1 to 6 to a system of “scaled scores”, and the grading of GCSE Mathematics will change from letter grades of G to A* to levels 1 to 9, from summer 2017.
As can be seen from the above overview this is significant change at all levels of the school education system and it has also occurred in a short period of time. Such change brings challenge to the teaching environment and may play a part in the poor levels of recruitment and retention of mathematics teachers (to be discussed in section 1.2.4). Also, each element of curriculum change brings professional development needs of being informed either in terms of new subject content or a renewed focus or emphasis, for example, on reasoning or on problem-solving.

1.2 Professional development for teachers

In this section I now turn attention to professional development for teachers of mathematics in England and explain the nature of the professional development landscape during which this research will be carried out.

1.2.1 Importance of teacher professional development

Access to professional development by teachers is widely acknowledged to improve outcomes for the children and young people that they teach. The Advisory Committee on Mathematics Education (ACME) recently stated that “A world-class education system is underpinned by a world-class professional development culture.” (Advisory Committee on Mathematics Education, 2013). Their report proceeds to recommend that the step of “ongoing learning provision for all teachers of mathematics that can, in turn, maximise learning of all students throughout their school and college careers” should be taken.

The Sutton Trust report, *Improving the impact of teachers on pupil achievement in the UK – interim findings (2011)* also made the link between access to professional development for teachers and the outcomes of their students. “The difference between a very effective teacher and a poorly performing teacher is large. For example during one year with a very effective maths teacher, pupils gain 40% more in their learning than they would with a poorly performing maths teacher” (The Sutton Trust, 2011) and that this fact has serious implications for the professional development of teachers.

It is not just education professional bodies that have identified this importance. Governmental organisations have too. The Office for Standards in Education, Children's Services and Skills (Ofsted) in the 2012 report, *Mathematics: made to measure* linked the
“involvement of all staff in professional development” to good practice (Office for Standards in Education, Children's Services and Skills, 2012).

So, we can conclude that there is a clear belief that the educational outcomes of young people are strongly linked to the professional development of their teachers, including that within mathematics education. This makes the area of professional development for mathematics teachers of crucial concern to society.

1.2.2 Perspectives on the purpose of professional development

There are various perspectives on the purpose of professional development. For example, to inform teachers on the findings of research, to advise them about curriculum change or changes to exam specifications. For other some teachers it may be to upskill them to teach different subjects or age groups. The ultimate aim of professional development is to change classroom practice and ultimately improve student outcomes, such as enjoyment, attainment in examinations or motivation to continue to study the subject further (Back* et al., 2009b). Therefore, there are different perspectives on professional development. The most common view taken on professional development is from that of the stakeholders such as the school or government e.g. Gray (2005). Most research takes this perspective and therefore measures the effectiveness of professional development by student exam performance. Less common is to take the teacher’s perspective, their needs and experience. However, we will see from the literature review that changing teachers’ beliefs and values is the only way to achieve anything other than superficial or short term change (Hoban* and Erickson, 2004). In this research I have decided to focus on this latter perspective, that of the teacher participants. The development of this priority is discussed in section 1.3.

1.2.3 Current landscape of teacher professional development

An important and current factor in the context of this research is the changing situation in terms of the main source of provision of professional development for mathematics teachers. In 2013, the Department for Education announced the development of approximately 30 new Maths Hubs located around England to “provide support to all schools in the area, across all areas of maths education” (Truss, 2013). In September 2016, there were 35 Maths Hubs, each led by a Teaching School. The reach of this network of Maths Hubs is intended to cover all English schools and colleges. In terms of professional
development for mathematics teachers their remit includes developing “high quality
specialist subject knowledge development” under the heading of “Supply of Specialist
Teachers of Mathematics” (Maths Hubs, 2016). At the time of writing in September 2016
there is no specific remit for the Maths Hubs programme to support the professional
development of current teachers.

1.2.4 Recruitment and retention of mathematics teachers
A second factor at the time of writing is the worryingly low numbers of mathematics
teachers within the profession. The current pressures around both the recruitment and
retention of mathematics teachers are well-documented (Advisory Committee on
Mathematics Education, 2014; Weale, 2015; Coughlan, 2015). This problem is widely
recognised as being due to a combination of factors.

Firstly, fewer people are entering the teaching profession. At the end of 2015 the BBC
reported that the improving economic conditions were leading to an increased number of
opportunities for graduates who might otherwise have chosen a career in mathematics
teaching during times of recession (Coughlan, 2015). Secondly, there is a greater demand
for mathematics teachers as the population of school students increases. In 2014, The
Guardian reported that the Department for Education’s own figures predicted that 800 000
more students will have entered the school system by the 2020s (Ratcliffe, 2014).

As we follow the route of graduates choosing to enter training to become secondary
mathematics teachers we meet the third factor. As more teachers are trained in schools
rather than in universities, the supply of new teachers has become concentrated around the
minority of schools providing the training. This results in other, non-training schools being
further removed, geographically and/or socially, from the source of new teachers.

Furthermore, unlike the established and successful schools allocated training
responsibilities and funding, these schools are more likely to be working in challenging
conditions, making them an even less attractive proposition to new teachers (Ratcliffe,
2016).

As well as the issues around recruitment of new teachers, retention of current mathematics
teachers is also a serious concern and has been since the start of the twenty first century. In
2007, a report published by the Royal Society stated that nearly a fifth of trainees did not
complete their training as mathematics teachers (Higgins, 2007). Of those that qualified 50% of mathematics specialists had left the profession within their first 5 years (Higgins, 2007). In 2015, the BBC cited “excessive workload, inadequate pay and complaints about endless political meddling” as the reasons for this high rate of attrition (Coughlan, 2015).

The government has responded to these concerns (and a parallel need for physics teachers) with a number of initiatives aimed at easing the pressures. In 2015, the Prime Minister’s Office announced a range of initiatives to bring an extra 2500 new mathematics and physics teachers into the profession. This included support for returning mathematics teachers, incentives for top graduates to train as mathematics specialists and fast-tracking for certain professionals entering mathematics teaching. Furthermore, conversion courses were to be offered to existing teachers of other subjects, aimed at bringing an additional 15 000 new mathematics and physics teachers into secondary schools (Education, 2015). It is still to be seen as to how successful these initiative and incentives will be in addressing the staffing crisis.

A final factor in poor rates of retention of mathematics at the time of writing is the rapid and significant changes to curriculum and assessment (see also section 1.1.2). Changes to the primary curriculum and key stage 3 came in September 2013; the new key stage 4 curriculum had to be taught from September 2014 with new GCSEs being taught from September 2015. The new A levels in Mathematics and Further Mathematics are scheduled for teaching from September 2017. Such curriculum reform brings about emerging professional development needs for both new and current mathematics teachers in terms of understanding new assessment regimes and their implications, new subject knowledge content and new pedagogical issues around the renewed emphasises on problem-solving and mathematical reasoning (Mathematics in Education and Industry (MEI), 2016).

1.3 MEI as the context for my research
My specific interest in effective professional development for teachers of mathematics grew from 2012 when I took up a role at Mathematics in Education and Industry (MEI). I will discuss the influence of working for MEI in a later section and here I provide information about MEI as context.
MEI is a charitable organisation with a board of directors/trustees. It states that it “is committed to improving mathematics education and promotes teaching and learning through different strands of activity” (Mathematics in Education and Industry (MEI), 2013b). It has three statements of mission:

“MEI exists to improve education in mathematics and to support mathematics learning in the workplace.

MEI innovates, develops and publishes teaching and learning resources, promotes inspirational teaching, and trains and motivates teachers.

MEI uses its expertise in curriculum development to influence the content of mathematics education.”

(Mathematics in Education and Industry (MEI), 2013c).

MEI grew in the early 1960s from a small group of like-minded school mathematics teachers and heads of mathematics departments (Mathematics in Education and Industry (MEI), 2013a). They shared a common and growing concern about the appropriateness of the school curriculum and qualifications for the demands of later employment and study. From these meetings came, amongst other initiatives, the BP-sponsored Mathematics in Education and Industry Conference in 1961, the Modular A Level in 1990 and support for students wanting to access the Further Mathematics advanced level qualification in 2000.

In 2016 MEI employs approximately fifty members of administrative and academic staff. Administrative and financial colleagues are based at the head office in Wiltshire and academic staff, including myself, work from home. The areas of MEI’s work are grouped under four strands, Curriculum and Resources; Business Development and Communications, The Further Mathematics Support Programme (FMSP) and Teacher Support. MEI manages the Further Mathematics Support Programme and is a consortium partner in the National Centre for Excellence in the Teaching of Mathematics (NCETM).

It is in the Teachers Support strand that MEI provides professional development for mathematics teachers. This is typically through single day courses, courses sustained over
an academic year and longer, and an annual three-day conference in the summer term of each year.

Single day events focus on areas of subject knowledge and pedagogy in specific areas such as *Introduction to A Level Mechanics* or *FRESH strategies for embedding problem-solving*. Participants on these one-day courses may have already attended previous MEI professional development days.

There are three main sustained professional development courses, Teaching Further Mathematics (TFM), Teaching Advanced Mathematics (TAM) and Teaching GCSE Mathematics (TGM). These run across academic years and can include face-to-face study days, online sessions in a virtual classroom, lesson visits and access to a bank of electronic teaching and learning resources.

The three-day annual conference is open to both residential and day participants. The conference sessions cover a wide range of content, including information on curriculum change, emerging issues, mathematics-specific pedagogy and also more unusual areas such as influential mathematicians from history. There are also plenary talks and social opportunities such as formal dinners and five-a-side football.

### 1.3.1 My role at MEI

I am employed as the Professional Development Coordinator for Key Stages 3 and 4. I initially designed the Teaching GCSE Mathematics (TGM) sustained professional development course and continue to develop and deliver this course. Typically, this involves 60 to 80 teacher participants enrolled on one of four or five cohorts across England.

Other responsibilities since 2012 have included designing and delivering sessions at both MEI’s annual conference and those of other organisations, including the Association of Teachers of Mathematics (ATM), the British Congress of Mathematics Education (BCME), the International Congress of Mathematics Education (ICME) and the National Centre for Excellence in the Teaching of Mathematics (NCETM).

I have co-designed and co-delivered professional development courses for new and aspiring leaders of mathematics departments (Head of Mathematics) and for tutors within the Royal Navy. Larger projects have included courses for teachers of London schools funded by the
London Schools Excellence Fund and a course for Professional Development Leads as part of a short-term responsibility as a Secondary Director at the National Centre for Excellence in the Teaching of Mathematics. The role requires me to keep informed about changes in mathematics education, such as curriculum and qualification reform and the latest findings from research on pedagogy. I work with a wide-range of external parties such as university and school partners, subject associations and funding bodies. I discuss the personal impact of these roles and responsibilities below.

1.4 Other influences throughout the course of my research

Whilst carrying out my research I regularly reported to colleagues at MEI on its progress. These occurred as agenda items at joint meetings of two teams, the Teacher Support strand and the Curriculum Development strand. These items would include reflections and discussions on a wide range of issues around my research. For example, our different personal experiences of Masters level learning, the potential role of research in our work designing and delivering professional development and advice and guidance on my developing research.

Some of the outcomes of these discussions were practical, for example the benefits and ethical considerations of different means for recording conversations. Other discussions were more philosophical, for example the idiosyncratic nature of mathematics teaching and its connection to what individuals value about mathematics.

In July 2016, I had the opportunity to attend the International Congress on Mathematics Education (ICME 13). This involved attending a number of lectures, participating in a Topic Study Group on In-service education, and professional development of secondary mathematics teachers and co-delivering a workshop, Designing mathematics tasks for the professional development of teachers who teach mathematics students aged 11-16 years with Craig Pournara of the University of the Witwatersrand, South Africa (Barker and Pournara, 2016). This was a very influential and informative experience as it exposed me to a wide range of methodologies from different international contexts. It gave me a greater appreciation for the need for both clarity and transparency in research and crystalised my personal preference for research to be practical in terms of informing future decision making.
This links in to a third influence during the course of my research. In 2016, I became a member of the GCSE working group for the Joint Mathematical Council of the United Kingdom (JMC). As part of this working group we have studied the changes to the GCSE Mathematics specifications from September 2015. We have made recommendations based on these changes, including the implications for the professional development of teachers. This has influenced my research by being a timely and powerful reminder of the constantly changing requirements of teachers and the pressures of teaching mathematics.

1.5 Positionality
This section is composed of personal reflections on the factors that have influenced my research approach and my methodology.

1.5.1 Background of the researcher
I am not related to any teachers and as a child I did not know any outside of my own schooling, so my experience of teaching and teachers began as a school pupil. From primary school age, I was very aware of teachers as individuals, rather than an homogeneous group. Despite the professionalism of the teachers I was taught by in the 1980s I was aware of their differing interests, senses of humour, religious beliefs etc. At both primary and secondary school I was more at ease with some teachers than others and admired teachers who were passionate about their subjects, enthusiastic about their work and positive about their students’ potential. Similar to many people, some of my earliest and most influential role models were the people who taught me. I believe that this formative experience has been an important contributing factor to my research recognising and placing importance on the teacher participants as individuals.

My own formal teaching experience began in 2004 when I joined a vocational training route in to teaching, the Graduate Teaching Programme (GTP). This led to me experiencing both the strengths and weaknesses of a non-traditional, vocational route in to teaching as opposed to the university route that was more common at that time, the Postgraduate Certificate in Education (PGCE) route. This means that my course in to teaching is similar to many of the participants I work with in my job today as the school-based training route has since grown.
I trained at an 11-18 comprehensive school in an English coastal town with a catchment area including a small seaside town, surrounding villages and farms. Some of the students and their families came from backgrounds of social disadvantage. This experience led me to greater appreciate the importance of the quality of teaching in terms of equality of social and financial opportunities for students. The mathematics department was staffed by teachers identifying as both specialist and non-specialist teachers and teaching assistants and was a very friendly and supportive team. Despite the diverse backgrounds and strengths of department members I was always under the impression that each of us was valued and appreciated by the others. This was a major influence on my valuing of diversity within communities of mathematics teachers. My experience of training to be a teacher was often very personally challenging and yet also very rewarding. After qualifying as a teacher and passing my first year as a Newly Qualified Teacher I went on to hold roles within the department as an Advanced Skills Teacher and later Head of Mathematics. In the latter role, I learned first-hand about the challenges of teacher recruitment and retention within mathematics education. I worked at this school until Christmas 2011.

In January 2012 I joined Mathematics in Education and Industry (MEI) as the Professional Development Coordinator for Key Stages 3 and 4. I have found the organisational culture at MEI to place a high value upon, and trust in, the professionalism and capability of its employees. This is expressed by the management and also demonstrated in the high degree of autonomy permitted to its workforce. I have both observed and personally experienced the benefits to the individual and organisation fostered by this approach. I believe that my experience of this culture has been another influence on my respecting and valuing the professionalism of teachers.

1.5.2 Values and beliefs

My background experiences, described above, have led me to believe that teaching is idiosyncratic and that strength is to be found within the diversity of a teaching community. Having reflected upon these beliefs as possible sources of bias, I hold these to be both rational and commonly held values.
As a result, these values have informed the approach taken. Within my research, I have remained committed to placing a high value and importance upon the personal experience and judgement of individual teachers.

1.6 Expectations
Throughout my research, I expect teacher participants on a professional development course to have different professional needs and therefore to have different experiences regarding which aspects of a given professional development course are effective. However, I also expect commonalities in the experience of, and opinions around, effective professional development to become suggested amongst participants sharing similar demographics. In my review of the current literature, this situation will be seen to be emerging knowledge in published work. I do not have any predictions on what these commonalities may be, or be predicted by, beyond the possibility that they be signalled by qualification or teaching background and experience.

1.7 Research aims and questions
The aim of my research is to address the title, What characteristics of secondary mathematics professional development courses do teachers find effective?

The specific research questions are:
1) What aspects of professional development sessions do teachers find effective and why?
2) Are there common themes for different groups of teachers?

These questions are informed by my experiences of leading courses. Firstly, I have found that teacher participants are themselves often surprised by the outcomes of professional development courses. For example, they report that they did not know what to expect prior to the course or that the course exceeded their expectations. This leads me to be curious about teacher participants’ perspectives on effectiveness after having had the experience of engaging with specific professional development. Secondly, my experience suggests that some participants report outcomes from a particular session that were unintended by the professional development lead. For example, they may identify characteristics of effective teaching in an activity that was intended with a purely subject knowledge focus.
1.7.1  “What aspects of professional development sessions do teachers find effective and why?”

The first question places the focus on the teacher participants’ perspective. This explicit emphasis in my research has been established earlier in this introduction. In the literature review we will see that this approach has some emerging foundations in recent and influential research, such as “Researching Effective CPD in Mathematics Education (RECME)”, which describes this as “privileging the teacher voice” (Back et al, 2009, p3).

1.7.2  “Are there common themes for different groups of teachers?”

The second question, regarding possible common themes for different groups of teachers, is a response to my intention for the research findings to have practical applications in my work, the work of colleagues and the work of other professional development leads. There is some evidence in the literature that professional development requirements differ according to the career stage of the teacher. The Advisory Committee on Mathematics Education (2013) recommends that professional development should be “appropriate to career stage and education phase”. Indeed, the findings of Kyeongsoo (2013) recommend that teachers’ needs be analysed before professional development occurs, so that the course can be tailored to meet these needs. Therefore the second question aims to collect data in order to group teachers by general and broad common characteristics.
1.8 Definitions of key terms used in this research

Throughout this research, I have had to decide upon certain and consistent phrases for some key terms for the sake of clarity. These are stated below.

**Professional development lead** is used to identify any person delivering, teaching or leading a session or activity identified as professional development. (What constitutes professional development will be discussed at length in section 2 of this research). The language of “professional development lead” was chosen to help distinguish between those providing professional development from those receiving it, as such leads may identify as teachers of mathematics. The term is currently that in use by the National Centre for Excellence in the Teaching of Mathematics in their professional support and guidance for people in such roles (National Centre for Excellence in the Teaching of Mathematics, 2015).

**Teacher participant** was chosen to create a distinction from the person leading the professional development. All of the professional development leads involved in this research have Qualified Teacher Status (QTS) and their role involves teaching mathematics in many senses of the word. Teacher participant is used to describe those involved in receiving professional development. In many ways, they may identify as being a learner, pupil or student during the professional development activities, but teacher participant is used to highlight the fact that many of them hold Qualified Teacher Status and most are day-to-day employed as teachers.

1.9 Outline of thesis

In this section, the importance of mathematics teacher professional development has been stated, based upon the significance and relevance to student outcomes. There has been an outline of the national context of this research in terms of the current mathematical education environment; a period of curriculum and qualification change and a rising crisis of the recruitment and retention of mathematics teachers. This section has also provided the background of the me as the researcher and the beliefs and personal experiences that inform my research. Finally, it has given the context of the organisation, Mathematics in Education and Industry, that provides the setting of professional development under consideration.
This section then went on state the aim of this research and the specific questions to be investigated.

Section 2 is the literature review. This section explores the current knowledge of the wider picture of professional development amongst professions and teaching, including statutory requirements and guidance. It also gives the position of advisory and professional bodies and organisations, reflecting a developing context of various influencing factors, before continuing to describe and critique an emerging body of knowledge of the effectiveness of teacher professional development in mathematics education. Finally, a gap within the literature is identified.

In section 3 the methodology is developed and stated. It emphasises an importance placed upon the perspective of the teacher participant and how data on this will be gathered at various times during a range of professional development courses.

Section 4 on the findings of the research describes what actually happened, as compared with that planned in section 3. An explanation is given of the classification spreadsheet that was developed for processing the large quantity of qualitative data gathered. A number of emerging themes are identified and commonalities for certain groupings of teacher participants are found. This provides some important new details addressing gaps in the current literature and some substantiation for the findings already suggested.

In section 5 a conclusion is presented. A summary of the findings is given and then considered in terms of its implications for future design and delivery of professional development. The limitations of this research are stated and possibilities for future research are suggested.

2 Literature review

This chapter explores the currently collated knowledge of what makes professional development effective for teachers of mathematics. As has been discussed in greater depth in the earlier section, this is of vital importance for two reasons. Firstly, because of its
significance to the experience young people have of mathematics learning, the outcomes from these experiences and therefore ultimately the impact it will have on their potential future and life choices. Secondly, at the time of writing, mathematics education is undergoing rapid and wide-ranging change in terms of curriculum content, assessment and qualifications at all school levels.

The literature review begins with the wider picture of professional development in England and the situation within teaching as compared with other professions. However, as this thesis is concerned with the context of mathematics teaching, the research of effective professional development in other professions will only be referred to when appropriate.

As part of this scene-setting there is a discussion of the statutory environment and how this is relatively limited in scope. Given this fact, there then follows an overview of the recommendations of certain influential bodies such as subject associations and professional bodies, those that seek to address the gap in regulation. Following this there is then a discussion of the emerging body of knowledge around professional development within teaching, identifying the most informative and influential sources from the literature. This is done in terms of both teaching in general and mathematics teaching in particular.

The later sections explore in greater detail the generalities that are developing. These come from a necessarily wide range of sources, not all highly relevant, due to there being only a short tradition of research in this area. The situation is one of complexities and subjectivities, including even the definition of what professional development can be and how it can be measured. Finally, a space in the research is found for a greater understanding of the effectiveness of professional development within mathematics from the teacher practitioner’s perspective.

2.1. Professional development within the other professions in England

Professional development is based upon an assumption that people will continue to learn and develop after their initial qualification in professional roles such as medicine (Jasper et al, 2006), law (The Law Society, 2016), accountancy (Chartered Institute of Management Accountants, 2016) and engineering (Engineering Council, 2016). In some professions, there is a statutory or self-regulatory responsibility to engage in professional development. For example, people engaged in medicine such as General Practitioners (GPs) and
psychiatrists can demonstrate their commitment to this responsibility via a professional
development plan (General Medical Council, 2013).

Different professions appear to place a different emphasis on different aspects of
professional development. For example, in nursing, reflection appears to be of importance.
Jasper (2016) states that in nursing, “Professional development is as much a cognitive
process as a technical one”. However, in other professions more emphasis may be placed
upon technical-updating and keeping informed on latest developments.
This context is important as currently there is only vague statutory or self-regulatory
requirements upon teachers to engage in professional development. These are developed in
the next section.

2.2. Statutory requirements of professional development for teachers
At the time of writing there is no statutory requirement for teachers to engage in
professional development, nor do they have any statutory right to access any such support.
The closest detailed stipulation at this point in time has been published since the start of
this research. It is a new Standard for teachers’ professional development published by the
Department for Education in 2016. This is advisory guidance and is intended to raise as a
priority teacher professional development and to increase the quality of provision. In their
covering letter the Teachers’ Professional Development Expert Group advised that, “the
Department for Education should champion the use of the standard, and use it to inform
policy development and any commissioning of professional development” (Teachers’
Professional Development Group, 2016; 3) but I note that it did not go so far as to advise it
becoming a requirement. The Department for Education themselves explain that the
Standards are a “minimum level of practice expected of teachers in England” (Department
for Education, 2013c). It is significant that in 2016, the Advisory Committee for
Mathematics Education (ACME) recommended that successful professional development
requires a commitment from all stakeholders, including government. Statutory requirement,
possibly combined with ring-fenced funding, could be viewed as such a commitment.
The Standard for teachers’ professional development plays a number of roles. Firstly, it
emphasises the link between effective professional development and effective teaching and
thus student outcomes. Secondly, the advisory group state that the quality of professional
development varies, explaining, “Not all professional development is equally effective”
Finally, before setting out their five standards they explain that they make a distinction between professional development programmes and activities. The latter could be “a one-day course as a stand-alone activity without a specific focus” (Department for Education, 2016; 5) and is judged to be unlikely to lead to impact on outcomes for students in the long run. A professional development programme is described as, “a sustained, coherent programme which includes structured, collaborative in-school activities for teachers to refine ideas and embed approaches” (Department for Education, 2016; 5).

The *Standard for teachers’ professional development* sets out five statements:

1. Professional development should have a focus on improving and evaluating pupil outcomes.
2. Professional development should be underpinned by robust evidence and expertise.
3. Professional development should include collaboration and expert challenge.
4. Professional development programmes should be sustained over time.

And all this is underpinned by, and requires that:

5. Professional development must be prioritised by school leadership.”

(Department for Education, 2016; 6)

Elaborating upon the first standard, the advice states that professional development should be relevant to the teacher participants and that it should make an explicit link between this relevance and student outcomes. Whilst it is difficult to imagine irrelevant professional development being effective, I believe that here the standard takes a position that professional development be measured by impact upon student outcome, as opposed to the teachers’ perspective. I am not convinced that there is always a clearly linked relationship between the two. Improving a teacher’s morale, motivation and confidence in the classroom may have a positive impact on their students’ attainment, but establishing causality would not be a trivial matter. Furthermore, another measure of effective professional development may be the extent to which it helps schools to address the challenges of addressing low teacher recruitment and retention. This is an important matter than needs meeting, but in
this way teacher well-being and career advancement may not always have an immediately observable and direct relationship with improving the outcome of their current students.

The second standard, “Professional development should be underpinned by robust evidence and expertise” (Department for Education, 2016; 6) makes the link that effective professional development is informed by “high quality academic research” (Department for Education, 2016; 8) and led by an informed and capable professional development lead. This is something that is reflected elsewhere in the literature and is discussed later in this review.

Standard three, *Professional development should include collaboration and expert challenge* (Department for Education, 2016; 6) presents another belief, that for professional development to be effective it should involve social interaction such as discussion, peer-support and possibly mentoring.

The fourth standard, *Professional development programmes should be sustained over time* (Department for Education, 2016; 6) takes the position that professional development is effective if it is ongoing rather than an isolated event. They use the phrase that it should be, “iterative, with activities creating a rhythm of ongoing support and follow-up activities” (Department for Education, 2016; 10) and elaborate that this is so it can incorporate elements of social learning such as feedback and opportunities for reflection and evaluation.

Finally, the *Standard for teachers’ professional development* makes an explicit appeal to the role of school leadership in ensuring that professional development be a priority and thus effective. In this they emphasise the importance of the wider context, that professional development be “part of a wider culture of evidence-informed reflection and discussion of teaching practice” (Department for Education, 2016; 11). They go further, stating that effective professional development strengthens school leadership and has expectations of school management beyond the duration of the professional development.

The *Standard for teachers’ professional development*, published in July 2016, has been followed up by a statement in March 2017 by the Education Secretary, Justine Greening. In
an address to the Association of School and College Leaders she stated a “a core commitment to the ongoing professional development of our teachers and leaders” (Greening 2017). I wonder if this suggests that further advisory guidance, or even statutory requirements, are imminent.

2.3. **Subject associations and advisory bodies**

In this section I explore the recommendations arising from the literature produced by relevant bodies concerned with mathematics education. Many of these combine research findings with their own areas and agendas of interest, influence and expertise. The many associations and bodies listed here often work collaboratively with each other, issuing joint statements on effective professional development or in offering professional development opportunities, such as conferences, together. They are presented in alphabetical order.

The **Advisory Committee on Mathematics Education** (ACME) is an advisory body that undertakes “evidence-informed analysis, harnessing and reflecting the expertise of the mathematics community” (Advisory Committee on Mathematics Education, 2017). This Advisory Committee was set up in 2002 jointly by the Royal Society and the Joint Mathematical Council (JMC, see below). They draw upon the expertise of an outer circle of expert members and have published two documents concerned with professional development of mathematics teachers in recent years. In 2013, they published the 16-page document, *Empowering teachers: success for learners.* In this, they refer to effective professional development as “professional development that improves mathematics teaching and learning” (Advisory Committee on Mathematics Education, 2013; 4) and identify a number of principles. They state that it:

- should be relevant to teachers and schools
- needs to be mathematics-specific
- should be tailored to the career stage of the teacher and the setting that they teach in
- needs to address subject knowledge and pedagogy
- is sustained and leads to change
- needs to be valued and facilitated by school staff
- is improved by networking and community-building
• needs to be led by experienced and expert people
• should be informed by research
• is effectively planned, resourced and evaluated
• encourages teacher participants to reflect and investigate.

The Advisory Committee also state that effective professional development is both an “entitlement and professional responsibility” (Advisory Committee on Mathematics Education, 2013; 4) which is a strong statement not emphasised elsewhere in the literature. The document takes a system’s perspective and recommends increased leadership from the government and enhanced roles for the National Centre for Excellence in the Teaching of Mathematics (NCETM, see below) in the quality assurance of professional development providers.

The Advisory Committee return to this theme of quality assurance at a national level in their later publication, Teachers of maths: supply, training and development (Advisory Committee on Mathematics Education, 2014) when they state that “The professional development of teachers of maths at all career stages and in all education phases needs to be improved” (Advisory Committee on Mathematics Education, 2014; 2).

The Association of Teachers of Mathematics (ATM) is a not-for-profit membership organisation for teachers of mathematics that seeks to increase understanding around the areas of enjoying, doing, learning and teaching mathematics (Association of Teachers of Mathematics, 2017). Its aims also include exploration and discussion of new ideas and their activities include providing professional development.

In their response to the call for contributions to the advisory panel of the Department for Education’s Standard for teachers’ professional development, the Association of Teachers of Mathematics stated that effective professional development is that which is
• up to date
• informed by research and evidence
• facilitates adaption to the individual teacher’s needs
• aimed at enhancing the teacher’s professional practice
• supportive of the teacher’s career development
• able to facilitate collaboration between teachers
• inclusive of tasks to be undertaken between sessions.

(Association of Teachers of Mathematics, 2015).

The **Joint Mathematical Council** is a coordinating body and a forum for discussion for its member societies and bodies concerned with all aspects of mathematics education (Joint Mathematical Council, 2017a). They also tend to play the role of an advisory forum for organisations such as the Department of Education. In terms of their advice on the professional development for teachers of mathematics, in March 2017 they published recommendations to providers of initial teacher training (as opposed to providers of professional development for teachers at all career stages), *Developing mathematics-specific pedagogy in Initial Teacher Education*. In this document, the Council emphasise that the content be on mathematics-specific pedagogy and enter a fairly detailed discussion about the issues that should be included. For example, “the contrasting and complementary roles of procedural/conceptual learning and relational/instrumental learning in developing learners’ competence and understanding in mathematics” (Joint Mathematical Council, 2017b; 1). Much of the document is taken up with exemplifying what the Joint Mathematical Council consider to be characteristics of good subject-specific pedagogy, and this level of technical detail and specification is unusual in the literature. The guidance also advises that the training include combinations of both collaborative learning and doing mathematics, for example, “it is essential that those on ITE programmes work collaboratively on mathematics tasks,” (Joint Mathematical Council, 2017b; 1) and opportunities for reflection and trying different resources. It is interesting to note that the latter should include “digital resources” (Joint Mathematical Council, 2017b; 2). Finally, although they do not make explicit reference to the qualities of a professional development lead, they do state that the trainee teacher should have access to “experienced specialist mathematics” (Joint Mathematical Council, 2017b; 2).

It is important to note that this document is aimed at *initial* teacher training rather than professional *development* of current teachers, which is the consideration of this research. However, I feel that there is sufficient relevance for it to be considered here.
The **Mathematical Association** (MA) is a membership organisation for teachers of mathematics that, “exists to support and promote confidence and enjoyment in mathematics for all, and especially young people” (Mathematical Association, 2016). Their activities include providing “personal professional development” and that it should be about, “affirmation, values – challenge too, but support to develop that deep thinking that nurtures your long-term growth and enablement, that enables you to go back refreshed and keeps you committed” (Mathematical Association, 2016). Through both its national conference and local teacher networks it could also be argued that the Mathematical Association also values collaboration and opportunities for discussion. I have been unable to source any statement from them on effective professional development of mathematics teachers.

The **National Association for Numeracy and Mathematics in Colleges** (NANAMIC) is a charitable organisation that supports mathematics education by providing professional development, a national conference and representing its members’ views (National Association for Numeracy and Mathematics in Colleges, 2017). They focus more on the teaching of students at post-16 level in Further Education Colleges, alternative provision etc. Separate to their collaboration with other bodies such as the Joint Mathematical Council and Advisory Committee on Mathematics Education. I have been unable to source any statement from them on effective professional development of mathematics teachers.

The **National Association of Mathematics Advisers** (NAMA) is a membership body representing professionals who work externally of their own place of work to support mathematics education (National Association of Mathematics Advisers, 2017). They run their own professional development opportunities, for example, local events and an annual conference (National Association of Mathematics Advisers, 2017). Again, I have been unable to source any statement from them on what makes professional development of mathematics teachers effective.

The **National Centre for Excellence in the Teaching of Mathematics** (NCETM) is a government-funded consortium supporting mathematics teachers with access to “high quality, evidence-based, maths-specific continuing professional development” (The National Centre for Excellence in the Teaching of Mathematics, 2017a). An element of
their work is assessing and awarding the *NCETM Continuing Professional Development (CPD) Standard* to providers of professional development to teachers of mathematics who they identify as meeting their quality standards. The standard outlines three components of effective professional development, that it should develop teachers’ mathematical subject knowledge, that it should enable teachers to use the outcomes in their teaching and that it should help teachers to construct a “pedagogical framework” (The National Centre for Excellence in the Teaching of Mathematics, 2016). Furthermore, they state that, “reflection, collaboration and sharing” (The National Centre for Excellence in the Teaching of Mathematics, 2016) are also aspects of effective professional development, citing the Advisory Committee on Mathematics Education (discussed above) as their source. Together with the three explicitly stated components, this suggests that the National Centre for Excellence in the Teaching of Mathematics identifies six aspects of effective professional development.

(It should be noted that Mathematics in Education and Industry (MEI) is a consortium member in the running of the National Centre for Excellence in the Teaching of Mathematics).

### 2.4. Quality assurance of standards for mathematics teacher professional development

There exist two current influences on the quality assurance of professional development for teachers of mathematics in England. The first is a principles document from the Advisory Committee on Mathematics Education. The second is a quality standard procedure from the National Centre for Excellence in the Teaching of Mathematics. Both of these are reviewed in more detail below.
2.4.1. **Principles document from the Advisory Committee on Mathematics Education**

The first influential document is the 2016 publication by the Advisory Committee on Mathematics Education (ACME) entitled *Professional learning for all teachers of mathematics* (Advisory Committee on Mathematics Education, 2016). This is an advisory document aimed at teachers, school leadership and providers for such professional development. It sets out five key elements for improving the professional development landscape for teachers of mathematics.

- Firstly, the professional development should facilitate the development of teacher participants’ mathematical subject knowledge and knowledge of how mathematics should be taught.
- Professional development should include opportunities for reflection and critical evaluation.
- Professional development should be individualised to each teacher participant. A “one-size fits all” approach is not appropriate.
- Collaborative learning should be a key part of professional development and include both challenge and support from an external party.
- Finally, professional development for mathematics teachers should be coordinated by all relevant parties, that is, “schools and colleges, initial teacher education and professional learning providers, multi-academy trusts, local authorities and mathematics experts” (Advisory Committee on Mathematics Education, 2016; 5). This coordination should facilitate high quality professional development for all stages of a teacher’s career.

The document is not just a set of recommendations for the quality of mathematics teachers’ professional development. It is intended to help address the gap between the provision in England as compared with other, international, settings which are seen as being less fragmented and more of a “coherent embedded system” (Advisory Committee on Mathematics Education, 2016; 4). This fragmented approach is identified as being a contributing factor to the worrying situation of poor teacher recruitment and retention.
2.4.2. The CPD Standard

The second important influence in terms of the quality assurance of professional development of mathematics teachers is the National Centre for Excellence in the Teaching of Mathematics’ CPD Standard (where CPD stands for Continuing Professional Development). This CPD Standard aims to support teachers and schools and colleges to identifying high quality providers of professional development in mathematics education. Such provision is not limited to professional development courses but any “appropriate” support (National Centre for Excellence in the Teaching of Mathematics, 2016). It could be viewed that this CPD Standard acts as the quality “kite mark” sought for over recent years by relevant bodies such as the Advisory Committee on Mathematics Education (for example, in Empowering teachers: success for learners, ACME 2013). All standard holders are identified as such on both the National Centre’s Professional Development Provider Directory and their Professional Development Calendar by the use of a yellow rosette.

Standard Holders are judged to meet 17 criteria statements indicating quality. The first five criteria are collected under the heading of, “Quality Mark 1 - Promotion: description of the provision” (National Centre for Excellence in the Teaching of Mathematics, 2017c; 1). These describe the professional development provider’s commitment to clearly communicating, in advance of the offer, aims and objectives of the work, the content and delivery methods, the intended audience, logistical information (such as date, time and fees) and if relevant, any accreditation.

The second quality mark, “Components of effective CPD in mathematics” (National Centre for Excellence in the Teaching of Mathematics, 2017c; 1), groups three statements concerned with ensuring that the provision will address one or more of “three strands of effective CPD (1) mathematical knowledge, (2) mathematics-specific pedagogy and (3) embedding into classroom practice” (National Centre for Excellence in the Teaching of Mathematics, 2017c; 1) and an explanation of which, if any, are not addressed. Also under the second quality mark are that the provider uses relevant practices and theories and that the offer is relevant to the teacher participants.

The third quality mark, “Ensuring high quality provision” (National Centre for Excellence in the Teaching of Mathematics, 2017c; 1) is the heading for the next five criteria. These
cover the use of high quality professional development materials and a comfortable venue; use of appropriate and effective methods of delivery (including the use of technology); that the content is based on relevant and up-to-date research or inspection evidence; use of non-trivial evaluation strategies; and, evidence of internal quality assurance systems for ensuring the quality of the offer provided. (“Inspection evidence” presumably refers to, for example, the recommendations of the Office for Standards in Education, Children's Services and Skills, commonly known as Ofsted).

The fourth and final quality mark covers four criteria under “Extending impact beyond the provision” (National Centre for Excellence in the Teaching of Mathematics, 2017c; 1). These statements outline the professional development provider’s commitment to encouraging teacher participants to reflect and collaborate; to facilitate teacher participants to make links between their professional development and impact on student learning; to support future on-going communication and collaboration between teacher participants and the wider mathematics education community; and, where appropriate, to support teacher participants on longer term learning such as working towards a Masters level accreditation.

By including this section in the literature review I hope to provide a clear picture of the wider context of this research and to highlight important influences and indicators on the quality of professional development. By doing so, it can be seen that a space exists for a greater understanding and appreciation for the teacher participant’s experience. Furthermore, whilst the second and third quality marks are perhaps more relevant to this piece of research, it is useful to note that the experience of a professional development offer extends beyond the actual content and includes the time before and after actual course days

2.5. Professional development for teachers: an emerging body of knowledge

Since the 1990s there has been a growing body of knowledge about the professional development of teachers (Loucks-Horsley et al., 2010). Research continues in to identifying and describing what can be considered as professional development for teachers. The description provided by Evans (2008) captures the currently accepted understanding that what constitutes professional development is of a very wide-ranging nature. She describes that it can be,
“conscious or unconscious, involves the development of any combination of enhanced knowledge, understanding, attitudes, skills and competences, lies on a scale of size ranging from “enormous to miniscule”, is highly personal yet often stimulated through interaction with others and although it is an internal and mental process it often leads to a change in professional practice.”

(Evans, 2008; 3)

Similarly, in 2013 the Advisory Committee on Mathematics Education uses the definition,

“generally understood to mean the on-going education of teachers following completion of formal training. CPD consists of educational activities which help to maintain, develop or increase knowledge, problem solving, technical skills or professional performance standards all with the goal that teachers can provide better classroom experiences for students.”

(Advisory Committee on Mathematics Education, 2013; 1)

There is a small number of highly influential works in this area, identified due to their scope or relevance to the specialised area of professional development of mathematics teachers. Few of these are situated in my area of interest, England, with most arising from the United States of America. In only one case is there a publication that combines a deep investigation, high degree of relevance and is set within a context of the English education system. This report is “Researching Effective CPD in Mathematics Education”, commonly referred to as “RECME” from 2009.

2.5.1. What Makes Professional Development Effective? Results from a National Sample of Teachers (Garet et al., 2001)

This was a nation-wide sample of 1027 teachers in the United States of America. The relevance of this sample to my research is that it investigated many of the factors identified within the literature as being key factors of effective professional development (examined and discussed at length later in this chapter). Garet et al take a quantitative approach to assessing these factors, asking individual teachers to rate them on a scale of 0 to 3 (with 0 equating to no change up to 3 indicating significant change). An average of the scores was
then produced to permit comparability. In this way, using the teacher participants’ opinions, the research approach is similar to that used within this research, albeit with a quantitative rather than qualitative method.

It should be noted that in the context of my research questions the relevance of this report is limited in two ways. Firstly, its sample included teachers of science as well as of mathematics. There are common factors as the disciplines themselves are similar but there are key differences within the contexts of teaching these subjects. For example, mathematics is more similar to English (literature and language) than science in terms of curriculum significance. Also, there is the complication that science teachers who identify as subject-specialists can still be expected to teach outside of their specialism, e.g. graduates of chemistry being routinely required to teach biology, physics or a general science programme.

The second limitation of this report in terms of my investigation is the context. This report is a national sample of teachers in American schools, rather than in England. Furthermore, it is especially concerned with the effect of curriculum reform and limits itself to data collected as part of the evaluation of a single federal reform program, and in some cases a single source of funding, the Eisenhower Professional Development Program. Given this, there may be an inbuilt bias towards certain groups of teachers or classifications of professional development.

The main findings of What Makes Professional Development Effective? Results from a National Sample of Teachers are that effective professional development:

- Is sustained over a period of time, rather than a one-off event.
- Is coherent with other professional development or training that the teacher is experiencing.
- Fosters communication and collaboration between teachers, especially between those from the same school or teaching in similar contexts.
- Focuses on mathematical content (or science as applicable).
2.5.2. *An Enquiry Into Continuing Professional Development for Teachers* (Gray, 2005)

A later publication, *An Enquiry Into Continuing Professional Development for Teachers* (Gray, 2005) addresses some of the gaps of Garet et al (2001) identified above. Firstly, it is specific to the teaching of mathematics (the responses of 43 school leaders and 46 classroom teachers were collected). Secondly, it is set within a context of England and Wales. In contrast to the Garet et al’s national survey (Garet et al., 2001), Gray takes a more qualitative approach, including the use of focus groups and interviews (Gray, 2005). However, in contrast to my own research question it considers a very broad definition of professional development. For example, it included being a member of a subject association, studying at university for a higher degree or running learning activities for the local community. As a consequence, the knowledge gained on characteristics of effective professional development is also broad and generalised.

An interesting distinction of Gray (2005) is that it identifies that different professional development needs are dependent upon the career stage of the teacher. This is a point given importance in the recommendations of later publications (e.g. the Advisory Committee on Mathematics Education, 2013).

A summary of the main findings of *An Enquiry Into Continuing Professional Development for Teachers* (Gray, 2005) are that effective professional development:

- Is good value for money and time.
- Needs to be informed by research relevant to the teachers’ needs.
- Led by a professional development lead with teaching experience and possibly expertise in research.
- Includes opportunities for reflection.
- Needs to include opportunities for teacher participants to improve their mathematics subject knowledge.
- Includes opportunities for “follow-up, support and networking” (Gray, 2005; 21).
- Offers on-going opportunities for feedback.
2.5.3. **Teacher Professional Learning and Development. Best Evidence Synthesis Iteration (BES) (Timperley et al, 2007)**

This wide-ranging and extensive piece of research is a synthesis of emerging knowledge around mathematics teacher professional development. It takes in international research, but with a New Zealand emphasis (Timperley et al, 2007; xxiii) and measures effectiveness by impact on student outcomes. The link between teacher activity and student outcome is of repeated significance to the authors and described by them as a “black box”, echoing the work Paul Black and Dylan Wiliam (for example, *Inside the Black Box: Raising Standards Through Classroom Assessment*, Black & Wiliam, 1998).

Timperley et al considered a total of 97 substantial and rigorous studies, analysing their findings against a framework of 84 separate characteristics they deemed could impact on the “professional learning environment” (Timperley et al, 2007; xxiii). These were wide-ranging aspects that went beyond the professional development itself, such as national policy and school environment.

As has already been noted above, this research was concerned with improving the experience of schooling on New Zealand students and thus the effectiveness teacher professional development is measured by impact on student outcome. However, despite these differences with the perspective of my own research, I feel that there is sufficient similarity of the New Zealand context with that in England, and, combined with the high rigour and quality of their research, to include their findings in my literature review.

The findings of **Teacher Professional Learning and Development. Best Evidence Synthesis Iteration (BES)** (Timperley et al, 2007) are detailed and wide-ranging. Many of the effective aspects are described as being necessary but not sufficient. The *necessary* conditions are summarised as effective professional development:

- Being consistent with the wider context of research and current policy.
- Being carried out over a sustained period of time.
- Being led by professional development leads who are both experts and external to the teachers’ organisation.
- Involving a wide range of activities.
- Providing opportunities for teacher participants to engage in collaboration with each other.
However, Timperley et al (2007) found that the professional development also needed two more aspects in order to be effective. Firstly, an external “rationale or catalyst” (Timperley et al, 2007; xlvi) was needed, with the example given being an awareness from teachers that their current teaching was not as effective as it might be. Secondly, effective professional development incorporated rather than replaced existing ideas of teacher practice.

2.5.4. “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al., 2009b)

The final key publication in the context of my research is the “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al., 2009b). This was commissioned by the National Centre for Excellence in the Teaching of Mathematics (NCETM) in order to provide “advice, guidance and recommendations” (Back et al, 2009; 3) for their current and future work. The data collection was carried out in the 2007/8 academic year by a core team of four researchers and a project manager. The intention was to provide a research base for advancing the professional development of mathematics teachers in England. The research had five aims covering what currently constituted professional development, what was found to be effective and what role the NCETM might take, via their website. The resulting publication, “Researching Effective CPD in Mathematics Education (RECME)” was a large-scale project covering all stages of the education system from pre-school to adult education. They identified a number of aspects of effective professional development for teachers and tutors of mathematics and this contributes significantly to the discussion later in this chapter.
The team developed a method of valuing two perspectives, that of the research team observing from the outside and that of teacher participants experiencing the professional development. They described the latter as “privileging the teachers’ voice” (Back et al, 2009b; 3). Due to the depth and breadth of the research, the authors suggest that their findings have value in terms of being applicable outside of the context of the English education system.

The headline recommendations of “Researching Effective CPD in Mathematics Education (RECME)” (Back et al., 2009b) were that effective professional development:

- Is led by a professional development lead with relevant and up to date expertise.
- Is composed of relevant and practical content including classroom resources and “ICT” resources (i.e. Information Communication and Technology, commonly referred to as digital technology at the time of writing).
- Is “simulating, enjoyable and challenging” (Back et al, 2009b; 3).
- Is given sufficient time to occur.
- Is also an opportunity for collaboration and discussion with other teacher participants.
- Focuses on mathematical content.
- Focuses on how students learn mathematics.
- Provides opportunities for reflection.
- Incorporates tasks for embedding learning in practice or reflecting upon learning.

2.6. The nature of professional development

It is noted in some of the literature that professional development is an inherently human activity that should acknowledge the whole person (Little, 1993). By this it is meant that professional development is not just an academic pursuit, it has social and intrapersonal aspects too. It should take in to account the experiences of the individual and reflect factors such as their personal development needs and career stage (Advisory Committee on Mathematics Education, 2013).

One implication of this is that professional development is not a straight-forward pursuit, Loucks-Horsley et al. (2010) describe it as “more art than science” (Loucks-Horsley et al, 2010; 21) and that there is “no ‘paint by numbers kit’ for professional development”

44
(Loucks-Horsley et al, 2010; 25). This may go some way towards explaining the lack of consensus and detail on what makes professional development effective.

A second implication of professional development being a subjective and individual experience is that it challenges teacher participants’ values and beliefs (Little, 1993; Advisory Committee on Mathematics Education, 2013). There are therefore many disincentives for participants to actively engage with professional development in a meaningful manner and the task of designing and engaging in professional development should not be underestimated (Ball, 1996). Due to this there is a caution expressed within the literature against over ambition in terms of the outcomes (Hiebert et al, 1996). Despite these barriers to professional development there is an understanding that professional development can be effective if teachers are persuaded of the outcomes in terms of benefits to their students (Blaize, 2003). This may link to the findings of the Advisory Committee on Mathematics Education (2013) who caution against professional development that reacts to the short-term pressures of current government school targets. They argue that “short-term, fragmented and/or reactive approaches” need to be countered by more substantial, long-term programmes that aim to benefit all learners (Advisory Committee on Mathematics Education, 2013; 8).

2.7. Characteristics of effective professional development

There is a growing consensus on what features contribute to effective professional development for teachers, either in general or in mathematics specifically (Weiss and Pasley, 2006). A number of characteristics are already regularly identified within the literature (Advisory Committee on Mathematics Education, 2013; Garet et al, 2001; Riding, 2006; Loucks-Horsley et al, 2010; Hiebert, 1999; Kennedy, 1998b). These features commonly appear in lists compiled by writers with these, or similar, labels:

- **Sustained.** Professional development is more effective if it is on-going and involves a “substantial number of hours”.
- **Subject-specific.** The professional development should be specific to these subjects and to teaching these subjects.
- **Active.** Professional development should not be passive
- **Embedded.** Opportunities to put learning in to practice should be provided.
• **Engage with research.** Professional development should include research to some extent.

• **Reflective.** The professional development should facilitate teachers to operate as reflective practitioners.

• **Collaborative.** In order to be effective there should be opportunities for teachers to discuss, share and interact.

• **Delivered convincingly** Teachers identified that professional development should be delivered “by example”.

Each of these is discussed in greater detail in the following section.

2.7.1. **Sustained duration**

There is a wide variation in the duration of professional development courses, from less than one day to many days spread over more than a year. (Kennedy, 1998b) describes the former as “one-shot workshops” (Kennedy, 1998b; 1) and criticises these as not being long enough to become a factor of change in teacher classroom practices. Blank et al. (2008) found that engagement of more than 50 hours in professional development led to “significant effects” (Blank et al, 2008; 1).

However, research recommends caution about using the duration of contact time with teachers in professional development as a key indicator of effective professional development (Kennedy, 1998b; Cohen and Hill, 1998; Timerley et al, 2007). All of these researchers found no correlation between duration of time spent on professional development courses and their measures of effectiveness. For example, Kennedy (1998) used the attainment of teachers’ students as her measure of effectiveness and found that the contact time teachers had in professional development was not a reliable predictor of improvement in student attainment. Timperley et al (2007) stated that,

> “While an extended time frame with frequent ongoing opportunities to learn does seem to be generally associated with professional development that results in positive outcomes for learners, it is not in itself a guarantee of success”

Timperley et al (2007; 75)

They argue instead that it is how the time is spent that is the important factor in the professional development being effective.
Very little mention is made of the length of a course valued by teachers as being a factor of effective professional development. Back et al. (2009b) reported that teachers expressed an appreciation for any amount of time spent away from the classroom as an opportunity to “stand back” and reflect.

2.7.2. Content
Out of the growing body of research, a noteworthy amount suggests that the content of professional development is found to be more significant than its possible structures and organisation (Kennedy, 1998b; Cohen and Hill, 1998; Timperley et al, 2007 and so on). However, it is apparent from the literature that a number of different themes emerge on the nature of the content addressed in professional development courses. A minority of courses focus on the sharing of classroom materials and resources. Weiss and Pasley (2006) conclude that if such courses are delivered with enthusiasm and are carefully designed then they can have an impact in the classroom, and thus be seen as effective. However, although including classroom materials can be helpful it can lead to a narrow experience for the participants who lose sight of key ideas and the wider landscape (Weiss et al, 1998). Greater evidence is found for the benefits of including mathematics and an expectation that participants will actually engage with doing some mathematics. Garet et al. (2001) find that a focus on mathematical subject content is more likely to be effective professional development in terms of enhancing knowledge and skills. Cohen and Hill (1998) expand upon this detail and find that the subject knowledge covered had to be limited to specific areas of mathematics, listing “fractions, measurement, or geometry” as examples (Cohen and Hill, 1998; 16). This is extended upon later, with recommendations that the mathematics needs to be of a challenging level for the participants in order to provide a context for reflection (Loucks-Horsley et al., 2010). One reason for this is suggested by Gray (2005). She finds that appropriately challenging subject content provides the opportunity to reflect with their peers in terms of people teaching the same aspects of the curriculum. Another suggestion put forward is that engaging in mathematics puts the teachers in the “students’ shoes” and gives teacher participants a renewed appreciation for the learners’ experience when engaging in learning new mathematics (Back et al., 2009b). Distinct from mathematical content is pedagogic subject content, i.e. mathematics-specific pedagogy. Shulman (1987) describes this as “the blending of content and pedagogy into an
understanding of how particular topics, problems or issues are organised, represented and adapted to the diverse interest and abilities of learning, and presented for instruction” (Shulman, 1987; 8). In Professional learning for all teachers of mathematics, the Advisory Committee on Mathematics Education (ACME, 2016) emphasise the importance of this combination, stating that, professional development should be delivered, “so as to actively develop the full spectrum of teachers’ mathematics specific knowledge, that is knowledge about mathematics and knowledge about how to teach mathematics” (Advisory Committee on Mathematics Education, 2016; 5). Finally, including how students learn mathematics was found to be factor of successful professional development (Kennedy, 1998b) and that this should be combined with teachers’ own subject knowledge and their ability to assess students’ mathematical understanding (Timperley et al, 2007).

Perhaps unsurprisingly a combination of both mathematical content and mathematical pedagogy content was repeatedly found to be an element of effective professional development (Blank et al., 2008; Weiss and Pasley, 2006; Back et al., 2009b et cetera). (Kennedy, 1998a) suggests a two-way relationship for this. Before considering how a student learns some mathematics, the teacher must understand the mathematics to be learned. Conversely, by understanding how a student learns a particular mathematical topic and the common misconceptions they may hold, the teacher gains more of an insight in to the mathematics itself. Timperley et al (2007) take a slightly different perspective, stating that their analysis found that, “No programme that focused solely on a generic pedagogy was successful in raising students’ achievement in mathematics” (my emphasis, Timperley et al, 2007; 78).

2.7.3. Active
A recurring factor from the literature is that professional development should be active. This is noted to be a relatively recent development and to have emerged from the mid-1990s onwards (Blank et al., 2008).

There is a slight variation in how “active” is used and defined. Riding (2006) describes how professional development is now viewed as involving active participation rather than something that is “visited” upon mathematics teachers. The Advisory Committee on Mathematics Education (2013) specify that teachers need to engage with mathematics themselves. Garet et al. (2001) do not mention subject knowledge but define active learning
as being “hands-on” and that effective professional development that provides teachers with the opportunity for such work is “more likely to produce enhanced knowledge and skills” (Garet et al, 2001; 933). Back et al. (2009b) reported that teachers were reported to value professional development that was “stimulating, enjoyable and challenging” (Back et al, 2009b; 5). The findings of Weiss and Pasley (2006) that “there is a growing recognition that learning is fundamentally situated in the context of authentic experiences” (Hoban and Erickson, 2004; 303) could also be argued that this requires active, as opposed to, passive learning. The contributions of Blank et al. (2008) are helpful in that they describe examples of what might constitute teachers engaged in active learning roles, “developing and presenting sample lessons, use of coaching and mentoring, developing new lessons or assessments, and interaction among teachers about ways to improve their practice” (Blank et al, 2008; 10). Timperley et al, 2007 found that the level of the mathematics activity could be either at the teacher participants’ own level of challenge or that appropriate to their students. What matters, they argued, is that it “provided a context in which teachers could collaboratively analyse a wide range of issues related to mathematics teaching practice” (Timperley et al, 2007; 87).

There is a note of caution in some findings that the importance of active learning not be overplayed (Garet et al., 2001). They found that the link between active learning and their measure of effectiveness, enhanced knowledge and skills, was “less strong”.

2.7.4. Embedded in practice

There is some consensus within the literature that professional development which seeks to support teachers in embedding their learning in their practice is more effective than otherwise. Weiss and Pasley (2006) describe embedding practice as approaches that allow “for integration of new knowledge in to practice, and include follow-up support” (Weiss and Pasley, 2006: 9). There is also a belief that a strength of embedded practice is that it takes a facilitating role for that other effective characteristic, reflection. It is argued that this happens because embedded practice provides teachers with time and encouragement to “try out new ideas” (Advisory Committee on Mathematics Education, 2013; 5). Hoban and Erickson (2004) develop this further by suggesting that it is more than time that is required for trying out new ideas. They argue that the professional development is a means of allowing teachers to take risks. Allowing teachers this personal freedom to experiment
“enhances their motivation to participate in the process of life-long learning” (Hoban and Erickson, 2004; 303). The Advisory Committee on Mathematics Education (2013) also make mention of this permission-giving.

Another reason emerging for embedded practice being effective is that it is seen to lead to change. Garet et al. (2001) argue that the results of their national sample indicate that professional development leads to improved practice and knowledge when it is coherent, i.e. when it is “integrated into the daily life of the school” (Garet et al., 2001; 935).

Finally, Ball (1996) goes some way to provide detail on what embedded practice might look like, “follow-up activities, usually in the form of long-term support, coaching in teachers' classrooms, or ongoing interaction with colleagues” (Ball, 1996; 3). However, she also acknowledges that exactly what might be meant by “follow-up activity” is still unclear.

2.7.5. Use of research

It is not always easy to distinguish between a recommendation that professional development be informed by research and that professional development provide opportunities for participants to actively engage with research. For example, Weiss and Pasley (2006) state clearly that there is a widely shared agreement that “high-quality PD programs are grounded in research and clinical knowledge of teaching and learning” (Weiss and Pasley, 2006; 2). Timperley et al (2007) found that, “All the studies with substantively improved student outcomes had a strong theoretical underpinning that was clearly communicated to teachers” (Timperley et al, 2007; 79). I would argue that recommendations such as these are not synonymous with professional development providing participants with an opportunity to reflect and critically examine research for themselves. Indeed, there is little mention of this as an aspect of effective professional development arising from the research literature.

The published recommendations of the professional subject associations follow a slightly different approach. The Advisory Committee on Mathematics Education (ACME, 2013) make repeated and strong statements on the use of research to inform professional development. For example, “Continued efforts should be made to facilitate effective communication and collaboration between teachers and researchers, so that students in the classroom benefit fully from advances in knowledge and understanding of the most effective ways to learn and teach mathematics” (Advisory Committee on Mathematics
Education, 2013; 11). Here they emphasise that there be relevance and applicability of research in the teachers’ classroom practice.

So it is interesting to note that a recommendation of the seminal report, “Researching Effective CPD in Mathematics Education (RECME)” Back et al. (2009a) stated that “It seems that it is important to provide teachers with opportunities to read and think about ideas from research” (Back et al, 2009a; 5) in terms of professional development encouraging participants themselves to engage with relevant research and professional literature.

Therefore, it appears that this is a possible factor in what constitutes effective professional development, but as identified by the researchers than by the data they collected from teacher participants.

2.7.6. Opportunities for reflection

A number of sources state that opportunities for reflection are an aspect of effective professional development (Gray, 2005; Loucks-Horsley et al., 2010; Ball, 1996; Blaize, 2003; Shulman, 1987). Indeed, it is found to be an important requirement by many researchers. Blaize (2003) says that it is “essential” for professional growth and Ball (1996) that it is central to learning how to teach. In 2013, the Advisory Committee on Mathematics Education noted reflection as an emerging characteristic of effective professional development going so far as to state that it, “improves mathematics teaching and learning” (the Advisory Committee on Mathematics Education, 2013; 4).

There is some variation as to specifically what teachers should be reflecting upon. Loucks-Horsley et al. (2010) include teachers reflecting upon their own learning as part of their definition, whilst Blaize (2003) emphasises reflecting upon their teaching and performance within the teacher’s classroom. Gray (2005) uses the phrase “reflective practioners” (Gray, 2005; 27) to describe the professional behaviour of a continual process of reviewing and refining of views and knowledge and that professional development should provide opportunities for teachers to engage with this process. Day (1999) widens the scope of reflection to include not only the individual’s own practice but also that of others. A number of writers list more than one form of reflection, for example “talking with others,
by keeping a journal, by engaging in action research” (Ball, 1996; 3) but as we shall see below, listing reflection activities is not sufficient knowledge.

Despite a wide acknowledgement of the importance of reflection, there are gaps noted in the research. Ball (1996) acknowledges that there is still more to be learned on the specifics of reflection in effective professional development and that in the literature, “Less attention is paid to what the specific objects and the nature of that reflection might be, leaving somewhat up in the air the variety of learnings that reflection might support” (Ball, 1993; 3).

Blaize (2003) refers to Elliot (1989) who voiced cautionary words that could be viewed as significant in the context of professional development facilitated by a third party professional development lead. He notes the existence of a perceived hierarchical model of reflection and that in terms of self-reflection it being “inhibited in the presence of an authority figure” (Blaize, 2003; 59).

Finally, Conway (2001) criticises an over-emphasis on the retrospective side of reflection. He argues that successful reflection must include prospective thinking as much as retrospective and that it is the gaining of “critical distance” that is important.

These concerns around recognised gaps in our knowledge demonstrate that not all reflection is necessarily successful reflection. They raise questions as to how reflection could be facilitated in a way that participants experience as being effective and leading to improvements in their practice.

2.7.7. Collaborative

Building upon the requirement discussed above for professional development to be reflective, some research indicates that this be linked to reflective, collaborative discussions with others engaged in the same training. Carnell (1999) describes that collaboration may mean even only paired work and that sharing the learning experience in this manner means that the process of professional development is enhanced.

Loucks-Horsley et al (2010) uses the phrase “supportive collegial communities” (Loucks-Horsley et al, 2010; 141) to describe the nature of this collaboration (in this case within the context of learning challenging mathematical subject content). This emphasises a lack of
hierarchy and a coming together of peers with shared expected outcomes. In their research in to the wider, cross-professional contexts of education, business and medicine, (Hoban and Erickson, 2004) describe the role of other members of the collaboration as being mediators of the individual’s learning. This is described as being different to a professional development lead’s facilitating role in so far as all members of the group are aiming to “make sense of the phenomena under consideration” (Hoban and Erickson, 2004; 5). The nature of collaboration is not only described as being supportive in an accepting, non-challenging manner. Carnell (1999) identifies a more active and challenging role of peers in collaborative work. He uses the term, “critical friend” to describe how professional development is effective when others in the group encourage “risk taking, change and problem solving” (Carnell, 1999; 42). Timperley et al (2007) found that, “participation in some form of learning community was a necessary but not sufficient condition” (Timperley et al, 2007; 88). Despite the benefits of collaborative learning, and even taking a loose definition of such participation, they found that other factors, such as external expertise were required for collaboration to be an effective element of professional development. A final nuance of collaboration is identified by Day (1999) who suggests that it is through discussion and reflection on others’ experience as well as their own that leads to a development of thinking and practice.

So, there is much agreement on the benefits of collaboration and some description of this involving discussion between two or more people. However, there was no development beyond this of how collaborative talk could be facilitated as part of effective professional development.

2.7.8. Nature of delivery
The characteristics of the professional development lead and how they deliver content is addressed by a number of sources within the literature. The most widely reported finding of this aspect is that those carrying out the training are seen by participants to “walk the walk” (Gray, 2005; Loucks-Horsley et al, 2010; Ball, 1996; Loucks-Horsley et al, 2010). Gray (2005) discusses the need for the presenters of professional development to “lead by example” and that participants described this as them “applying solid classroom principles to the provision”. Loucks-Horsley et al. (2010) extend this “walking-the-walk” to being a
requirement for the professional development to lead to change in the classroom. They explain that teachers need to experience the style of teaching for themselves, as opposed to merely learning about it from secondary sources, and that this leads to implementation in the classroom. Finally, Ball (2005) highlights that this is not always straightforward. She uses the word modelling to describe the delivery as being by example, but cautions, “Though often heard, this advice is quite vague and is variously interpreted” (Ball, 2005; 4).

The Advisory Committee on Mathematics Education (2013) recommend that professional development be “facilitated by experienced and well-qualified experts” (Advisory Committee on Mathematics Education, 2013; 4) but there is no consensus in the literature as to how any of these terms, experience, well-qualified or expert, should be defined. This raises the question as to whether this should refer to experience as a teacher, as a teacher of mathematics or a teacher of professional development. Does experience and knowledge in one area compensate for a lack in another? That is, can a successful teacher of mathematics of many years lead effective professional development even if they have no or limited experience in educating teachers?

There is limited mention of the personal characteristics of the professional development lead. (Ball, 1996) describes the sharing of information and distributing of ideas and resources with “enthusiasm and clever quips” (Ball, 1996; 12). However, she cautions that this does not necessarily lead to impact. She argues that these professional development sessions lead to teachers receiving a quantity of classroom resources but that “their potential is restricted by the lack of critical discussion” (Ball, 1996; 12). If there is no impact in the classroom, can the professional development be described as effective?

Finally, Weiss and Pasley (2006) also describe that a “walking-the-walk” delivery is not enough. Not only should the professional development model good teaching, it should also include opportunities for participants to discuss and critique exactly what is good practice about the methods used.

So, in summary, there is considerable mention of how the professional development is delivered, as much as what is delivered, if it is to be effective. However, although delivery is considered important and valued by participants there is little mention of how participants identify effective delivery beyond that it models good practice.
2.8. **How the effectiveness of professional development is measured in the literature**

There is variation across the literature in terms of how professional development is judged to be effective or otherwise. Five levels of evaluation for teacher professional development are suggested by Guskey (2002). This is a helpful ranking for locating the choices and preferences of other researchers discussed below as well as my own later choices:

1. participants’ reaction. The initial level of satisfaction of the teachers.
2. participants’ learning. The new knowledge and skills of the teachers.
3. organisational support and change. The impact on the school, for example, and how the organisation reacted to change
4. participants’ use of new knowledge and skills. [This corresponds to Blank et al’s “change in practice” below].
5. student learning outcomes. That is, the impact on students. This includes the common measure of their performance but Guskey also includes their confidence, well-being and attendance at school. The Department for Education’s *Standard for teachers’ professional development* (Department for Education, 2013c) strongly emphasises student outcome as the measure of effectiveness of teachers’ professional development.

Guskey indicates that there is an increasing degree of complexity as you move from level 1 to level 5, and that an accurate measure of one level requires the measuring of earlier levels to also be successful.

Guskey’s third level around organisational change is not as comprehensively present in the literature in general. Blank et al. (2008) identify three common measures of professional development effectiveness across their study:
- gains in teacher knowledge (Guskey’s level 2)
- change in classroom instructional practice (Guskey’s level 4)
- improvement in student achievement (Guskey’s level 5)

However, Blank and his team express concern that measures that were planned across their selected sample were not always implemented or identifiable in their findings. The most promising method in their opinion was one that measured change in teacher practice (present in four of their twenty-five case studies). This is perhaps unsurprising given that Blank’s focus was on state-wide curriculum change in the United States of America.
In Kennedy’s 1998 survey of in-service programmes for mathematics and science teachers in a United States of America context she indicated a preference for an “eventual influence on student learning” (Kennedy, 1998; 1), equivalent to Guskey’s level 5. However, in terms of how student learning was improved, she shows a preference for student performance in tests as opposed to, say, rate of student progress, student enjoyment of the subject, student inclination to study the subject further etc. She notes that this is a common method across her case studies because of the number of such instruments for measuring student attainment already available in mathematics (as opposed to science).

Finally, the seminal “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al., 2009b) takes a broad picture of all of the possible outcomes of teacher professional development. They describe their report as concerning itself with “teacher and school change” (Back et al., 2009b; 84) as a measure of the effectiveness of professional development. For the former they include reported change in teacher attitude and ‘learning’ (arguably that described as “knowledge and skills” elsewhere in the literature). “School change” covers change in teacher practice (Guskey’s level 4 as well as his level 5) and change in student learning, attitudes and behaviour.

There appears to be a little presence of Guskey’s first level of evaluation, teacher voice and their early impressions of the professional development experience. Guskey describes the initial satisfaction as the easiest type of information to gather. Although it could be criticised for measuring only the “entertainment value” of professional development, these initial impressions are nonetheless valid (Guskey, 2002).

2.9. Conclusion of the literature review

So, in summary, a knowledge of what factors contribute to effective professional development is emerging from the literature. There is a growing consensus as to what characteristics should appear in such lists, but no single, definitive list. There is no suggestion that these lists are complete or that they will not need to evolve over time as the landscape of mathematics education continues to change. Furthermore, there is a growing understanding of what each factor’s properties should be, e.g. the duration of a course is
generally agreed to be a factor and professional development courses that are sustained over a number of days are generally considered more effective than a short, one-day course. A quantitative approach was popular in the early 21st century, with researchers attempting to give these lists of characteristics of effective professional development a numeric value. This appears to be because there was very much a systems perspective, with emphasis on successful system change such as curriculum reform (Little, 1993; Blank et al, 2008). There was less focus placed upon the experience of the teacher participant and the personal, as much as the professional, development of the individual. However, in more recent years a growing recognition of the social and personal nature of professional development has led to greater investment in research utilising qualitative methods. Arguably, although the Advisory Committee on Mathematics Education hint towards this, little attention has been paid to the demographics of teacher participants and as to whether details such as the career stage or qualification background of the individual plays a role in what characteristics of professional development they may find effective.

The latest and large scale project of professional development for teachers of mathematics in England, “Researching Effective CPD in Mathematics Education (RECME)”, makes an explicit decision to include and value the teachers’ voice. This forms an established foundation for my own research in addressing the effectiveness of professional development of mathematics teachers from the perspective of the teacher participant. At this stage I find myself curious about the extent to which the teacher participant’s view would concur with others’ perspectives of effective professional development, such as that of researcher observers. Secondly, “Researching Effective CPD in Mathematics Education (RECME)” sets the scene for my own research to attempt to add clarity and detail to the currently broad and general lists of characteristics of effective professional development for teachers of mathematics. At this stage of my research I found myself asking unanswered questions such as,

- What are some of the specific characteristics of subject-specific content that lead to it being effective professional development?
- What are some specific examples of active learning that teacher participants find effective?
• How does professional development specifically support teacher participants in embedding their learning in their teaching?
• How should professional development use research evidence if it is to lead to effectively supporting teacher participants?
• What are some specific examples of reflective practice that teacher participants find effective?
• What are some specific examples of collaborative learning that lead to teacher participants effectively discussing, sharing and interacting?
• What characteristics of a professional development lead are teacher participants likely to find effective?

3 Methodology and research methods

This section is concerned with the development of my methodology and the choice of my research methods. Up to this point the context and intended aims of my research have been explained in section 1. The detailed explanation of my background, beliefs and general positionality established there will be apparent as an important thread in this section and seen to carry great influence in the decisions made here.

Furthermore, from the review of literature examined in section 2, important considerations will remain present in this section. Firstly, the emerging established knowledge is intended to be built upon and secondly, that the identified gap in this knowledge concerned with the teacher participants’ perspective will be addressed.

In section 3.1 the evolution of a subjectivist and interpretivist methodological position is described. Subsequently, in section 3.2 an appropriate research approach (multiple case study) and methods are identified. Greater detail on the specific research strategy and research instruments is provided in section 3.3. A triangulation of two qualitative approaches, questionnaires and interviews, is described, with section 3.4 focusing upon the logistics of the questionnaire data collection and section 3.5 on the interview-related data collection.

In section 3.6 the issues of validity, reliability and generalisability are described and explanation given to how these are to be addressed in this research. Section 3.7 describes the considerations given to the important ethical questions arising in this research. An
initially considered research instrument, considering the professional development lead’s view, is described and why the ultimate decision to not use it is explained in section 3.8. Section 3.9 forms a summary of the key decisions made.

3.1 Philosophy and methodology

In section 1 I outlined a relevant personal history and stated my positionality. Here, I provide greater detail on my philosophical position in terms of research. As Grix (2004) writes, “If we are to present clear, precise and logical work, and engage and debate with others’ work, then we need to know the core assumptions that underlie their work and inform their choice of research questions, methodology, methods and even sources” (Grix, 2004; 57). Furthermore, Neuman (2006) writes this is important because the qualitative researcher should begin with a “highly self-aware acknowledgement of social self” (Neuman, 2006; 15).

Over the course of this Masters research my philosophical position has evolved significantly. Initially the dual influences of both my educational background in mathematics and the sciences and a personal interest in science were the main factors. I started my studies from a strongly positivist position. By positivist I mean an ontological assumption that the reality of, in this instance, effective professional development for mathematics teachers would exist external to the teacher participants involved, as a “given ‘out there’ in the world” (Cohen, Manion & Morrison, 2008; 7). Grix (2004) describes such a positivist position as “the view that reality is thought to exist independently of our knowledge of it”. This in turn had led to me having a strongly epistemological standpoint that knowledge is “hard, objective and tangible” (Cohen, Manion & Morrison, 2008; 7) and therefore evident and obvious. In the context of my work and research this would be that professional development for teacher participants on a mathematics course is something that could be viewed and identified by the researcher. Initially, and without further consideration, I informally envisaged that this research would require me to adopt the role of an observer in my research. Such a methodological position had, once again informally and without reflection, led to me picturing using quantitative and positivist research methods of observation and measurement.

Before planning the data collection, I spent a year conducting a literature review and completing a University of Hull module on research methods. In keeping a reflective
journal during this time, I noted my developing comprehension of the nature of professional development. Firstly, I realised that a certain view of professional development is one that most struck a chord with me. As discussed in detail in the literature review, different positions are held on the what constitutes professional development for teachers and its purpose. For instance, Guskey (2002) categorises these as changes in the teacher participants’ satisfaction levels; a change to their knowledge and skills; a change in their practice; change at a school or college organisational level; and, the impact on students and the outcomes of their learning. Due to these different interpretations of professional development for teachers, different positions are held in how the effectiveness can be measured. For example, measuring the change in student outcomes as measured by exam results or investigating the value of worth of professional development as measured by school leadership (see literature review for further discussion of these ideas). However, on reflection I found that my position was developing to view teacher professional development as a personal experience, one of individual interpretation and a personal “making sense of”.

In adopting this position, I also came to be of the opinion that this experience involves a multitude of factors. This “making sense of” is sometimes internal and at other times it involves discussion with others. It is sometimes deliberate, methodical and reflective and at other times it is unexpected or informal and is constructed by quiet, personal revelations. Given a belief in these characteristics, I decided that professional development is experience-based and can therefore only be known through the teacher participants’ expressed responses.

After this year of reflective and evolving thinking I also began to realise that my understanding of the nature of reality, and my ontological beliefs around knowledge, were moving to ones of subjectivism. My position of the social nature of professional development was that which Cohen et al (2008) describe as “softer, personal and humanly created” (Cohen et al, 2008; 8). I had come to highly value the experience of the individual and their personal interpretation of that experience and how they chose to express it. This led to me taking an interpretivist methodological position in my research. Neuman (2006) describes interpretivism as to mean taking an interest in individuals’ personal feelings and motivations and how they shape their decision-making. In terms of the nature of the effectiveness of professional development, it would not be an external reality that I could
observe but would instead involve describing the effectiveness of professional development as seen, felt and experienced by the teacher participants.

3.2 Research approach and methods
Following on from the previous section outlining the development of an interpretivist position for the purpose of this research project, this part explains how I chose my research methods.

The choice of research methods is intrinsically linked to the methodological position (Grix, 2004; Hart, 2005; Silverman, 2014 et cetera). As explained above in section 3.1 having not adopted a positivist approach a purely empirical method was not chosen as an appropriate means for measuring and collecting data of people’s experience. Empirical, quantitative methods seek to enumerate that which is studied and then measure it (Grix, 2004; Neuman, 2011; Cohen et al, 2008 et cetera). Quantitative methods therefore not chosen encompassed:

- **Surveys** A survey approach was not chosen for two reasons. Firstly, and significantly, it would not be congruent with my interpretivist approach. My beliefs around professional development meant that I highly valued the internal aspects of reflection, thoughts and feelings of the participants, aspects that are difficult to observe and easy to misinterpret. Secondly, I did was not confident that I could play the role of both observer and participant as the professional development lead. Leading professional development means paying careful attention to the teacher participants, similar to how teaching means paying careful attention to students’ behaviour. This “paying attention” to teacher participants is not the same as observing them from a researcher’s perspective. There would be the further complication of having to record my observations. Therefore, even had I taken a positivist ontological position, I concluded that I wouldn’t be able to carry out an observational survey whilst performing my professional role.

- **Analysis of the literature**. As has already become apparent in the literature review (section 2) there is not yet a great wealth of writing in the area of professional development for mathematics teachers. Any meta-analysis would by necessity have to take in to consideration a wider range of, perhaps, teachers of subjects other than mathematics or a more broad and wide definition of what can constitute professional
development. Neither of these were specific enough to address the gap in knowledge as identified in section 1, namely what characteristics of secondary mathematics professional development courses teachers find effective.

- **Structured or systematic observations.** Grix (2004) describes these as observations in which the researcher models or structures their observations around certain foci and their data collection in predetermined formats (Lewis-Beck, 2004; McNeill & Chapman, 2005). The researcher carries out their data collection with predetermined “categories, concepts or classifications in mind” (Grix, 2004; 130). Once again, I decided that this research method did not match my methodological position of prioritising the teacher participants’ perspective. I wanted to research what they found significant rather than imposing my own structures.

Once having decided upon an interpretivist methodology, I then considered what qualitative methods would be appropriate research aims and questions. Qualitative methods not selected for this particular research project and relevant rationale are explained below.

- **Observations (unstructured).** In an unstructured observation, the researcher records events without a pre-determined classification system and the form of recording and categories and themes emerge as a result (Grix, 2004; Cohen et al, 2008). I decided against this because observations may have been biased by my perspective, especially when in the role of the person leading the professional development. Once again, my focus placed value and importance on what the teacher participants would view as important, not what I would. Also see above, the complications around the conflict of me being both researcher-observer and my responsibility as a professional development lead.

- **Ethnography.** An ethnographic study is an immersive form of observation. Hart (2005) describes an ethnography as “direct observation” which occurs over a long period of time, focusing on the social interactions of different members of a community. Grix (2004) describes ethnography as a long-term study and more suited to a researcher being required to submerge themselves in the wider lives of a certain culture or community. Some parallels do exist between an ethnographic approach and that which I ultimately choose, in as much as I will sometimes be
researching within the context I work in. I will collect data at key points from, in one example, a professional development course that I lead. However, in the context of this research, a truly pure ethnographic method would likely have involved me joining the professional development course as a teacher participant myself. This method was not chosen due to the significant financial and time costs. Furthermore, participants on a training course are not commonly defined as a community or culture.

- **Action research** would likely have involved one or more of the teacher participants to have taken a pro-active and participatory role in the research, e.g. in the design and analysis of the research. This was an interesting option as firstly, I was aware of parallels with the current popularity for classroom research and lesson study currently in mathematics departments in schools and colleges (National Centre for Excellence in the Teaching of Mathematics, 2013). Secondly, it would have met my self-determined criteria that the research should value the teacher participants’ perspective. However, action research requires not an insignificant investment from the participant which is not an opportunity I have access to. Furthermore, the research describes how action research is typically more suited to those in management and leadership roles within the organisation being researched (Hart, 2005). In this way, there are once again some similarities with the method I am selecting and the one opted against (ethnographic), insofar as I will sometimes be researching within the context of my own work and always within the context of my employers.

- **Focus groups.** This research method is most closely related to my eventual multi-case study choice, but was decided against on the basis of cost, especially to the time-constrained teacher participants on the professional development courses.

I have chosen to take a **multiple case study** approach because of my belief that professional development involves a personal response. (This belief is reflected in the literature, e.g. (Evans, 2008) as noted in the literature review, section 2. Furthermore, I believe that both teaching and a teacher’s development are idiosyncratic). A case study focusing on individuals’ experience of professional development would mean that these experiences and interpretations could be examined in that context. Finally, I was curious
about the view that professional development is about relationships, i.e. the interactions between a participant and the professional development lead and other participants.

Case studies are almost synonymous with qualitative research (Neuman, 2011). Cohen et al (2008) describe them as being specific, qualitative cases which can represent and illustrate the general. The benefits of case studies are that they provide a richness and depth to research, balancing both description and analysis (Cohen et al, 2008). Furthermore, I was interested in the research findings having a relevant and practical application in my work and that of colleagues and as Neuman (2011) identifies, a case study of individual people can be connected to wider applications by the researcher.

I decided to use questionnaires and interviews (involving a combination of closed and open questions) to develop the multiple case study.

- **Questionnaires.** Cohen et al (2008) explain that a questionnaire is “a widely used and useful instrument for collecting survey information, providing structured [data]” (Cohen et al, 2008; 317). The perceived constraints of questionnaire use in this research project are the possibly limited responses and mis-interpreted prompts by the teacher participants linked in part to a poor questionnaire design. However, I felt that these were counter-balanced by the benefits of straightforward analysis (comparative to other methods) and ease of data collection (i.e. not requiring the involvement of the researcher).

- **Interviews.** Hart (2005) defines interviews as “talking to selected respondents on a specific topic to find answers” (Hart, 2005; 357). They are a good choice of research method for this project as their use will address some of the weaknesses of questionnaires identified above. The benefits of interviews as a research method are identified as a method of accessing people’s (in this case teacher participants’) beliefs, values, experiences and understanding (Silverman, 2014). Furthermore, a well-performed interview is likely to elicit more considered and thoughtful responses (Byrne, 2004, cited Silverman, 2014).

A mixed method approach combining questionnaires and interviews has been chosen, an approach known as “methodological triangulation” (Mason, 1996; 25, cited Silverman, 2014). As the questionnaires will be conducted first, followed at a later stage by the interviews, this will be an example of method triangulation defined as “two or more research methods to investigate the same phenomenon” (Grix, 2004; 137). My reason for
choosing this approach is in order to strengthen the reliability and validity of my research and findings (Grix, 2004). The specific questionnaires and interviews to be conducted for this research are now discussed in greater detail in the following sections.

3.3 Strategy and Research instruments

In the last section I explained my decision for collecting subjective, qualitative data and therefore using a combination of interviews and questionnaires, including both closed and open questions. In this section I provide an overview of the timing and types of data collection processes that are to be carried out on paper. Two questionnaires are to be used in different ways, one for each of the research questions:

1) **What aspects of professional development sessions do teachers find effective and why?**
2) **Are there common themes for different groups of teachers?**

Below follows a description in more detail of the specific research instruments.

3.3.1 Research instrument: **Participant general information questionnaire**

The first questionnaire is to be completed by the teacher participants at the start of the data collection only. If teachers are intending to participate on more than one day, I will not ask them to complete this again. This would involve too much repetition for the teacher participant, may lead to a loss of good will and will not lead to the potential generation of any meaningful information. The only reason it may have been useful is if the research was investigating preferences in effective professional development over a very short timeframe. This does not apply to my particular research questions.

The **participant general information questionnaire** is intended to address my second research question, “Are there common themes for different groups of teachers?” In section 1 I described my expectations that commonalities would exist in terms of what was found to be effective professional development by teacher participants sharing similar backgrounds. I am not certain what these signalling factors will be specifically. Therefore, the **participant general information questionnaire** asks participants for basic demographic information and more specific information on their professional situation / career stage:

- Demographic information requested will be their gender (female or male) and age group (30 or under; 31 – 40; 41 – 50; 51 – 60; and, over 60). These categories are
deliberately limited and broad for privacy reasons and to encourage a response that more specific age groups might prove a barrier to.

- **Professional situation / career stage questions are:**
  - length of time teaching and,
  - length of time teaching mathematics.

Both of these questions invite categorical responses (I am training; I am in my first year as a teacher (e.g. NQT); 2-4 years; 5-10 year; 11-19 years; and, More than 20 years). These categories are not of equal length. It is generally considered that the difference between a trainee teacher and a teacher in their first year of qualified practice will be greater in terms of needs than, say, the difference between a teacher of 18 years and 19 years.

- There then follows four open questions, designed to reflect my interpretivist position. I intend to avoid any bias that might be created by directly asking the teacher participants if they are “subject specialists”, “qualified in mathematics” et cetera. There are different definitions of what constitutes being a “maths specialist” for example, and I would like to create a situation where teacher participants are able to make a personal interpretation based upon their own self-identification. The questions are:
  - Please describe your role/position at work
  - Please briefly describe your qualifications in terms of mathematics
  - Please briefly describe your experience and/or qualifications in terms of teaching
  - Please briefly describe the age / stage of students you teach

- Finally, I ask teachers to include their first and last name, so that demographic information can be matched to responses in the second questionnaire and I also ask whether they would like to provide their email address for follow-up questions. I decide upon this in order to reflect the importance my research placed on the individual’s personal experience. I have chosen not to use numerical identifiers or codes because this might create an impersonal impression of my research, and thus form a barrier to personal responses.
All of these questions are confined to one side of A4 paper, with the intention that a shorter document would be more likely to be completed by time-constrained professionals such as teachers.

### 3.3.2 Research instrument: Participant questionnaire on effective professional development

This questionnaire is to be completed by each teacher participant on each course day where data will be collected. Where the professional development course lasts for more than a single day, data will only be collected at a few key points. This restriction is for two reasons. Firstly, so that participating in the data collection will not impact significantly or negatively on the teacher participants’ experience of the professional development. The second reason is due to the financial and opportunity costs of me attending every course day.

Throughout the day teacher participants are to be given verbal reminders by myself to capture their thoughts on this document. This is intended to happen at two or three points during the day, whenever there is an appropriate opportunity to remind the teacher participant that will not otherwise intrude on the professional development lead’s work or the teacher participants’ experience. There will always be a reminder at the end of the course day for any final contributions to be recorded on paper.

The participant questionnaire on effective professional development is composed of two open questions that addressed my first research question, “What aspects of professional development sessions do teachers find effective and why?”:

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Reflecting on aspects of the course that were particularly effective or ineffective for you personally, please describe the particular aspect and explain what made it effective or ineffective.

<table>
<thead>
<tr>
<th>Session identification, e.g. title, timing or description</th>
<th>Aspects that were effective or ineffective and why. (Please decide for yourself what you define as an “aspect”).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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This form is two sides of A4-size paper and at the bottom of the second page the teacher participants are once again asked for their names. This is so that I can cross-reference their responses with their demographic information. Teacher participants are also invited to write
their email address if they feel that they would be available to respond to any follow up questions.

In section 3.4 detail is provided on how the data collection via questionnaires is to be performed and how this data will then be analysed. Similarly, section 3.5 provides detail on how the interviews are carried out and the subsequent analysis.

3.4 Professional Development Lead questionnaire
Initially, I had considered collecting additional data in the form of background information from the Professional Development leads. For each day of the courses when the teacher participants are to be asked if they would like to submit the *Participant questionnaire on effective professional development* (see section 3.3.2) I was going to approach the Professional Development lead to also submit information. I envisaged this to include detail on the structure of their training sessions and also an explanation as to the intended purpose of different activities. I was curious as to what degree the intended outcomes would match the perceived experience of the teacher participants. Furthermore, I had good access to the professional development leads to easily facilitate this.

However, during the initial stages of the data collection I have decided against this. The primary reason is a methodological one. I have already identified a gap in the literature in terms of judging the effectiveness of professional development from the teacher participants’ perspective. I suspect that a procedure of cross-referencing these viewpoints with the intentions of the professional development lead may lead to the focus being taken away from the teacher participants’ experience.

A secondary reason for deciding against a Professional Development lead questionnaire is the time taken for these to be completed, prior to the course day, by time-constrained colleagues.
3.5 Data collection: questionnaires

Section 3.4 provides detail on when and where data collection via questionnaire was carried out in this particular research project. It explains that four courses that were intended to be used, of which only three were actually used. For these three courses detail is provided on the particular course model, content and number of proportion of teacher participants who were involved in the research.

3.5.1 Planned professional development courses

My initial plan was to collect data at four different professional development courses. These are described below. These are sampled from a combination of two different factors, one-day or sustained professional development courses and courses led by myself or a colleague. They are arranged in a matrix here:

<table>
<thead>
<tr>
<th></th>
<th>Course led by myself</th>
<th>Course led by colleague(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single day course</strong></td>
<td><em>FRESH</em></td>
<td><em>Mechanics</em></td>
</tr>
<tr>
<td><strong>Sustained course</strong></td>
<td><em>Teaching GCSE Mathematics (TGM)</em></td>
<td><em>Teaching A Level Mathematics (TAM)</em></td>
</tr>
</tbody>
</table>

*FRESH ideas for getting students using GeoGebra* was a one-day professional development course. It is one title from a family of courses aimed at the experienced teacher of mathematics. This particularly title was for teacher participants looking to support their students in engaging with the free mathematical software, GeoGebra. In the year of my data collection, academic year 2015/16, this title did not run as expected and so I was unable to use this in my data collection.

*Mechanics* is also a one-day professional development course, “appropriate for any teacher who will be teaching the new AS/A level Mathematics and has not previously taught mechanics” (Mathematics in Education and Industry (MEI), 2013a). Teacher participants enrolled on the Teaching Advanced Mathematics course (see below) are offered a complimentary place, but this is not a requirement for joining the course. The course day I attend will be in January 2016 at The National Council for Voluntary Organisations.
(NCVO) in London. 11 teacher participants are on the course and eight teacher participants chose to engage with my data collection. The course was led by one of my colleagues.

Teaching GCSE Mathematics (TGM) is a sustained professional development course for “those new to teaching secondary mathematics” (Mathematics in Education and Industry (MEI), 2013c). In 2015/6 the course had cohorts in three different venues, Kings Heath near Birmingham, Altrincham near Manchester and London. I chose to collect data from the largest cohort, that held in London at The National Council for Voluntary Organisations (NCVO).

In addition to a substantial online element of videos and live sessions in an online classroom the course includes five face-to-face study days across the academic year:
Days 1 and 2 consecutively in October 2015
Day 3 in January 2016
Days 4 and 5 in June 2016

It was from these face-to-face study days that I decided to draw upon for my research. I chose to collect data at the three points in the year that we met, days two, three and four. Twenty-one participants were on the course and 20 participants chose to opt in to my data collection. This course was led by myself.

Teaching A Level Mathematics (TAM) is similarly a sustained professional development course, in this case it is, “designed to support teachers of GCSE Mathematics who wish to teach A level Mathematics for the first time” (Mathematics in Education and Industry (MEI), 2013b). As with the Teaching GCSE Mathematics course there is an online element of recordings and live interactive sessions. Unlike Teaching GCSE Mathematics, the course runs over eight study days, includes the opportunity to study for Masters level credits and involves lesson visits at the teacher participants’ schools. I chose the Manchester Metropolitan University cohort at which in 2015/16 the study days ran on:
Day 0 29th June 2015
Day 1 28th September 2015
Days 2 and 3, 25th and 26th November 2015
Days 4 and 5, 18th and 19th March 2016
14 were on the course in this cohort and nine participants chose to engage with the data collection. Two of the five who chose not to participate volunteered the explanation that they felt that they wanted to concentrate on the mathematics subject knowledge. This course was led by of my colleagues and some sessions were delivered by lecturers from the university education department. I decided to collect data on the face-to-face study days 1, 4 and 7.

3.5.2 Planned timeline of data collection
The data collection was carried out on the respective course days across the academic year 2015/16:

<table>
<thead>
<tr>
<th>Professional development course (see section 3.5.1)</th>
<th>Day of course</th>
<th>Month of course day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Advanced Mathematics (TAM)</td>
<td>Day 1 of course days 0 to 8.</td>
<td>September 2015</td>
</tr>
<tr>
<td>Teaching GCSE Mathematics (TGM)</td>
<td>Day 2 of five-day course</td>
<td>October 2015</td>
</tr>
<tr>
<td>Teaching Advanced Mathematics (TAM)</td>
<td>Day 4 of course days 0 to 8</td>
<td>November 2015</td>
</tr>
<tr>
<td>Teaching GCSE Mathematics (TGM)</td>
<td>Day 3 of five-day course</td>
<td>January 2016</td>
</tr>
<tr>
<td>Mechanics 1</td>
<td>Single day course</td>
<td>January 2016</td>
</tr>
<tr>
<td>Teaching Advanced Mathematics (TAM)</td>
<td>Day 5 of course days 0 to 8</td>
<td>March 2016</td>
</tr>
<tr>
<td>(Interview data only)</td>
<td>Day 7 of course days 0 to 8</td>
<td>June 2016</td>
</tr>
<tr>
<td>Teaching GCSE Mathematics (TGM)</td>
<td>Day 5 of five-day course</td>
<td>June 2016</td>
</tr>
</tbody>
</table>
Note that the Teaching Advanced Mathematics (TAM) course is composed of 8 course days, labelled from 0 to 7, this is due to historical reasons and the first course day (day 0) falling in the summer term of the previous academic year.

3.5.3 Treatment of questionnaire responses

The responses collected via the questionnaires were anticipated to have the typical and distinctive characteristics of qualitative data. Namely, that the data would be non-numeric and non-measurable. The choice of wording, “Aspects that were effective or ineffective and why. (Please decide for yourself what you define as an “aspect”)” is a single and very open prompt, as opposed to being closed, and would therefore lead to a variety of interpretations and a wide range of responses from the teacher participants that were qualitative in nature. Therefore, each response would be distinctive and collectively they would be highly varied. This degree of individuality was permitted in order to reflect the value that I, the researcher, and thus the research, was placing on the personal experiences and perspectives of the teacher participants.

Due to the nature of the qualitative data collected, a process of coding, organisation and analysis was anticipated. Silverman (2014) identifies three widely accepted approaches for analysis of such data. These are briefly summarised below for the purpose of describing which method I chose and why.

- **Content analysis.** In content analysis, a number of categories are identified and then text-based documentation is assessed for instances of each category. It is predominantly used for descriptive purposes (Neuman, 2011). Each instance of a categorical piece of data is counted and recorded under the appropriate heading. Importance is placed upon the categorisation in terms of the reliability and replicability of the analysis by a future researcher. Content analysis is mainly reserve for large quantities of text-based materials such as newspaper articles (Silverman, 2014; Neuman, 2011). For a number of reasons, I therefore decided against using content analysis. I hoped that the findings of this research would have practical applicability to future professional development, perhaps only in my own work and/or that of colleagues. The analysis would therefore have to go beyond description to hypothesising explanations. Secondly, “mass
communication” (Silverman, 2014; 116) was not an appropriate description of the data I was intending to collect.

- **Narrative analysis.** This is a “way to describe the structures of stories” (Silverman, 2014; 126). This was an interesting option, as it would meet the requirements of methodological position (i.e. valuing the experiences and personal truths of the individual teacher participants). However, my aim was to conduct a multiple case study and consider the responses of a fairly substantial number of people. Narrative analysis, however, is more concerned with presenting a “chronologically linked chain of events in which individual or collective social actors have an important role” (Neuman, 2011; 474) and my research was limited to one year’s worth of professional development for a not insignificant number of people.

- **Grounded theory.** Compared with content analysis, grounded theory does not begin with a predetermined set of categories. Possible categories are tentatively identified and later developed into the definitive set of options for analysis (Neuman, 2011). A key aspect of grounded theory is that the initially identified categories are modified as a response to further analysis of the data (Silverman, 2014).

I have decided upon a grounded theory approach as an effective compromise between involving a number of teacher participants and managing such a number of responses, and processing data that is rooted in the population it seeks to investigate.

### 3.5.4 Categories for a grounded theory approach

Having decided upon a grounded theory approach (see 3.5.4), I am aware of different sets of categories that already exist within the literature. I do not want to base my research in isolation of this established knowledge, so I have returned to the literature to further investigate themes that have already emerged from research. The two important sources are considered below.

In the seminal work, “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2009b) a number of common themes are identified. These are described as, “interrelated factors that contribute to effective CPD for teachers of mathematics” (Back et al, 2009b;1) (where CPD stands for Continuing Professional Development, used interchangeably with Professional Development but emphasising the belief that professional development is never complete).
The themes of effective professional development identified in the “Researching Effective CPD in Mathematics Education (RECME)” research by the teacher participants are:

**Leadership.** Specifically, the expertise of the person leading the professional development.

**A practical approach.** Professional development is deemed effective if it includes examples of teaching resources and if it is “grounded in classroom practice” (Back et al, 2009b; 5).

**Stimulation, challenge and enjoyment.** Challenge alone, combined with insufficient support, is identified as contributing to ineffective professional development. Effective professional development needs also to be encouraging and enjoyable.

**Time** in terms of opportunity to reflect being provided outside of the classroom.

**Networking.** This term is used to describe opportunities for teacher participants to meet other teachers and tutors from other schools or colleges.

The following factors are identified by the researchers (as opposed to being reported by teacher participants):

**Area of focus (mathematics)** i.e. the content is subject-specific to mathematics teaching.

**Students’ learning of mathematics.** Back et al (2009b) use this to describe plan-do-review cycles over a sustained period of time that focus on the teacher participants’ students’ learning of mathematics.

**Encouraging reflection.** This description includes engagement with research.

**Expecting and supporting change** in terms of trialling new approaches in the practice of the teacher participants and an expectation that they will be accountable for sharing these experiences.

**Supporting the embedding of change.** This emphasises collaborative opportunities to support the previous point.

I have decided that it is not appropriate to use the same headings from “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2009b) as described above. These are mostly derived from third parties observing or interpreting interviews of the teacher participants rather than as solely identified by the teacher participants themselves. In contrast, I have decided to focus solely on the latter in this research, based upon the value I have decided to place on their perspective.
In addition to “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2009b), discussed above, another relevant piece of research is based on the professional development of secondary science teachers. This was “Science Teachers Professional Learning in the Context of a Continuing Professional Development Course” (Kyeongsook, 2013). This is partly relevant in so far as it considered the teacher participants’ perspective and that the teaching of science is similar to that of mathematics (for example, it is a compulsory school subject, it is quantitative and there are similar pressures on the recruitment and retention of subject teachers).

Kyeongsook (2013) identifies a range of characteristics for effective professional development for mathematics teachers.

**Differentiated to meet the personal needs of individual teacher participants** in terms of the areas of the curriculum they are teaching.

**Content covered** includes both subject knowledge and pedagogic approaches. This is also seen as contributing to the above characteristic of meeting individual teacher participants’ needs.

**Course quality.** Properties such as “good scientific models and teaching strategies” (Kyeongsook, 2003; 218) are identified as contributing to teacher participants’ own understanding of science subject knowledge.

**Demonstration lessons.** Another characteristic, linking the above heading of quality, is that teacher participants should experience the strategies and models from the position of students engaging in a classroom activity. This is identified as an effective characteristic for experienced teacher participants who have strong subject knowledge as much as for teacher participants with less teaching experience or personal subject knowledge.

**Opportunities for discussion** with others was identified as a strength because it led to teacher participants reflecting upon their own experiences.

Once again, I have decided not to use these as an initial starting point for my classification system. Firstly, they are only a small aspect of a much larger consideration of professional development. For example, Kyeongsook (2013) also considers the school environment that the teachers are working in and the support and barriers provided by school leadership. The main difference, in my opinion, was that the definition she uses for evidencing effective professional development was “promoting teacher learning”. She refers at one point to
“impact on teachers’ change in knowledge and practice” (Kyeongsoo, 2003; 218). I felt that the scope of my research was wider in terms of not being limited to teacher participant learning. In my research, I defined “effective professional development” as that identified and defined by teachers. For example, it might also include teacher participant engagement or enjoyment or teacher participants receiving resources that they found relevant.

From this point, I have decided upon a grounded theory approach, neither isolated from, nor overly constricted by, existing literature.

Each response from a teacher participant will be taken from their hand-written questionnaires and recorded in a spreadsheet (a comment being defined as a sentence or paragraph separated by blank space in the questionnaire and/or the use of a different pen). Once all of the responses from the first round of data collection are collated I will perform an initial review of the responses. As I read through the responses for the first time I intend to identify and record emerging common themes. I am aware of the categories previously identified within the literature by researchers carrying out related research, but will not allow these to restrict my categorising of this data. Once the headings are compiled from the first review, all of the teacher participants’ comments will then be read again and classified by key words or short phrases under one or more of these headings. If a single teacher participant makes different comments at different times under the same heading I have decided to double-count them as individual responses in recognition of the strength of feeling and experience.

3.6 Data collection: interviews
The purpose of carrying out interviews is to explore at greater depth the opinions and experiences of some of the teacher participants as to what they are finding effective about the professional development course they are currently engaging with, and why. The interviews are one part of a mixed method triangulation (in combination with the questionnaire data collection described above). As Grix, (2004) states, “questionnaires are most effective when used in conjunctions with other methods, especially one or more varieties of the interview technique” (Grix 2004; 128). Due to the restrictions of time and teacher participant availability I do not envisage interviewing every teacher participant who submits a response to the paper questionnaires. Instead, all teacher participants are to be sent an email invitation to participate in an interview on a given date. The responses to
these emails will then form small focus groups of willing people (and who will therefore be self-selected). Compared with the paper survey data collection described above, it is envisaged that the interviews will allow me, if necessary, to reframe and rearticulate the key questions in a manner that leads to data collection that more directly addresses the research questions.

3.6.1 Rationale for including interviews
An key factor throughout this research has been the importance that I have placed upon the teacher participants’ perspectives. There are two key drivers for this. Firstly, that there is the lack of a “teacher voice” in the established literature. Secondly, that I hold the teacher’s experience in high regard. They, the teacher participants, are the focus of the professional development and it is their experience, whether positive or otherwise, that will lead to effective or ineffective outcomes for other stakeholders. The teacher’s opinion is to be valued because it is their practice that the student experiences that is identified as one of the major factors in the successful outcomes of that student’s education (see literature review for references, for example ACME, 2013).

For this reason, I intend to elicit the effectiveness or ineffectiveness from the teacher participants’ experience. I do not intend to conduct a strict interview. A strict interview (also described as a structured interview) is as described. Grix (2004) describes such an interview as one in which the questions are predetermined and not diverged from. They are typically closed and have the advantage of comparability of responses from different interviewees (Silverman, 2014). Neither have I chosen to use a completely informal interview due to the fact that this is not an initial exploratory data collection but a follow-up process. In order to do this, I will use a semi-structured interview, meaning that I will benefit from the advantages of flexibility in terms of investigating responses in greater depth and pursuing “unexpected lines of enquiry” (Grix, 2004; 126).

Three interviews are to be carried out during the data collection phase on the final three days of the data collection process:
<table>
<thead>
<tr>
<th>Professional development course (see section 3.4.1)</th>
<th>Day of course</th>
<th>Month of course day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Advanced Mathematics (TAM) <em>(Interview data only)</em></td>
<td>Day 5 of course days 0 to 8</td>
<td>March 2016</td>
</tr>
<tr>
<td>Teaching Advanced Mathematics (TAM)</td>
<td>Day 7 of course days 0 to 8</td>
<td>June 2016</td>
</tr>
<tr>
<td>Teaching GCSE Mathematics (TGM)</td>
<td>Day 5 of five-day course</td>
<td>June 2016</td>
</tr>
</tbody>
</table>

### 3.6.2 Interview process

My first decision has been to only interview teacher participants from the two sustained professional developments courses, Teaching Advanced Mathematics (TAM) and Teaching GCSE Mathematics (TGM) and not the single day courses. This was primarily decided on the basis of avoiding any research activity that might have a detrimental effect on the teacher participants’ professional development experience. By waiting to hold interviews until later in the course, I will have already established a personal relationship with the teacher participants and mitigated against any negative impact on their professional learning.

In terms of the one day course, Mechanics 1, there was the lack of an established researcher–teacher participant relationship but also some practical considerations in terms of time constraints. On such courses people tend to have restricted travel arrangements and less flexibility around timings for the day. I feel that without having already established a personal relationship with the teacher participants it is not appropriate to ask them for such a commitment of their time.

Before each interview teacher participants will be invited to participate by email. The emails remind them about my role on the course (as a researcher) and the purpose of my research. It clarifies that participation or non-participation will have no impact on whether they were successful in gaining any certification associated with the professional development course.
3.6.3 Interview questioning
The interviews are only intended to address my first research question, “What aspects of professional development sessions do teachers find effective and why?”. I hope that the group nature of a small focus group will facilitate a collaborative and reflective approach to responses. I will not seek further information on the second research question, “Are there common themes for different groups of teachers?”. This question is more associated with the personal background and career position of the individual. I believe that this would be adequately covered by the paper survey. Also, it is of a more private nature that individuals may not otherwise feel comfortable elaborating on in front of other teacher participants.

I intend to start each interview with the same introduction, a reminder of the purpose of my research and an open question for participants to respond to the question, “What aspects of this professional development have made it effective?”. After one person has replied, I will invite others to build upon this with their own experience in terms of similarities and differences.

I will record all of the interviews with an audio recording device, with full knowledge and consent of the participant. During the interviews, I will keep note of key ideas from their replies on a timesheet. This means that I can refer back to earlier responses during the interview but also quickly find the relevant comment in the recording after this initial data collection.

3.6.4 Treatment of interview responses
As soon as possible after the interviews are conducted, I will carry out an initial review of the time sheet records. During this I can clarify any abbreviations that I have used in the spur of the moment and use annotations to more accurately link notes to specific prompts or teacher participant respondents. The purpose of this is to capture my initial impressions as close to the interview happening as possible.

At a later, second stage I will perform a more thorough review of responses, identifying common emerging themes. This will require more time and space to reflect and consider than the initial review. At this time, I will be able to access the audio recordings in order to seek any required clarifications. As with the questionnaire data collection, I intend to take a grounded theory approach, identifying categories as they emerge rather than against ones already predetermined.
3.6.5 Dual role in the final interview

For the final interview, on the Teaching GCSE Mathematics (TGM) course, I will be both the professional development lead and also the researcher/interviewer. This may introduce a limitation on my data collection, in terms of this dual role effecting the type of comment participants felt able to share. If a poor professional relationship has been established, it may mean that participants are reluctant to participate in the interviews or to make contributions. Alternatively, a good working relationship may have presented a barrier to participants sharing negative comments or identifying ineffective aspects of professional development.

3.7 Validity, reliability and generalisability

There is a continuing debate within the literature as to the extent by which validity, reliability and generalisability are applicable to qualitative research (Kvale, 1995, Golafshani, 2003 et cetera). Golafshani (2003) explains that this is due to the historical development of these measures in the quantitative tradition and therefore their positivist perspective. Kvale describes them as a “scientific holy trinity” (Kvale, 1995; 20), central to (natural) scientific research but divorced from the reality of everyday life. The debate is whether concepts that have arisen from a quantitative approach are still relevant from a postmodern perspective of what constitutes truth.

However, the counter-argument is that these terms can and should still be applied. Some writers have reinterpreted the terms in their everyday meanings of credibility, trustworthiness, transferability, dependability and confirmability (Lincoln and Guba, 1985). Eisner (1991) argues that they are relevant as they help us decide whether a case study is well-chosen and to cast light upon a situation that might otherwise be perplexing or unclear (Eisner, 1991).

The position I take in this research is one of moderation and pragmatism. I do not seek to go so far as to discard the benefits of a discussion of these terms with the intention that leads to this research retaining the aspects of validity, reliability and generalisability. The hope is that this will support my research in terms of being sound and well-grounded, and my findings useful and applicable. The definitions adopted below are to be taken as working definitions and it is important to be mindful of the extent to which they are not fully accepted as discussed above.
For the purpose of this research I work on the basis of the following two definitions of validity. Firstly, being that which “determines whether the research truly measures that which it was intended to measure” (Joppe, 2000, cited Golafshani (2003); 599) and “whether a method investigates what it is intended to investigate” (Kvale, 1995; 21-22). The title of my research is, “What Characteristics of Secondary Mathematics Professional Development Courses do Teachers find Effective? The factors of my research that make the findings valid are that the case studies are composed of:

- Participants who are identified as mathematics teachers, and
- are actively enrolled on mathematics professional development courses.

Furthermore, the questionnaires contribute to the validity in that they ask the teacher participants what aspects of the professional development they find effective. The use of interviews further enhances the validity of my research by cross-referencing the findings of the questionnaires, and permitting greater investigation of, and coherence to, the research questions.

The challenges to the validity of my research are that I have decided to measure the effectiveness of professional development from the teacher participants’ perspective. There are other commonly held measures, such as change to classroom practice, adherence to curriculum change and/or student outcomes as discussed in section 1. The second challenge is to include events of data collection where I would be both researcher and participant (in the role of professional development lead).

For the purpose of this research the definition of reliability as, “The extent to which results are consistent over time and an accurate representation of the total population under study” (Joppe, 2000, cited Golafshani (2003); 598) is adopted.

The reliability of my research and that to which it can be generalised, is debatable. It is a small-scale project involving a small proportion of the population of mathematics teachers in England. Case studies are used to enhance knowledge and understanding of a specific, limited situation rather than to present an argument for wide generalisability (Silverman, 2014). Given the current lack of research centred on the experience of the teacher participant, and as expressed by the teacher participant, the case study approach seems relevant at this stage of understanding. Given this context I think that a use of multiple case studies is helpful, as it will highlight any apparent themes or differences between groups of teacher participants defined by given commonalities. Furthermore, as Flyvbjerg (2006)
argues and concludes, “One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods” (Flyvbjerg, 2006; 231). The main criticism of the reliability and generalisability, I would argue, is that I have limited my case study to that of one professional development provider, Mathematics in Education and Industry (MEI). In addition, this research is not a longitudinal project. Research conducted over a longer period with the same teacher participants, given available resources, would provide for greater generalisability. McNeil and Chapman (2005) state that, “Any method that involves a lone researcher in a situation that cannot be repeated, like much participant observation research, is always in danger of being thought unreliable” (McNeil and Chapman, 2005; 9). It is my intention that by providing significant detail on how this research is carried out another researcher would be able to repeat it and a reader would be in a position to judge the extent to which it measures what it pertains to measure and the level of applicability to the wider population.

3.8 Ethical considerations

In this section I discuss the various ethical aspects of my research. At the first level, my research complied with the University of Hull’s “Ethical Principles, Guidelines and Procedures for Research and Teaching” (University of Hull, 2015). The five guiding principles of this are concerned with maintaining high standards; ensuring that the research is conducted in accordance with all relevant frameworks and standards; supporting a research culture of integrity; dealing with allegations of misconduct; and, strengthening the integrity of the wider research community (University of Hull, March 2015). In line with the requirements of the Faculty Of Education, my submission to the Ethics Committee was concerned with the correct procedure of approaching the teacher participants and working with them, including submitting copies of the relevant correspondence. It detailed how I would inform teachers about their possible participation and how to contact key people, such as my supervisors and the University, in the event of a concern. My research proposal was approved by my university supervisors and submitted to the ethics committee in August 2016. I gained permission before starting my data collection.
As part of this submission, outlined above, I sought, and received the formal permission of Charlie Stripp, Chief Executive of Mathematics in Education and Industry (MEI) as all of the data collection was to be carried out during MEI professional development courses. I also sought and received the permission of MEI colleagues leading the professional development courses. Where the course included input from university personnel, my attendance on the course and purpose of my research was explained and they were given the opportunity to opt in. Giving this information and seeking such permission was repeated at every point of data collection.

3.8.1 Teacher participants’ permission
The most careful consideration had to be taken with the involvement of the teacher participants. It was of great importance to be very clear in any communication that any involvement in the research would play no part in their passing the course or otherwise. It was explained that the research was being carried out by myself as part of a Masters Research programme, and not as a Mathematics in Education and Industry (MEI) employee or on behalf of MEI. Finally, it was explained that the data collected about their experience was not part of the course evaluation. The formal consent form was displayed on the whiteboard at the front of the room as well as being available by email or in hard copy. All participants were given the opportunity to opt in, as opposed to opting out which they may not have felt able to, should they have wished to. As the data collection evolved and I carried out interviews, again the process was re-explained. In this manner, I was able to gain informed consent from all of the teacher participants.

3.8.2 Privacy
The privacy of both teacher participants and professional development leads was considered throughout the research. Pseudonyms are used for all those participating in the research for the purpose of privacy and confidentiality. Completed paper surveys were stored in a locked filing cabinet in my home office. Electronic files were stored in my personal password-protected laptop. They were only be used for the purpose of this research project. Audio recordings of the interviews were stored on my password-protected smart phone. On completion of my Masters research paper documentation will be shredded and discarded and audio files deleted.
3.9 Summary
Firstly, this section has built upon the findings of the literature review where a number of perspectives on effective professional development for teachers had been identified. This is due to the range of “stakeholders” involved (teachers, students, students’ parents, school leaders and those involved in the future employment and education of the students). It is also due in part to the choice of different measures of effectiveness, such as change in teacher practice, student attainment et cetera. This has established the lack of a clearly defined and discrete list of characteristics of effective professional development for teachers of mathematics.

My interest has focused on an apparent gap in the literature that assesses the effectiveness of a professional development course solely from the perspective of the teacher participant. As a result, an interpretivist, constructivist methodological approach emerged. A selection of research methods based mainly on grounded theory was selected and data is to be collected that will value and prioritise the experience and voice of the teacher participant.

In summary, the research question, “What aspects of professional development sessions do teachers find effective and why?” will be investigated by a series of a combination of open questionnaire and semi-structured interviews with small, self-selecting focus groups. The second research question, “Are there common themes for different groups of teachers?” will be addressed by a short paper-based questionnaire.

4 Findings
In this section I detail the outcomes of my data collection. I begin with a profile of the teacher participants, using the results of their responses to the Participant general information questionnaire. Different possible criteria for grouping the teacher participants are explored, including by gender, age group, length of career (teaching), length of career (teaching mathematics), teaching role, level of mathematics qualification, level of teaching qualification status and age of students they are teaching.

Then there follows an exploration of the eight themes emerging from the data collection that are described in detail. There is also inclusion of aspects of ineffective professional development which emphasises the idiosyncratic nature of teachers and teacher professional development.
An extensive comparison is made of aspects of effective professional development as identified by different groupings of the teacher participants. Some means of grouping them are found to be helpful in identifying commonalities, but others are found not to be significant.

I then move on to examining the results of three separate interviews conducted with different groups of the teacher participants. Similar to the findings from the Participant questionnaire on effective professional development themes identified in the interviews are given and described. I use the same themes that emerged in the earlier data collection, and thus also give consideration to alternative ideas.

Towards the end of this section I cross-reference my findings with that as established in the seminal report in this area, Researching Effective CPD in Mathematics Education (RECME) (Back et al, 2009b). A separate mention is given to a specific aspect of effective professional development, the use of digital technology.

4.1 Profile of the teacher participants

Teacher participants were asked to respond to two personal demographic questions, two professional situation / career stage questions and four open questions about their mathematics teaching experience and mathematics qualifications. The responses are collated in table 4.1 at the end of this section. Finally, teachers were asked provide their email address if they were open to being approached to participate in any follow-up questions.

4.1.1 Gender

Of the 36 total respondents, 23 were female and 13 were male. How representative is this of the teacher population? Data on the gender make up of secondary teachers in the United Kingdom is relatively scarce. However, a 2014 survey from the Department for Education, “Statistical Workforce in England: November 2013” (Department for Education, 2014) states that that about 80% of school staff are female and 75% of secondary school teachers are female. The former statistic includes support staff such as teaching assistants who do not have Qualified Teacher Status (QTS).

However, this balance is not thought to be reflected in mathematics. The 2007 Royal Society report looked at data available on new entrants to mathematics teaching and
reported that “In mathematics… males account for more than half of all PGCE course applicants across England, Wales and Scotland. Generally, too, more males than females are accepted on to these courses” (Higgens & Martin, 2007; 44). There is believed to be a positive correlation between the proportion of female and male students taking an A level in a subject and the proportion of female and male applicants to teach the subject. It is not known as to whether there is any degree of causation (Higgens & Martin, 2007). However, there is historically a male domination of mathematics, for example within the study of post-16 mathematics or teaching of mathematics at University (The Guardian, 2013). My respondents however were almost exactly two thirds female, which raises some interesting questions about how representative my data is of the UK teaching profession as a whole. The most recent information, such as the Royal Society report above is from 2007, ten years old at the time of writing. Could it be that the proportion of female and male mathematics teachers is changing? Perhaps in light of the changing economic climate or campaigns to attract more girls and women in to STEM (Science, Technology, Engineering and Mathematics) subjects? Alternatively, could it suggest that a greater proportion of mathematics teachers engaging in mathematics professional development are female?

4.1.2 Age

For the purpose of privacy and thus analysing the data I used three age groups, 30 years and younger, 31 to 40 years old and 41 years and older. There was a wide range of ages present on the courses, from people in their twenties to their fifties. The distribution was skewed to the younger end of the range.

The national picture in terms of the ages of mathematics teachers is unclear and reflects an apparent period of change in terms of poor retention within the profession (discussed in depth in section 1.2.4). In 2007, The Royal Society reported that, “almost a third (30.1%) of mathematics teachers in the England sample were found to be over 50” (Higgens & Martin, 2007; 61) and therefore shortly due to retire. About 20% were reported to be in their twenties (Higgens & Martin, 2007; 61). Seven years later only about 16% of secondary teachers are found to be aged 50 years and over (Department for Education, 2014; 7) and the percentage of teachers under the age of 30 had risen to 25% (Department for Education, 2014; 8). (Note that the latter figures reported by the Department for Education are for all secondary teachers, not mathematics teachers at secondary).
The skew towards younger teacher participants in the responses is not unexpected as the three professional development courses they were on are aimed towards people teaching a certain stage of mathematics for the first time. These new-to-stage teachers are more likely to be younger teachers.

4.1.3 Length of career (teaching)
In terms of length of time teaching (any subject) there was also a wide range. Three participants were still in initial teacher training (the shortest career length) and three had been teaching for over two decades (the largest career length). The modal class was of teacher participants who had been teaching between five to ten years. This is an interesting skew. It could be that the modal length of career is currently between five to ten years, and so the large proportion engaged in this professional development just reflects the fact that this career length is of a larger proportion of the whole population. However, current findings are that over half of mathematics teachers leave teaching within their first five years (Higgins & Martin, 2007) so I suspect that it is more a case of those engaging in mathematics professional development are not typical of the teaching profession as a whole. That is to say, that they are from the smaller proportion of teachers who stay in the career longer than five years.

4.1.4 Length of career (teaching mathematics)
Only 34 teachers chose to respond to this question and excluding the nine teachers in training or with Newly Qualified Teaching status, there was a shift of shorter teaching times. That is, of the teachers with careers of more than 2 years’ teaching most had been teaching mathematics for a shorter time period. This means that they had spent some of their teaching career teaching subjects other than mathematics, and under some definitions could be characterised as non-subject specialists.
I suggest that this high proportion of “subject-changers” is to be expected in professional development that seeks to support teachers who are moving to teaching mathematics or moving to teaching a new school stage of mathematics. The Teaching Advanced Mathematics (TAM) and Mechanics courses are aimed at post-16 mathematics and therefore more likely to attract specialist mathematics teachers from secondary schools aiming to teach older students the next qualification of mathematics. In contrast, the
Teaching GCSE Mathematics (TGM) course is aimed at those new to teaching secondary mathematics and more likely to attract teachers with no prior experience of teaching mathematics.

The findings support this. Of the ten respondents on the Teaching GCSE Mathematics (TGM) course with more than 2 years’ teaching experience, exactly half had been teaching mathematics for a shorter length of time. However, for those on the other courses of 15 respondents, only two had been teaching mathematics for fewer years (one teacher participant did not respond to this question).

### 4.1.5 Teaching role

All 36 teachers responded to this question. 24 of the teacher participants identified as a teacher of *mathematics* mentioning the subject within their description. Of these, six included an additional mention of a position of responsibility within their description, such as department leadership or pastoral duties.

Of those who did not identify as a mathematics teacher,

- one was a university undergraduate student.
- three described their role in terms of career stage abbreviations, NQT (for Newly Qualified Teacher) and RQT (Recently Qualified Teacher) or merely as “teacher”.
- Another two teachers used a characteristic of their students to describe their role (i.e. “Adults” or “functional skills to level 2”).
- Four teachers explicitly identified as a teacher of a subject other than mathematics (i.e. Information Technology, chemistry, engineering or technology).
- Two teachers identified as support staff, such as Learning Support Assistant, but specialising in mathematics and with mathematics teaching responsibilities.

There is no agreed definition of a mathematics subject specialist (Higgens & Martin, 2007) and it has been a constant priority throughout this research that what makes effective professional development for mathematics teachers is explored from the teacher participants’ perspective. In this case, it was important to me that the teacher participants who were defined as mathematics teachers (or otherwise) were so defined on the basis of how they self-identified.

It is interesting to see the other types of identification that teacher participants used, such as their career stage or a descriptor of their students.
4.1.6 Mathematics qualification

There was a wide range of responses to the question, “Please describe briefly your qualifications in terms of mathematics”. I classified these responses into three groups, school level, (for example, GCSE or O Level Mathematics), post-16 study other than university level (for example, A level Mathematics) and university level mathematics and beyond. Most responses were straightforward based upon this classification system. However, one teacher participant responded that she was “SEN trained” (i.e. qualified in Special Educational Needs). In the absence of any mention of a mathematics qualification I made the decision to include her in the group that were qualified up to school level mathematics.

There were only five teacher participants who reported only school-level mathematics qualifications. The modal group was those that had studied towards a post-16 qualification in mathematics (17 teacher participants). This may meet the criteria for subject specialism as defined by the then Department for Education and Skills in 2003 who stated that “an adequate qualification in the particular subject must be the basis for effective subject teaching” (DfES, 2005; 5).

14 teacher participants reported having a qualification in mathematics at university level or beyond and this meets the 2006 National Foundation for Educational Research (NFER) criteria for subject specialism (Moor et al, 2006). This is interesting as above, in 4.1.5, we see that 24 of the teacher participants self-identified as a teacher of mathematics, albeit this is not synonymous with being a subject specialist of mathematics.

4.1.7 Teaching qualification

There was a smaller range of responses to this question so I initially decided to classify the responses in terms of no teaching qualification or QTS (Qualified Teacher Status). On attempting the classification, it became clear that a third classification was required, that of studying towards a teaching qualification. Not all responses were easy to classify, in such cases I cross-referenced against their other responses in order to make a decision. For example, if their response didn’t mention any qualification (just experience) and their response to number of years teaching was “I am training to be a teacher” then I classified their teaching qualification as “training towards a teaching qualification”.

89
Eight teacher participants stated that they were working towards a teaching qualification but a significant 26 stated that they were qualified teachers. Only two teacher participants indicated that they had no teaching qualification. On further investigation, one of these indicated that they were a Teaching Assistant working with small groups of students and the other was qualified as a sports coach and had extensive pastoral duties at their school of employment. Both of these “unqualified” teachers were participants on the Teaching GCSE Mathematics course.

4.1.8 Age of students taught

Again, I used a small number of categories in order to classify a wider range of response. I chose three age groups to reflect stages of education in the English context. The first was 11 – 16 years (15 responses), the second was 16 years and above (only seven responses) and I included a third category for those teacher participants responding that they taught across this age range (another 15 responses). There was one teacher participant who taught in a prison and therefore all of his students were over the age of 18 years old. I decided to include his responses in the category of 16 years and above.
Table 4.1 Summary of Teacher participants’ general demography and professional background

<table>
<thead>
<tr>
<th>Gender</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>30 years and under</th>
<th>31 to 40</th>
<th>41 to 50</th>
<th>51 to 60</th>
<th>60 or over</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of time teaching</th>
<th>I am training</th>
<th>I am in my first year as a teacher (e.g. NQT)</th>
<th>2-4 years</th>
<th>5-10 years</th>
<th>11-19 years</th>
<th>More than 20 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

2 participants did not respond to this question.

<table>
<thead>
<tr>
<th>Length of time teaching mathematics</th>
<th>I am training</th>
<th>I am in my first year as a teacher (e.g. NQT)</th>
<th>2-4 years</th>
<th>5-10 years</th>
<th>11-19 years</th>
<th>More than 20 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>13</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

2 participants did not respond to this question.

<table>
<thead>
<tr>
<th>Identity as a mathematics teacher</th>
<th>Identifying as a teacher of mathematics</th>
<th>Description did not include identification as a teacher of mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics qualifications</th>
<th>Secondary school level</th>
<th>Post-16 study</th>
<th>University level and beyond mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>17</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching qualifications</th>
<th>Unqualified</th>
<th>Training towards teacher qualification</th>
<th>Qualified Teacher Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>8</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ages of students taught</th>
<th>Predominantly 11-16 year olds</th>
<th>Predominantly 16 years old and above</th>
<th>A mixture of both age groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>
4.2 Teacher participant responses to the questionnaire

The second part of the data collection was the open questionnaire described in 3.3.2, the Participant questionnaire on effective professional development. The prompt for teacher participants was, “Aspects that were effective or ineffective and why. (Please decide for yourself what you define as an “aspect”)?” Due to the nature of this instruction teacher participants’ responses were qualitative in nature and therefore varied widely. In order to classify the data, I did an initial read through of the responses and found a small number of over-arching descriptions emerging:

- Doing mathematics
- Receiving resources
- Opportunities for discussion
- Opportunities for reflection
- Pedagogic approach is valued
- Mathematics approach is valued
- Use of digital technologies
- Characteristic of the Professional Development lead

I used these as headings for classifying each individual response from the teachers. Below follow six examples of how I classified these comments.

Simple example 1

<table>
<thead>
<tr>
<th>Session</th>
<th>Aspects described</th>
<th>Doing mathematics activity</th>
<th>Receiving resources</th>
<th>Opportunities for discussion</th>
<th>Opportunities for reflection</th>
<th>Pedagogic approach is valued</th>
<th>Mathematics approach is valued</th>
<th>Use of digital technologies</th>
<th>Characteristic of PD lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>GeoGebra</td>
<td>Can see lots of uses of it in the classroom – effective visual representation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here, the comment, “can see lots of uses of it in the classroom – effective visual representation” in reference to a session labelled “GeoGebra” (a mathematical software programme). I classed this as Use of digital technology.

Simple example 2

<table>
<thead>
<tr>
<th>Session</th>
<th>Aspects described</th>
<th>Doing mathematics activity</th>
<th>Receiving resources</th>
<th>Opportunities for discussion</th>
<th>Opportunities for reflection</th>
<th>Pedagogic approach is valued</th>
<th>Mathematics approach is valued</th>
<th>Use of digital technologies</th>
<th>Characteristic of PD lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indices</td>
<td>Great starting point. No need to remember rules - students can work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Great starting point. No need to remember rules - students can work out for themselves” is categorised as Mathematics approach is valued as it refers to a relational perspective on mathematics rather than instrumental.
Simple example 3

The response, “Reminding me to look at expressions in terms of pictures (area)” is categorised as Mathematics approach is valued as it refers to the use of multiple representations.

Complex example 1

<table>
<thead>
<tr>
<th>Aspects described</th>
<th>Doing mathematics activity</th>
<th>Receiving resources</th>
<th>Opportunities for discussion</th>
<th>Opportunities for reflection</th>
<th>Pedagogic approach is valued</th>
<th>Mathematics approach is valued</th>
<th>Use of digital technologies</th>
<th>Characteristic of PD lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very effective as we could get on with the task, have a discussion then share our ideas even when they conflicted with the tutor’s thoughts. Good use of practical resources.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The teacher participant identifies a pedagogic session and their response is, “Very effective as we could get on with the task, have a discussion then share our ideas even when they conflicted with the tutor’s thoughts. Good use of practical resources”.

In this example, I draw out three effective characteristics, with the respective categories seen highlighted in blue in the screen shot:

- “Have a discussion then share our ideas…” Opportunities for discussion.
- “…even when they conflicted with the tutor’s thoughts”. Characteristic of the professional development lead.
- “Good use of practical resources”. Pedagogic approach is valued.

Complex example 2

“Drawing the circle with the triangle & slit – very neat. And opened up opportunity for a lot of questions” refers to a practical activity that introduces circle theorems using a paper folding activity. I classified this as a comment that valued both the mathematics approach (first sentence) and pedagogic (second sentence) approaches.

Complex example 3

<table>
<thead>
<tr>
<th>Aspects described</th>
<th>Doing mathematics activity</th>
<th>Receiving resources</th>
<th>Opportunities for discussion</th>
<th>Opportunities for reflection</th>
<th>Pedagogic approach is valued</th>
<th>Mathematics approach is valued</th>
<th>Use of digital technologies</th>
<th>Characteristic of PD lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own knowledge. Multiple representations. Build own knowledge rather.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
answering a question with a question but good for developing own understanding and knowledge. Questioning knowledge. Origin and foundations off. Clarification of functions and mapping”. I categorised this under the headings:

- Characteristic of professional development lead, due to the use of the lead’s name in the aspect column and reference to “own knowledge” and “Annoying habit of answering a question with a question but good for developing own understanding and knowledge”.

- Mathematics approach is valued, due to the comment, “Clarification of functions and mapping”.

- Pedagogic approach is valued, due to the comment, “Build own knowledge rather than chalk-talk and follow” and “Questioning knowledge”.

If the response indicated a negative experience under one of these headings I used a red tone in the colour-coding. It was interesting to note that overwhelmingly the aspects described by participants were positively expressed, there were only six such examples out of a total of 345 categorised comments.

Some teacher participants provided entries for as few as three sessions. Other teacher participants made over a dozen responses. My analysis considers each of the individual responses rather than individual teachers, valuing each aspect identified by any teacher participant and not impacted by how many other responses they may already have provided. In section 4.2.1 below I provide further detail and discussion of each of these headings.

### 4.2.1 Categories emerging from the questionnaires

**Doing mathematics** Some teacher participant responses made positive reference to being given the time and opportunity to personally engage in mathematical activity. This supports the findings of the earlier “Researching Effective CPD in Mathematics Education (RECME)” which found, “many teachers seemed to enjoy doing mathematics and thinking about connections within it.” (Back et al, 2009b; 3). Specific activities as identified by the teacher participants included descriptions of the physical presentation of the mathematics,
such as, “card sort”, “using white boards”, “practical experiments”, “using the blocks”, “use of foam cards” and “hands on activity”.

At other times the teacher participants described how they experienced doing mathematical activities, with mention of “enjoyment” the most common response words. One teacher wrote in reference to an effective aspect of professional development, “Getting to do some fun maths! (Reminds me why I love it and gets me excited for doing it with my students on Monday morning)”.

Other responses indicated the benefit of doing mathematics due to being able to experience learning from the students’ perspective. One teacher wrote “Having to do it in a totally different way from that to which I’m used - gives a real insight to what it's like to do it for the first time”. Another teacher found that “making similar mistakes that students would make and how to help them” was effective professional development. This opportunity for empathy is also tentatively suggested within the “Researching Effective CPD in Mathematics Education (RECME)” report, “Engaging in mathematical activities may have encouraged teachers to consider what it feels like to be a student, hence making them more sympathetic to students’ needs” (Back et al, 2013b; 3). This was a suggestion from the team of researchers rather than something they reported directly as a teacher view. However, my research appears to support this with evidence from teacher participants.

**Receiving resources.** Some comments referred to the professional development providing access to high quality classroom resources that the teacher participant felt they otherwise wouldn’t have access to. A range of different activities were explicitly mentioned – card sorts, consolidating activities etc. Matching activities in particular were mentioned by numerous teacher participants. Such matching activities are identified by Swan as being effective because, “these types of activity encourage learners to ‘have a go’ as they can move the cards around if they change their mind. It also encourages discussion as learners have to explain to each other” (Swan, 2005; 15). Another quality of a resource that was highlighted as being particularly well-received was a reference to “real life” contexts. As well as mentioning specific resource types, some teacher participants explained why they found receiving certain resources effective professional development. Of particular note were activities that “can be transferred easily to lessons” and “Like seeing great resources that are easy to find/share and then apply to teaching even if topic is challenging”. One teacher participant valued an activity that was applicable to their own
learning later, stating “Things to do to take away. Things to do myself”. I thought that one particularly insightful response was from a teacher who reflected, “Clearly excellent resources that can be used in the classroom but the material was too advanced for my current understanding”. I think that this suggests that it is the relevance or appropriateness to the classroom that is valued and not necessarily the teacher participants’ own stage of learning.

The final quality of a resource that made it an aspect of effective professional development was that it added variety to a teacher participants’ repertoire, with one reporting, “makes me think and vary activities”.

**Opportunities for discussion.** An emerging theme was from teacher participants valuing the time and opportunity to discuss their learning with others. Most responses just stated “discussion” as an aspect of effective professional development, for example, “enjoyed all discussions” but others elaborated. Some valued discussion because it meant that they could share ideas, with one teacher participant going so far as to describe, “enabled incredibly valuable discussion to further my learning / understanding”. A different teacher participant wrote that discussion gave them “the time and space for mathematical discussion”. A final example was, “Lots of interaction and discussion which was very effective in proving a point and promoting understanding and reflection”. Some comments reflected attitudes that were open to challenge as much as reinforcements, for example sharing experiences with both, “fellow / likeminded teachers and teachers with different backgrounds”. Another teacher participant valued the opportunity to discuss because it led to a critical reflection of the professional development. A further example was, “discussion of possible difficulties / strengths / extensions”.

The 2013 “Reseaching Effective CPD in Mathematics Education (RECME)” report (Back et al, 2013b) highlighted similar characteristics of effective professional development, grouping them under the label of networking. This included the opportunities to meet and talk with teachers from both similar and different contexts and both formal and informal conversations.

**Opportunities for reflection.** This was sometimes a subtle distinction to make with opportunities for discussion. However, I felt that some characteristics identified by teacher participants referred more accurately to reflection than discussion. Teacher participants identified a number of different opportunities to reflect. The first included time to think (as
opposed to talk and listen) for example, “Made me think about what I do outside of SOW [scheme of work]” and “Interesting also to think about how the same idea (eg using diagrams) can be used to help the weaker students and challenge others”.

The second aspect was being given time to record their thoughts, with one teacher participants writing, “Lack of explanation was very effective for provoking deeper thought and reflection”.

However, despite me making a distinction here between discussion and reflection, they remained closely related for some teacher participants, e.g. “Reflecting on the effectiveness of a lesson helps to evaluate how you could apply or, more importantly adapt the ideas and resources, to use in the classroom. This is particularly valuable when discussed in small groups with other teachers”.

It is interesting to note that “Researching Effective CPD in Mathematics Education (RECME)” also identifies an opportunity to reflect as an aspect of professional development, with one key difference,

“Initiatives that encouraged teachers to become more reflective often engaged them with research and professional literature related to teaching and learning mathematics. It seems that it is important to provide teachers with opportunities to read and think about ideas from research.”

(Back et al, 2013b; 5)

The use of research is emphasised here, but not one teacher participant in my research made explicit mention to the use of research. Neither did they appear to in “Researching Effective CPD in Mathematics Education (RECME)”, as this characteristic comes from the list that is suggested by the researchers’ observations and interviews but not specifically mentioned by a teacher (Back et al, 2013b).

**Pedagogic approach is valued.** This was by far the most extensive category in terms of number of teacher participants’ responses.

Some responses identified positive characteristics of the teaching activities and strategies advocated or exemplified in the professional development sessions. For example, when a teaching activity required the teacher participants to collaborate in order to solve a problem, “Problem solving - effective as a team” and, “creating and breaking down problems seems a great way of developing understanding”. A particular case of this was in reference to multiple representations for example, “Use of a diagram to represent algebra. This really
helped me to see what the concept looked like”; “Visual resources excellent to promote deeper understanding”; and, “Use of diagrams as extra challenge - really helpful to think about extension activities that do not require any extra subject knowledge or teaching”.

Questioning techniques were another pedagogic approach valued by teacher participants as being effective, for example, “…an interesting discussion on different styles of questioning. This will have a direct impact on my teaching through use of specific strategies” and “I will use the ideas of questioning, especially the idea of giving an answer and asking students to come up with the solution”.

Other teacher participants identified topic-specific examples, such as,

- “A very different and more effective way to introducing trigonometry”
- “for the n\text{th} term use the diagrams could prove useful”
- “Great practical way to introduce circle theorems visually”
- “Enjoyed using the blocks. Can link to other topics such as histograms, cumulative frequency”
- “Visual representations of completing the made it clear how it worked”
- “Really good way to introduce Venn diagrams. Very interactive”

Furthermore, some teacher participants identified a teaching ethos of what Dan Meyer has called Be Less Helpful (Meyer, 2010). For example, “Very effective as we could get on with the task, have a discussion then share our ideas”; “…great AfL and to hand over teaching to students”; and, “Excellent activity, brilliant progression. It leaves the student to think for themselves and discover the instructions”.

A minority of teacher participants identified practical and real-life contexts as an aspect of valuable pedagogy for teaching probability, “Good football fixture list and disease testing, shows real life application” and “Great way in to probability. Helped to see its application in the real world”.

A second minor category under pedagogic approach was in response to addressing the needs of students with differing levels of prior attainment, “Interesting also to think about how the same idea (eg using diagrams) can be used to help the weaker students and challenge others”; “Engaging, suitable for all abilities”; and, “A variety of ways of reinforcing or consolidating and extending learning”.

98
Mathematics approach is valued. Less common were responses that valued how mathematics was presented, for example when there was an emphasis on mathematical rigour,
- “Emphasis on 1st Principles” in reference to differentiation in calculus.
- “Level of rigour described/expected within various pieces of content shown/shared”
- “Good to be posed questions that showed the importance of clarity of thought”
or as a coherent body of interconnected ideas,
- “I liked the… under pinning to previous knowledge.”
- “Creating links between areas and manipulating the shape”
- “Proving other laws using a few building from KS3 - means less to 'learn' as can apply original ideas to new ideas.”
- “Visual, big picture explanations. Linking different aspects of quadratics”

Use of digital technologies. This could be seen as a sub-group of the headings above concerned with resources and pedagogy. During the data collection two main software programmes were extensively used, Autograph (http://www.autograph-maths.com/) and GeoGebra (https://www.geogebra.org/). These are both mathematics-specific packages that include geometric, algebraic and statistical functions. On a few occasions, other web-based interactivities were used. During the courses, the use of these packages was sometimes modelled by the professional development lead and at other times the teacher participants were taught how to use them.

In this category of comments the professional development was identified as effective if the result was confidence in the teacher participants to use the software themselves, for example, “Excellent to have the demo to familiarise with the tools/options. Effective to be given the basics, to then explore the software for myself. Determined to embed its use in lessons regularly!”; “fantastic session. Really useful and ironed out lots of the little glitches that I have encountered”; and, “Brilliant. It was great to have an opportunity to practice using the software. I feel that I will be more confident in using in future”.

Furthermore, the use of mathematical software was sometimes given as effective professional development because its use was also identified as effective mathematics teaching. For example, “Animations! Makes things easier to visualise”; “it is very useful to
depict/explain both geometry and graphs”; and, “Can see lots of uses of it in the classroom - effective visual representation”.

One comment made a specific reference to the potential of digital technology for immediate and practical application in the classroom, “Activities that can be transferred easily to lessons”.

**Characteristics of the Professional Development lead.** A final categorisation was of comments that referred to the nature of the person leading the professional development. Some teacher participants valued the professional development lead creating a critical learning environment, “Very effective as we could… share our ideas even when they conflicted with the tutor's thoughts” and, “Opportunity to question session leader, critically”. Other teacher participants valued the fact that the session leader explained his choices, “[the professional development lead] being involved / responding to comments”. Others highlighted the professional development lead’s availability for support during mathematical tasks, “Assistance when needed with our problems” and, “The help given was really useful”.

Finally, teacher participants valued the style of delivery, “well lead by [first name of professional development lead]” and their credibility, “Having CPD delivered by someone who has lots of classroom experience and draws upon it frequently for illustrations or explanations” and “Appreciated the short bits about your teaching methods”.

Qualities of the professional development lead was an aspect of effective professional development as identified in “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2013b). Back et al found that teachers valued knowledgeable and experienced leadership and that it was a “key importance” (Back et al, 2013b; 3).

**4.2.2 Ineffective aspects emerging from the questionnaires**

The prompt given to teacher participants in the survey was to record, “Aspects that were effective or ineffective and why”. Despite this only nine responses described an ineffective aspect. This surprised me as I don’t think that the prompt was biased against teacher participants stating ineffective aspects. The small number of ineffective aspects in itself is quite telling in so far that overwhelmingly the professional development was generally experienced in a positive manner.
The nine ineffective aspects were described by only seven participants, and were more likely to arise on the course that lasted only one day.

Two of the ineffective comments referred to the pedagogic approaches. One teacher participant wondered whether the pedagogic approach being shared would conflict with a perceived requirement to teach the full curriculum, stating “I don't know how I would get through the scheme of work using these strategies”. Another questioned whether the pedagogic approach being shared was advantageous over their current approach.

The most common aspect identified as ineffective was when the mathematical activities were at too challenging a level. One teacher participant commented, “Personally can find it taxing maintaining a high level of engagement for an extended period. (Could just possibly be due to conceptually challenging material… and maybe that it's Saturday)” reflecting the pressures that teachers are under in terms of lack of time. Another teacher participant valued the quality of the teaching resource but found that the pace of the activity went too quickly for them personally.

The third aspect identified as ineffective was that a discussion activity was too prolonged with the teacher participant saying, “Dislike repetitive nature of whole group feedback especially after mix up of participants prior to this. Is this discussion unnecessary?”

One teacher participant on the Mechanics day stated that they were a physics subject specialist and therefore found the balance of physics and mathematics not enough in the favour of the mathematics, “Nothing new here - I'm a physics teacher :( Too much physics, not enough maths”.

Finally, two teacher participants responded to an extended writing session, involving them writing 500 words independently. This was intended to support them in writing at Masters level as the course included the opportunity to gain credits towards a Masters qualification. One teacher participant wrote, “Does the structure allow for different approaches to learning about writing? Too much rush! (perhaps). How will feedback help, if at all, when it arrives?”. The other suggested that this would be better done collaboratively and just as an outline “:( time spent writing - perhaps time to prepare ideas / structure a paragraph (even as a group?) without actually writing it in such a limited time space”.

101
4.3 Detailed findings

In this section I explore the findings in terms of different groupings of the teacher participants. I differentiated by as many factors as the data collection permitted, comparing those teacher participants giving one response to those offering another. The groupings considered are:

- Teacher participants on the GCSE level professional development compared with those on the Advanced level.
- Female teacher participants vs male.
- Teacher participants grouped by age.
- Teacher participants grouped by length of teaching career.
- Teacher participants grouped by length of time teaching mathematics.
- Teacher participants self-identifying as mathematics teachers compared with those not.
- Teacher participants grouped by own mathematics qualification.
- Those with Qualified Teacher Status (QTS) versus those without.
- Teacher participants grouped by age of students taught.

For each comparison, I identify different themes that emerge or the lack of any significant differences.

4.3.1 Participants on GCSE-level mathematics course versus those on the Advanced level mathematics course

Responses from teacher participants on the Teaching GCSE Mathematics (TGM) course were compared with those from teacher participants on the other two courses aimed at post-16 level three qualifications (Teaching Advanced Mathematics (TAM) and Mechanics).

Both groups showed a strong appreciation for the pedagogic approach shared by the professional development lead. This suggests that there is a perceived opportunity for learning more effective teaching strategies, approaches and activities irrespective of the level of mathematics qualification being studied. The GCSE-level course (Teaching GCSE Mathematics (TGM)) attracts teacher participants who could generally be described as “new to teaching secondary mathematics” and so it is not surprising that they would be interested in a pedagogic exploration of “how to teach mathematics”. However, it is
perhaps surprising that teacher participants on the post-16, level 3 courses were just as likely to value pedagogic approaches as aspects of effective professional development. It could be expected that these teacher participants were more likely to be experienced and successful teachers of mathematics from a pedagogic perspective. There could be an expectation that their focus would be on learning subject knowledge. However, these findings suggest that they are as likely to place value on pedagogy as teacher participants on the GCSE-level mathematics course.

There was also value placed by teachers in both groups on the mathematics approach modelled. Both groups of teacher participants found learning about new approaches to mathematics an aspect of effective professional development and this was irrespective of the level of mathematics they were aiming to teach. This is an interesting point compared with the finding above. It suggests that for both groups of teacher participants there is a desire to, in very broad terms, develop both their personal subject knowledge and teaching skills. Quite often at the start of a professional development course I find that people express a preference for one or the other. This suggests that such an early distinction may be superficial and/or short-lasting.

However, those on the advanced mathematics professional development courses were more likely to show appreciation for receiving resources than those on the GCSE course. I hypothesise that this is due to the smaller range of resources available for teaching at post-16, level three qualifications. For mathematics taught at GCSE-level there is a wide availability of teaching resources freely available (e.g. at the time of writing, the Times Educational Supplement (TES) website claims 333 pages of resources for “data and statistics” and 28 for “advanced statistics, the latter being a more likely description of teaching resources for statistics at post-16, advanced level mathematics).

Similarly, the teacher participants on the Teaching Advanced Mathematics (TAM) course and Mechanics courses were more likely to value the opportunity to discuss their learning with other teacher participants. Again, I suspect that this may be due to supply and opportunity. There are more teachers of GCSE Mathematics than there are for level 3 mathematics, and teaching teams are therefore likely to be larger. Teachers of GCSE students are likely to be part of a larger team of colleagues than teachers of level 3 students and therefore already have more opportunity to discuss mathematics teaching. Whereas even in a sixth form with a substantial team of level 3 mathematics teachers, they are likely
to be in smaller numbers. It may be possible that teachers of advanced level mathematics have less opportunity to meet others teaching the same subject at the same level. Therefore, they may value the opportunity more highly as an aspect of effective professional development.

4.3.2 Female versus male response
There were no discernible differences as to aspects of effective professional development based upon the sex of the teacher participants. Both groups appeared to be as equally like to value any given aspect of the professional development. This was not a surprising outcome as my literature review had found no suggestion that there would be a difference. Furthermore, I have not had the impression that a difference exists from my experience as a teacher-learner or as a leader of professional development. However, I thought it worthy of investigation as some people, for example, are known to express the opinion that women are more likely to prefer discussion-based learning and men more likely to prefer learning through “doing”. My findings do not provide any evidence to support this position.

4.3.3 Age of teacher participants
All three divisions based upon age valued the pedagogic approaches shared by the professional development lead. The participants who were 30 years and younger showed a slightly greater value of opportunities for discussion, with one explaining, “discussion with colleagues and [having] the time and space for mathematical discussion”. I am uncertain as to why this may be the case. Is it a case of younger people showing a preference for verbal communication in general? Or is a verbal, social transaction form of learning in particular valued by younger people?

Opportunity for reflection appears to be the most divisive characteristic of effective professional development based upon the age of the participants. The younger participants reported a greater preference for activities that facilitated them to reflect upon their practice. The older group, aged over 41 years, only mentioned this as an effective characteristic twice. Again, this is a curious distinction and I was unable to detect any suggestion of a reason for this in the literature.

Finally, the findings above beg the question that if older participants show a preference for neither discussing their learning nor reflecting personally upon their learning, what do they value? Well, it appears that in line with all of the age groups, the older group of teacher
participants (41 years and above) expressed valuing both the pedagogic approaches shared and the mathematical approaches as aspects of effective professional development.

4.3.4 Length of time teaching
Notably the teacher participants who were still engaged in initial teacher training did not make one mention of a preference for receiving resources or the opportunities to discuss with peers as aspects of effective professional development. I suggest that this is more due to these learning needs being more than adequately met on their training courses rather than them not being needed at all.

Along with those who had been teaching for the longest period (11 years or more) the newest teachers also expressed no value for the characteristics of the professional development lead. One teacher participant wryly observed, “[The lead allows us to] build own knowledge rather than chalk-talk and follow. Annoying habit of answering a question with a question but good for developing own understanding and knowledge”. I am not sure why those with more teaching experience would be more likely to find this effective professional development, as it is an aspect also identified in the literature. “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2009b) states, “Leadership of the CPD was identified by teachers as of key importance and they especially valued leaders with wide knowledge and understanding of current practice” (Back et al, 2009b; 3). I wonder whether at the start of their teacher training, teacher participants just hold an expectation that leaders of professional development will have this knowledge and understanding as compared to their own “novice” levels? However, this reasoning does not explain why those with the most teaching years (11 years or more) would also not value such expertise. Those teacher participants who did value the characteristics of the professional development lead as an aspect of effective professional development all came from those who had been teaching for 1 to 10 years.

Similarly, it was only these teacher participants (teaching for 1 to 10 years) that showed appreciation for the opportunity to reflect upon their learning as part of the professional development. I suggest that those in their initial teacher training are already engaged in a high level of reflection as they learn a new profession. Similarly, perhaps those teacher participants whose teaching career has lasted more than a decade have done so, in part, by being highly reflective practitioner’s?
Those in their training year showed a significant preference for the opportunity to engage in mathematics and to learn about methods of teaching mathematics. This suggests that for trainee teachers, a focus on mathematics and mathematics-specific pedagogy is the priority. Unlike those in their training year, those who had been teaching for 11 years or more also made no mention of valuing the opportunity for discussion. Aside from the above, teachers at all stages of career length showed preferences across the remaining categories, with value for pedagogic approaches once again the most commonly valued aspect of professional development.

4.3.5 Length of time teaching mathematics

The responses of teacher participants who were still in their training year showed the least range of responses, reflecting the findings above (length of time in teaching). Predominantly they valued the pedagogic approaches to teaching mathematics modelled on the course and valued the opportunity to participate in mathematical activities. Regarding the former point, one teacher participant stated, “Thought it was an excellent way of teaching quadratics” referring to a specific piece of pedagogy. Another explained a more general principle, “Creating and breaking down problems seems a great way of developing understanding”. I believe that this preference amongst new mathematics teachers makes sense. In terms of engaging in mathematical activity, one of the trainee teacher participants wrote in reference to the use of physical algebra tiles, “Using cards/white board gave an insight to how a learner would feel made it effective”. People who may have had less exposure to engaging with mathematics recently are perhaps more likely to value such an opportunity than those who have been teaching (and perhaps doing) mathematics for some time. So, perhaps novelty of opportunity adds to its effectiveness as an aspect of professional development?

For all other teacher participants, the pedagogic approaches shared were once again found to be the most popular characteristic contributing to the effectiveness of the professional development. In contrast with those in training or their first year of teaching, the more experienced teacher participants of mathematics (teaching mathematics for two years or more) valued receiving teaching resources. One stated, “Straight forward and can easily be used with students. Activities that can be transferred easily to lessons” and I believe that this identifies a preference for easily applied resources. This is a curious outcome because
people who have been teaching a given subject for longer are more likely to have seen and collected a larger number of teaching resources.

4.3.6 Identity as a mathematics teacher

Once again, there was no separation between which teacher participants showed an appreciation for activities that involved discussion of pedagogical approaches; it remained the most popular aspect of effective professional development for all. However, those who self-identified as mathematics teachers were more likely to find opportunities for both discussion and reflection effective characteristics. One teacher recorded, “Opportunity to question session leader, critically, and sharing ideas with the group. Using these ideas to question my own practice” and another teacher, “Chance to discuss and have thoughts in teacher mode. Evaluating how it would be used in the classroom.”. These two sample quotes demonstrate the link that those self-identifying as mathematics teachers made between discussion and reflection.

4.3.7 Mathematics qualification

Interestingly, teacher participants who reported a mathematics qualification at university level showed a less strong preference for pedagogic approaches. They found other aspects, such as the opportunity to reflect upon their learning and receiving teaching resources, just as effective. One participant emphasised that thinking time led to the professional development session being helpful and interesting,

“Getting to try the card sort for ourselves - helps you see where the issues and Eureka moments might come. Use of diagrams as extra challenge - really helpful to think about extension activities that do not require any extra subject knowledge or teaching. Interesting also to think about how the same idea (e.g. using diagrams) can be used to help the weaker students and challenge others”.

Teacher participant with university-level mathematics qualification.

Categorising by level of mathematics qualification was the only organisation of the data that highlighted this difference. Teachers reporting the lowest level of mathematics qualification (typically secondary school mathematics such as GCSE Mathematics) were far less likely to report finding opportunities to reflect or discuss their learning as effective.
4.3.8 Teaching qualification

Once again pedagogic approaches were valued by all participants. However, those who were engaged in teacher training also tended to report that they found mathematical activities effective professional development, both doing mathematics themselves or learning about mathematical approaches.

In addition to the pedagogic sessions, qualified teacher participants were more likely to value receiving resources and the opportunity to discuss their learning. In contrast, teacher participants who described themselves as not having any professional qualifications in teaching were much more focused on mathematical activities, similar to those in training. For instance, one such teacher participants wrote, “Extended time to play with tiles etc. - really getting to grips with what is going on”. They valued activities where they were doing mathematics and/or learning about new mathematical approaches.

4.3.9 Age of students taught

It is interesting to note that categorising teacher participants by the age of the students they teach showed no strong discernible patterns on what aspects of their professional development that they found effective.

4.4 Findings from the interviews

In this section I detail the content of the three interviews that formed part of my data collection. Firstly, there is a brief description of how the interviews proceeded with reference to that as described and intended in my methodology. There then follows an in-depth explanation of each the three interviews. Each description includes a pen potrait of the interviewees, using information from their responses to the Participant general information questionnaire and then a commentary on the content of the actual interviews. These commentaries are structured under headings using the themes that initially arose from the Participant questionnaire on effective professional development data. Importantly, some themes emerge that are identified as being more significant to the teacher participants than others.

In contrast to this I also highlight potential themes that were not apparent from the data collection but that did appear in the interviews. Finally, there is a comparison with the
themes as identified in the seminal research, “Researching Effective CPD in Mathematics Education (RECME)” (Back et al, 2009b), including an interesting observation regarding teacher participant engagement with research.

4.4.1 Treatment as actually happened (vs that to be described in methodology)
As initially planned, only teacher participants from the two sustained professional developments courses, Teaching Advanced Mathematics (TAM) and Teaching GCSE Mathematics (TGM) were interviewed. This was partly due to the expectation that a developing positive relationship between myself and the teacher participants would facilitate the interviewees feeling it an emotionally safe environment in which to make contributions. The quality of the responses, in terms of honesty and personal reflection, indicate that this is what happened.

Available time proved to be a limiting factor as the interviews were conducted on course days and around the hours committed to the professional development. Unfortunately, compared with the expected durations, this meant that sometimes the interview had to be shorter than planned due to unexpected events such as a late-arriving lunch. Two of the interview groups were smaller than anticipated, with only two interviewees participating in each one. Again, this was due to unexpected events, in terms of the second interview one of the teacher participants who had volunteered to be interviewed was delayed as they travelled to the course. The third interview was more successful in terms of group size, with a total of six teacher participants being interviewed.

Each interview started with the same introduction, a reminder of the purpose of my research and an open question for participants to respond to the question, “What aspects of this professional development have made it effective?”. After one person volunteered to offer an initial response I invited others to build upon this with their own experience in terms of similarities and differences.

After everyone had had the opportunity to respond to the first question, my follow up questions were all less-structured. At these times, I took the opportunity afforded by an interview to ask for clarification and/or further detail of the points initially raised. By using a semi-structured interview in this way, I was able to engage the natural rapport that had developed between myself and the teacher participants (Silverman, 2014).
4.4.2 Interview 1

The first interview took place at study day 5 in March 2016 with two teacher participants from the Teaching Advanced Mathematics (TAM) course. All teacher participants had been invited to contribute to an interview and a selection of available times were offered. Only two teacher participants were eventually able to participate due to considerable time constraints. We formed a small focus group at midday before the start of study day 5 and we used a separate room to that which the other teacher participants were using for lunch. This meant that we had both privacy and calm and also quiet conditions for an interview. Initially we had hoped to meet for up to 30 minutes but ultimately had only 12 minutes of recorded interview time due to catering delays with the pre-study day 5 lunch.

Both of the participants on this occasion were female. Interviewee 1, referred to here as Leanne, was in her twenties and was completing her initial teacher training. She identified as a teacher of mathematics (responding “maths teacher” to the relevant demographics question) and her highest mathematics qualification was a subject knowledge enhancement course at university level. She was teaching mathematics to students across the ages of 11 to 18 years old at the time of the interview.

Interviewee 2, named as Carol here for anonymity, also identified as a teacher of mathematics (“lecturer in mathematics” in the open demographics question). However, she was older than Leanne (in her forties) and had been teaching for longer (indicating five to ten years). She had extensive mathematics qualifications herself (including at graduate level) and unlike Leanne had Qualified Teacher Status (QTS). At the time of completing the demographics questionnaire she responded that she taught only students aged 16 to 19 years.

Opportunities to reflect. The first teacher to reply to the question, “What aspects of the professional development make it effective?” was Leanne. She identified that the sessions were practical and placed the teacher participants in the position of being a learner. She explained, “we are the students”. She described the effect of this as “powerful”, using that word more than once. When I asked why it was powerful she replied that it was the combination of experiencing the teaching and then having time allocated to reflect and adapt the teaching resources.

The second teacher, Carol, elaborated on Leanne’s response saying that this aspect of the professional development had had impact for her because “you try the new ideas,
strategies… [et cetera] and experience for yourself that it works”. She used the word, “real” to describe this experience.

From this point, the interview became more of a discussion between the two teacher participants, with me summarising and seeking clarification.

**Doing maths** After further discussion both participants came to the conclusion that it was the blend of experiencing *doing* some mathematics (an activity or question, for example) and then having time to reflect (*opportunities for reflection*) and to create similar activities. It was this two-fold combination that led to the professional development being effective. They also valued the opportunity to be creative in terms of adapting resources or attempting to apply the strategies to other areas of mathematics. When asked to elaborate on why this was found to be effective they explained it was because this investment in the creation of the resource then gave them impetus to use it in their own teaching.

**Opportunities to discuss** Carol also explained why the opportunities to discuss learning contributed to the professional development being effective. She described that it meant the training felt less of an isolated experience, indicating that a collaborative approach added value to the professional development. Also, it created what could be termed a “cognitive space”. She explained that if the session content was all subject knowledge-based that it, “would have been too much”. This suggests that time spent *not* learning mathematics and a break from working on one’s own subject knowledge is as important as the opportunity to do so.

**Characteristics of the professional development lead** A final point agreed by both participants was that the professional development lead was a strong role model. They commented that they were left excited to apply his teaching strategies in their own classroom. For example, one trait they found added the effectiveness of the professional development was his style of questioning.

**4.4.3 Interview 2**

The second interview took place at study day 7 in June 2016, again with two teacher participants from the Teaching Advanced Mathematics (TAM) course. We used the timing that had proven most popular at the previous interview and so once again met at midday
before the start of study day 5. With no external factors disrupting the interview we this time had a full thirty minutes for the interview. The conversation was still in flow when we had to draw it to a close in order not to be late for the start of the professional development. As before in interview 1, there were two interviewees. Interviewee 3, referred to here as Emma was in her thirties. She declined to report how long she had been teaching mathematics but responded that she had been teaching for five to ten years. A later response indicated that this had been in mathematics, but that this year was her first teaching towards the A level qualification. She was self-identifying as a mathematics teacher (“maths teacher and progress leader for KS3”) and her highest mathematics qualification was Advanced Level Mathematics. She had Qualified Teacher Status (QTS) and at the time of responding to the data collection was teaching students across years 7 to 12 (i.e. from the start of secondary school to the first year of post-16 mathematics). The other participant was interviewee Carol, described above in section 4.4.1. Thus, this second interview had a different feel to the first as it was composed of two teacher participants at a similar career stage and slightly closer in age.

**Opportunities for discussion.** The initial question, “what aspects of TAM, in terms of professional development, have you found effective?” provoked an almost joint response with both interviewees answering and finishing each other’s sentences. Both Emma and Carol agreed that working with others was an important factor, using words such as “working”, “discussing” and “learning” with others. Both participants agreed that they had little opportunity to seek help from colleagues in their day-to-day work and found that learning subject knowledge from others (not just the professional development lead) had a “big impact”. Carol said that these informal opportunities were more effective than the formal activities, “just the fact [of] having us in the same room”. She used an example of a discussion around trigonometry, and how another teacher’s thoughts might lead to significant changes in how the topic is taught back in her own school. Elaine felt that the structure of Teaching Advanced Mathematics (TAM) encouraged discussion because so many of the activities encouraged collaboration, and she mentioned that it was the face-to-face element that meant the study days were more effective professional development that online or other forms of distance learning. I asked whether more formal, “networking” opportunities such as extended lunch breaks would be a way of facilitating this. Both disagreed with this, feeling that it would feel “forced”.
Also, Carol felt that meeting with the same people repeatedly at each study day was an asset, as it encouraged more “open” discussion. This was supported by the professional development lead asking people to sit and work with others at different points in the course and encouraging them to be in contact outside of the study days.

**Characteristics of the professional development lead.** The second factor that both agreed upon was the quality of the professional development lead’s teaching. Emma introduced this aspect, describing it as “amazing”. Carol said that watching how he modelled good teaching was effective for her, especially when it addressed elements of her own practice that she felt were “weak” ones. Carol did not feel intimidated by the quality of mathematics teaching being too high, explaining that even when it was “too good” it gave her something to aim for. Emma specified that for her, the professional development lead’s style of teaching “challenges [her] expectations of students”.

At a later point, Carol used the terms “informed” (about the current curriculum and qualification landscape) and “expert” to describe the characteristics of an effective professional development lead.

At this point, there was a bit of a tangential discussion between all three of us about stage of life and career and the effectiveness of professional development. I explained that this was something I hoped my research would shed light upon. Carol felt that at a younger age, with fewer care commitments outside of school and fewer leadership responsibilities within school, she would have gained more benefit from the Teaching GCSE Mathematics (TAM) course.

**Doing maths** collaborative, mathematical activities such as card sorts were identified as an effective aspect because they led to ideas “bouncing” between teacher participants in a pedagogically curious manner. Carol described this as being encouraged to “network in a more organic way” rather than being told to, “go and chat and get to know each other”.

**Participating with colleagues from the same school** Both felt that the professional development would have more impact on a department if more than one colleague attended. I did not pursue this line of thought during the interview as this observation seemed to fall
more under a heading of “impact of professional development on a department” rather than “what makes professional development effective for a mathematics teacher”.

**Opportunities for reflection** Carol made positive reference to the sessions that focussed on reflection rather than doing mathematics. This was seen as distinct to being asked to “just discuss” because it involved “really taking apart” the mathematics activities that had happened earlier. It meant that issues were raised and then discussed, with the challenges and solutions coming from other teacher participants far more often than from the professional development lead. Emma liked the structure of modelled maths lesson followed by a reflection and then another modelled maths lesson followed by a second reflection.

I asked a follow-up question to investigate exactly what made a reflection activity effective and the response was that they should be “structured”. Starting with a group consensus of what actually happened (perhaps as a timeline of the lesson) was agreed to be an effective activity, Emma reported reflecting the use of this in her own classroom, asking her students “what maths have we used?”. Reference to reading material (in this instance, set reading between study days) was also seen as effective. (Emma found the requirement to write a “feedback sandwich” as ineffective because needing two positive comments and one suggestion for improvement was too rigidly structured. Carol agreed, saying that it interrupted the “organic flow” of her thoughts).

After 30 minutes, I drew the conversation to a close so that the interview was concluded in good time for the teacher participants to prepare for the start of the professional development day.

**4.4.4. Interview 3**

The third interview took place after the end of study day 4 in June 2016 with six teacher participants from the Teaching GCSE Mathematics (TGM) course. All teacher participants were invited to share their thoughts, but only one available time was available and thus offered. The interview was held at the end of the penultimate study day, in the same room as the course had taken place but after other members of the cohort had left for the day. This was for the purpose of confidentiality in terms of non-interviewees remaining to overhear the interview and also for the purpose of minimal distraction. Six teacher
participants volunteered to join the group and one large focus group was formed. (Study day 4 ran consecutively with study day 5 and so participants were more likely to be spending the night locally and not have significant travel arrangements that afternoon). With six teacher participants, this group was a larger, more diverse, one compared to the previous two interview groups. As before there were only 30 minutes available for the interview and the discussion was therefore a lively one.

One concern, raised in the methodology is that my dual role as professional development lead and researcher/interviewer may have had an adverse impact on the willingness of teacher participants to identify and share negative aspects of the professional development. In the event, no negative aspects were identified, and so it will not be known whether a different researcher would have learned more. However, a willingness to participate from a significant number of participants is, in some part, evidence that my dual role did not hinder the data collection.

Interviewee 4 will be referred to as Jim. He was in his twenties, had gained Qualified Teacher Status (QTS) and was in his first year of both teaching and teaching mathematics. He had a high level of personal mathematics qualifications (university Batchelors degree) and unsurprisingly he self-identified as a “teacher of mathematics”. Jim was teaching students aged 11-18 years old. With this demographic information, Jim was one of the most mathematically qualified teachers, most new to his teaching career, of all of the interviewees.

Interviewee 5 will be named Jack for the purpose of this thesis. Similar to Jim, Jack was in his twenties at the time of participating in Teaching GCSE Mathematics (TGM). He was still in training and had not yet completed his NQT (Newly Qualified Teacher) year. His own mathematical background was A level mathematics in terms of qualifications. He also self-identified as a, “Teacher of maths”. He was teaching students aged 11-19 years old (atypical age range due to it being a specialist school).

Interviewee 6 will be referred to as Sally. Sally was in her forties and indicated that she had been teaching for more than five years, but that this was her first year of teaching mathematics. She indicated that she had Qualified Teacher Status and her degree level qualification was in education. She was unusual insofar as she described her teaching role in terms of how many days per week she taught (four) but because she included the
wording “teach maths” I included her as a teacher self-identifying as a subject specialist. Her teaching responsibilities were for students aged 11 to 16 years. Sally’s own mathematical background was at A level.

Interviewee 7, known here as Julien, was in his thirties. As above with Sally, Julien had been teaching for between five and ten years and has Qualified Teacher Status, but was teaching mathematics for the first time that year. He identified as a mathematics teacher but also included his pastoral role in his description. Julien’s own mathematics qualifications were up to post-16 / A level. He reported teaching students aged 11 to 16 years.

The penultimate person, interviewee 8, will be referred to as Paul. Paul was in his thirties and had been a teacher of mathematics for his teaching career of over five years (but no more than ten) with Qualified Teacher Status. His own mathematical qualifications were at post-16 level (Advanced level mathematics). Paul self-identified as a teacher of mathematics and was teaching students across the age range 11 to 16 years.

The final interviewee, interviewee 9 will be referred to as Keith. Keith was in his fifties and was in a second career of tutoring for the past 5 to 10 years. He did not self-identify as a mathematics teacher, but used a description of his place of work (an alternative provider of education) as a tutor of adults working at Functional Skills level. He had Qualified Teacher Status. His highest personal mathematics qualification was secondary school Mathematics.

**Mathematical approach is valued** Julien started the discussion from my initial prompt of, “what aspects of the professional development make it effective?”. He started by sharing his personal reflection of the difference between the teaching modelled on the course and the teaching he had experienced as a student at school himself. For Julien, the impact from the professional development was the evidence he had on the impact it had in terms of the level of understanding encouraged in the learner. He explained,

“I was taught from… rote… ‘this is the formula, this is how you use it’ and you go and use it. Maybe because I found it easy to remember formulas, it was always easy for me to process maths. But coming here has made me totally understand it so in the classroom I am now able to draw out the understanding from the kids... they end up telling me”. Later on, Julien picked up on the use of
practical approaches, “knowing that there are practical concepts that actually prove that they exist… that for me is the best thing ever”.

“Julien” Teacher participant with post-16 mathematics qualification.

Paul took up the responses at this point and explained that for him the professional development was effective because he was seeing new methods and approaches of teaching topics that he was already familiar with. He mentioned the making of connections between different areas of mathematics, such as transformations of graphs and completing square. “Connection” was a key word that other interviewees returned to throughout the interview.

**Pedagogic approach is valued** Paul valued the opportunity not only to experience different teaching approaches, but also the opportunity to work with others. He valued sharing different mathematical approaches in solving problems. He identified in the professional development an encouragement to explore different methods and that this valuing of different solving methods (as opposed to the actual solution) was well-modelled. The conversation returned to Julien who said that the course had “inspired [him] to teach in a completely different way”. This impact on teaching was identified as evidence that the professional development was effective. He returned to the mention of ‘connections’. “Also, I wanted to say… how we are able to relate one topic to another. If I hadn’t have come here I wouldn’t have done that”. Jack also reiterated that it was the making of connections between mathematical topics that made the professional development effective (“inspiring”) for him and Paul said that it was “satisfying to see how things work and fit together”.

I then invited Keith and Jim, who had not so far spoken, to respond to the prompt of what made the professional development effective. Keith said, “liberating is not too strong a word. I’m new to maths, I’m new to teaching maths… I think it’s the bit about representation”. (Here Keith is referring to the use of multiple representations of one concept in mathematics, such as the algebraic and graphical representations of a function). He found that he was able to make connections with similar pedagogic approaches in geography. He liked having learned to use the software GeoGebra and having a “little play/experiment” himself and modelling this with his students as, “we can play with it”
whereas previously his approach would have been more directed at the exam and just knowing a fact rather than understanding it.

I interrogated this a bit further, what had led the course having this impact on Keith’s more relaxed, exploratory approach? He replied, “well, I think that from day 1… the devices of representing in different ways – foam blocks, words, numbers, picture, algebra…”. For me, this summarised the two points made above by Julien (use of physical manipulatives) and Paul (multiple representations). Keith said that it had fundamentally changed his view of mathematics, “It was broader than what I thought of just numbers”.

**Receiving resources** For Jim it was also the pedagogic approaches shared that made the professional development effective. He felt, “every day we leave here there’s a topic we’ve covered in the course, I know that when I teach it, it’s going to be pretty good”. He identified that this included receiving resources (his example was on multiple representations) and that it was their “novelty, but not a bad novelty” that meant that they were an aspect of effective professional development.

Jim also explained why the pedagogic approaches were useful to him as a mathematics graduate. He felt that the professional development had an impact on his teaching when it modelled to him how to explain an idea to someone who was struggling to understand (in contrast to himself who had generally understood the first time as a learner of mathematics at school).

In terms of a possible combination of both receiving resources and pedagogic approaches valued, Keith valued the planning tools and Assessment for Learning techniques (as opposed to learning/classroom resources).

**Use of digital technologies** Keith found the sessions and resources associated with the mathematical software, GeoGebra, an effect aspect as he had activities “ready to go” in the classroom.

**Opportunities for discussion.** On this point, Keith explained that there was a benefit in terms of retention of professional learning, saying, “talking it helps you remember it”. Jim found that this was something he was now developing with his students, encouraging them that it was acceptable to risk saying something that may turn out to be wrong.
Doing maths towards the final minutes of the interview Jack explained that having not studied mathematics himself for about ten years, the opportunity for engaging in mathematical activity left him feeling capable in his own ability to attempt unfamiliar problems with his students.

Characteristic of the Professional Development Lead Certain aspects of my, the Professional Development Lead’s, behaviour were identified as inspiring and confidence-building. Towards the end of the interview Jack identified the use of questioning as something he felt that he had benefitted from personally and also had been able to adopt in his own teaching practice immediately. Keith and Jim explained that they found my way of waiting for answers from them, the learners, very effective for their professional development. Keith felt that he had learned that as the teacher he didn’t have to have all of the answers all of the time, “That way of handling things… has brought a freedom that for me in the classroom, almost I feel that I don’t need to know…’let’s have a look at this’; ‘what about this..?’; ‘does anyone know..?; ‘let’s have a look’”. (I clarified with the teacher participants that they realised that this was a teaching approach on my behalf and that often I did “have the answers”).

The discussion led to an elaboration that it was a combination of both experiencing good mathematics teaching as a learner and seeing that certain behaviours could be adopted in their own practice, that was an aspect of effective professional development.

Other aspects arising from interview 3
One theme that hadn’t arisen before in the data collection was the idea of the course being a safe learning experience. Jim explained that, “I guess, you know, there are loads of different levels of understanding of the maths in here, I don’t know, I’m sort of ‘upper middle’ maybe? So, I know that there’s people know more than me and less than me, and I don’t think that anyone feels intimidated or threatened by the fact that anyone in the room...”. At this point it was picked up by Jack who agreed that the style of leadership led to discussion in a way that was collaborative and ‘safe’. This was an environment that he believed was encouraged and facilitated by me, the Professional Development Lead.

Towards the end of the interview only Jim, Jack and Keith remained. They explained that without the course they would not be where they were now. Keith felt he wouldn’t be able
to teach mathematics at all and Jim that he would be far behind where he was now. As a Newly Qualified Teacher (NQT) he felt that his school were very impressed with his progress and that he “massively put this down to this [the Teaching GCSE Mathematics course]”.

With only a few minutes remaining, I asked whether any aspects had not been effective professional development. Jim explained that the course had encouraged him to take risks in his teaching that had paid off. Had he taken any risks that hadn’t paid off, and what had happened? Keith answered, that he had tried sharing the unit circle approach to trigonometry with some of his adult students who had expressed curiosity about his participation on the professional development, but he had forgotten some of the details. He felt that this had been unsuccessful with the students because it was a leap of context from the concrete, real-world mathematics they were doing at a pre-GCSE level. I’m not sure if this can be interpreted as an aspect of the professional development being ineffective.

4.4.5 Themes emerging from the interviews

In the third interview, two themes emerged that had not been apparent in the Participant questionnaire on effective professional development, namely that two aspects of effective professional development are that it be within a safe learning environment and that it had enabled them to make progress within the teaching profession in a way that they couldn’t imagine having happened had they not participated.

In terms of themes that had not emerged in the interviews, but had emerged in the Participant questionnaire on effective professional development there were none. All eight themes were identified at least once. However, again the most convincing argument was made for pedagogic approaches valued being the strongest theme, with more people finding that an aspect of effective professional development than any other.

Finally, there was for me a surprising outcome from the interviews. In the interviews, there was an emphasis and strength of feeling from the teacher participants that had not been apparent to me in the Participant questionnaire on effective professional development. I found that I was starting to notice certain key words emerging, rather than a phrase. These would be introduced by one teacher participants and then emphasised and/or repeated by others. The first word that emerged in this way was, “confidence”. This was given in response to teacher participants identifying that professional development was effective if it
inspired confidence in them in terms of their own teaching. A second key word was, “powerful” in reference to aspects of professional development that teacher participants believed had had a significant impact on their learning. A final key word was “connections”, given in reference to the professional development encouraging links between different areas of mathematics. This could have been a possible direction for further research. However, I felt that these words were slightly more related to ways of identifying that professional development had been effective, rather than identifying aspects of effective professional development.

4.5 Comparison with established findings from the literature

In section 3.4.3 Treatment of questionnaire responses, I identified a number of aspects of effective professional development as already identified by the seminal 2013 report, “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al, 2013b). In this part, I compare and contrast the findings of this research with those findings to identify areas of agreement and conflict.

RECME’s first group of themes were those emerging from their research with teacher participants and professional development leads:

- **Leadership**, i.e. the expertise of the person leading the professional development was comparative with my final heading, **Characteristics of the Professional Development lead**. Both of these categories described the expertise and experience of the person leading the professional development as contributing to the professional development being effective. In my research teacher participants identified both the professional development lead’s teaching style and also the softer skills (e.g. being supportive, having an encouraging manner etc) as effective aspects of professional development.

- **A practical approach**. This covered the professional development including examples of teaching resources and examples from the classroom. I believe that this corresponds with my heading of **Receiving resources** but could also perhaps include **Mathematics approach is valued** as it goes beyond the just the physical resources to encompass teaching strategies.

- **Stimulation, challenge and enjoyment**. Aspects of support and encouragement did appear in my research findings, but more often under the heading of **Characteristics of the Professional Development**. Teacher participants did identify “challenge” and I
included these under the heading of **Pedagogic approach is valued**. I believe that this indicates that there is some overlap here. At other times my findings included references to “fun” and “enjoyment” in comments I included under the theme of **doing maths**.

- **Time**, in itself was not an emerging theme from my research. However, in terms of the description from “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al, 2013b), “[participants] valued the time that their involvement in the CPD initiative gave them to focus on their professional practice. This often involved release from the classroom, standing back from their day-to-day practice and reflecting on their practice” Researching Effective CPD in Mathematics Education (RECME) report (Back et al, 2013b; 5) this was supported by my findings. I have included this under the theme of **Opportunities for reflection**.

- **Networking**. This term was used in RECME to describe opportunities to meet teachers from other schools or colleges. Similarly, in my research this was identified as a much-valued aspect by teacher participants, under the heading of **Opportunities for discussion**.

The “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al, 2013b) also listed five factors that were identified by the researchers rather than explicitly reported by teacher participants):

- **Area of focus (mathematics)** that is, that the content of the professional development was subject-specific to mathematics teaching. I believe that this was reflected in my own findings, under the headings of **Mathematics approach is valued** and **Pedagogic approach is valued** due to the nature of all of the professional development courses researched being specific to mathematics. None of the professional development sessions experienced during the research could be said to be generic to any other school subject.

- **Students’ learning of mathematics**. Back et al (2009b) use this to describe cycles of a plan-do-review format that focused on the teacher participants’ students’ learning of mathematics. This was not identified in my own research. However, I do not feel that my research contradicts this finding as such activities (perhaps in the form of action research or lesson study) was not a form of professional development investigated.
• **Encouraging reflection.** Interestingly, my research provides evidence of this as an aspect of professional development from the *teacher participants’ perspective*. In this way, my research may be seen as significantly strengthening this finding. Furthermore, it was one of the most commonly identified aspects of effective professional development. However, conversely, “Researching Effective CPD in Mathematics Education (RECME)” report (Back et al, 2013b) includes teacher participants’ working with research as part of the reflection process. My research found no evidence to support this, not one teacher participant stated that they valued engaging directly with the research an aspect of effective professional development.

• **Expecting and supporting change** was described by RECME as an expectation that teacher participants would trial new approaches in their practice and also be accountable for sharing these experiences. Such interim tasks formed part of the professional development courses included in this research, but my findings did not suggest that teacher participants found them to be an aspect of effective (or ineffective) professional development.

• **Supporting the embedding of change.** This emphasised the provision of opportunities for teacher participants to collaborate with each other in the application of the above point. Even though my research findings did not explicitly support this, aspects of collaboration were strongly valued, for example, under the heading of opportunities for discussion and, perhaps, doing mathematics. As one teacher participants stated, discussing their work with other teacher participants was an “incredibly valuable discussion to further my learning / understanding”.

Thus, I believe that it has been a useful exercise to cross-reference my findings with those of the established literature. It adds weight to the findings to observe that the findings of my research, from a teacher participants’ perspective, has significant areas of over-lap with research from a researcher/observers’ perspective.

**4.5.1 A focus on the use of digital technologies as constituting an aspect of effective professional development**

As has already been noted, a particular sub-group of two of the themes (receiving resources and pedagogic approach valued) emerged, the use of digital technologies. Mainly, the use of two mathematical software programmes were extensively observed during the data
collection, Autograph (http://www.autograph-maths.com/) and GeoGebra (https://www.geogebra.org/). Both demonstration by the professional development lead and an expectation of use by the teacher participants were included in this use. Teacher participants identified more than one feature of the use of digital technology that was effective, namely, time given for learning how to use the software; provision of expert support in learning its features; sharing of resources and thus increased confidence in using the software themselves; and, modelling of good practice.

The use of digital technology is obviously a recent development in mathematics education arising from the development and spread of computers and latterly other digital devices and thus a recent development in mathematics teacher training. My decision to classify Use of digital technology as a distinct theme is supported by the literature. Clark-Wilson et al (2011) wrote for the Joint Mathematics Council that,

“As the development of a technologically enriched student learning experience occurs at the level of the classroom, such change has to be supported by both school leaders and accompanied by sustained professional development opportunities for teachers. The process of adopting digital technologies requires teachers to take risks in their teaching, supported by appropriate technical, didactical and mathematical expertise. With increased autonomy, schools will need to take more responsibility themselves for professional development and support for teachers in this process.”


Similarly, the Advisory Committee on Mathematics Education (ACME) identify the same need in 2014, this time in linking teacher professional development to student outcomes in terms of student learning,

“ACME believes that teachers need to: develop deeper mathematical subject knowledge, pedagogical content knowledge and other professional learning, including the use of digital technologies”.

(Pennant, 2014)
As such, I believe that it is a significant finding of my research that such provision is now identified by the teacher participant as an aspect of effective professional development.

5. Conclusion

This section draws together the findings of this research and thus seeks in part to address the gap within the literature highlighted earlier. That is, how the effectiveness of professional development for mathematics teachers is experienced by the teacher participants themselves.

The first section summarises what effective aspects of professional development have been identified by the teacher participants who participated in this data collection, and includes specific examples of good practice. There then follows some consideration for delivering professional development to specific groups of teachers, for example, those still in teacher training. An important aspect identified by all teacher participants has been pedagogic approaches and section 5.3 explores a specific dilemma associated with this that has arisen during the data collection.

Following this there is then a description of the implications this research has presented for my own work in designing and delivering professional development for mathematics teachers. Finally, there is a discussion of the limitations of this research and a section on opportunities for further research.

5.1. What do teacher participants find effective?

In this section I summarise the eight aspects of professional development that make it effective, as identified by the teacher participants who contributed to this research. It is intended to be practical guidance for providers and leaders of professional development for mathematics teachers and to offer specific examples of good practice. The final section highlights aspects of professional development that were identified as ineffective and to be avoided.

It should be noted that the consistently most important aspect was the sharing of pedagogic approaches (5.1.5).
5.1.1. **Doing mathematics**
The opportunity to engage with mathematical activities was valued by teacher participants because it contributed to improved levels of engagement and enjoyment on the professional development. Teacher participants expressed that experiencing a variety of physical presentations of mathematical activity led to such sessions being effective. In my data collection, such types of activities included card sorts and matching resources, use of mini whiteboards, “practical experiments”, use of multilink cubes, activities with foam algebra tiles and more generically, “hands-on” resource.

Secondly, teachers also described that for the session to be an aspect of effective professional development, the mathematics had to engage them at their own level of challenge. This is due to having the opportunity to experience the activity from a student or learner’s perspective.

5.1.2. **Receiving resources**
Teacher participants valued the sharing of resources, but reported a number of qualifying requirements. Firstly, they needed to be easily transferred to the classroom with few barriers. For example, paper-based resources should not require a great deal of preparation in terms of photocopying or ‘cutting out’. Cost of reprographics was also a concern. Similarly, technology-based resources needed to be within the teacher participant’s skill level with the software used. Any barriers such as these meant that teacher participants were unable to envisage trialling their use in their own classroom, something that they judged to be a requirement of effective professional development.

A second aspect, that was desirable rather than essential, was that the resource be fairly novel to a teacher participant’s classroom. For example, my personal anecdotal experience is that a high-quality resource such as a jigsaw activity made with the Tarsia software is less effective for a specific teacher participant if they are already familiar with such an activity. If it is new to an individual, then it is found to be effective professional development as it is widening the teacher participants’ knowledge base and repertoire of resources.

Other possible characteristics of a “high quality” resource, as identified by the teacher participants, included ones that used a real-life context or involved matching different
representations (e.g. card sorts with algebraic functions to be matched to their graphical representation).

5.1.3. Opportunities for discussion
Teacher participants highly valued the opportunity to work collaboratively with others and to have conversations, covering both each other’s experience of teaching and each other’s learning on the course. Discussion opportunities were only identified as effective, however, if they were natural rather than forced. Natural discussion arose from shared mathematical experiences and were seen as important cognitive spaces from engaging in constant mathematics. Conversely, lengthy and informal “networking opportunities” such as an extended tea and coffee break were not experienced as effective. Finally, some facilitated ‘mixing’ was seen as effective. Being asked to work with different people at different times in a course day led to more discussions with more people, and this was seen as helpful to professional development.

5.1.4. Opportunities for reflection
Similar to the opportunities for discussion, opportunities for reflection were also considered important. Whilst discussions were seen as brief interludes from the challenge of doing mathematics, mathematical learning was seen as being integral to the reflection activities. This combination was judged as important for the reflection to be seen as an aspect of effective professional development. Effective reflection activities included being given time to consider how a specific mathematical activity would need to be adapted for their individual classrooms or time to consider how similar activities could be created for teaching other areas of mathematics. Reflection opportunities were judged to be more effective if there was some structure provided by the professional development lead. An example of this shared in the data collection was for a reflection to start with teacher participants reaching a consensus on what had actually happened, for example, a timeline of the mathematics activity or session.

5.1.5. Pedagogic approach is valued
Separate to the mathematic subject knowledge content of sessions, learning about a number of generic, pedagogic techniques was found by teachers to be effective.
Learning how to teach problem-solving was valued by teacher participants, including learning how to model solving problems as a teacher at the front of the classroom. Teacher participants felt that they had learned how to take a playful, exploratory approach to teaching problem-solving and had gained the knowledge and confidence that they did not have to possess all of the answers, all of the time.

In a similar vein, experiencing the professional development lead show appreciation for different solutions for a given problem was seen as effective.

Equally, experiencing a “be less helpful” approach from the professional development lead also proved effective because it was seen to be effective and successful mathematics teaching. “Be less helpful” is an idea that emerges from the literature on effective mathematics teaching and learning. It refers to the idea of allowing students to experience the feeling of being perplexed, and therefore the desire to learn more and to find a solution. A distinction is made between being less helpful resulting in perplexity and being unhelpful, resulting in complete confusion and an inability to make progress (Zucker, 2012).

Another pedagogic approach that was valued was learning how group work could be facilitated by the teacher. “Group work” in the context of mathematics teaching refers to learning activities involving students working in groups of three or more, as opposed to working alone or in pairs (Pennant, 2013). Group work is viewed within the literature as being important for facilitating opportunities for students to listen, question, explain, convince, respond, enquire, share, reflect, communicate clearly and concisely and collaborate (Woodham, 2013). This list of benefits is subsequently seen to lead to the development of the problem-solving skills of the individual student.

However, a number of barriers present themselves to a teacher attempting to facilitate group work successfully within a classroom. For example, students’ reluctance to collaborate and some students’ still developing learning skills in terms of working as a group and staying focused on the task (Blatchford et al, 2005).

Therefore, advice, ideas and modelling of how to facilitate effective group work was welcomed by teacher participants.

In terms of pedagogic subject knowledge, making connections between different areas of mathematics was valued as effective professional development. Teacher participants
valued learning how connecting different areas of mathematics through multiple representations of a single concept, was effective mathematics teaching. This was exemplified by the professional development lead making explicit what the connections were and how they could be experienced through the use of multiple representations card sorts or use of a single representation as a method for solving different types of problems (such as the proportion bar applied to the contexts of, for example, fractions, solving equations and constructing pie charts).

The proportion bar, also known as the bar model and Singapore bar, is a diagrammatic representation of a proportional relationships, and thus seen as an important bridge between the concrete experience and abstract representation in the concrete, pictorial and abstract triad. The proportion bar is viewed as a significant pedagogic technique due to being, “a way of revealing the mathematical structure within a problem and gaining insight and clarity as to how to solve it” (National Centre for Excellence in the Teaching of Mathematics, 2014). It plays an important role in primary mathematics, where students meet proportional relationships within the contexts of fractions and ratio for example but is also widely applicable to secondary level mathematics, for topics such as reverse percentage change and conversion problems.

- Use of different questioning techniques was another generic pedagogic technique that teacher participants identified learning about as an aspect of effective professional development. On the course days when I collected data, these techniques included effective use of mini whiteboards during questioning and answering activities with students, and the planning and implementation of different question stems (see Watson & Mason, 1998).

- A final theme around pedagogic approaches was when teacher participants identified teaching approaches for specific mathematics topics. For example, the use of the unit circle to introduce trigonometry. The commonality that these separate approaches had was that they tended to be viewed as novel, and new to the individual teacher participant.

In addition to these categories above, a minority of teacher participants mentioned two more themes. Firstly, some found pedagogic approaches of using real life contexts effective professional development and secondly some teacher participants valued learning about “low-floor, high-ceiling” activities. By this term, I mean mathematical classroom activities
that all students can access and start, but by which no student is held back from progressing further.

5.1.6. Mathematics approach is valued
Teacher participants valued a focus on mathematics that could be described as rigorous. It is not trivial to identify the specifics of what this might mean, and there is some considerable challenge in describing it. I suggest that a “rigorous mathematical approach” may include, an emphasis on the use of correct terminology; communication of methods that are fully complete; use of connections (discussed below); and, pursuing solutions that are efficient and elegant.

One factor more readily identified by the teacher participants, was that of making connections between different areas of mathematics. Repeatedly, the use of multiple connections was described as an aspect of effect professional development. An example of this was observed on the Teaching Advanced Mathematics (TAM) course and involved teacher participants in the role of the student matching algebraic representations of functions to sketches of graphs. An example on the Teaching GCSE Mathematics (TGM) course involved teacher participants matching cards with different diagrammatic, word, numeric and algebraic representations of the same linear sequences.

Use of digital technologies
In a sub-group of section 5.1.2 above, teacher participants valued receiving “standalone” digital resources, i.e. ones that could be easily applied in the classroom immediately. Examples observed during the data collection included website-based activities such as The Moving Man interactivity at https://phet.colorado.edu/en/simulation/moving-man and GeoGebra files, such as Venn diagrams for HCF and LCM https://www.geogebra.org/m/xJupYKBw (Barker, 2015).

The second aspect of the use of digital technologies that was found to be effective by teacher participants was when professional development provided time, space and expert support for them to learn how to use the software themselves. For example, on the Teaching GCSE Mathematics (TGM) course, there was a session entitled, “Getting started with GeoGebra”. The outcome of this was teacher participants learning how to use GeoGebra to create their own interactive files.
5.1.7. Characteristics of the Professional Development lead

The findings suggest that teacher participants valued three characteristics in the people leading their professional development. Firstly, they respected leads who encouraged open and inquisitive learning environments, especially by being open to criticism of the content of the course. In this way, a lack of defensiveness was appreciated. Secondly, in terms of questioning, teacher participants valued professional development leads who would engage in answering questions and sharing their knowledge. Being up-to-date with the latest information on curriculum development and changes to qualifications was valued as part of this sharing.

Finally, one to be used with caution in my personal opinion. The findings suggested that teacher participants valued the professional development lead sharing anecdotes from their own teaching. I believe that in referring to their classroom experience, some leads were viewed by teacher participants as having increased credibility and a genuine appreciation of the contexts that teacher participants are working in and the conditions and challenges that they face. Anecdotes can be used to provide rich, interesting and convincing examples. However, I would have concerns that too many personal anecdotes may give the impression that the professional development design is based on one person’s experience rather than research evidence. Furthermore, overuse of anecdotes may be seen as a conversational tangent from the focus of the teacher participants’ professional development.

5.1.8. Creating a safe learning environment

Teacher participants identified two factors that led to the creation of a safe learning environment. Firstly, the sustained professional development courses that ran over a number of days led to professional relationships being built. In turn, a level of familiarity and mutual understanding increased the feeling of emotional safety. The second aspect was that of the style of leadership of the person leading the professional development. Teacher participants identified an encouragement of discussion where contributions were valued and debate was not discouraged.

There were two results arising from the creation of a safe learning environment, both to do with risk-taking. Firstly, teacher participants felt able to contribute to discussions, and to take risks in testing their ideas out loud. The second aspect of risk-taking was that teacher participants found that the encouraging and support ethos of the course encouraged them to
take risks in their classroom practice. Both of these aspects paid dividends in terms of the results leading to increased confidence and competence in their teaching.

5.1.9. Potential aspects of professional development that should be minimised

Only three characteristics were identified as being ineffective by some of the teacher participants. The findings of this research suggest that the following should be used with caution or minimised.

Firstly, a continuously high level of challenge. This was described both in terms of the level of mathematics or the pace that the mathematics was being considered. A continuously high level of mathematical challenge, or activities that progressed too quickly, were both found to be ineffective. The day should include more accessible activities as much as ones with high levels of perceived difficulty. The findings suggest that the design of professional development should take in to consideration teacher participants’ “energy levels” at different times of the day. For example, perhaps motivation may dip immediately after a meal or concentration may wane towards the end of the day.

The second aspects that should be avoided are prolonged discussion or writing activities. Whilst teacher participants valued opportunities to talk with each other, they were wary of informal opportunities that lasted too long. There was some feeling that these were “time-filling” exercises. My findings suggest that extended lunch times for “networking” that perhaps work well at conferences are best avoided on courses. Similarly, long writing activities are best avoided. Where writing was required, teacher participants expressed a preference for outlining or “bullet-pointing” over prose.

The third characteristic of ineffective professional development as identified by teacher participants was when the content of the course included too many pedagogic approaches that were a significant challenge to their current practice. From experience, I know that an example of this is a proposal of spending more classroom time on fundamental ideas that underpin later mathematical topics. This is a key principle of effective mathematics pedagogy as identified within the literature on effective mathematics teaching. For example it is a common characteristic of mastery teaching of mathematics, “Significant time is spent developing deep knowledge of the key ideas that are needed to underpin future learning” (National Centre for Excellence in the Teaching of Mathematics, 2016b; 1). Many teacher participants, in my experience, find this a new and thought-provoking idea, not least
because it is often felt to be in conflict with perceived pressures to “cover the full curriculum”. For some teacher participants, this is a significant challenge to their current practice and beliefs about mathematics education. Therefore, despite there being an evidence base for some pedagogic approaches, including too many such challenges in a course may actually become characteristic of ineffective professional development.

5.2. What aspects should be considered for different groups of teacher participants?

The following suggestions are stated in the context of this small-scale study and the limitations of the research should be kept in consideration. However, these statements are included here in the hope that they are relevant and informative to other leaders of professional development for mathematics teachers.

A reminder once again, significantly learning about mathematics-specific pedagogic approaches was consistently considered an effective aspect of professional development.

Courses aimed to support teacher participants on Advanced level mathematics courses. My findings suggest that whilst there are many commonalities between these two groups of teacher participants in terms of what they find effective aspects of professional development, there are some differences that should be held in mind. Teacher participants on professional development aimed at teaching Advanced level mathematics in particular, should include the sharing of teaching resources, perhaps due to the relative lack of such resources being more widely available at this level of student learning. Sharing of resources can perhaps sometimes be viewed as a low-quality, less stimulating form of supporting teachers, but in this research, it has been identified as an effective aspect of professional development by the teacher participants themselves. I believe that it is important to make the same connection that the teacher participants did, by linking it to this next aspect. Those on courses aimed to support teacher participants on Advanced level mathematics courses valued the opportunity to discuss their learning with each other. I think in this way, sessions that include the exploration of new (high-quality) resources should be combined with opportunities to discuss, critique and reflect upon them.

Courses with predominantly younger cohorts of teacher participants. Younger teacher participants were more likely to value the opportunity to discuss their learning with each
other. On some courses, those that attract cohorts of relatively younger teacher participants (such as on Teach First training routes, perhaps) it may be more appropriate to include more or longer discussion activities. Again, these should not be without context. Discussion without context such as extended “networking lunches” were not identified by teacher participants as aspects of effective professional development. All age groups in this research, including those aged below 30, highly valued learning about new pedagogic approaches.

**Professional development for those still in teacher training.** Courses to support those teacher participants still engaged on routes in to teacher training should include more opportunities for engaging in mathematical activities and learning about pedagogic approaches specific to mathematics. Such teachers were less likely to value opportunities to discuss their learning, perhaps given that this already forms a significant amount of the training, given their stage of professional learning.

**Professional development for experienced teachers of mathematics.** The findings of this research suggest that such teacher participants form cohorts who particularly value the opportunity to reflect upon their learning. Once again, the key finding is that pedagogic approaches are the most important aspect of effective professional development and thus context for this reflection to occur. Furthermore, in contrast to their colleagues at an earlier career stage, they valued the receiving of new resources. Courses aimed at groups of such teacher participants should therefore include more opportunities for reflection and the sharing of resources.

**Professional development for “non-mathematics teachers”**. For those teacher participants who did not self-identify as mathematics teachers, they were less likely to value opportunities for either reflection or discussion. In line with their preferences, sessions that are more focused on learning about mathematical approaches, pedagogic approaches and opportunities to engage in mathematical activity are more likely to be experienced as effective professional development.
5.3. A dilemma for the professional development lead

I feel that one of the findings presents a dilemma for people designing and leading professional development for mathematics teachers. An effective aspect, repeatedly identified by the teacher participants, was the use of multiple representations to teach mathematics.

Multiple representations

“Multiple representations” is a term used to describe the phenomenon in mathematics of a single concept or idea having a number of different presentations. For example, the idea of “three fifths”, given here in words, can also be represented in a numerical format, \(\frac{3}{5}\), as a position on the number line, as a rectangle split in to five equal parts with three chosen, or as three whole rectangles split in to five equal parts, and so on. Their importance for learning and teaching is that they “allow learners to construct meanings and links between the underlying concepts” (Swan, 2005; 19).

Quite commonly at secondary level mathematics, multiple representations include algebraic, numeric, graphical, diagrammatic and words (Swan, 2005), and all of this can be given on screen or paper. However, one of the advantages of multiple representations is with the use of “physical manipulatives” such as multi-link cubes, Cuisenaire rods and algebra tiles. As the findings of this research show, the use of these resources in professional development is also valued by the teacher participants. Thirdly, the use of digital software such as GeoGebra provides another, dynamic representation. This another link to this research, with the use of digital technology also being identified as an aspect of effective professional development.

I believe that the significance of multiple representations for a designer of professional development presents a dilemma in so far as considering exactly what makes multiple representations such an important aspect of effective teacher learning. Is it due to the fact that it such an important element of mathematics pedagogy, with powerful implications for student learning? If so, then it will remain an important consideration in the delivery of
effective professional development. Or is it due to a current level of novelty about the use of multiple representations in English schools? If it is more the latter, then the implication is that eventually it would not be such an effective aspect of professional development. The dilemma for professional development leads is what mathematics-specific pedagogy would replace it to maintain the level of effectiveness?

5.4. Implications for my future work
Carrying out this research has already had a number of implications for my own work as a professional development lead at Mathematics in Education and Industry (MEI). Valuing the perspective of the teacher has been a focus of this research throughout and the findings have constantly reinforced the individual experience of the teacher participant engaging in mathematics professional development. It appears to be a worthwhile endeavour for professional development leads to carry out a brief survey of the backgrounds and motivations of teachers registering for a course. This could include the context in which they teach, brief information on their students in terms of key stage or qualification studied, the teacher participants’ level of mathematical qualification and their intended outcomes from the course. This would facilitate the professional development content and/or structure being adapted for the specific learning needs of the teacher participants attending, and thus increase the effectiveness. However, meeting the requested intended outcomes expressed in such a survey would need to be balanced with the benefits of presenting teacher participants with unexpected outcomes. Such unanticipated results of the professional development were some that teacher participants expressed being of most value and I would not want these to be lost in future work.

As has already been noted, each individual teacher has specific and individual needs. However, a number of different commonalities emerge for groups of teachers sharing some common characteristics. Unsurprisingly, a strong theme of pedagogy specific to mathematics has existed in my work. This is unsurprising because it needed to be present in order for teacher participants to identify it as an aspect of effective professional development. However, the findings reinforce the level of significance that it carries for all teacher participants. As such, I have noticed it becoming more explicit in my own work.
Secondly, I have realised the value that teacher participants place on distinct reflection opportunities as part of their professional development experience, and I am now making more of a conscious decision to include these at each stage of a course. Importantly, I am linking these closely to context activities around pedagogy, doing mathematics and exploring new resources. Furthermore, I have adopted some of the specific reflection strategies identified as effective, for example, starting a reflection discussion by the whole group reaching a consensus in terms of a “what actually happened?” timeline.

As noted above, the receiving of resources is of particular interest to teachers of post-16, Advanced level mathematics. This finding brings to mind the recent Underground Mathematics project (https://undergroundmathematics.org/). This is a “free web-based resources that support the teaching and learning of post-16 mathematics. It is funded by a grant from the UK Department for Education and based at the University of Cambridge. [Aiming] to help make post-16 mathematics a richer, more coherent and more stimulating experience for students and teachers alike” (Underground Mathematics, 2017). These high-quality resources aimed at Advanced level mathematics have been accompanied by a one-day professional development course led by Mathematics in Education and Industry (MEI). Such partnerships are perhaps a model for further exploration in the future.

5.5. Limitations of this research
This research was concerned with investigating the effective professional development of mathematics teachers, from their perspective. However, the scope of this study was limited to a small sample. Firstly, all of the teacher participants were enrolled on courses run by Mathematics in Education and Industry (MEI). So, although some convincing themes emerged from the research, they were limited to the context of a course organised by a single provider. Secondly, for ethical reasons, all of those who participated in the sample were volunteers. This means that the findings are limited to those who felt in a position to contribute. On all courses, a number of participants did not opt-in to the research. Perhaps they felt too busy to participate, or already struggling with sufficient challenge in completing the course. This thus raises the question about what aspects busy or struggling teacher participants find effective in professional development. Another aspect of this sample is that only those who were in attendance could participate in the research. The
thoughts and opinions of those with poor attendance, or non-completion of the course are still unknown.

A second limitation of this research is the **time frame**. Teacher participants completed surveys and took part in interviews during the actual professional development. The research findings do not extend beyond this and cannot bring clarity to what aspects may be deemed effective in the longer term, with the benefit of hindsight.

As has been repeatedly stated, this research has emphasised the **teacher voice**. Many other measures of the effectiveness of professional development were identified earlier in this research. For example, student outcomes in terms of attainment in exams, engagement in learning or increase in confidence. Alternatively, the view of school leadership, perhaps as measured by the teacher participant’s adherence to a new curriculum or pedagogic approach. The findings of this research are limited to effectiveness as measured by the teacher participants’ opinion. Where teacher participants expressed that the quality of their teaching had changed, this could have been corroborated by interviewing their students. However, the scope of this as a piece of Masters research precluded such further investigation.

Furthermore, to play devil’s advocate, it could be argued that any change or improvement that teacher participants reported as evidence of effective professional development could be due to **factors external** to these courses. Professional development is not limited to attending courses, but could involve university study, membership of a subject association, or running alternative learning provision within the local community (Gray, 2005).

The limitations of this research are largely due to the scope permitted by a small-scale, Masters-level project, and some of the limitations may be due to the fact that it was carried out on a part-time basis by a researcher in full time employment. Secondly, it has always explicitly aimed to give space to the thoughts and feelings of the teachers participating in the professional development courses. The wider context of professional development of mathematics teachers would require a larger research project with a longer time frame available.
5.6. **Opportunities for further research**

All of the data collection for this research programme was carried out during the course of 12 months. Furthermore, it was all performed during the delivery of the professional development courses (with Teaching Advanced Mathematics (TAM) and Teaching GCSE Mathematics (TGM) being the sustained courses and Mechanics being a one-day course). An interesting extension of this research would be to carry out a longitudinal study of the same teacher participants. By this I mean reconnecting with the teacher participants at times in the future for further data collection. Throughout this project, it has been an explicit aim to judge the effectiveness of professional development for mathematics teachers from the perspective of the teacher participants themselves. There would not appear to be a conflict in continuing with this focus by asking them to feed back on the effective aspects with the benefit of hindsight. Having had time for reflection, and time to put their learning into practice, do teacher participants identify different aspects as having been effective? Are different aspects perceived to have a benefit in the longer term, as compared with the shorter term?

One of the limitations of this research project is that it sought contributions from teacher participants who volunteered to take part. This is characteristic of such a small-scale project due to limited resources. However, it was also due to ethical considerations, as the teacher participants had to be assured that their participation, or otherwise, would have no impact on their involvement in the professional development or successful completion. If resources of time and funding allowed in the future, I believe that approaching those who wouldn’t otherwise be naturally positioned volunteers would produce particularly insightful and interesting findings. By this, I envisage for example approaching any teacher participants who had not attended a course day. Teacher participants experiencing barriers to their attendance on, or completion of, a course may likely have different requirements from their professional development and therefore identify significantly different aspects of effectiveness.

Another limitation of this research was that it only examined professional development courses led by Mathematics in Education and Industry (MEI). There is evidence to suggest that the findings are more widely applicable, given how they complement other findings in this emerging body of literature. However, it would be interesting to see if teacher
participants who choose other providers for their professional development would identify different aspects of effectiveness.

I was particularly motivated by this research having practical and specific recommendations for my own design and delivery of professional development, and that of my colleagues and other professional development leads. In this aspect, it is a successful start. However, I believe that further specific examples of good practice (as experienced by the teacher participant) could be identified.

For example,

- Participants valued engaging with mathematics using a variety of resources. In addition to learning about the use of card sorts, mini whiteboards, practical experiments, multilink cubes, and foam algebra tiles, what other generic, practical resources may be found to be effective experiences by teacher participants?

- In terms of receiving resources as an aspect of effective professional development teacher participants identified the benefits of the resources as being new and original to them and easily transferable to the classroom. A third aspect that is not such a main theme of my professional development offers is the use of “real world” contexts. Further research in to this would be of particular relevance as the new post-16 Core Mathematics qualifications predominantly use such settings for the teaching, learning and assessment of content.

- Teachers valued opportunities for discussion, but with the proviso that it be an organic development of their learning. Further investigation in to the nature of such “organic conversations” and how to successfully facilitate such learning discussions, would be useful to the future design and delivery of effective professional development.

- Similar to the above, how best to facilitate reflection? Personally, I have recently started to explore the use of professional reflective journals, and am aware that they play a not insignificant role in other professions. For example, two teacher participants on my course have had a medical background in nursing and explained about the important and integral role that reflective journals have in that profession. It strikes me that the teaching profession could learn from such knowledge arising from other contexts.

- The use of new pedagogic approaches was the most important aspect of effective professional development as identified by the teacher participants. It was the area that
they provided most detail for, in terms of what this may look like, and would therefore seem to offer potential for greater investigation. There is current interest in the use of the mathematics-specific multiple representation the proportion bar, within the teaching of primary mathematics, and this is now being more widely applied to the secondary mathematics of key stage 3. The proportion bar has enjoyed success with primary teachers, many who identify as non-specialists of mathematics. How will the needs of secondary mathematics specialist teachers differ? Furthermore, what will follow the use of multiple representations and the proportion bar as the next significant development in mathematics pedagogy?

- A “rigorous mathematical approach” was found to be valued by teacher participants, but as discussed above there remains much potential to identify the specifics of what is meant by this term when used by them. I have suggested that it may include an emphasis on pursuing clear written and verbal communication of mathematical ideas, the use of correct terminology, the making of links between different areas of mathematics when teaching, and, pursuing efficient and elegant solutions. However, these would just be my intuitive starting points, based upon experience. I wonder if identifying examples of high and low rigour would be a worthwhile next step.

- Use of digital technologies within the teaching and learning of mathematics and mathematics teacher professional development is already an area of growth within the research, indicating significant interest and potential in learning more.

- The characteristics of the professional development lead is a significantly interesting idea at the time of writing due to the changing landscape in terms of where mathematics education professional development is based. There is a move away from sources of external expertise (such as Local Authority advisors) towards the expansion of internal, school-based teachers leading professional development as part of the Maths Hub programme. This is similarly reflected in initial teacher training moving from university-based Postgraduate Certificate in Education (PGCE) routes to school-based training such as School-centred initial teacher training (SCITTS). It would be interesting to learn what, if any, effect this has had on the professional development leads’ characteristics of expertise and experience.
A safe learning environment was found to be an important factor in supporting the risk-taking element of teacher professional development. It would be interesting to learn more about what role risk-taking is perceived to play in changing teachers’ beliefs, attitudes and classroom practice.

Finally, there were aspects of the professional development courses by Mathematics in Education and Industry (MEI) that were not explicitly researched in this project. For example, the courses often require the completion of interim tasks, including pre-reading, reflection activities, designing of teaching resources, trialling and reflecting upon teaching resources or strategies and so on. Also, the professional development courses often include an online element of access to banks of resources, instructional videos, discussion forums and live, interactive online sessions. None of these were explicitly mentioned by the teacher participants during the data collection. It may be because none of the contributors identified them as effective aspects of the training, but it may also be because of their minds were focused on the face-to-face study days as these were when the data collection was carried out.
6. Bibliography


143


GREENING, J. 2017. Justine Greening: teacher development key to school improvement 10 March 2017, address to the Association of School and College Leaders.


SILVERMAN, D. 2014. Interpreting Qualitative Data, 5E. London: SAGE.


Appendix A: Permission to research from Chief Executive of MEI

The FACULTY OF EDUCATION ETHICS COMMITTEE
CONSENT FORM – For Institutions/Organisations

I, Charlie Stripp of Mathematics in Education and Industry (MEI),

Hereby give permission for participants on MEI professional development courses to be involved in a research study being undertaken by: Debbie Barker and I understand that the purpose of the research is: to explore participants beliefs and experiences of what makes professional development effective or ineffective and that involvement for the institution means the following:-

That participants on MEI professional development courses, such as TAM, TGM, FRESH (etc) be asked to consider taking part in this research and that those agreeing will be asked to complete the following documentation (attached):

- Participant general information (probably electronically before the course commences)
- Participant questionnaire on effective professional development during the professional development day

That the professional development lead (MEI employee) be asked to complete (copy attached):

- PD lead questionnaire on effective professional development (before the course and also to have the opportunity to amend or add after the course).

That MEI documentation such as flyers and pre-course information emails be collected.

I understand that

1. the aims, methods, and anticipated benefits, and possible risks/hazards of the research study, have been explained to me.

2. I voluntarily and freely give my consent for the institution/organisation to participate in the above research study.

5. I am free to withdraw my consent at any time during the study, in which event participation in the research study will immediately cease and any information obtained through this institution/organisation will not be used if I so request.

3. I understand that aggregated results will be used for research purposes and may be reported in scientific and academic journals.
4.1 I agree that

4. The institution/organisation MAY / MAY NOT be named in research publications or other publicity without prior agreement.

5. I / We DO / DO NOT require an opportunity to check the factual accuracy of the research findings related to the institution/organisation.

Signature:  

Date: 28 July 2015

The contact details of the researcher are:
Debbie Barker, [redacted postal address and email]

The contact details of the secretary to the Faculty of Education Ethics Committee are
Clare McKinlay, Research Office, Faculty of Education, University of Hull, Cottingham Road, Hull, HU6 7RX. Email: c.m.mckinlay@hull.ac.uk tel. 01482-465031
Appendix B: Participant general information questionnaire

Participant general information

I ask for this information because I am interested in whether course participants with similar backgrounds share common experiences of effective CPD courses, or not.

**Gender**

- Female
- Male

**Age**

- Under 30
- 31 – 40
- 41 – 50
- 51 – 60
- Over 60

**Length of time teaching**

<table>
<thead>
<tr>
<th>How long have you been teaching?</th>
<th>How long have you been teaching mathematics?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am training</td>
<td>I am training</td>
</tr>
<tr>
<td>I am in my first year as a teacher (e.g. NQT)</td>
<td>This is my first year teaching mathematics</td>
</tr>
<tr>
<td>2-4 years</td>
<td>2-4 years</td>
</tr>
<tr>
<td>5-10 years</td>
<td>5-10 years</td>
</tr>
<tr>
<td>11 - 19 years</td>
<td>11 - 19 years</td>
</tr>
<tr>
<td>More than 20 years</td>
<td>More than 20 years</td>
</tr>
</tbody>
</table>

Please describe your role/position at work

Please briefly describe your qualifications in terms of mathematics

Please briefly describe your experience and/or qualifications in terms of teaching

Please briefly describe the age / stage of students you teach

First name

Last name

Would you be willing to provide Debbie with more detail about your experience of Professional Development? If so, please provide an email address.
Appendix C: Participant questionnaire on effective professional development

Participant questionnaire on effective professional development

Reflecting on aspects of the course that were particularly effective or ineffective for you personally, please describe the particular aspect and explain what made it effective or ineffective.

<table>
<thead>
<tr>
<th>Session identification, e.g. title, timing or description</th>
<th>Aspects that were effective or ineffective and why. (Please decide for yourself what you define as an “aspect”).</th>
</tr>
</thead>
</table>

Please feel free to continue overleaf.
<table>
<thead>
<tr>
<th>Session identification, e.g. title, timing or description</th>
<th>Aspects that were effective or ineffective and why. (Please decide for yourself what you define as an “aspect”).</th>
</tr>
</thead>
</table>

First name

Last name

Would you be willing to provide Debbie with more detail about your experience of Professional Development? If so, please provide an email address.
**Appendix D: Interview record**

What aspects of professional development make it effective?

**Find effective?**

**Why is it effective?**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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</table>
Appendix E: Image of the raw data spreadsheet

This image shows the left-hand side of the spreadsheet (names and email addresses redacted):

<table>
<thead>
<tr>
<th>Course</th>
<th>Gender</th>
<th>Age</th>
<th>Teaching for</th>
<th>Teaching math for</th>
<th>Please describe your role (classification)</th>
<th>Please describe your Math Qualifications</th>
<th>Please describe your experience in qualitative terms of teaching</th>
<th>Teaching qualification achieved</th>
<th>Please describe the age/range of students you teach</th>
<th>Calculation</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGM</td>
<td>F</td>
<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Big Ideas</td>
<td></td>
</tr>
<tr>
<td>TGM</td>
<td>F</td>
<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Lesson planning</td>
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<tr>
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<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Trigonometry</td>
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<tr>
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<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Big Ideas</td>
<td></td>
</tr>
<tr>
<td>TGM</td>
<td>F</td>
<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Quadratics</td>
<td></td>
</tr>
<tr>
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<td>F</td>
<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Question</td>
<td></td>
</tr>
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<td>TGM</td>
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<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Paper folding</td>
<td></td>
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<td>TGM</td>
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<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Completing</td>
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<td>30 and Under</td>
<td>2-4</td>
<td>Maths, Maths</td>
<td>BGCSE</td>
<td>NQT</td>
<td>OTC-16</td>
<td>NQT of Mathematics for STATS</td>
<td>Year 7 - 11: 11-16</td>
<td>Games</td>
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<tr>
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<td>30 and Under</td>
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<td>Year 7 - 11: 11-16</td>
<td>Calculators</td>
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</table>

Scrolling to the right gives the categorisation of the comments:

<table>
<thead>
<tr>
<th>Issues</th>
<th>Student Provided</th>
<th>Teaching Mathematics</th>
<th>Learning Environment</th>
<th>Opportunities to Discuss</th>
<th>Opportunities to Reflect</th>
<th>Multiple approach to work</th>
<th>Teacher support</th>
<th>Stacking</th>
<th>Standards of work</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Ideas</td>
<td>Very effective as we could get on with the task, have a discussion then share our ideas even when they conflicted with the tutor's thoughts. Good use of practical resources.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>For access to the raw data (anonymised) please email <a href="mailto:deborah_barker2@hotmail.com">deborah_barker2@hotmail.com</a></td>
</tr>
<tr>
<td>Lesson planning</td>
<td>Excellent and useful resource to encourage more effective planning especially the whole class activity on the first lesson on completing the square.</td>
<td>1</td>
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<tr>
<td>Trigonometry</td>
<td>A very different and more effective way to introducing trigonometry especially the whole class activity on the first lesson on completing the square.</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Big Ideas</td>
<td>Card sort. shapely area with algebraic, Effective because it got me thinking and forced my brain to consider different processes.</td>
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<tr>
<td>Quadratics</td>
<td>Different way to show/teach it.</td>
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</tr>
<tr>
<td>Question</td>
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<td>1</td>
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</tr>
<tr>
<td>Paper folding</td>
<td>I didn’t see the circle theorems until the end - really good. completing the circle B will be passing on to my department.</td>
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</tr>
<tr>
<td>Completing</td>
<td>Thanks to the diagrams I now really understand.</td>
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<tr>
<td>Trig</td>
<td>Similar to above. I have always used SOWHTGA. Want to give this a go.</td>
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<tr>
<td>Calculators</td>
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</tr>
</tbody>
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