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Mathematics Teacher Change and Identity in a Professional Learning Community

Million Chauraya

A thesis submitted to the Faculty of Humanities, University of the Witwatersrand, Johannesburg, in fulfillment of the requirements of the degree of Doctor of Philosophy

Johannesburg

2013

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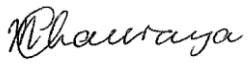
……  ……...

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Abstract

Professional learning communities are receiving attention in research on in-service teacher professional development. Arguments for professional learning communities emphasize teacher learning as a long-term, continuous, developmental and collaborative process. Such learning is viewed as necessary for supporting sustained improvements in teachers' teaching practices and learners' learning. The study reported in this thesis drew on these ideas to investigate how mathematics teachers learned in a professional learning community, and how their learning influenced changes in their teaching practices and identities.

The study was a pilot for a larger, on-going project at the University of the Witwatersrand. Using the ideas of situated learning theory and data-informed practice, the case study involved a professional learning community of five mathematics teachers and the researcher. The study was conducted in one township high school in Gauteng, South Africa. The professional learning community participated in a year-long professional development intervention, which consisted of a set of developmental and structured professional learning activities. The activities involved analyzing learner errors in mathematics, identifying learners' learning needs, planning and teaching innovative lessons for addressing the learning needs, and reflecting on how the lessons supported learners' learning. The study investigated how teacher participation in the opportunities for learning was linked to shifts in their teaching practices and identities.

The results show changes in teachers' practices and their identities. Two teachers made shifts in their mode of teaching, task selection and implementation, and in their ways of engaging with learners' ideas. Two other teachers made shifts in task selection. The shifts were sustained by one teacher in her teaching of the post-intervention lessons. All the teachers shifted in their ways of identifying themselves as members of communities. During and after the intervention, the teachers identified themselves as members of the professional learning community, and expressed visions of progressively learning together and improving their practice together. The shifts in teaching practice and teacher identity are explained by the opportunities for learning in the professional learning community. The results show how the links among teacher learning, teachers' teaching practices and teacher identity were supported or constrained by features of the professional learning community.

Key words

Professional Learning Community, Teacher Learning, Teacher Practice, Teacher Identity

Acknowledgements

I thank my supervisor, Professor Karin Brodie, for her consistent and insightful comments from the beginning of the study to the finalization of this thesis. She was always available when I needed advice and clarification on various aspects of the study. I also thank her for her role in setting up the Data Informed Practice Improvement Project (DIPIP), and creating opportunities for me to discuss the activities and features of the professional learning community with her, the DIPIP team, and the wider community of researchers in this field.

My gratitude goes to the School Management Team (SMT) of the school in which the study was conducted. They granted me access into the school and kept on extending their welcome to me for the entire duration of the study.

I sincerely thank the mathematics teachers and learners who participated in the study. The teachers sacrificed their own time and participated in meetings that often extended beyond the agreed time without any complaints. The learners agreed to be video-recorded and interviewed. My sincere thanks also go to the parents and guardians of the learners who gave permission for their children's participation in the study.

My gratitude is extended to my fellow doctoral students and the Data Informed Practice Improvement Project facilitators who assisted me throughout the study. They sacrificed their time to help me in data analysis and writing of the thesis.

I thank the Data Informed Practice Improvement Project (DIPIP) directors for allowing me to carry out the study within their project. They also allowed me to use their templates, and that greatly assisted me in the study.

Lastly I salute my wife, Efiritha, and our children, Joyleen, Josyleen and Jacqueleen, for their unwavering support throughout the period of my studies. They tolerated my absence for long periods of time in the interest of my studies.

I thank you all.

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Abbreviations

DIPIP Data Informed Practice Improvement Project

MQI Mathematical Quality of Instruction

FET Further Education and Training

CHAPTER 1

INTRODUCTION

1.1 Background to the study

In-service teacher professional development has long been recognized as fundamental to school improvement and learner achievement. Participation in professional development programmes is integral to teachers' professional lives. Different professional development programmes have been driven by different needs. Most programmes have been driven by issues that include: curriculum innovations; the need for improving learners'[1] performance; and developments in knowledge and technology. Curricular reforms within education systems create demands for teachers to acquaint themselves with the implied changes and to implement such changes in their professional practice. In post-apartheid South Africa a number of curricular reforms were initiated within the education system in an effort to address the imbalances associated with the apartheid education system (Bennie & Newstead, 1999). The history of education in post-apartheid South Africa highlights how in-service teacher professional development efforts accompanied curriculum changes. The Outcomes-Based Curriculum (OBE) is an example of curriculum reforms targeted at reforming teachers' teaching practice. The reforms were originally introduced in 1997 and were reviewed in 2002 leading to the Revised National Curriculum Statements (Grades R-9) (RNCS) and the National Curriculum Statements (Grades 10-12) (NCS) (Department of Education, 2002). The recently introduced Curriculum and Assessment Policy Statements (CAPS) were a result of a further review of the RNCS and NCS. All these curricular changes created the need for inducting teachers into each new reform. Such induction has commonly been done through workshops and short courses, in most cases at central venues within school districts and provinces.

International studies on learner performance have raised a number of issues pertaining to learners' performance in mathematics and science. Some of these studies are: the Trends in International Mathematics and Science Study (TIMSS); the Monitoring Learning Achievements (MLA); the Southern Africa Consortium for Monitoring Educational Quality (SACMEQ), and

[1] The word 'learners' is used in the South African context to refer to pupils or students.

Performance in International Student Achievement (PISA) (Reddy, 2005). South Africa participated in the first three studies but did not participate in PISA. Reports emanating from these studies have highlighted some implications for mathematics and science teaching and learning in various countries (e.g. Gonzales, et al., 2009). The common theme has been a call for improving mathematics and science instruction (e.g Jones, 1989), and this has amplified the need for in-service professional development for practicing teachers. Recommendations such as: restructuring the mathematics curriculum; improving mathematics textbooks; improving learning conditions; use of technology; teaching thinking skills and problem solving; and preparing teachers adequately to teach mathematics have been made for improving learner achievement in mathematics (Jones, 1989). Government departments, non-governmental organizations, and research institutions such as universities have mounted various in-service professional development programmes and projects to support improvement in instruction and learners' performance. However there is an emerging consensus that current professional development programmes have failed to result in significant improvements in teachers' teaching and learners' learning.

Most contemporary in-service teacher professional development programmes use workshops; while some programmes blend workshops with on-going school-based professional development approaches, which include: peer coaching, mentoring, and teacher learning communities. Research on in-service teacher professional development has been driven by the need for developing knowledge about programmes that can result in improved teaching and the achievement of required student outcomes. The theme in contemporary research on in-service teacher professional development has been an emphasis on teacher learning. The quest has been to develop knowledge on how teachers learn and how such learning is linked to changes in teaching practice and learners' learning.

The limitations of workshops and short courses have been highlighted in the literature (e.g. Borko, 2004; Edwards, 2000; Knight, Tait, & Yorke, 2006; Stein, Smith, & Silver, 1999). The following citation captures some of the views of about workshops:

> Several years ago, I attended a workshop that introduced high school and college teachers to new pedagogical techniques that could "revolutionize the teaching of mathematics". I returned from the workshop energized by what I had seen and determined to reform my ways forever. The

> reality of implementing these new ideas, however, hit me when my first attempt to introduce an innovative activity failed miserably with my students. Somehow, the results that my students produced were nothing like those demonstrated in the workshop. In an attempt to fix the problem, I sought help from my colleagues, only to hear discouraging words and an assurance that "those kinds of things" never really work anyway. I slowly slipped back to my old way of teaching (Edwards, 2000, p. 777).

The limitations of workshops as learning contexts for teachers include: the short duration of the workshops; the fragmented rather than continuous nature of the learning involved (Borko, 2004); the focus on disseminating information to teachers rather than co-constructing information with teachers; lack of support for teachers when they go back to their working contexts; and the inaccurate assumption that what teachers learn in a workshop gets transferred intact into their teaching practices (Kazemi & Hubbard, 2008).

Other factors that militate against workshops as a teacher professional development model include: teachers' strongly-held beliefs about the nature of mathematics and what it means to teach mathematics (Edwards, 2000; Ernest, 1988; Golafshani, 2004; Handal, 2003; Karaagac & Threlfall, 2004); the perception that change implied in such in-service programmes is 'imposed', which may lead to teacher resistance (Edwards, 2000; Jansen, 2004); the failure by most in-service programmes to take into consideration the realities of classroom situations (Cohen & Ball, 1999); lack of follow-up support provided to teachers after attending the in-service workshops (Ramatlapana, 2009); and the implied view of teacher change as an event rather than a process (Edwards, 2000). Workshops last from a few hours to a number of days; hence they are structured as events rather than continuous processes. Each workshop is designed to address a specific aspect of teachers' professional practice, and the connections among these aspects are usually not evident to teachers (Abdal-Haqq, 1995). This fragmentation of teachers' professional knowledge militates against sufficient learning by teachers for them to change their practices. Fullan (2007) highlights other limitations of current teacher professional development programmes by pointing out that:

> The problem (is that) there is almost no opportunity for teachers to engage in continuous and sustained learning about their practice in the settings in which they actually work, observing and

> being observed by their colleagues in their classrooms and classrooms of other teachers in other schools confronting similar problems (p. 35).

Contemporary thinking on in-service teacher professional development advocates for a shift from workshops and short courses to on-going and continuous teacher learning in and from practice. The current vision of professional development is that which "involves teachers in the dual capacities of both teaching and learning and creates new visions of what, when, and how teachers learn" (Vescio, Ross, & Adams, 2008, p. 80). The vision is supported by arguments for job-embedded professional development in which teachers learn in and through practice (Kazemi & Hubbard, 2008). Such professional development is viewed as more likely to support long-term changes in teachers' practices. Characteristics of such professional development include being: school-based and embedded in teachers' work; collaborative and providing opportunities for interaction with peers; focused on student learning; and being continuous and coherent rather than fragmented (Abdal-Haqq, 1995; Hiebert, Gallimore, & Stigler, 2002). The effectiveness of such professional development programmes is believed to lie in ensuring adequate teacher collaboration to produce shared understanding; a focus on problems of curriculum and instruction; and being of sufficient duration to ensure progressive gains in knowledge (Little, 1993). Brodie (2011c) highlights six characteristics that underpin the current view of successful professional development programmes. Such programmes: "are long-term and developmental; focus on artefacts of practice such as student thinking, tasks and instructional practices; make use of actual classroom data; encourage design and reflection on the part of teachers; are job-embedded (school-based) … and promote the development of professional learning communities" (Brodie, 2011c, p. 25).

In their review of the literature on contemporary thinking on teacher professional development, Borko, Jacobs and Koellner (2010) classified characteristics of high-quality professional development into three categories. Content characteristics relate to situating the content of the professional development in practice and focused on learners' learning. Content characteristics include engaging "teachers in inquiry about the concrete tasks of teaching, assessment, observation, and reflection, and provides them with the opportunity to make connections between their learning and their classroom instruction" (p. 549). Process characteristics refer to teachers "modelling preferred instructional processes, engaging teachers in active learning, and

building a professional learning community" (p. 550). Structural characteristics refer to structuring the activities of the professional development in such a manner that they are on-going, sustainable, and provide teachers with opportunities to "engage in cycles of experimentation and reflection" (p. 550). Put together these characteristics describe high quality professional development that is likely to improve teachers' teaching and learners' learning. However research evidence on how professional development programmes with these characteristics result in significant changes in teachers' teaching and learners' learning is limited (Borko, et al., 2010; Knapp, 2003).

These arguments have led to the introduction of school-based teacher professional development approaches to support long term, relevant teacher learning. Such initiatives include peer coaching (Kohler & Ezell, 1999; Showers & Joyce, 1996; Zwart, Wubbels, Bergen, & Bolhuis, 2009); mentoring (Evertson & Smithey, 2000; Lin, 2007; Wang & Odel, 2002); and school-based teacher learning communities (Dam & Blom, 2006; Englert & Tarrant, 1995; Hollins, McIntyre, DeBose, Hollins, & Towner, 2004; Strahan, 2003). The study reported in this thesis belongs to the category of school-based teacher learning communities. The study was based on the idea of professional learning communities as an alternative teacher professional development model. Arguments for professional learning communities are explored in the next section.

1.2 Professional learning communities

Contemporary teacher professional development models are mostly underpinned by the notion of professional learning communities. Professional learning communities are groups of teachers "sharing and critically interrogating their practice in an on-going, reflective, collaborative, inclusive, learning-oriented, growth-promoting way" (Stoll & Louis, 2007). Definitions of professional learning communities emphasize teacher learning. Such learning is school-based and involves teachers collaborating in inquiring and reflecting on their practice. The on-going nature of teacher learning in professional learning communities supports sustainable changes in teaching practices. Key features of learning in professional learning communities include: the use of school-based evidence for collective inquiry; connecting research-based knowledge with evidence from school-contexts to develop new meanings (Jackson & Temperley, 2008);

challenging long-held assumptions and practices; and trying new ideas and practices that provide new learning experiences for learners (Katz, Earl, Jaafar, Elgie, & Foster, 2008).

Professional learning communities are regarded as organizational structures in which teachers can learn and develop their instructional practices. These communities support teachers to learn from one another, and have the capacity to promote and sustain teachers' learning with the ultimate focus of improving learners' learning (Stoll & Louis, 2007). Professional learning communities are seen as fostering teacher learning through the nature of the collaboration which produces shared understandings, focuses on problems of curriculum and instruction, and is of sufficient duration to ensure progressive gains in knowledge (Little, 1993). In professional learning communities teachers have opportunities for collaborating in pursuing shared purposes and developing collective responsibility for student-learning (Jackson & Tasker, 2002). Effective professional learning communities provide opportunities for deepening understanding through challenging taken-for-granted practices, and proposing and testing solutions with the goal of improving the quality of classroom instruction (Katz, Earl, & Jaafar, 2009). According to Brodie (2012a) "Professional learning communities support teachers to use their experience, evidence from their classrooms, their own and their colleagues' insights, and knowledge from research to decide what they need to learn and how they can learn it" (p. 4952).

A key feature of learning in a professional learning community is engagement in cycles of analysing school-based data; identifying learners' learning needs and hence teachers' learning needs; and trying out and reflecting on new practices (Timperley, 2009). These learning cycles create platforms for dialogues that "enhance constructive sense-making and meaning-giving" (Geijsel & Meijers, 2005, p. 426). Professional learning communities offer contexts in which such dialogues can take place. In the dialogues teachers discuss a local problem, why it is a problem and how the problem can be resolved. Problems of practice are discussed and changes in practice are suggested and tested as ways of resolving identified problems.

According to Borko (2004) research "provides evidence that strong professional learning communities can foster teacher learning and instructional improvement" (p. 6). This observation resonates with Little's (2002) assertion that "strong professional development communities are important contributors to instructional improvement and school reform" (p. 936). However not all professional learning communities succeed in changing teachers' practices and improving

teachers' and learners' learning. Little (1999) highlights the distinction between 'traditional communities' that coordinate to reinforce traditions, and 'teacher learning communities' where teachers collaborate to reinvent practice and share professional growth. This distinction highlights the possibility of professional learning communities recycling long-held assumptions and practices, leading to little change in teachers' teaching practices and learners' learning. Katz, et al. (2009) point out that collective activities, even though well-intentioned, may lack a clear needs-based focus and fail to address real teaching problems. These observations about professional learning communities raise the need for more research-based knowledge about how professional learning communities foster real professional learning and change among teachers. The study reported in this thesis seeks to contribute to knowledge about the work of professional learning communities by analyzing teacher learning and teacher change in one professional learning community of mathematics teachers.

1.3 Statement of the problem

Arguments for professional learning communities emphasize learning, both for teachers and learners (Easton, 2008; Fullan, 2007; Katz & Earl, 2010a; Louis & Marks, 1998). For example, Katz and Earl (2010b) assert that professional learning communities are "fundamentally about learning – learning for pupils as well as learning for teachers, learning for leaders and learning for schools" (p. 28). The predominant claim is that successful professional learning communities support teacher learning, which leads to changes in teachers' practices and improved learning for learners. Although there is the emphasis on learning, knowledge of how such learning for teachers and learners occurs is still being developed.

For Timperley, et al. (2007) teacher learning occurs through what they refer to as the teacher inquiry and knowledge-building cycle. The cycle involves: teachers inquiring and identifying their learners' learning needs; using learners' learning needs to identify their own learning needs; deepening professional learning and refining skills; engaging learners in new learning experiences; reflecting on the impact of the changed teaching; defining new learners' needs; and engaging in the cycle again. While the cycle adds valuable knowledge about how teacher learning and learners' learning can change in professional learning communities, research-based knowledge of how the cycle works in practice is still being developed. For example it is

important to understand how teachers identify problems of practice or critical learners' learning needs which are of such significance that the cycle results in fundamental changes in teachers' teaching and learners' learning. For Katz, et al. (2009) it is important for professional learning communities to have a clear learning focus which is challenging, shared and understood. Deepening understanding entails challenging existing knowledge and assumptions, something which can lead to conflict in the community. Research-based knowledge of how teachers collaboratively deepen their professional knowledge and deal with conflict is still not well-documented in the literature. Thus there is a need for developing more research-based knowledge of how teacher learning occurs in a professional learning community.

There has been extensive research on how successful communities work and the difficulties in sustaining them (McLaughlin & Talbert, 2001). In their review of studies on how professional learning communities affect teaching practice and learners' learning, Vescio, et al (2008) highlight the gap in knowledge of how teacher learning is linked to teaching practice and learners' learning. All the studies they reviewed did not provide sufficient details of how the link was established. Studies that have shown specific changes in teaching practices as a result of participation in professional learning communities do not provide details of how the shifts were connected to specific learning instances in the community (e.g. Englert & Tarrant, 1995). In a seminal review of studies on professional learning communities the focus was on the following aspects: definition of a professional learning community; what makes professional learning communities effective; how professional learning communities are created and developed; features of professional learning communities; and sustainability of professional learning communities (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). The question of how teachers learn in professional learning communities was not addressed explicitly in the review.

Another area that has not been well-researched in relation to the work of professional learning communities is the role of teacher identity. Teacher identity has long been seen as key in research about teacher professional development and practice. Studies that have researched teacher identity have focused mainly on pre-service teachers. The focus has been on developing knowledge about how pre-service teachers' identities evolve within structured and formal professional development programmes (e.g. Drake, Spillane, & Hufferd-Ackles, 2001; Samuel & Stephens, 2000; Smith, 2006). The importance of attention to teacher identity is based on the

influence of identity on "teachers' sense of purpose, self-efficacy, motivation, commitment, job satisfaction and effectiveness" (Day, Kington, Stobart, & Sammons, 2006, p. 601). Thus teacher identity is believed to have an influence on the decisions that teachers make in relation to their professional practice and the affective attitudes which they develop about teaching as a profession.

From a communities of practice perspective, identity is regarded as a key construct which influences individuals' participation and ways of relating and engaging with others in community (Wenger, 1998). For Wenger (1998) identity has to do with how individuals perceive themselves in community with others, and how they are viewed by others. A fundamental idea of Wenger's view of identity is the contiguity of learning to identity. Learning is defined as increased participation in a community of practice (Lave, 1993; Lave & Wenger, 1991). Learning occurs within the practices of communities in social and cultural contexts (Wenger, 1998) and is regarded as becoming a better participant in practice (Brodie, 2005). This conception of learning resonates with the view of teacher learning envisaged in professional learning communities. Yet there has been little focus on teacher identity as a key feature in arguments for professional learning communities.

Definitions of professional learning communities emphasize group coherence, collaboration and collective learning (Stoll & Louis, 2007), among other features. Group coherence and collaboration allude to the need for group identity if professional learning communities are to succeed in supporting collective learning. Group identity means having a strong sense of belonging to the group and a collective responsibility for the learning efforts of the group. Collective learning depends on relationships of trust which support challenges without fear of offending or being offended. Individuals need to experience the professional learning community as a safe, non-threatening environment in which they can raise uncertainties or difficulties, with the confidence and trust that they will be supported and helped by others (Koellner-Clark & Borko, 2004). Open acknowledgement of what one does not know leads to possibilities for real new learning (Katz, et al., 2009). These ideas place identity at the core of developing effective professional learning communities. Understanding teacher learning in a professional learning community requires attention to both the teachers' in-coming and evolving identities as members of a community.

1.4 Purpose of the study

This thesis focuses on a mathematics teacher professional learning community in one high school, and contributes to knowledge about what and how teachers learn in a professional learning community, as well as how such learning connects to shifts in teachers' teaching practices and identities. The purpose of the study was to analyze: what constituted the learning focus of the community and the extent to which it was shared and understood; how teacher learning was supported; what forms of mathematics teachers' professional knowledge were developed; and how new understandings informed the teachers' design and reflection on new learning experiences for their learners. The study sought to establish how learners' learning needs were identified and how these needs informed the teachers' learning needs.

In the study the professional learning community engaged in conversations in which different forms of teacher professional knowledge were at the core of the learning conversations. Teacher professional knowledge includes knowledge of the subject content, pedagogical content knowledge and knowledge of the learners (Shulman, 1987). It was therefore important to distinguish between the different forms of teacher knowledge that were discussed in the professional learning community and what new understandings were developed with respect to each form of knowledge.

An important aspect of professional learning communities is an understanding of features that support teacher learning. These include: challenging existing knowledge and assumptions; collaboration for joint sense-making; rigorous inquiry; and productive relationships that tolerate moderate professional conflict (Katz, et al., 2009). In the study it was important to understand what supported the teachers in deepening their understanding through the collaborative inquiry process, and how challenging existing understandings supported the development of new understandings.

Another key purpose of the study was to analyze the connection between teacher learning in the professional learning community and shifts in their teaching practices. Borko (2004) and Vescio, et al. (2008) have highlighted the gap in knowledge about the connection between teacher learning and teachers' teaching practices. It was an important focus of this study to understand how the observed shifts in the teachers' teaching practices could be explained by the

opportunities for deepening professional knowledge in the professional learning community. Of specific importance was an analysis of how the teachers worked with knowledge developed in the professional learning community translated into shifts in their teaching practices. Such a connection was perceived to be of significance in terms of contribution to knowledge about teacher learning and changes in teachers' teaching practices.

I have argued for attention to teacher identity as a way of understanding both teacher participation and learning in a professional learning community. In the study I focused on teacher identity as a way of explaining how the individual teachers engaged with others and participated in the activities of the professional learning community. Of significance to the study was to understand how the teachers' identities co-evolved with participation and learning in the professional learning community, and how the identities supported community coherence and the development of productive professional relationships.

The final purpose of the study was to examine the linkages among teacher learning, teacher identity and teachers' teaching practice. Such an analysis was considered to be important in view of the nature of the activities of professional learning activities which followed the teacher inquiry and knowledge building cycle (Timperley, et al., 2007). The cycle provides for reflection on knowledge and practice, which supports learning in and from practice (Kazemi & Hubbard, 2008). In such a learning environment, changes in teacher knowledge, identity and teaching practice are likely to co-occur and co-shape learning. In the study I considered it important to analyze how the three constructs informed each other as they co-evolved in the professional learning community. In this thesis I suggest a possible framework that explains teacher learning and teacher change in the professional learning community.

1.5 Research questions

The following research questions guided the study:

1. What shifts, if any, occurred in the teachers teaching practices during the teachers' participation in the professional learning community?
2. What shifts, if any, occurred in the teachers' identities as they participated in the professional learning community?

3. How were the observed shifts in practice and identity connected to the opportunities for learning in the professional learning community?
4. What features of the professional learning community supported teacher learning in the professional learning community?

1.6 Significance of the study

The findings of the study are significant in a number of ways. The study shows how a professional learning community supported teacher learning and changes in teaching practice and teacher identity. In the thesis I show how the teachers in the professional learning community used understandings of learners' thinking in mathematics as a learning focus to deepen their professional knowledge. The forms of mathematical professional knowledge which the teachers discussed include: subject content knowledge; pedagogical content knowledge; knowledge of the curriculum; and knowledge of their learners errors. These forms of knowledge constitute some of the knowledge domains which are critical for teachers' professional practice (Shulman, 1987). The thesis shows how opportunities for deepening understanding in these knowledge domains were created in the professional learning community. Findings about what and how teacher learning was supported in those opportunities contributes to knowledge about how teachers learn in a professional learning community.

Another contribution of this study lies in analyzing the connection between teacher learning in the professional learning community and teachers' teaching practices. By analyzing four teachers' teaching practices before, during and after their participation in the professional learning community, the findings show specific areas of the teachers' teaching practices in which there were shifts. The thesis shows how the domains of teacher professional knowledge which were discussed in the professional learning community were connected to the observed shifts in the teachers' teaching practices. Such connections serve to highlight the potential of learning in professional learning communities to result in changes in teaching practice. The findings contribute to knowledge of how teacher learning is linked to changes in teaching practices.

The findings about the role of teacher identity in the work of the professional learning community are significant in a number of ways. Professional learning communities survive on group cohesion or identity, among other factors. Identifying with the group supports participation

and learning in community with others. The study investigated how the teachers' identities shifted in the professional learning community. The findings show how teacher identity informed and was informed by the teachers' participation in the community; which contributes to the knowledge about the role of teacher identity in the work of professional learning communities. Specifically the findings show how individual teachers' identities influenced their participation in the professional learning community. Since participation is fundamental for teacher learning in community, the findings connect teacher identity to the core work of professional learning communities. The findings also highlight the role of teacher identity in the group dynamics of the professional learning community which is a significant contribution to knowledge about features of such communities which support group coherence and the development of productive relationships.

The thesis also presents findings on the analysis of features of the professional learning community which supported the teachers' learning. Features such as relationships of trust and confidence in the community, having a shared learning focus, and challenge were found to have significant influence on the interactions in the conversations of the professional learning community. Findings about the role such features in the work of the professional learning community contribute to knowledge of what and how specific features of professional learning communities support teacher learning.

A significant contribution of the thesis lies in the explanation of teacher learning in the professional learning community through a framework that depicts the connections among knowledge, teacher identity and teaching practices. A fundamental point which is raised in the thesis is the co-evolution of these factors in the activities of the professional learning community. Developing a possible framework for explaining how these factors co-evolved in the professional learning community as a way of understanding how teacher learning occurred in the community is a significant contribution to knowledge of how teacher learning, teacher identity and teaching practices are important objects of analysis in the quest for understanding the work of professional learning communities.

1.7 Overview of the thesis

In this chapter I have detailed the background and motivation for the study. I have also presented the research problem which I set out to study, the research questions which guided the research effort and the contribution of the study to knowledge about the work of professional learning communities. In the next chapter I present the theoretical framework which informed the study and review current literature on professional learning communities in order to locate the study in this field. In chapter three I describe the research design for the study which includes the research participants; the activities of the professional learning community; the data collection and analysis procedures; ethical considerations; and how rigour was attained in the study. In chapter four I present results pertaining to shifts in the teachers' teaching practices in the professional learning community drawing from data about the teachers' teaching before, during and after their participation in the activities of the professional learning community. In chapter five I present findings in relation to shifts in the teachers' identities. In chapter six I analyze the connections among the opportunities for teacher learning which were created in the professional learning community and the observed shifts in the teachers' teaching practices and identities. In chapter seven I present results of the analysis of features of the professional learning community which supported or constrained teacher learning. In chapter eight I propose a framework for explaining teacher learning by analyzing the co-evolution of teacher knowledge, teacher identity and teaching practices in the professional learning community. The chapter also presents implications and limitations of the study.

CHAPTER 2

THEORETICAL PERSPECTIVES AND LITERATURE REVIEW

2.1 Introduction

In this chapter I discuss the theoretical perspectives which guided the study. I also discuss the main concepts which were central to the study and the relevant literature associated which each concept. The main concepts in the study are: professional learning community; teacher learning; teachers' practices; and teacher identity. The chapter identifies the gaps in knowledge about professional learning communities which are addressed in the study.

2.2 Theoretical perspective: Situated learning

The study was guided by the theory of learning as social practice (Wenger, 1998). The theory is located within situated perspectives on teaching and learning which regard learning as occurring within the practices of communities in social and cultural contexts (Brown, Collins, & Duguid, 1989; Greeno & Gresalfi, 2008; Hanks, 1991; Lave, 1993; Lave & Wenger, 1991; Wenger, 1998). The selection of the theoretical perspective was informed by the nature of teacher professional learning communities, which are commonly established in school contexts, for the purposes of engaging in regular collective reflection on teachers' practices and learners' learning in an on-going manner (Stoll & Louis, 2007). The teachers' learning in this case is situated in their professional context and in their practice, and occurs through participation in community with others. It is the situated nature of teacher learning in professional learning communities which motivated a focus on situated learning theory as the guiding theoretical perspective for the study.

Among situated learning theories, Wenger's (1998) theory of learning as social practice was found to be the most appropriate theory for guiding the study. The following ideas from Wenger's theory resonate with teacher participation and learning in professional learning communities. The theory regards learning as social practice and as increased participation in communities of practice (Lave, 1993; Wenger, 1998). According to the theory, learning, thinking and knowing are "relations among people engaged in, with and arising from the socially and

culturally structured world" (Lave, 1993, p. 67). Participation in the practices of a community is critical for learning, and learning is defined as becoming a better participant in practice (Brodie, 2005). According to Borko (2004) "Situative theorists conceptualize learning as changes in participation in socially organized activities, and individuals' use of knowledge as an aspect of their participation in social practices". Meanings are co-constructed and negotiated in the community, which implies that knowledge is a property of the community. Knowledge is socially mediated and open-ended as meanings emerge and are changed in the course of social activity (Lave, 1993). Learning is viewed as a process of becoming a member of a community of practice, and is a way of "being in the social world, not a way of coming to know about it" (Hanks, 1991, p. 24). The development of capabilities is a consequence of participation in situated social practices (Knight, et al., 2006). According to Wenger (1998) engaging in a practice entails negotiating and constructing meanings in the community. These characteristics of learning through participation in community practices capture the essential features of learning in teacher professional learning communities, a point which I elaborate in Section 2.2.2 below.

2.2.1 Wenger's theory of learning

A detailed description of Wenger's theory of learning as social practice is presented in this section to highlight the main concepts of his theory which informed the conceptual framework, the research design and the analysis of data in my study. The theory is based on the following assumptions: people are social beings, knowledge is a matter of competence in valued enterprises, learning is participating in the pursuit of such enterprises, and meaning is what learning ultimately produces (Wenger, 1998). In the theory, participation refers to the "process of being active participants in the *practices* of social communities and constructing *identities* in relation to these communities" (Wenger, 1998, p. 4). Such participation shapes what people do, who they are, and how they interpret what they do (Wenger, 1998).

Wenger's (1998) theory articulates further the ideas behind the situated nature of learning. The theory has four interconnected components of learning, as shown in Fig. 1 below. They are: practice, meaning, community and identity, and in the theory each component is further presented as a constitutive part of learning.

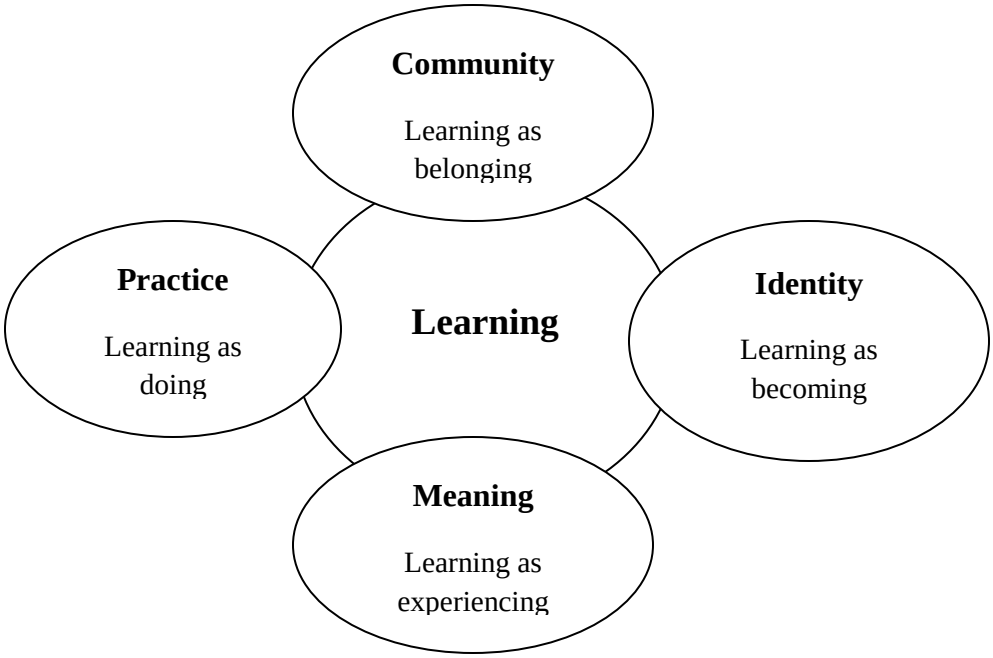

***Fig.1*: Components of Wenger's theory of learning as social practice (p.5)**

According to Wenger (1998) the four components of the theory are "interconnected and mutually defining" (p. 5), hence any one of them can be an entry point in discussing the theory. I begin by discussing 'practice'. Wenger describes a practice as involving the explicit "tools, language, documents, symbols, well-defined roles, procedures, regulations…, as well as the implicit theories, ideas, ideals, relations, underlying assumptions, shared world views…" (p. 47) of a shared enterprise. This view locates a practice as the "property of a kind of community" (p. 45). According to Wenger a practice is something that a community develops over time and continues to improve in the pursuit of its shared enterprise. Engagement in a practice entails learning about the explicit and implicit aspects of a practice within a community of practice.

There is a connection between practice and meaning in that engaging in practice entails negotiating and constructing meanings in a community, which in turn creates a social identity within the community of practice. In Wenger's (1998) theory, meaning is underpinned by the concept of negotiation of meaning. Wenger (1998) views negotiation of meaning as an experience in which "we produce meanings that extend, redirect, dismiss, reinterpret, modify or confirm the histories of meanings of which they are part" (pp. 52-53). The term 'negotiation of meaning' implies engagement with others in co-constructing and modifying meanings. Thus

meanings are “historical, dynamic, contextual and unique” (Wenger, 1998, p. 54). Modifying meanings is a process of learning.

Since negotiation of meaning is a process through which communities of practice construct meanings for their experiences within their practice, the process implies active participation by members of the community. Wenger (1998) describes participation as “the social experience of living in the world in terms of membership in social communities and active involvement in social enterprises” and “combines doing, talking, thinking, feeling, and belonging” (Wenger, 1998, pp. 55-56). Through participation, a sense of membership within the group is fostered; hence participation is a source of identity formation. Members of a community of practice develop identities which manifest themselves even outside the contexts of engagement, which means participation is also much broader than engagement in a particular practice (Wenger, 1998). Linking these ideas to teaching implies that participation entails not only engaging in the practice of teaching with others, but also the social experience of living and being recognized as a teacher even outside the school contexts. In this sense participation is constitutive of identity.

In using the term ‘community’, Wenger (1998) associates it with practice, and argues that practice gives coherence to communities, hence the term communities of practice. Community has three dimensions: mutual engagement, joint enterprise and shared repertoire (Wenger, 1998). Mutual engagement entails doing things together and negotiating meanings with one another, and the mutual relationships that enable and sustain the engagement. Mutual engagement is supported by the joint enterprise of a community of practice. A joint enterprise is the negotiated focus of the activities of a community of practice, to which the community has mutual accountability, responsibility and ownership (Wenger, 1998). A joint enterprise “is defined by the participants in the very process of pursuing it.” and “it creates relations of mutual accountability that become an integral part of the practice” (Wenger, 1998). The shared repertoire of a community of practice refers to the shared resources which have been “produced or adopted in the course of its existence, and which have become part of its practice” (Wenger, 1998, p. 83). The resources include “routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions or concepts” (Wenger, 1998, p. 83), and these form the shared repertoire of a community, which serves as a resource for negotiation of meaning.

Identity constitutes the fourth key component of Wenger's (1998) theory of learning as social practice. Identity is a relational phenomenon between the individual and the social which is constituted and shaped through participation in different social contexts. Identity has to do with community membership, which is a sense of belonging to a community. Identity is also defined as a learning trajectory, i.e. "We define who we are by where we have been and where we are going" (Wenger, 1998, p. 149). Identity is connected to practice in that a practice depends on a community in which members engage with and acknowledge each other, which means "practice entails the negotiation of ways of being a person in that context" (Wenger, 1998, p. 149). The ways of negotiating may not be explicit, but involve how one engages and relates with others in the activities of the community of practice. Hence identity is connected to the other components of the theory.

In adopting Wenger's theory as the guiding framework for the study I took cognizance of the limitations of the theory. Some of the limitations have been highlighted in the literature (e.g. Graven & Lerman, 2003; Hodkinson & Hodkinson, 2004). One critique of the theory is on how learning is enabled from a community of practice perspective. Given that teachers' primary concern is how their teaching enables learners' learning, the challenge is to relate learning in a community of practice to learning mathematics and learning to teach mathematics (Graven & Lerman, 2003). This is compounded by the use of vignettes in Wenger's book that are far removed from teaching and learning in classroom contexts, and the down-playing of the role of teaching in learning in the theory (Graven & Lerman, 2003). Kazemi and Hubbard (2008) highlight the limitations of analyzing teacher learning in professional development contexts only. They argue that teacher learning occurs through the co-evolution of their participation in two contexts over time; the professional development contexts and the classroom contexts. In either context the teachers develop meanings that are enacted and reflected upon in the other context, a process that Kazemi and Hubbard (2008) refer to as learning in and from practice. Hence analyzing teacher learning requires a multi-directional analysis of both contexts, something that is not emphasized in Wenger's theory. In their argument for analysing teacher learning in across both contexts, Kazemi and Hubbard regard learners' work as records of practice that teachers use in professional development and in classroom contexts. Thus learners' learning needs are used to inform teachers' learning needs in both professional development contexts and classroom

contexts (Brodie, 2011c; Katz, et al., 2009). The challenge in using Wenger's theory lies in articulating learning in the professional learning community. In the theory much of the learning is tacit rather than explicit, making it difficult to use the theory to analyse learning in the community. Thus in my study I adopted the idea of 'opportunities for learning' rather than 'learning'. This is further explained in Chapter 3.

Another criticism of the theory has been the loose definition of communities of practice. According to Wenger communities of practice are everywhere and people belong to different communities of practice at different times (Wenger, 1998). This wider use of communities of practice as over-lapping creates problems of identifying communities of practice and the learning that occurs in those communities (Hodkinson & Hodkinson, 2004). In using the theory in my study there was a need for a tighter definition of the community of teachers participating in the study. The 'professional learning community' in this study was a tighter form of community of practice because of the following features: the community was constituted by mathematics teachers in one department and in one school; and the learning activities were structured, developmental and time-framed with a clear learning focus.

According to Wenger's theory, identity is one of the key components of the learning in a community of practice. In the theory identity is presented as multi-faceted, i.e. learning as identity construction; identity as modes of belonging; identity as negotiated experience through participation and reification; and identity as learning trajectories (Wenger, 1998). While these dimensions of identity are meant to highlight the connection of identity to the other components of the learning theory, working with all these dimensions in analyzing learning can be cumbersome. For the purposes of this study I focused on identity as modes of belonging to analyse the teachers' identities as members of communities. Further analyses of the data using the other dimensions of identity may illuminate other findings in relation to the teachers' identities in the professional learning community.

2.3 Conceptual framework

The main concepts which formed the conceptual framework for the study are: professional learning community; teacher practices; teacher identity and teacher learning. In this section the meanings of these concepts are discussed as well as how they are linked to the theoretical

framework of the study. Although the four concepts are explained separately, in a professional learning community they are in mutually co-shaping relationships. I explore these relationships further in Chapter 8 in relation to the findings of the study.

2.3.1 Professional learning community

The term 'professional learning community' is one of a number of terms used to refer to teacher groupings or communities. Other terms which have been used in the literature include: teacher inquiry groups (Hammerman, 1997); study groups (Birchak, et al., 1998); communities of practice (Wenger, 1998); networks of critical friends (Krainer, 2003); networked learning communities (Earl & Katz, 2005; Kubiak, 2003); collaborative cultures (Englert & Tarrant, 1995); and knowledge management teams (Jackson & Leo, 2003). The various terms are linked to different conceptions of the same idea of groups of teachers collaborating and cooperating in certain aspects of their professional practice. Such communities have the following as defining features: shared goals and endeavours; collaboration; collective inquiry; collective learning; and collective responsibility. The different conceptions depend on the goals, activities and contexts of particular groups. A professional learning community has defining features which are somewhat different from other conceptions of teacher community. A fundamental defining feature of professional learning communities is professional learning for both teachers and school leaders (Katz & Earl, 2010a). Professional learning occurs within a cohesive group in which collective knowledge is developed through engagement with data about learners' learning (Brodie, 2011c). Teachers draw on their professional knowledge and knowledge from research to interpret data about their learners in order to identify their learners' learning needs and their own learning needs. Professional learning occurs under the guidance of an expert, or 'critical friend', who supports collective construction of knowledge and reflection on understandings (Katz, et al., 2009).

In this study the professional learning community consisted of five mathematics teachers in one high school and the researcher as facilitator and 'critical friend' (Katz, et al., 2009). The defining features of the professional learning community were: a shared focus on understanding learner errors in mathematics; joint reflection on understanding of mathematical concepts which were

critical for learners; joint lesson planning and reflection on the efficacy of the lessons in dealing with learners' learning difficulties.

2.3.2 Teacher learning in a professional learning community

Teacher learning in a professional learning community is an on-going inquiry process in which teachers collectively develop new meanings about their professional practice. Learning involves working together towards a common understanding of concepts and practices (Stoll & Louis, 2007). Learning involves "creating meaning from activities and situations from lived experiences …" and this occurs "within the context of social relationships with other members of the community who have similar, if not identical, issues and concerns from the realm of practice" (Buysse, Sparkman, & Wesley, 2003, p. 267). Teacher learning in this case involves collective inquiry and knowledge creation, which "requires that individuals consider explicit knowledge and share, question, and possibly adapt their tacit knowledge, in order to create new collective explicit knowledge" (Katz & Earl, 2010a, p. 31). As indicated in the previous section, data about learners' learning is critical for the inquiry process in the professional learning community. Through inquiring into data members of a professional learning community continuously engage in questioning various aspects of their practice and learners' learning, and try out various collectively conceived strategies in on-going efforts to improve their practice. Such collective inquiry is a defining feature of teacher learning in a professional learning community. Inquiry in this sense means engaging with others in seeking to know through exploration (Jaworski, 2003b), and developing new understandings that in turn inform future actions. Teacher learning in a professional learning community involves: challenging each others' assumptions about teaching and learning; discussing new ideas that challenge existing knowledge; diversity of opinion; discussing points of disagreement rather than of agreement; maintenance of the mathematical focus of the conversations; treating participants' ideas as objects of inquiry; and joint sense-making (Katz, et al., 2009). Learning in a professional learning community is thus a social process through which teachers negotiate new meanings and social relations through their participation in a practice.

2.3.3 Teacher practices in a professional learning community

In a teacher professional learning community there are two types of practices. The first type refers to the actual work of teaching in classrooms, which in this study is referred to as teaching practice. Teaching becomes a professional learning community practice in the sense that collective reflection on teaching supports learning in such a community. The second type of practice refers to how a professional learning community engages in its activities. This practice involves the use of artefacts of practice such as student thinking, tasks and instructional practices as part of the work of the professional learning community. The practice also refers to the experiential knowledge and theories from the field of teaching and learning which the teachers draw on during the collective inquiry process in the professional learning community. This type of practice of a professional learning community is defined by the ideas, theories, artefacts, practitioner knowledge (Jackson & Temperley, 2008) and knowledge from research, all of which shape the community's mutual engagement towards a shared enterprise (Wenger, 1998). In this thesis I refer to this type of practice as the community practice and it refers to the professional learning activities in which the professional learning community engaged. The activities involved teacher conversations about testing and the South African curriculum, learner errors in mathematics, learners' learning needs and teachers' learning needs, and innovative mathematics lessons for addressing learners' learning needs. The conversations involved teachers in reflecting on their professional knowledge and teaching practices, thereby creating opportunities for deepening their own understandings. Details of the activities are presented in Chapter 3.

2.3.4 Teacher identity in a professional learning community

There are several different definitions of identity in the literature. Some authors view identity as how individuals define themselves and how they are defined by others (Gee, 2001; Grootenboer, Smith, & Lowrie, 2006; Wenger, 1998), while others classify identity as a relational and socio-cultural phenomenon which emerges through interaction (Bucholtz & Hall, 2009) and through participation in communities of practice (Bjuland, Cestari, & Borgersen, 2007; Wenger, 1998). A common theme in these views of identity is the social nature of identity, i.e. as a feature of how individuals relate to others in social contexts. MacLure's (1993) view of identity as a tool which people "*use*, to justify, explain and make sense of themselves in relation to other people, and to

the contexts in which they operate" (p. 287) alludes to the role of identity in human interactions within social contexts. Other conceptions of identity include a person's sense of belonging to a group, and achievement within the norms of the group (Bjuland, et al., 2007), or a person's self-concept which is constituted by an awareness of membership of a social group, the values associated with that membership, and feelings associated with that membership (Pennington, 2002).

Wenger's (1998) view of identity as modes of belonging resonates with many of the above conceptions. Wenger describes three modes of belonging which he argues are worth considering in making sense of identity formation in communities of practice: engagement, imagination and alignment. Engagement is the "active process of involvement in mutual processes of negotiation of meaning" (Wenger, 1998, p. 173), which entails the formation of a community of practice and is a source of identity formation. Imagination "refers to the process of expanding our self by transcending our time and space and creating new images of the world and ourselves" (Wenger, 1998, p. 176). Wenger likens imagination to "looking at an apple seed and seeing a tree" (p. 176). Imagination is thus a creative process through which we create images of ourselves and others beyond the immediate time and context; hence it is a source of identity formation. Alignment refers to "coordinating our energy and activities in order to fit within broader structures and contribute to broader enterprises" (Wenger, 1998, p. 174). Through alignment broader enterprises are formed and participants are connected by the "coordination of their energies, actions and practices" (Wenger, 1998, p. 179).

In this study teacher identity was regarded as the ways in which teachers perceive themselves as members of communities through the way they described themselves in relation to other mathematics teachers. Teacher identity in this sense refers to ways of engaging with others in community practices and how teachers imagine themselves and their roles in the current and future collective activities of the professional learning community. Teacher identity has to do with how the teachers express their agency to work with ideas developed in the professional learning community as part of their professional practice.

The decision to derive the definition of teacher identity as used in this study from Wenger's view of identity as modes of belonging was based on the temporal and social nature of identity. In a professional learning community the teachers are exposed to opportunities for developing new

social relationships with their peers as well as new understandings of themselves as teachers as they deepened their professional knowledge. Through active participation in professional learning activities with others, teachers develop identities as members of a professional learning community.

2.4 Linking the conceptual framework to the theoretical framework

In this section the concepts which form the conceptual framework are explored further in relation to the theoretical framework. This is meant to highlight ideas in both the theoretical and conceptual frameworks which informed the research design, methods and analysis used in the study.

2.4.1 Professional learning communities and communities of practice

There are many similarities between professional learning communities and communities of practice. Wenger (1998) describes communities of practice as groups of people who share a concern or a passion for something they do and learn how to do it better. Wenger and Snyder (2000) describe the activities and goals of communities of practice as sharing "experiences and knowledge in free-flowing, creative ways that foster new approaches to problems", with knowledge being the "primary 'output'" (p. 140). According to Wenger communities of practice can be both formally and informally constituted. Members of a community of practice collaborate to further the goals and interests of their practice. Examples of communities of practice are golf players who meet regularly to practice and improve their playing skills, or music lovers who share a passion for a certain genre of music but who may not meet formally but communicate through various means. Wenger (1998) asserts that "Communities of practice are an integral part of our daily lives. They are so informal and so pervasive that they rarely come into explicit focus, but for the same reasons they are also quite familiar." (p. 7). According to Wenger (1998), a community of practice is defined by three dimensions: mutual engagement, a joint enterprise and a shared repertoire. The three dimensions were explained in section 2.2.1 above. Community refers to members engaging in joint activities, discussing, helping each other and sharing information within their domain of interest. A practice is defined by the; and the shared repertoire of resources such as "experiences, stories, tools and ways of addressing problems" (p. 1). In line with this definition teachers in a school, district, or province often create

communities of practice. They share the same domain of interest which is teaching; they share information about their practice both formally and informally; and they share the same repertoire of resources. However these teacher communities are not necessarily professional learning communities.

According to Stoll and Louis (2007) professional learning communities are more formally constituted, with set goals that have specific targets within the broader practice. A fundamental feature of professional learning communities is professional learning. With respect to teacher professional learning communities, Katz and Earl (2010a) emphasize that such communities are "fundamentally about learning – learning for pupils as well as learning for teachers, learning for leaders, and learning for schools" (p. 28). From Stoll and Louis' definition, learning in a professional learning community occurs in a formally constituted and cohesive group whose focus is on inquiring collaboratively into their practice and developing new understandings about specific aspects of their practice. The goals of the collaboration include: challenging practice, focused professional learning, deepening understanding, proposing and testing solutions, and improving the quality of classroom instruction (Katz, et al., 2009). The activities of professional learning communities include: using classroom data to establish a clear and defensible learning focus (Brodie, 2011c; Katz, et al., 2009), and drawing on knowledge from teachers' experiences and from research to inquire collectively and develop new understandings about learners' learning and teachers' teaching practices. According to Brodie (2011c) the activities are a form of data-informed professional development in which local data "has to be brought into contact with current knowledge and research in order for teachers to find ways forward with their problems of practice" (p. 27). An example of a teacher professional learning community is mathematics teachers in a school meeting to inquire into a problem of practice such as learners' learning difficulties in a specific mathematics topic. The goal of the collaborative inquiry in this case is to improve learners' learning through joint reflection and deepening of the teachers' own professional knowledge, and changing teachers' teaching practices.

2.4.2 Learning in professional learning communities and Wenger's theory

Learning in professional learning communities is similar to learning as portrayed in Wenger's theory of learning as social practice. The location of professional learning communities as

special forms of communities of practice justifies the use of Wenger's theory of learning as social practice to analyse learning in professional learning communities. In Wenger's theory learning is regarded as situated in everyday human activities, which means participation is integral to learning. Learning is grounded in daily activities; inseparable from the environments in which knowledge is used; and a result of social processes that involve the negotiation of meanings with others (Buysse, et al., 2003). Learning in professional learning communities involves teachers participating in community and developing new meanings about their professional practice. In line with this view of learning, teacher learning within the workplace takes place through "teachers' participation in activities within the school context" (Kwakman, 2003, p. 152), and as being underpinned by three principles: learning as participation; learning as social in nature; and learning as necessary for teachers to develop professionally. Learning in a professional learning community is situated within the teachers' context of professional practice and ideas are developed in relation to the local environment and research. The ideas find immediate trialling and implementation as teachers develop the agency to work with the ideas in their teaching practice.

2.4.3 Professional learning and practice

One of the components of Wenger's (1998) theory of learning is practice. For Wenger a practice is defined by such things as the tools, procedures, language, theories, ideas, and relations which shape a community's shared enterprise. Wenger (1998) refers to practice as "the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action" (p. 5). Practice is a process by which people experience the world and perceive their engagement as meaningful. For Wenger (1998) "*Practice is about meaning as an experience of everyday life*". This implies that engaging in practice is learning and is a way of negotiating meanings. A practice defines a community of practice and it is through participation in the practice that a group identity is formed. In a professional learning community teachers engage in two types of practice, both of which are mutually co-informing. Teachers engage in teaching practice as part of their everyday work. The professional learning activities constitute another type of practice. Teaching as a practice involves continuous reflection on practice and in practice (Kazemi & Hubbard, 2008). Usually the teachers' engagement in the practice of teaching is a

lonely experience; teachers rarely have opportunities to discuss their teaching with others in community. In professional learning community teachers talk about their teaching experiences, which provides opportunities for collective interrogation of teaching and developing new understanding which in turn inform teachers' teaching.

As indicated earlier on the second type of practice refers to the activities of a professional learning community. This type of practice has parallels with the practices of a community of practice in Wenger's theory. In both a community of practice and professional learning community participation in community practices involves ideas, theories, artefacts, histories and the development of new meanings which support collective engagement towards a shared enterprise. In both cases engagement in the practice entails learning. The practice defines the community in both cases. Thus reference to ideas about practice as learning in Wenger's theory helped in analyzing the work of the professional learning community in this study.

2.4.4 Teacher identity and identity in a community of practice

According to Wenger, identity "serves as a pivot between the social and the individual" and it "reflects the mutual constitution between individuals and collectives" (1998, p. 146). Wenger describes identity as a "*negotiated experience"* as people define who they are by where they have been and where they are going. In communities of practice members develop new understandings of themselves in relation to others through the experience of participation in community practices. This means identity is negotiated in community practices and is part of people's practices, language, artefacts, and world views which reflect the social relations developed in the community. Individuals' thoughts make use of concepts, images, and perspectives that they understand through their participation in social communities.

The main features of Wenger's (1998) conception of identity that resonate with teacher identity in a professional learning community include the social nature of identity, how it is located between the individual and the social, and how it is shaped by participation and membership in a community. In a professional learning community teachers develop meanings of themselves as members of a community through collective participation and engagement with others. How the teachers imagine themselves as they engage with others and the ways in which they align themselves with community practices, influence the development of identities as members of a

community. This understanding of teacher identity resonates with Wenger's view of identity as modes of belonging. The view highlights identity formation as negotiating ways of belonging to a community through engagement, imagination and alignment. In a professional learning community identifying oneself as a member of a professional learning community supports mutual engagement in the practices of the professional learning community. Having a strong sense of belonging in a professional learning community entails identifying oneself as a member of the community. Teacher identity supports participation with others in a professional learning community. It also supports building of productive social and professional relations with others. Teacher identity is fundamental to how teachers engage in the practices of a professional learning community. In this study the ideas which relate teacher identity to Wenger's theory were used to develop an analytical framework for analyzing the developing identities of the teachers at various stages of the intervention.

2.5 Features of successful professional learning communities

Current literature on professional learning communities highlights the importance of a number of features that support professional learning communities. Such features include: purpose and focus; relationships; collaborative inquiry; the use of evidence or data; and leadership (Katz & Earl, 2010a). Successful professional learning communities have a shared understanding of the learning focus (Boudett, City, & Murnane, 2008; Fleming & Thompson, 2004; Katz, et al., 2009). A learning focus defines the purpose and goals of collaboration. Establishing a learning focus may be done through the identification of learners' learning needs (Katz, et al., 2009). Once learners' needs have been identified as the focus of the collaboration, the teachers need to work out why learners persistently struggle in that area of mathematics; why their current teaching has not improved learners' learning; and what they can do to support learners' learning in that area (Brodie, 2011c). Having a learning focus serves to guide the collaborative activities of the professional learning community and prevents engaging in 'activity traps' (Earl & Timperley, 2008; Katz, et al., 2009). Katz, et al. (2009) define 'activity traps' as "those 'doings' that, while well intentioned, are not truly needs based and have the effect of diverting resources (both human and material) away from where they are most necessary" (p. 24). For Earl and Timperley (2008) 'activity traps' refer to "moving quickly to doing, to being busy and to feeling productive without sufficient attention to selecting the right things to do in the circumstances" (p.

2). Engaging in activity traps may not result in significant learning which is necessary for improvements in practices.

Collaborative inquiry is regarded as fundamental for the work of successful professional learning communities. Collaboration supports sharing knowledge, joint and critical reflection on understanding, as well as joint sense-making that often leads to new insights (Boudett, et al., 2008). Collaborative inquiry involves collective questioning and reflecting on practice (Jaworski, 2003b), as well as challenging knowledge and connecting group conversations to learners' learning needs. Rigorous collaborative inquiry that challenges knowledge, assumptions and practice leads to deepening of understanding, and proposing and testing solutions (Katz, et al., 2009). Brodie (2011c) asserts that "There is general agreement that in order to truly shift practice in ways that support learner improvement, teachers must be willing to challenge their own practice and give up long-held beliefs if these are seen to not be working." (p. 27).

An important feature that is related to collaboration is evidence or data that provide a rationale for the collaborative inquiry. Data for a professional learning community come from a number of sources that include "national or international test results, teachers' own tests, interviews with learners, learners' work and classroom observations" (Brodie, 2011c). The use of data to inform instructional decisions is referred to as data-informed practice. Data-informed practice is the process of "transforming data into knowledge and blending it with wisdom for use in planning and decision making in schools" (Earl & Katz, 2002, p. 1004). In a professional learning community, data-informed practice involves teachers collaboratively engaging in professional learning conversations that are designed to make sense of various forms of evidence which can result in changes in learners' learning (Brodie, Shalem, Sapire, & Manson, 2010). According to Brodie (2011b) data-informed practice as a model of teacher professional development "suggests that teachers themselves, with some expert guidance, can and should interpret the full range of data that is available to them and that their interpretations will suggest areas of learners' learning needs and hence teachers' learning needs." (p. 27). Inquiring into data provides evidence for decisions that can result in changes in practices and significant learner improvement. Evidence makes it possible for making decisions that are data driven rather than based on personal suppositions (Katz, et al., 2009). According to Earl and Timperley (2008) professional learning "conversations that are grounded in evidence and focused on learning from that evidence have

considerable potential to influence what happens in schools and ultimately enhance the quality and the efficiency of student learning" (p. 1). Analysing how professional learning communities work requires paying attention to how data and knowledge from research inform the collective inquiry and decision making processes of the communities.

Another important feature of professional learning communities are the relationships that develop through the community interactions. Productive interactions are enhanced if teachers view the professional learning community as a safe, non-threatening environment in which they can raise uncertainties or difficulties, with the confidence and trust that they will be supported and helped by others (Koellner-Clark & Borko, 2004). Relationships of trust and confidence in the community support tolerance and respect of each others' ideas and open acknowledgement of weaknesses. Open acknowledgement of what one does not know leads to possibilities for real new learning (Katz, et al., 2009). Collective rigorous inquiry depends on relationships of trust and challenging of each others' ideas in a professional way. Katz, et al. (2009) use the term 'relational trust' and indicate that relational trust includes "respect for each other's dignity and ideas, and belief in each other's competence" (p. 40). Relationships of trust and confidence enable professional learning through interactions that respect the dignity of individuals while challenging thinking and practice. Such relationships are not a given in any professional learning community. They develop over time as individuals come to know each other's strengths and weaknesses, and take responsibility for each other's learning. Successful professional learning communities cultivate and nurture the development of such relationships. Analyzing the work of professional learning communities therefore requires attention to the development and nature of relationships among the members of the community, and how such relationships support professional learning in the community.

Another feature of successful professional learning communities is having supportive leadership and 'critical friends' (Katz, et al., 2009). A supportive school leadership provides both moral and structural support to the work of professional learning communities. Structural support refers to the provision of resources such as time, venues for meetings, any necessary equipment, and communication channels (Toole & Louis, 2002). A supportive leadership empowers professional learning communities through affording and supporting opportunities for making decisions and testing solutions. A 'critical friend' refers to an outsider who participates in and supports the

work of a professional learning community. Being an outsider, a critical friend "can observe what may not be apparent to insiders, facilitate reflection on issues, ask questions, probe for justification and evidence to support perceptions, and help reformulate interpretations." (Katz, et al., 2009, pp. 90-91). A critical friend facilitates the inquiry process by challenging assumptions, and by pushing for deeper thinking and interpretations in a non-judgmental way. A critical friend also provides leadership by reminding participants of what has been achieved and guiding what still needs to be done. The facilitation role of a critical friend is demanding. Facilitation requires courage to challenge thinking and assumptions; ability to make in-the-moment decisions of what and when to probe for deeper thinking; sensitivity to the needs of individuals; and being knowledgeable enough to provide information necessary for pushing the inquiry process further (Katz, et al., 2009). Facilitation is thus a fundamental structure of successful professional learning communities. Successful facilitation develops over time, it requires learning. In analyzing how professional learning communities work it is important to examine how facilitation develops and supports the collaborative inquiry process and the achievement of the goals of the collaboration.

The features of successful professional learning communities described above were used in the study to understand teacher learning in the professional learning community.

2.6 Professional learning communities: a review of literature

Research on professional learning communities has focused on three main areas: teacher learning; how teacher professional communities impact teaching practices and student learning; and features of successful professional learning communities. The studies reviewed in this section are in these three broad categories. Studies in the first category address the question of what and/or how teachers learn in community. Studies in the second category have sought to link teacher learning in community to teachers' teaching practices and learners' performance. The third category refers to studies that have sought to explore features of professional learning communities which enhance teacher learning.

It is worth noting that some of the studies do not specifically use the term 'professional learning community'. This is attributed to a lack of agreement in the literature on the definition of a professional learning community (Stoll & Louis, 2007), and the use of various terms to refer to

such teacher communities (e.g. Birchak, et al., 1998; Englert & Tarrant, 1995; Hammerman, 1997; Jackson & Leo, 2003; Krainer, 2003). For expediency in the review I refer to the teacher communities in the various studies as professional learning communities.

2.6.1 Teacher learning in professional learning communities

The studies reviewed in this section had teacher learning in professional communities as their main focus. Some of the studies have included a focus on identity in addition to teacher learning. The common findings of the studies describe what and how the teachers learned in professional development contexts, and in some cases how the teachers' identities changed through participation in professional development contexts. Table 2.1 below presents a summary of the review of studies in this category. The studies by Graven (2002, 2004) and Nel (2012) were in South Africa, a context in which the study reported in this thesis was conducted.

The results underscore the importance of collaboration, challenging teaching practice, joint reflection on practice, reflective dialogue, sharing information, and observing each others' teaching for teacher professional learning. Several issues arise from these studies that have a bearing on my study.

Of the eight studies cited in Table 2.1 five were subject specific (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Graven, 2002, 2004; Horn, 2005; Horn & Little, 2010; Nel, 2012). Of these five, three were specifically on professional learning communities of mathematics teachers, and two were on groups of mathematics teachers which developed into communities of practice in in-service professional development programmes (Graven, 2002; Nel, 2012). (In Horn (2005) teachers in the mathematics departments were not referred to as professional learning communities, although from the paper they were functioning as professional learning communities.) The studies involving mathematics teachers are related to my study in a number of ways. My study is on mathematics teachers' professional learning community and contributes to knowledge of teacher learning in a subject-specific professional community; specifically in mathematics. Four of the studies relied entirely on data that consisted of teachers' self-reports about their own learning (Andrews & Lewis, 2002; Doppenberg, Bakx, & Brok, 2012; Nel, 2012; Newman & Mowbray, 2012). The reliance on self-reports with little or no triangulation with other data sources militates against the validity of research findings.

Table 2.1 Research studies on teacher learning in communities

Author (s) and year	Participants and data collection methods	Study focus	Results
Doppenberg, Bakx and Brok (2012)	Fourteen teachers and seven principals in seven primary schools. Non-subject specific. Semi-structured interviews	Teacher collaborative learning contexts, activities and outcomes in their regular professional work	Contexts: varied, mostly school meetings and same grade meetings. Activities: observing each others' teaching, sharing information and joint planning. Learning outcomes: collective knowledge, shared targets, and shared responsibility
Newman and Mowbray (2012)	Early childhood teachers and university academics collaborating in projects on practitioner inquiry. Teacher self-reports through interviews	Collaboration to build research networks between teachers and academics	Teachers learned research skills, leadership capacity, self discipline, and knowledge of professional practice
Nel (2012)	In-service mathematics teachers enrolled for the eighteen months Advanced Certificate in Education in Mathematical Literacy programme	Teacher learning of the content and the development of identities as teachers	Increased knowledge of the Mathematical Literacy curriculum; reported changes in practice and identities; and development of community
Horn and Little (2010)	Two professional learning communities in different schools: one in Mathematics; one in Literacy. Audio and video-recorded community meetings	How problems of practice were dealt with in the conversations	Mathematics group: deeper learning; addressed problems of practice. Literacy group: less learning; problems of practice not addressed.
Borko, Jacobs, Eiteljorg and Pittman (2008)	Middle school mathematics teachers in a project (STAAR); recordings of teacher conversations around video of their teaching and learners' learning using mathematical problems over two years.	How teacher conversations about video recordings of lessons changed over three iterations of a Problem Solving Cycle	Teacher conversations around mathematical problems and video lessons became more focused, deeper and more analytical. Stronger professional community was developed
Horn (2005)	Teachers in two mathematics departments in two schools. One department met frequently as a professional community; in the other teachers hardly met as a department, preferring to meet as a school-wide community. Participant observation of each department's meeting.	How and what mathematics teachers learned through their work contexts	Teachers learned differently in the two communities through sharing understandings of curricular materials, school-wide reform slogans, challenging school classification systems such as learner abilities, and discussing classroom practices
Andrews and Lewis (2002)	All teachers in one school; school-wide community; non-subject specific. Self-reports of the teachers' perceptions of their own learning	Trialling school-wide pedagogy based on collaboration, shared practice and reflective dialogue	Teacher learning through: challenging practice, reflection on practice, reflective dialogue, tolerance, and sharing experiences
Graven (2002, 2004)	Senior phase (grades 7-9) mathematics teachers enrolled for the two-year Program for Leader Educators in Senior-phase Mathematics Education (PLESME)	The learning mechanisms by which the teachers became professional and confident mathematics teachers	Learning in a community of practice as involving the complex intersection of five components of learning: meaning, practice, identity, community and confidence

My study uses both teachers' self-reports and audio and video-recorded data to analyze teacher learning. Although all studies indicate a focus on what and how teachers learn in professional learning communities, the results indicate a concentration on how the teachers learned and less on what the teachers learned (Andrews & Lewis, 2002; Doppenberg, et al., 2012; Graven, 2002; Horn, 2005). The study by Nel (2012) analyzed what the teachers learned in relation to the content of the Mathematical Literacy curriculum. The study by Horn and Little (2010) details how teachers in one mathematics professional learning community learned about a problem of practice and generalized their learning to principles of teaching. The study by Borko, et al (2008) shows how teacher conversations around mathematical problems and video recordings of their teaching and learners' learning progressively became more productive, and highlights how on-going teacher conversations in community can support productive teacher talk and learning. The study by Horn (2005) indicates broad areas of teacher professional knowledge such as curriculum knowledge in which the teachers reported having learned, with no specific details or examples of what was particularly learned.

Two of the studies included a focus on teacher identity in analysing teacher learning in communities of practice (Graven, 2002; Nel, 2012). Similarities between these studies and my study were in relating identity to teacher learning in community; and in using Wenger's theory to analyse identity. A major difference between these studies and my study was in the view of identity adopted in the analyses. The two studies analyzed identity as ways of becoming certain types of teachers. In my study I analyse identity as ways of belonging to communities of practice. The two studies and my study indicate a growing interest in mathematics teacher identity in research on teacher professional development in South Africa.

2.6.2 Linking professional learning communities to teachers' teaching practice and student learning

The studies reviewed in this section focused on connecting teacher learning to teachers' teaching practices and learners' learning. Table 2.2 below summarizes these studies. A review of the studies in Table 2.2 reveals some issues which are linked to my study, some of which are similar to the issues raised in the previous section.

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Table 2.2 Research studies connecting teacher learning to teaching and learner outcomes

Author (s) and year	Participants and data collection methods	Study focus	Results
Katz and Earl (2010)	Selected teachers in 662 schools that were part of 66 networks in the Networked Learning Communities (NLC) Programme in England. Survey of teachers' self-reports on a number of themes	How six features of networked learning communities enabled the success of the networks	Teacher participation in network linked to learner achievement; changed thinking and teaching practices; network schools more focused on learners' needs; leadership linked to changed thinking, teaching and learners' learning; inquiry linked to changed thinking and teaching; relationships of trust that supported joint work.
Higgins and Parsons (2009)	Teachers participating in the New Zealand Numeracy Development Project. Surveys of teacher self-reports	How participation in the project influenced teacher knowledge and teaching	Improved content knowledge, changed assumptions about students, and changed teaching of numeracy
Strahan (2003)	School administrators, teachers, and parents in three schools. Open-ended interviews	How professional learning communities collaborated to sustain reform agendas	Collaboration on activities targeted at improving teaching and learners' learning. Reported improved teaching and learners' results
Dunne, Nave and Lewis (2000)	Teachers in twelve schools that were selected from sixty-two schools participating in the Critical Friends Groups (CFG) project. Observation of CFG meetings, interviews with CFG and non-CFG teachers, samples of learners' work	How collaboration in CFG groups resulted in changed teaching and learners' learning	CFG teachers reported: more opportunities for learning, experimenting with new ideas, changing teaching approaches, improved learner achievement.
Louis and Marks (1998)	Teachers in eight elementary, eight middle and eight high schools. Questionnaires; classroom observations of seventy-two mathematics and seventy-two social studies teachers; interviews with teachers; administrators and other school stakeholders; samples of students' work	How school-wide professional communities influence teacher pedagogy and students' achievement	Teacher professional community correlated with teacher pedagogy, classroom organization, and students' achievement
Englert and Tarrant (1995)	Three teachers on the Early Literacy Project and researchers from Michigan State University. Interviews with teachers about their experiences	Collective designing of instructional approaches to literacy	Changed teaching approaches

A common feature of the studies is reporting of positive findings about the influence of professional learning communities on teachers' teaching practices and/or learners' learning. Of the five studies in Table 2.2 only one study was subject-specific and provides details of mathematical principles which guided the teachers' work in the project (Higgins & Parsons, 2009). Four of the studies relied solely on teachers' self-reports about their experiences in the projects to connect teacher learning to teaching practices and learners' learning (Englert & Tarrant, 1995; Higgins & Parsons, 2009; Katz & Earl, 2010a; Strahan, 2003). In three studies the teachers reported changes in their teaching as a result of their participation in the collaborative environments fostered in each project. In some cases the teachers reported improved learner achievement. The study by Katz and Earl (2010a) reported associations among teacher participation in professional and networked learning communities and reported changes in thinking, teaching practice and learners' learning. This study established how six key enablers of teacher learning in community were associated with teacher reports about changes in their thinking, teaching and learners' learning. These findings relate more to how professional and networked learning communities support teacher learning without addressing what the teachers learned.

The absence of results from the analysis of other data such as observation of classroom practices and learners' achievement militates against the validity of the self-reported changes in practice and learner achievement. Of interest in studies of this nature is information about the specific activities which the teachers participated in and which could explain the changes in teaching and learner achievement. Of the five studies above only one provides details of such activities (Higgins & Parsons, 2009). It should be acknowledged that in the case of the other studies, details of teacher activities could be provided in other more comprehensive writings about the respective projects; hence this observation is limited to the specific articles cited in Table 2.2.

Studies that included observations of classroom practice did not provide details of what changed in the teachers' teaching (Dunne, Nave, & Lewis, 2000; Louis & Marks, 1998). In the same studies there is also no indication of whether the teachers' teaching practices before their participation were observed and recorded to support claims of specific changes in teaching. In my study the participating teachers' teaching practices were video-recorded before, during and after their participation in the professional learning activities of the professional learning

community. The data enabled analysis of shifts in specific aspects of the teachers' teaching. I also analyzed the activities in which the teachers participated for links to the observed shifts in teaching practices. A limitation of my study is that it does not include analysis of learner achievement, and makes no claims about improvements in learners' achievement.

2.6.3 Features of successful professional teacher communities

Table 2.3 below presents a review of the studies on features and structures of professional learning communities which accounted for the success or otherwise of such communities.

Some of the features include: community, leadership, context, relationships, inquiry, and collaboration. These studies differ from those presented in Tables 2.1 and 2.2 above in that they focus more on factors which supported the successful functioning of the professional learning communities and less on what the teachers learned in those professional learning communities.

The findings of the studies address the question of how such features supported the work of professional learning communities. Out of the five studies presented in Table 2.3 two were subject specific (Koellner-Clark & Borko, 2004; Nelson, Slavit, Perkins, & Hathorn, 2008) and one of them studied professional community among mathematics teachers (Koellner-Clark & Borko, 2004). Only one study reported findings from teacher self-reports only (Sargent & Hannum, 2009). The other studies relied on data beyond teacher self-reports, including observations of professional learning community meetings.

The findings of the studies highlight the following as features that enhanced the success of the professional learning communities: school leadership, collaboration, and shared vision, reflection on practice and learners' learning needs, relationships of trust and the development of community. From their findings, Grossman, et al. (2001) developed a model for explaining how teacher community develops. The model is based on four dimensions of teacher community and it explains how each dimension develops from 'Beginning' to 'Evolving' to 'Mature'. Two studies highlighted factors that constrained the work of the professional learning communities (Sargent & Hannum, 2009; Wood, 2007). Time, curricular demands, systemic accountability policies, and inadequate district support were reported as constraining factors on teacher participation in, and the success of, professional learning communities.

Findings from these studies provided insights into my analysis of features of the professional learning community in my study. My study analyzed the influence of similar factors on the professional learning community in the study.

Table 2.3 Research studies on features of professional learning communities

Author (s) and year	Participants and data collection methods	Study focus	Results
Sargent and Hannum (2009)	Teachers participating in teaching and research groups in eleven rural primary schools in China. Survey questionnaires for 646 teachers and principals; interviews with thirty teachers	The nature of factors affecting professional learning communities in the schools	Factors: time, curricular demands, school leadership, rewarding professionalism
Nelson, Slavit, Perkins and Hathorn (2008)	Twelve facilitators participating in a large project working with professional learning communities in Science and Mathematics in twenty-two schools. Narratives, interviews, documents, and video and audio recordings of meetings	Features of a professional learning community of facilitators which supported learning about facilitation skills	Features: collaborative norms, shared vision, communication avenues, and shared leadership
Wood (2007)	Teachers and principals in schools one district participating in the Learning Communities (LC) project in United States. Interviews, focus-group interviews, observations of learning communities' meetings and classrooms, e-mail correspondences, observations of LC leaders, documents	How the Learning Communities (LCs) were functioning	Successes of LCs: critiquing professional practice, identifying learners' problems, developing action plans and reflecting on the efficacy of the plans. Constraints: systemic accountability policies, focus on community-building, inadequate district support
Koellner-Clark and Borko (2004)	Sixteen middle school teachers participating in the STAAR project based at the University of Colorado. Video-recorded teacher conversations in the project	How professional community was established	Professional community established through: formation of relationships, working on problem-solving tasks. Community manifested through: explaining to each other, building on others' ideas, admitting weaknesses, giving praise and laughing
Grossman, Wineburg and Woolworth (2001)	English and Social Studies teachers (22) in one high school meeting twice a month over two and half years to develop an interdisciplinary curriculum; recordings of conversations	How teacher community developed in the first eighteen months	Teacher community developed from 'Beginning', to 'Evolving' to 'Mature' on the dimensions: 'Formation of group identity and norms of interaction', 'Navigating fault lines', 'Negotiating the essential tension', and 'Community responsibility for individual growth'

2.6.4 Issues emerging from the review of literature

A number of issues arise from the methodologies and findings of the studies reviewed in the previous sections. A common methodological trend among the studies was the reliance on self-reported data in the form of surveys and interviews, with little triangulation with other forms of data to validate participants' claims (e.g. Andrews & Lewis, 2002; Nel, 2012; Newman & Mowbray, 2012; Strahan, 2003). The use of self-reports in research has limited validity and there is a need to use other forms of data besides interview and survey data in order to validate participants' claims. A few studies used other forms of data such as: video-recordings of teachers' teaching, video and audio-recordings of teacher conversations in communities, questionnaires and observation of actual teaching practices (e.g. Borko, et al., 2008; Dunne, et al., 2000; Graven, 2002; Grossman, et al., 2001; Horn, 2005; Horn & Little, 2010). Data in my study was collected using a number of techniques such as individual and focus-group teacher interviews, video-recording of the teachers' teaching and audio-recordings of professional learning community meetings. The triangulation of data from a number of sources was intended to enable deeper analysis of various aspects of the professional learning community, and to increase the validity of the findings.

Another issue relates to studies on subject-specific professional learning communities. Out of the nineteen studies reviewed above, ten were subject specific. Of these ten studies seven studied mathematics teacher professional learning communities or communities of practice. This observation shows that there is limited research on subject-specific professional learning communities, especially in mathematics. It is in this area that my study can make a contribution. Studying a professional learning community of mathematics teachers enables detailed analysis of teacher learning of specific mathematical subject content and pedagogical content knowledge, both of which are at the core of teachers' professional knowledge and practice.

The studies reviewed above were grouped into three themes. The first theme is about teacher learning in a professional learning community. Studies that investigated teacher learning addressed the question of what and how teachers learn in a professional learning community (e.g Andrews & Lewis, 2002; Borko, et al., 2008; Graven, 2002; Horn, 2005; Horn & Little, 2010; Nel, 2012). The findings on how teachers learned in community show that teacher learning

occurred through: collaboration with others (e.g. Andrews & Lewis, 2002; Borko, et al., 2008), challenging each other, reflection on practice, and sharing experiences in reflective dialogues (Andrews & Lewis, 2002; Doppenberg, et al., 2012; Graven, 2002; Nel, 2012); and was supported by conversations around mathematical problems, video-recorded teacher lessons (Borko, et al., 2008), and problems of practice (Horn & Little, 2010). The findings on what teachers learned highlight: research skills, leadership capacity, self-discipline, knowledge of professional practice (Doppenberg, et al., 2012; Nel, 2012; Newman & Mowbray, 2012); and the development of tolerance, community, shared responsibility (Andrews & Lewis, 2002; Doppenberg, et al., 2012). The findings of these studies informed my study in a number of ways. The findings indicate that significant teacher learning can occur through collaboration, reflection on video-recorded teachers' lessons in the community, and conversations around problems of practice. In my study the teachers collaborated in developing their professional knowledge through collective analysis of their learners' learning needs and reflection on their teaching practices in community. The findings also provided guidance on how deep learning can be supported in a professional learning community, and the significance of challenge, reflective dialogues, and sharing information to teacher learning.

The results reported in the above studies highlight some gaps in knowledge about teacher learning in professional learning communities. In the reported findings there is lack of specificity on the knowledge that the teachers learned which is connected to the practice of teaching. Although some of the studies indicate that the teachers learned in areas such as research skills, leadership capacity, self-discipline, knowledge of professional practice, tolerance, etc, such learning is not closely linked to the subject content and pedagogical content knowledge that is necessary for teachers' teaching practices. Only the study by Nel (2012) analyzed teacher learning about the content of a mathematics curriculum, although the data was limited in that it consisted of the teachers' self-reports of what they learned. Some of the studies are silent on what the teachers actually learned. For example the studies on mathematics professional learning communities do not provide details of what the teachers learned in terms of mathematical subject content and pedagogical content knowledge (Borko, et al., 2008; Graven, 2002; Horn, 2005; Horn & Little, 2010). My study sought to elaborate on the forms of mathematics teachers' professional knowledge that can be learned in a professional learning community of mathematics

teachers by providing details of the subject content and pedagogical content knowledge that the teachers had opportunities to learn about.

Another issue raised in the findings relates to collaboration and the development of community. In two of the studies reviewed above the teachers developed into communities of practice and changed their identities as professional teachers (Graven, 2002; Nel, 2012). My study sought to elaborate on these findings by analyzing the development of teacher identity as an important construct in supporting group cohesion and collaboration in a professional learning community.

The second theme in the reviewed studies is the connection between teacher learning in professional learning communities and teaching practices. A methodological limitation of most studies was the reliance on teachers' self-reports about their changed teaching practices with no validation by observing the teachers' actual teaching (e.g. Englert & Tarrant, 1995; Higgins & Parsons, 2009; Katz & Earl, 2010a). Three studies involved observing the participants' teaching, (e.g. Dunne, et al., 2000; Graven, 2002; Louis & Marks, 1998), but only the study by Graven provides details of the actual observed changes in practice and how such changes were identified. All the studies, including Graven's do not provide evidence of the teachers' teaching before participation in the professional learning communities, weakening claims of changes in teaching practice. My study addressed these methodological limitations by video-recording the teachers' teaching practices before, during and after the intervention in order to analyse shifts in the teachers' teaching, and connecting the shifts to the activities of the professional learning community.

The findings of the studies under this theme were relevant to my study in various ways. The findings highlight: teachers' changed thinking and teaching practices through participation and collective inquiry in networked learning communities (Katz & Earl, 2010a); improved subject content and pedagogical content knowledge in the classroom, and changed teaching practices; and teacher experimentation with new ideas and changing teaching practice (Dunne, et al., 2000; Graven, 2002; Higgins & Parsons, 2009). A common theme in the findings is that teachers changed their teaching practice through collaboration and inquiry in community with others, something that was partly the focus of my study. Limitations of the findings include the lack of detail on the specific changes in the teachers' teaching practices and what accounted for the changes in the professional learning community. The finding about improvement in subject

content knowledge does not elaborate on the actual knowledge of numeracy in which the teachers improved and how such improved knowledge accounted for particular changes in the teachers' teaching of numeracy (Higgins & Parsons, 2009). The study by Nel (2012) does not give details of specific mathematics content that the teachers' learned in the programme. My study sought to contribute to these gaps by analysing developments in the teachers' subject and pedagogical content knowledge, and connecting the developments in knowledge to changes in the teachers' teaching practices.

The third theme of the reviewed studies is on features of professional learning communities that affect professional learning communities. The findings indicate that the features can be put into two categories: features that are external, and those that are internal to the professional learning community. External features that were found to support or constrain the work of professional learning communities were: time, curricular demands, school leadership, district support, and systemic accountability policies (Sargent & Hannum, 2009; Wood, 2007). Findings on internal features of professional learning communities highlight the following as features that supported the work of professional learning communities: collaborative norms, shared vision, shared leadership (Nelson, et al., 2008); critiquing practice, identifying learners' needs and developing action plans for dealing with the needs (Wood, 2007); forming relationships and developing community (Koellner-Clark & Borko, 2004). The contribution of my study in this area was in providing details and examples of how some of these features supported or constrained the teachers' participation and learning in the professional learning community. The study by Koellner-Clark and Borko (2004) elaborated on the indicators of the establishment of community, namely explaining to each other, building on each others' ideas, admitting weaknesses, giving praise and laughter. Although my study did not analyse the establishment of community, these indicators were analysed in terms of how they (indicators) supported teacher learning and the development of teacher identity as members in a community, something that was not addressed by the reviewed studies. All these findings were relevant for my study, as they made me aware of features that could support the development of a professional learning community. This was significant since this was my first time to establish and facilitate a professional learning community.

In addition to teacher learning and teachers' teaching practices my study also investigated the development of teacher identity in the professional learning community. Three studies from those reviewed in the previous section analyzed the development of identity in a professional learning community or communities of practice (Graven, 2002; Grossman, et al., 2001; Nel, 2012); although the study by Grossman, et al does not specifically use the term identity. These studies show how the teachers developed into communities of practice and changed their identities through participation in community with others. The development of community signifies identifying with the group, which is part of identity (Wenger, 1998). The sense of belonging in community with other teachers provides group cohesion to the community and supports teachers' agency to participate in the activities of the professional learning communities. Teacher identity is therefore central to how teachers participate and learn in community with others. The three studies did not specifically analyze the individual teachers' identities before and after their participation in the study, relying mainly on the teachers' self-reports during interviews on their espoused changes in their identities. My study analyzed shifts in teachers' identities at different stages of the study. The analysis involves examining how the teacher identity fostered the teachers' participation and relationships with others in community.

2.7 The Data Informed Practice Improvement Project (DIPIP)

In South Africa a research project that works with mathematics teachers' professional learning communities has been running since 2008. The Data-Informed Practice Improvement Project (DIPIP), which is based at the University of the Witwatersrand, establishes and develops mathematics professional learning communities in schools. The teachers engage with data from different sources to better understand learner errors (Brodie, 2011c). The project has been running since 2008 and has gone through three phases. Phases 1 and 2 were from 2008 to 2010, and phase 3 has been running from 2011. In phases 1 and 2 about 50 Grade 3-9 mathematics teachers from different schools worked at the university in groups of 3 to 4 teachers with a graduate student or university staff member and a government appointed subject advisor (Brodie, Shalem, Manson, & Sapire, 2008). In phase 3 of the project, mathematics teachers in the same school work with a DIPIP facilitator (a graduate student) as a professional learning community. The study reported in this thesis was a pilot study for phase 3 of the project, was conducted in 2010, and was informed by phases 1 and 2 of the project.

The focus of the DIPIP project is to support teacher learning in professional learning communities through working with classroom data. A fundamental idea behind DIPIP activities is data-informed practice. Data-informed practice is the process of "transforming data into knowledge and blending it with wisdom for use in planning and decision making in schools" (Earl & Katz, 2002, p. 1004). In the professional learning communities data-informed practice involves teachers collaboratively engaging in professional learning conversations that are designed to make sense of various forms of evidence (Brodie, et al., 2010). Currently learner errors constitute the data into which teachers collectively inquire. The DIPIP position on errors is that "errors are a normal part of the learning process and should be expected and embraced rather than denied and avoided" (Brodie, 2012a). The activities of the project engage the teachers in conversations about the validity and reasonableness of learners' errors and the thinking behind the errors. In the conversations the teachers also relate their understanding of learner errors to their instructional practices.

The project has produced some results, which have been reported in the literature. Results from the first two phases of the project raise some interesting issues about teachers' learning in community. The focus of the two phases was on "how to transform data collected from testing into structured learning opportunities for teachers." (Brodie, et al., 2008, p. 4). The findings from these phases indicate that there was significant teacher learning and some shifts in practice through participation in the professional learning communities. In the reported findings the authors link specific activities and learning opportunities to particular domains of teacher knowledge. The findings also highlight how project mechanisms such as facilitation by a university-based expert supported the teachers' learning.

Drawing from initial findings from the project, Brodie et al. (2008) show how the project supported teachers' insights about the intended curriculum through engaging in evidence-based conversations. Using the idea of "accountability conversations", Brodie and Shalem (2011) show how the teachers accounted "for their current and shifting practices, for the constraints on their practice and their learning, for learner thinking, and for the links between their practices and learner thinking" (p. 436). The findings show how the conversations were opportunities for the teachers to talk about their practices in relation to learners' thinking, which is important for deepening pedagogical content knowledge. The teachers "were able to use their learners' actual

errors to think about the nature of learner errors and misconceptions more generally and the teacher's role in addressing these." (p. 436).

A key focus of the DIPIP project is to support teachers' learning about how to engage with learner errors in ways that provide access to mathematics. By analyzing episodes from two teachers' lessons that were discussed in professional learning communities Brodie (2011a, 2012b) shows what the teachers learned about learner errors through reflection on particular errors with others in the project. Reflecting on the episodes in the professional learning communities involved conversations that sought to understand the learners' thinking behind the errors, and alternative ways in which the teachers could have dealt with the errors. Thus the conversations were learning spaces in which the teachers learned about learner errors. In her analysis of three episodes from the first teacher's lessons, Brodie (2011a) shows how the teacher experienced success and challenges in engaging with learner errors. From the conversations in the professional learning community the teacher learned how to engage appropriately with learner errors (Brodie, 2011a). The teachers in the professional learning community learned that errors arise from interactions between teacher, learner and mathematics rather than the learner alone, hence the need for patience when engaging and dealing with errors more generally in class (Brodie, 2011a). For the second teacher Brodie (2012b) shows how a conversation in the professional learning community about a learner's error relating to the equal sign supported the teacher's learning about how to engage appropriately with errors in class. By reflecting with others in the community the teacher realized how she had led the learner to the correct answer without asking the learner to explain her thinking. In her reflections the teacher asserted that she had learned about the limitations of leading questions in engaging with learner errors and expressed a desire to make efforts to use such questions less frequently in her teaching. From the conversations in the professional learning community Brodie (2012b) argues that the teachers learned that: errors often result from correct and incorrect mathematics; and how to distinguish between an error and the reasoning behind the error. The results show that reflecting on the two teachers' teaching in the professional learning communities supported the teachers' learning about learner errors and how to engage with errors during their teaching.

In another paper Brodie (2012a) analysed three episodes in the professional learning community conversations to illustrate what and how the teachers learned about learner errors. In the first

episode a learner's error in labelling the axes of a Cartesian plane generated a conversation in the professional learning community in which the teachers learned about identifying the learners' reasoning behind errors. In her analysis of the conversation, Brodie argues that the teachers learned how to distinguish an error from the reasoning behind the error, and that there is often valid and invalid mathematics in an error. In the second episode a conversation about whether '$4x \times 5x = 20x$' is correct or incorrect created an opportunity for the teachers to learn about their own mathematical knowledge through challenging each other constructively in the professional learning community. In the third episode the teachers had an opportunity to learn about accounting for errors without blaming learners. In the conversation the teachers began to link errors to teaching practices by using examples from their own experiences as learners. In the conversation the facilitator highlighted the complexity of accounting for errors by drawing the teachers' attention to the roles of the learner, the teacher and the mathematics in producing errors. Drawing from the three episodes, Brodie (2012a) argues that the professional learning community supported teacher learning about learner errors through supporting and challenging each other, and providing alternative interpretations of errors. In the same paper Brodie also highlights the crucial role of the facilitator in supporting the teachers' deeper understanding of learner errors.

In another paper Shalem and Sapire highlight the teachers' challenges in explaining learners' errors and the crucial role of the facilitator in providing conceptual and alternative interpretations to learner errors (Shalem & Sapire, 2012). Another significant finding was that teaching jointly planned lessons provided teachers with opportunities for applying their understanding of the role of errors and misconceptions. Teachers made efforts to engage with learner errors in their teaching but some of them still ignored learner errors (Shalem, 2012).

The results presented above from Phases 1 and 2 of DIPIP indicate that the project investigates three aspects which are significant to the work of professional learning communities, namely: teacher learning, teachers' teaching practices and features of the professional learning communities which support the work of successful professional learning communities. The results show that the conversations in the professional learning community were significant opportunities for the teachers to deepen their understanding of learner errors and their ways of engaging with errors in their teaching.

The study reported in this thesis was conducted in 2010 as a pilot study for DIPIP Phase 3. In South Africa this was the first time that a study of this nature had been conducted, i.e. a professional learning community in a school focused on learner errors. Hence the study contributes to the implementation of DIPIP Phase 3 as well as to knowledge about how subject-specific professional learning communities can be implemented in the South African context. The newly introduced Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011-2025 (Department of Education, 2011a) proposes the nationwide establishment of professional learning communities in schools between 2011 and 2017. This study contributes by providing knowledge which may help the realization of this vision.

2.8 Summary

In this chapter I have presented the theoretical framework for the study. Wenger's (1998) theory of learning as social practice was used as the theoretical framework of the study. I have presented the key concepts which formed the conceptual framework for the study; namely professional learning community, teacher learning, teachers' practice, and teacher identity. I also showed how the concepts are linked to the theoretical framework of the study. I explained the contribution of the study to knowledge on teacher professional learning communities. This was done through a review of literature on professional learning communities, highlighting the gaps in existing knowledge to which the study contributes. In the next chapter I present details of the research design and show how the design is linked to the theoretical and conceptual frameworks. I also describe the research methods used in the study as well as the data collection and analysis strategies used.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents the research design and methodology which guided the study. The chapter includes: the research design; the research site and participants; research methods and instruments; data collection and analysis procedures; validity and reliability; and how ethical issues were addressed in the study. Since research is systematic process of collecting and analyzing data for the purpose of addressing the research questions it is important that the selected research design and methods be relevant and appropriate to the goals of the study. The chapter articulates the research methods used in answering the research questions.

3.2 Research Design

The research design is the theoretically grounded framework which describes how the study was conducted and it indicates how empirical evidence for answering the research questions was collected and analyzed (McMillan & Schumacher, 2006). The study was a qualitative case study (McMillan & Schumacher, 2006) of one professional learning community in one school. The focus of the research study was to determine how a professional learning community, which worked on a number of professional learning activities, influenced changes in teacher practices and identities. As the teachers participated in the various activities, the teachers' teaching practices and identities were studied in relation to teachers' knowledge gains in their professional practice. As Wenger's (1998) theory states, teacher identity and teaching practice are qualitative phenomena which are constituted by a variety of other qualitative aspects of teachers' practices. To understand how these aspects of teacher practice and identity shifted through participation in the professional learning community, it was important to adopt qualitative strategies of data collection and analysis.

The following characteristics of qualitative research made it appropriate for the purposes of the study. The basic assumption of qualitative research is that "social settings are unique, dynamic, and complex" (Hatch, 2002, p. 9). In qualitative research the researcher interacts with the selected participants in their settings in order to describe and analyze the participants' actions,

beliefs, thoughts and perceptions (McMillan & Schumacher, 2006). Qualitative research "seeks to understand phenomena in context specific settings" (Golafshani, 2003, p. 600) and qualitative methods enable the detailed description and explanation of phenomena in ordinary natural environments (Hatch, 2002; Hitchcock & Hughes, 1995). Other characteristics of qualitative research which made it suitable for the study included: its focus on understanding social phenomena from the participants' perspectives, the use of multi-method interactive data collection strategies, the role of the researcher as an active participant, the collection of data over a long period of time, and the focus on the social meanings that the participants make of the phenomenon (Hatch, 2002; McMillan & Schumacher, 2006). In a professional learning community, issues involved in teacher participation are multifaceted and nuanced. To understand the interplay among factors that influence teacher participation and learning in such a context entails attention to details of how teachers participate and interact with their peers.

A case study approach was adopted based on the suitability of such a design for the purposes of the study. According to Yin (1994) a case study is an empirical inquiry that "investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13). McMillan & Schumacher (2006) assert that in a case study the researcher focuses on one phenomenon in order to understand it in depth, where the one phenomenon "may be one administrator, one group of students, one programme, one process, one policy implementation, or one concept" (p. 316). While the general conception of a case study is based on its focus on a unit, some authors have classified case studies according to the purpose of the study (Bassey, 1999; Yin, 1994). Stenhouse (1985) describes an educational case study as concerned with the understanding of educational action and enriching the "thinking and discourse of educators either by the development of educational theory or by refinement of prudence through the systematic and reflective documentation of evidence" (p. 50).

The study reported in this thesis is a case study of one professional learning community that was established and studied in one high school. The professional learning community in the study is a case of professional learning communities engaged in error analysis. There are several features of case study research that made the design suitable for the purposes of this study. The intention of the study was to understand how teachers learn in a professional learning community, and

how such learning explained observed shifts in teaching practices and identities. A case study design was motivated by the desire to explain shifts in teachers' teaching practices and identities within the complexity and subtlety of the real life contexts of the teachers' practice and the professional learning community (Denscombe, 2007). Studying phenomena such as teacher learning and identity within a professional learning community involves unravelling the interrelationships that exist among the complex issues involved in teacher participation in community.

3.3 Research site and participants

The study was carried out in one high school and involved five mathematics teachers. Selecting the school and participants was done with a number of considerations. In the following section I explain how the school and participants were selected.

3.3.1 Selection of school and participants

The selection of the school and participants was done through purposive sampling (McMillan & Schumacher, 2006; Teddlie & Yu, 2007). Purposive sampling involves selecting samples by considering their suitability for answering the research questions, providing the required information and serving the research purposes (Teddlie & Yu, 2007). My study required an in-depth analysis of how teachers learn in a school-based professional learning community and how such learning is linked to shifts in teaching practices and teacher identities. The need for in-depth analysis informed the decision to limit the study to one professional learning community in one school. Limiting the study to one school also served the purpose of reducing the challenges of establishing a community. Since the teachers already knew each other; had been working in the same subject area for some time; and often met to discuss issues about their subject in the school, some basic elements of a teacher community were already in place, which made it easier to establish a professional learning community.

As a pilot study of the DIPIP project, and in line with the DIPIP model, the goal of the study was to establish and work with one professional learning community of mathematics teachers in one high school for purposes of informing the larger project. The focus of DIPIP is job-embedded teacher learning in school-based professional learning communities of mathematics teachers. A key factor in purposively selecting the school was the Deputy Principal's background and

experiences in DIPIP. The Deputy Principal of the selected school was a mathematics teacher and had participated in Phases 1 and 2 of the DIPIP project. Because of his familiarity with the project, he supported the negotiation of access to the school and the mathematics teachers' consent for participation in the study, as well as the activities of the professional learning community.

Another factor was the support of the school leadership, which has been found to be fundamental for the success of professional learning communities (Katz, et al., 2009). The nature of the intervention in terms of the teachers' time and commitment in relation to other school demands required that the school have a supportive leadership. Having a supportive leadership meant that that time and other infrastructural needs were availed to the professional learning community by the school administrators. The extended nature of the study required that the selected school be functional in terms of stability in teacher retention and supporting teachers in their instructional needs.

A number of schools were visited towards the end of 2009 to assess the suitability of each school and to negotiate access. From those schools one was selected.

3.3.2 The research site

The school in the study is in Gauteng in South Africa just outside Johannesburg. The school is located in a former informal settlement which was upgraded to a formal residential township[2]. The school was newly established and during the year of the study (2010) it had Grades 7 to 11. In 2011 the school had its first class of Grade 12, and it stopped intakes of Grade 7 classes. From then the school had classes from Grades 8 to 12 like most high schools in South Africa starting from 2011. Each grade level had a number of classes, which were not streamed according to ability. The school was classified as no-fee paying and depended on government financing for all its operations. In terms of funding from the government the school was a Section 20 school[3]. The school had a feeding scheme for learners from impoverished home backgrounds.

[2] In South Africa informal settlements are the areas where people build their own makeshift housing structures without the approval of local governments. These settlements have often been upgraded to proper residential townships by building proper houses and providing other infrastructure.
[3] A Section 20 school has a financial budget which is handled by the District Office. The school submits its purchase orders to the District Office.

3.3.3 The research participants

There were eight mathematics teachers in the school, including the deputy principal, but only five chose to participate in the study. The study was originally planned to start in January 2010 and end in November of the same year. Due to a month-long nationwide teachers' strike in August 2010 in South Africa, the duration of the study was extended to March 2011. The five teachers participated in the study until it ended. Table 3.1 below able shows a summary of the five mathematics teachers' biographical data.

Table 3.1: The teachers' biographical data

Characteristic	Tandeka[4]	Mandla	Jeffrey	Janeth	Bongiwe
Prof. Qualification(s)	SPTD	B.Sc. (Hons); ACE	HDE	Dip. Ed. & ACE	Dip. Ed.; ACE & B. Ed. (Hons)
Major teaching subjects	Mathematics, Physical Science	Mathematics, Geography Science, Technology	Mathematics, Physical Sciences, Technology	Mathematics, Physical Science	Mathematics, Physical Science.
Years of teaching	5 years	15 years	5 years	11 years	10 years
Mathematics teaching experience	3 years	10 years	5 years	11 years	10 years

Tandeka holds a Senior Primary Teaching Diploma (SPTD). This was a three-year teaching qualification awarded by former Colleges of Education in South Africa to non-graduate teachers specializing in teaching at Senior Primary School Level. Her major teaching subjects were Mathematics and Physical Science. She has five years teaching experience, three of them in the current school. During the study she was teaching Mathematics and Natural Science to Grade 7 and 8 classes. In 2010 she worked with a Grade 7 mathematics class on the study. The following year when the school ceased enrolling Grade 7 classes she worked with a Grade 8 mathematics class on the study.

Mandla has a Bachelor of Science Honours (B.Sc.) degree with majors in Mathematics and Geography. He also has an Advanced Certificate in Education (ACE) in mathematics. An

[4] Names of teachers are pseudonyms.

Advanced Certificate in Education is a certificate offered by universities to in-service teachers who want to upgrade their qualifications and extend their knowledge and teaching in their area of specialization. He has fifteen years teaching experience, and had been teaching in the current school for three years. In 2010 he was teaching one Grade 8 mathematics class in addition to some geography classes. In 2011 he was teaching geography classes only but he continued to participate in the study.

Jeffrey has a Higher Diploma in Education (HDE), with Mathematics, Physical Science and Technology as his major teaching subjects. Higher Diploma in Education was a four-year teaching qualification offered by some former Colleges of Education in South Africa to non-graduate teachers. He has five years teaching experience and had been in the current school for four years. In 2010 he worked with a Grade 8 mathematics class in the study. In 2011 he worked with a Grade 9 mathematics class.

Janeth holds a Diploma in Education (Dip. Ed.) with specialization in teaching at secondary school level and an Advanced Certificate in Education (ACE) in mathematics. The Diploma in Education was a 3-year teaching qualification awarded to non-graduate secondary school teachers by the former Colleges of Education in South Africa. Her major teaching subjects were Mathematics and Physical Science. She has eleven years teaching experience in a number of secondary schools. She had been in the current school for three years. During the study she was teaching Grades 10 and 11 Mathematical Literacy classes. In 2010 she worked with a Grade 10 class, and in 2011 she worked with a Grade 11 class.

Bongiwe had a Diploma in Education with specialization in teaching at secondary school level. She has an Advanced Certificate in Education in mathematics. Her major teaching subjects were Mathematics and Physical Science. During the study she was studying for a Bachelor of Education Honours degree (B. Ed. Hons), which is a two-year, part-time degree programme for in-service teachers. She has ten years teaching experience and had been in the current school for two years. Bongiwe was the Head of Department (HOD) for Mathematics and Science in the school. In 2010 she worked with a Grade 9 mathematics class in the study. In 2011 she selected a Grade 10 class.

3.4 Ethics and negotiating access

Research involves human beings and may be personally intrusive to the research participants (McMillan & Schumacher, 2006). Qualitative researchers therefore have to observe ethics in the conduct of research. Ethics have to do with the respect for the rights of participants in research. Ethical considerations include informed consent, confidentiality, anonymity, privacy and fairness (McMillan & Schumacher, 2006). In the study these ethical considerations were taken into account in both negotiating access and the conduct of the study.

As part of ensuring the observation of ethics in the study I applied for ethics clearance from the Wits University Ethics Committee, which was approved (Protocol number 2009ECE171) (see Appendix A). The process of negotiating access involved applying to the Gauteng Department of Education (GDE) for approval to conduct the research in the province. The application was approved (see Appendix B). After identifying the research site, meetings were held with the school administrators and mathematics teachers to negotiate access into the school and informed consent to participate in the study. The principal of the school gave her verbal approval and helped set up the meeting with the mathematics teachers. After explaining the study, four teachers out of a possible five agreed to participate in the study, and they completed the teachers' informed consent forms (see Appendix C). The fifth teacher joined the professional learning community after three months and also signed the informed the consent form. One of the initial teachers moved from the school at the end of the first term. The replacement teacher agreed to join the community and she signed the informed consent forms.

For the purposes of the study each teacher was asked to select one class to work with. The learners in the selected classes and their parents or guardians were asked to complete and sign informed consent forms (see Appendices D and E). In the consent form, each learner was asked to give his or her consent to participate in the study; to be interviewed and audio-recorded; and to be video-recorded during mathematics lessons. The parents or guardians were asked to give similar consent for their children. In both the teachers' and learners' consent forms the right of the participants to anonymity was assured and no real names are used in this thesis and any other papers written about the findings of the study. All the learners in the selected classes and their parents signed the informed consent form, indicating their consent to participate and be recorded in the study.

3.5 The Intervention: DIPIP activities in a professional learning community

As indicated previously, the research study reported in this thesis was a pilot to Phase 3 of the Data Informed Practice Improvement Project (DIPIP). DIPIP works with a set of professional learning activities for mathematics teachers in professional learning communities. In the study the professional learning community worked on the DIPIP activities for a period of twelve months, in 2010 and part of 2011. The activities in the professional learning community constitute what I refer to as the intervention. The DIPIP activities are: analyzing learner errors on international tests; mapping mathematics tests onto the South African mathematics curriculum; interviewing learners; identifying leverage mathematics concepts for learners from the error analyses; reading and discussing literature in relation to the identified leverage concepts; and designing, teaching and reflecting on lessons based on the critical concepts (Brodie & Shalem, 2011). A key activity for the DIPIP project is the analysis of learner errors, where learner errors are seen as reasonable and as a normal part of the learning process (Brodie, 2012a). Based on this view of errors, one of the goals of the project is to help teachers to embrace rather than avoid errors in their practice (Brodie, 2011c).

The DIPIP activities are designed to support teachers in identifying learners' learning needs through the error analysis process, which in turn inform their (teachers) own learning needs (Brodie, 2012a; Katz, et al., 2009; Timperley, 2010). Using evidence from classroom data the teachers deepen their own professional knowledge and work with the newly created knowledge to develop new instructional strategies which may improve their learners' learning. The activities of the professional learning communities in DIPIP draw on what Timperley et al. (2007) refer to as the teacher inquiry and knowledge-building cycle (Figure 3.1 below).

The DIPIP activities can be mapped onto the cycle. The entry point into the cycle is the identification of knowledge and skills which students need. In DIPIP this corresponds to testing learners, analyzing learner errors, and interviewing learners to determine the critical concepts for learners. The next two stages in the cycle correspond to the concept development and curriculum mapping activity in DIPIP. In concept development, teachers reflect on their own understanding of the identified critical concepts for the learners.

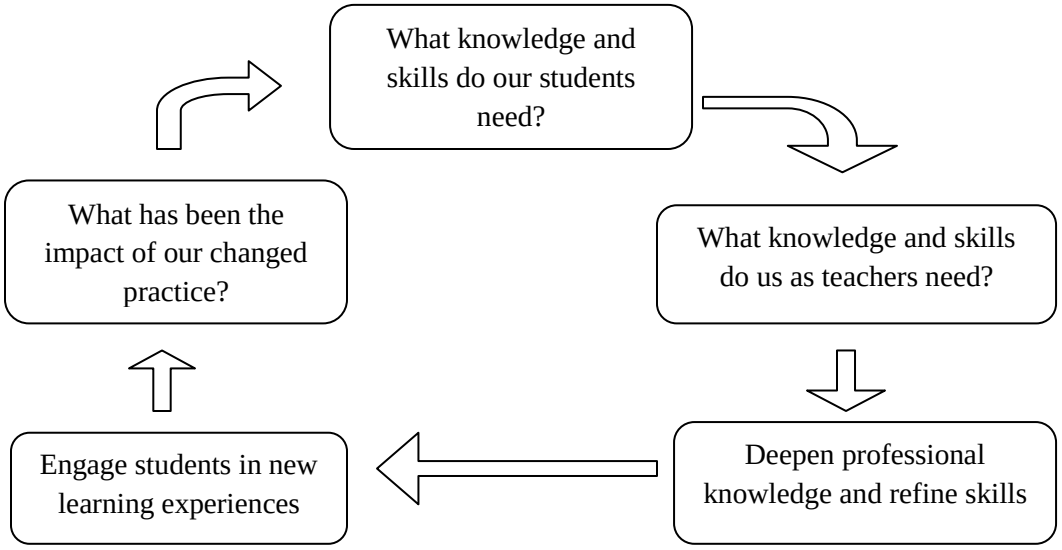


Fig. 3. 1: Teacher inquiry and knowledge-building cycle (Timperley, et al., 2007)

The activity includes reading articles from literature to deepen understanding and planning innovative lessons for addressing learners' learning needs. The next stage of the cycle relates to teaching the jointly planned lessons in DIPIP. The last stage of the cycle corresponds to the joint lesson reflections activity in DIPIP. In lesson reflections the professional learning community reflects on each teacher's lesson to determine the extent to which learners' learning needs were addressed in the lesson. In DIPIP, lesson reflections can lead to the identification of more learners' learning needs which leads to engagement in the cycle again.

3.5.1 The activities of the professional learning community

The professional learning community in this study met for two hours every week during school term time to work on the professional learning activities. Each teacher worked with one class on these activities. Due to the disruption to the professional learning activities caused by the nationwide teachers' strike in 2010[5], the final activity was done the following year in 2011. By then the classes which the teachers were teaching had changed. One teacher, Mandla, had moved to teach only geography classes in 2011. However he continued participating in the meetings of

[5] Details of how the strike affected the activities of the professional learning community and data collection and activities of the professional learning community are presented in the data collection section below.

the professional learning community. Table 3.2 below shows the class which each teacher worked with on the professional learning activities.

Table 3.2: Classes which the teachers worked with in the study

Teacher	Class in 2010	Class in 2011
Tandeka	Grade 7	Grade 8
Jeffrey	Grade 7	Grade 9
Mandla	Grade 8	None
Bongiwe	Grade 9	Grade 10
Janeth	Grade 10	Grade 11

Test construction and testing learners

The first activity was designing tests and testing learners. The use of teacher designed tests was a departure from the previous DIPIP approach of working with an international standardized test. Since the learners to be tested were in Grades 7 to 10, the professional learning community decided to set two tests, one for Grades 7 and 8 and the other for Grades 9 and 10. Designing the tests was done in one meeting. Each teacher brought ten test items to the meeting and from the pool of test items the two tests were compiled. Inadvertently all the teachers brought test items on Learning Outcome 1 (LO1): Number, Operations and Relationships[6]. This could be attributed to the fact that since this was early in the first school term of the year the teachers were teaching topics in LO1. Thus both tests tested learners on this LO1 only (see Appendices H and I). Learners in the selected classes then wrote the tests and each teacher marked the test scripts for his or her own class. Each teacher then summarized the errors made by the learners in his or her class on each test item. The summaries were made on an error capturing template (see Appendix J). On the template each teacher included the names and total numbers of learners who made particular errors. Capturing errors on the template was the first step in analyzing the learners' errors and the activity provided each teacher with an opportunity to have an initial picture of the range and scale of errors which his or her learners made on the test. Marking of the test scripts and capturing errors were done simultaneously with another activity, the curriculum mapping activity.

[6] The then South African mathematics curriculum had five Learning Outcomes: Number, Operations and Relationships; Patterns, Functions and Algebra; Space and Shape; Measurement; and Data Handling (Department of Education, 2002).

Curriculum mapping

The curriculum mapping activity was done in three two-hour meetings. The activity involved mapping the two tests onto the South African mathematics curriculum. A curriculum mapping template was used for this activity (see Appendix K). The purpose of the curriculum mapping activity was to examine the extent to which the test items matched the mathematics curriculum. The activity was also an opportunity for the teachers to deepen their understanding of the mathematics curriculum and how they assess it. For each test item in the tests the process involved: identifying the assessment standard(s) in the National Curriculum Statements (NCS) (Department of Education, 2002) which matched the test item; the mathematical concepts and knowledge which was required to answer the item; justifying matching the test item to the assessment standard(s); and identifying when the content in the test item is taught; and to what other mathematical and non-mathematical areas the test item is linked. Curriculum mapping was a circular process which involved forward and backward movement between the test items and the NCS (Brodie, et al., 2008). The activity provided the teachers with the opportunity to talk about, understand, and criticize the NCS, and to reflect on their own assessment practices and how these align with the curriculum.

Constructing data walls

The next activity was to design data walls (Cruz, 2009) from the summaries of learner errors from the different classes. The data walls were charts on which summaries of the learners' errors on each test item were made. Two data walls were made, one for the Grades 7 and 8 learner errors and the other for the Grades 9 and 10 learner errors. In making the data walls the professional learning community decided to include only the test items on which more than forty percent of learners in each class had made errors. This was a decision made for purposes of working with manageable data and focusing on more common errors. The professional learning community was aware that such a decision led to the loss of some less frequent and potentially interesting errors. Each data wall showed, against each test item, the correct response; the percentage of learners in each grade who had got the test item wrong; the errors made on the test item; and names of learners who made the error. The community agreed to include only errors which they deemed to be common in the data wall. Common errors were those errors made by a

number of learners across the classes who wrote the test; although in some cases some non-common but interesting errors were also included. Interesting errors were made by at least two learners and were 'puzzling' to the teachers, hence the interest in finding out the learners' reasoning behind such errors. Limiting the types of errors recorded on the data walls enabled capturing manageable data which the community worked with in analyzing the errors. The purposes of the data walls were to expedite the error analysis process without having to resort to the actual test scripts, and to facilitate the identification of common errors and patterns of errors across the different grades. The activity created an artefact from which patterns of learner errors could be identified more easily, hence facilitating the identification of critical mathematical concepts for the learners. Two meetings were held on the activity of constructing data walls.

Error analysis

Four two-hour meetings were held on the error analysis activity. Error analysis was done using the data walls, thus the focus was only on the test items and errors which had been captured on each data wall. The process involved: describing the mathematical content in each test item; analyzing the different solution strategies which learners could use to get the correct answer; analyzing the learners' thinking and reasoning in making each error; and identifying possible mathematical concepts which were linked to the error, which were referred to as critical concepts. Critical concepts were those mathematical concepts whose mastery was essential for learners to answer particular test item correctly.

The error analysis process was guided by an error analysis template (see Appendix L). In the activity, describing the mathematical content of a test item and analyzing the possible solution strategies created opportunities for the teachers to deepen their understanding of the mathematics in each test item. Analyzing the actual learner errors involved conversations about the thinking and reasoning that could have led to the error. Explaining the learners' thinking behind the observed errors created opportunities for the teachers to see errors as reasonable and as a result of some reasoning on the part of the learners. The process also created opportunities for deepening the teachers' knowledge of mathematics and accounting for learner errors (Brodie, 2012a).

Analyzing learner errors was complemented by learner interviews. Each teacher interviewed some learners in his or her class about those errors which the professional learning community felt they needed more information on. Learner interviews have been found to be an important pedagogical tool for teachers' understanding of their learners' capabilities (Higgins & Parsons, 2009). In interviewing the learners the teachers used a learner interview protocol (see Appendix M). In preparing and guiding the teachers in conducting the interviews the protocol was discussed and I conducted the first few interviews in the presence of the teachers. It was emphasised that the idea was to find out what the learners were thinking rather than to teach the learners.

Concept identification

Two meetings were held on this activity of identifying major critical concepts, or 'high leverage concepts' from the analysis of errors on both tests. High leverage concepts are those mathematical concepts which have an effect across a number of other mathematical topics in the curriculum (Brodie, 2012a). Identifying the critical mathematical concepts involved discussing linkages among the critical concepts linked to specific test items which were identified during the error analysis process. It also involved categorizing test items according to the mathematical concepts involved, thereby bringing together errors made on similar test items and the critical concepts on these test items. Such categorization helped to identify patterns in learners' thinking on similar test items, and hence the identification of high leverage concepts. The conversations about the connections among the critical concepts created opportunities for the teachers to deepen their understanding of links among mathematical concepts. From the error analysis the professional learning community identified six mathematical high leverage concepts across the two tests. For each high leverage concept the specific learners' learning needs were identified. Table 3.3 summarizes the high leverage concepts that were identified.

Table 3.3: List of high leverage concepts that were identified

Concept	Specific learning needs related to the concept
Ratios	• Meaning of a ratio • Meaning of the algorithm for dividing a quantity in a given ratio
Equivalent forms of rational numbers	• Connections among common fractions, decimals and percentages • Meaning of algorithms for expressing one number in another equivalent form • Recurring decimals
Order of Operations	• Simplification of multi-operations numerical expressions that do not involve brackets • Meaning of BODMAS
Place Value	• Place value of digits in a number, especially decimal numbers • Ordering numbers that involve decimals
Directed Numbers or Integers	• Meaning of negative integers as stand-alone numbers • Difference between the minus sign as used in negative numbers and the operational meaning of the minus sign
Indices	• Meaning of terms of the form a^x

Concept development cycle 1

The activity of concept development involved selecting two concepts on which to design lessons, teach the lessons and reflect on the lessons. Having identified the high leverage concepts for the learners, the professional learning community selected two concepts to work on in the next activity. The concept of 'Rational Numbers' was selected for Grades 7 and 8. For Grades 9 and 10 'Ratios' was selected. Concept development involved reading and discussing some research articles, and other literature, on learners' learning of the selected concepts. For both concepts Chapters 1 and 3 in Lamon (1999) were read and discussed. Two research articles were also read. The first one was Mazzocco and Devlin's (2008) study on children's rational number sense. The other one was Steinthorsdottir and Sriraman's (2009) study of fifth grade learners' development of proportional reasoning in Iceland. The readings were given to the teachers a week before discussion. The readings were opportunities for the teachers develop deeper understanding of the two concepts and the challenges which learners face in learning the concepts in other countries. Reading and discussing the readings was guided by a set of questions which helped to focus on the key issues related to the mathematical concepts (see Appendix N). The information from the readings was used in planning lessons for teaching the concepts.

The lesson planning conversations were guided by a protocol which was referred to as an action plan (see Appendix O). The process involved agreeing on the plan of action adapted from Buffett, Teoh and Martinezs' (2008), in which the following questions were to be answered:

- What is the unit of improvement?
- What are the goals of the action plan?
- What are the strategies to be used?
- What will the plan look like in the classroom?
- What is the theory behind the proposed teaching strategies?
- How do we assess progress?

In the plan the unit of improvement was the mathematical concept to be taught, which was the critical concept identified during the error analysis activity. For Grades 9 and 10 the unit of improvement was ratio, and for Grades 7 and 8 the unit of improvement was rational numbers. The goals of the action plan articulated what was to be learnt by the learners for each of the identified mathematical concepts. In both cases emphasis was on the conceptual meanings of each concept and the meanings of the algorithms associated with each concept. Strategies to be used referred to the instructional strategies and mathematical tasks which were to be used in teaching the lesson. What the plan would look like in the classroom referred to the community's vision of how the strategies would be enacted in the instructional situation. The theory referred to a theoretical justification for implementing the plan as agreed. In this case the agreed theory was that increasing the learners' participation by engaging them in discussing mathematical ideas in groups was likely to improve learning. A possible teaching approach that was suggested and discussed was involving learners in discussing mathematical tasks in groups and then reporting their solutions in whole-class discussions. The idea was to select appropriate mathematical tasks that would support learners' conceptual understanding of rational numbers and ratio respectively. Learners would discuss these tasks initially in small groups and later in whole-class discussions. Discussing this teaching strategy in the professional learning community involved extended conversations in which teachers' assumptions about learners' abilities to work without the teacher were challenged. Some extracts from these conversations are presented in Chapter 6,

Section 6.2.1. This strategy was suggested for implementation in teaching the jointly planned lessons. Sample tasks which the teachers could use were discussed, but the choice of tasks for use in the lessons was left to individual teachers. The last question referred to identifying strategies for monitoring progress during the teaching of the lessons. This question was meant to plan for reflecting on the lessons and referred to how to determine the extent to which the goals of the lessons were achieved. Appendix O outlines the ideas that were agreed upon during the PLC conversations.

Once this plan was agreed, a lesson plan was developed using the lesson planning protocol that was being used in the school (see Appendix P). Two meetings were held on the lesson planning. The structure of the actual lesson plans followed the school's lesson planning template Appendices Q and R.

Each teacher taught the planned lesson to his or her grade. According to the plan each teacher was supposed to teach at least three lessons in order to cover the goals and content for each concept. However it was possible to video-record only one double lesson for each teacher due to the teachers' strike which took place at this point in the activities of the professional learning community.

As part of the first cycle of concept development the next activity was joint reflection on the video-recorded lessons taught by the teachers. Each teacher's lesson was played back and discussed. The reflection process involved analyzing the extent to which each lesson had achieved the set goals and the learners' response to the instructional strategies used in the lesson. The process was guided by a template (see Appendix U). Conversations in the lesson reflection activity provided the teachers with opportunities to observe and talk about each others' teaching. Such deprivatisation of practice is considered supportive of reflection on practice and teacher learning in community (e.g. Andrews & Lewis, 2002). Three meetings were held on this activity. From the reflections, aspects of both concepts which the community felt had not been covered or had not been understood by learners formed the focus of the next activity.

Concept development cycle 2

The second cycle of concept development involved re-planning the lesson taught in cycle 1 using information from the community reflection on each teacher's teaching of cycle 1 lesson. Cycle 2

of the concept development activity was done in the first two months of 2011 due to the disruption caused by the teachers' strike in 2010. In re-planning the lesson the community agreed on using common worksheets with tasks which covered what was felt the learners still needed to learn with respect to each concept (see Appendices S and T). Each teacher then taught one double lesson using the relevant worksheet. The lessons were video-recorded. Two meetings were then held on reflecting on these lessons. Reflecting on the lessons involved asking the same questions as in the first cycle of lesson reflections.

3.5.2 Schedule of the activities and the teachers' strike

Initially the intervention and data collection were intended to last a period of at most eleven months from January 2010 to November 2010. Data collection commenced in January 2010 and ended in February 2011 at the end of the intervention. The extension into 2011 was necessitated by a month-long nationwide teachers' strike in August 2010. The strike started during the second week of August and ended at the beginning of the second week of September. During the strike no classes were held at the school and teachers were not available for after school activities and so the activities of the professional learning community were halted throughout that period. The disruption affected the concept development cycle 1 and the subsequent activities. When the strike started cycle 1 lesson planning had been completed and the teachers were about to start teaching the jointly-planned lesson. The lessons were taught when the strike ended. Another effect of the strike was the pressure it created on the teachers and the professional learning community when the strike ended. The teachers were facing pressure to catch up with the school's schedule of events such as completing the year's teaching and setting internal examinations. The remaining professional learning activities had to be rushed in order to make up for the lost time. Thus only one double lesson of each of concept development cycles 1 and 2 planned lessons were taught and video-recorded for each teacher. Details of each data set and how the data was collected are presented in the following sections.

3.5.3 The researcher's role in the intervention

In the research study I assumed two roles. My first role in the intervention was that of a 'critical friend' (Katz, Sutherland, & Earl, 2005). In this role I facilitated the planning and

implementation of the activities of the professional learning community. As a critical friend I participated in the meetings by setting up the goals of each meeting; guiding the conversations; providing insights and stimulating reflections on concepts and issues being discussed; and summarizing collectively developed meanings and decisions for purposes of the following activities (Katz, et al., 2009). A key feature in my facilitation role was to support the teachers' engagement with data from their classrooms in ways which distantiated them from their classrooms (Shalem & Brodie, 2007). Distantiation meant that the teachers had to engage with data about their learners' errors critically and objectively for meaningful analysis and collective construction of meanings from the analysis. According to Katz, et al. (2005) distantiation occurs through an expert, or critical friend, who visits the school regularly to work with the teachers in collecting, analyzing and interpreting data. As a 'critical friend' my role involved observing what the teachers, as insiders, failed to notice as worthy for discussing and reflecting on. My role also involved challenging assumptions and knowledge, explaining complex data when necessary, probing for justification and evidence to support claims and perceptions, helping in formulation of interpretations, and monitoring progress (Katz, et al., 2005).

My second role was that of a researcher as a participant observer for data gathering purposes. According to Hatch (2002), in qualitative research the researcher is positioned as a data gathering instrument. This feature of qualitative research enables the direct collection of data from the research context. As a participant observer I actively participated in the activities of the professional learning communities while collecting data at the same time (Opie, 2004). While assuming the role of participant observer can introduce a level of bias (Opie, 2004), such a role afforded me opportunities to observe and make sense of the actions, decisions, intentions and understandings of the participants. My role as a participant observer enabled me to identify and analyze some aspects of the teachers' participation in the professional learning community which could not be captured by the formal data collection strategies used in the study.

3.6 Data and data collection procedures

In this study a variety of data collection strategies were used. This is consistent with case study research which allows the researcher to use multiple methods of data collection from a variety of sources (Bassey, 1999; Denscombe, 2007; Yin, 1994). Using multiple methods for data

collection implies the use of a variety of research instruments. The methods and instruments should enable the researcher to gather sufficient data to address the research questions. The data collected should enable the researcher to "explore *significant* features of the case, create *plausible* interpretations of what is found, test the trustworthiness of these interpretations, construct a *worthwhile* argument,…convey *convincingly* to an audience this argument, provide an audit trail by which other researchers may validate or challenge the findings or construct alternative arguments" (Bassey, 1999, p. 65). The data collection strategies and instruments in this study included semi-structured interviews, video-recordings, audio-recordings, researcher journal entries, and artefacts produced and used during the professional learning activities. The use of multiple sources of data, or data triangulation (Yin, 1994), helped me in analyzing and generating findings about the teachers' learning in the community and shifts in their teaching practices and identities. The use of multiple sources of evidence, or the "development of *converging lines of inquiry*" (Yin, 1994, p. 92) served as a source of validity for the claims made about various aspects of teacher learning in a professional learning community. Details of the data collection process and strategies are described in the following sections.

3.6.1 Teacher interviews

Two types of teacher interviews were used in the study; individual teacher interviews and focus group interviews. For both types of interviews semi-structured interview schedules were used (see Appendices F and G). All the interviews were audio-recorded and later transcribed for analysis. Semi-structured interviews are open-ended but are fairly specific in intent (McMillan & Schumacher, 2006). The use of semi-structured interview schedules helped me to maintain the focus of each interview and at the same time allowing the teachers the flexibility to provide alternative and detailed responses to the questions (Opie, 2004).

In the individual teacher interviews each teacher was interviewed separately before and after the intervention. Before the intervention the purpose of the interview was to get to know the teachers individually, as well as collect their biographical data and data about their histories as teachers. In these interviews the teachers were asked about their professional qualifications, mathematics teaching experience, how they perceived themselves as teachers, their views about learner errors, and how they collaborated with other teachers in the department. After the intervention the

purpose of the individual teacher interviews was to collect data about each teacher's views about his or her participation and learning in the professional learning community. The interviews were also intended for seeing shifts in teacher identities and the teachers' views on learner errors.

Two focus group interviews were conducted during the intervention period. The interviews involved engaging all the teachers in discussing their experiences of participating as a community at different stages of the intervention. I moderated the discussions by using the focus group interview protocol. The first focus group interview was conducted after the error analysis activity. The purpose of the interview was to get the teachers' reflections on the activities of curriculum mapping and error analysis, and on their experiences of collaborating together in these activities. The second focus group interview was conducted at the end of the intervention. The purpose of the interview was to collect data about the teachers' reflections on the two cycles of the concept development activity, about their experiences of the whole intervention, and the sustainability of the professional learning community.

3.6.2 Lesson observations

Video-recorded lesson observations were conducted for each teacher prior to the intervention, during and after the intervention. Table 3.4 below shows details of the lessons which were video-recorded and later analyzed for each teacher. The purpose of the video-recorded lessons was to collect data about each teacher's teaching practices before, during and after the intervention. The lessons which the teachers taught as part of the concept development activity were video-recorded both for the purposes of the professional learning community and for research purposes.

The professional learning community reflected on each lesson taught by the teachers during the concept development activity. The purpose was to analyze how the lesson was conducted and the extent to which learners' difficulties in their learning of the critical mathematical concept were addressed. Observations from the lesson reflections informed the professional learning community's next activity.

For research purposes the lessons were analyzed for shifts in the teachers' teaching when compared to their teaching before the intervention and after the intervention. For one teacher, Mandla, no video-recording of his teaching was done during cycle 2 of the concept development activity and after the intervention since he was no longer teaching mathematics.

Table 3.4 Summary of video-recorded lessons

Teacher	Stage of the Research	Lesson and Topic	Class
Bongiwe	Pre-Intervention	L1: Ratio and Proportion	Grade 9A
		L2: Profit and Loss	Grade 9A
		L3: Profit and Loss	Grade 9A
	During Intervention	L1: Ratio	Grade 9A
		L2: Ratio (re-planned)	Grade 10B
	Post-Intervention	L1: Direct proportion	Grade 10B
		L2: Graphs	Grade 10B
Janeth	Pre-Intervention	L1: Percentage Increase and Decrease	Grade 10F
		L2: Loans	Grade 10F
		L3: Compound Interest	Grade 10F
	During Intervention	L1:Ratio	Grade 10F
		L2: Ratio (re-planned)	Grade 11B
	Post-Intervention	L1: Ratio	Grade 11B
		L2: Rational Numbers	Grade 11B
Jeffrey	Pre-Intervention	L1: Square Root	Grade 7D
		L2: Square Roots and Cube Roots	Grade 7D
	During Intervention	L1: Equivalent Fractions	Grade 7D
		L2: Equivalent Fractions (re-planned)	Grade 9A
	Post-Intervention	L1: Area and Perimeter of Rectangles	Grade 9A
		L2: Data Handling- Pie Charts	Grade 9A
		L3: Angles	Grade 9A
		L4: Functions and Graphs	Grade 9A
Tandeka	Pre-Intervention	L1: Angles	Grade 7A
		L2: Angles	Grade 7A
	During Intervention	L1: Equivalent Fractions	Grade 7A
		L2: Equivalent Fractions (re-planned)	Grade 8A
	Post-Intervention	L1: Perimeter and Area of Rectangles	Grade 8A
		L2: Triangles	Grade 8A

Although he was video-recorded before he joined the intervention and he taught the jointly planned lesson during cycle 1 of the concept development activity, the data was considered incomplete to analyze for shifts in his teaching practice. Hence only the video-recorded lessons for the other four teachers constituted the data which was analyzed for shifts in the teachers' teaching practices.

3.6.3 Audio-recorded professional learning community meetings

All the meetings of the professional learning community were audio-recorded as part of data collection for the study. Table 3.5 below summarizes the meetings of the professional learning community which were audio-recorded and later analyzed.

Table 3.5: List of audio-recorded meetings of the professional learning community

Nature of meeting	Number of meetings
Test Construction	1 session
Curriculum Mapping	3 sessions
Constructing Data walls	2 sessions
Error Analysis (including learner interviews)	4 sessions
Concept Identification	2 sessions
Lesson Planning 1	3 sessions
Lesson Reflections 1	3 sessions
Lesson Planning 2	1 session
Lesson Reflections 2	2 sessions
Total	**21 sessions**

The purpose of the audio-recording was to collect data about the substance of the conversations in relation to the goals of each activity, including the teachers' development of new understandings about their professional practice and their participation in the professional learning community.

3.6.4 Researcher's field notes

As part of the data collection process I made field notes on all the meetings. I made the notes in a journal of the research activities throughout the data collection process. Specifically I made notes on each meeting with respect to such issues as: the focus of the meeting; the achievements of the meeting; the teachers' attendance and how the individual teachers participated during each meeting. The notes helped me to record what could not be captured on audio, such as the teachers' behavioural expressions of their participation in the community. During video-recording of lessons I made field notes on the lessons as a way of gathering as much data as possible about each lesson. The field notes complemented the other data during the analysis.

3.7 Data analysis

Analyzing the data required the use of qualitative data analysis techniques. Unlike in quantitative data analysis, in qualitative analysis there are often no clearly laid down procedures for

analyzing data (Hatch, 2002; Hitchcock & Hughes, 1995; McMillan & Schumacher, 2006; Yin, 1994). The complexity of analyzing qualitative data is compounded by the form of the data which is mostly transcripts of conversations, interviews or descriptions of objects, events or processes. Making sense of such data is the challenge of qualitative data analysis. Qualitative data analysis is a process which involves categorizing data and identifying relationships (McMillan & Schumacher, 2006), looking for patterns, themes, consistencies and exceptions in the data (Hatch, 2002; Hitchcock & Hughes, 1995). It is also described as a process of "examining, categorizing, tabulating, or otherwise recombining the evidence to address the initial propositions of a study" (Yin, 1994, p. 102) and involves noticing, collecting and thinking about interesting things (Seidel, 1998). These descriptions highlight the complexity of analyzing qualitative data in order to derive meanings that can be used to answer research questions.

The first data set to be analyzed was the teachers' video-recorded lessons. The data were analyzed for shifts in the teachers' teaching practices by comparing their teaching before the intervention to their teaching during and after the intervention. The second data set, which was analyzed for shifts in the teachers' identities, were transcripts of individual and focus group interviews; field notes of my observations of the teachers' participation in the professional learning community; and selected transcripts of the teachers' comments during the professional learning community meetings, especially the teachers' descriptions of themselves during the lesson reflection activities. In order to account for the observed shifts in the teachers' teaching practices and identities, I then selected and transcribed episodes in the audio-recordings of the professional learning community meetings which were connected to the observed shifts. I also selected and transcribed episodes in the meetings which indicated features of the professional learning community that supported the teachers' participation and learning.

3.7.1 Analyzing teaching practices

Analyzing the teachers' lessons for shifts in teaching practice was done using the Mathematical Quality of Instruction (MQI) coding tool (Hill, 2010) (see Appendix V).

Table 3.6: Summary of MQI dimensions used in the study

Dimension	Sub-dimensions	Description
Mode of Instruction	Direct Instruction	Teacher controls and dominates content delivery; high amount of teacher talk
	Whole Class Discussion	Teacher has students discussing, explaining, sharing thinking and commenting on each others' ideas
Richness of the Mathematics	Linking or Connections	Teacher's or students' linking or connecting mathematical ideas or procedures
	Explanations	Teacher's or students' explanations that explain why a procedure works, why a solution makes sense, or why an answer is correct
	Multiple Procedures or Solution Methods	Using multiple solution strategies for a single problem or problem types
	Developing Mathematical Generalisations	Teacher and/or students develop mathematical generalisations from instances or examples
	Mathematical Language	Teacher uses, and supports students' use of, correct technical language and explicit mathematical terminology
	Overall Richness of the Mathematics	The depth of the mathematics offered to students, which t is not an average of the above
Working with Students and Mathematics	Thorough Remediation of Student Errors and Difficulties	Instances in which students' errors and misconceptions are substantially addressed
	Responding to Students' Mathematical Productions in Instruction	How the teacher understands and responds to students' new mathematical thoughts
	Overall Working with Students and Mathematics	Overall teachers' interactions with students around the mathematical content, which is not an average of the above
Errors and Imprecision	Major Mathematical Errors or Serious Mathematical Oversights	Teacher errors that include incorrect solution procedures, incorrect definitions of terms, serious omissions of key ideas
	Imprecision in Language or Notation	Teacher errors in mathematical notation, in mathematical language, or in general language
	Lack of Clarity	Unclear teacher utterances: mathematical point is distorted, muddled of confusing; neglecting key points in a solution
	Overall Errors and Imprecision	An overall estimate of teacher errors and imprecision
Student Participation in Meaning-Making and Reasoning	Students Provide Explanations	Students' explanations that include why a procedure works, the meaning of an answer, why a solution procedure is better
	Students' Mathematical Questioning and Reasoning	Students: ask questions that include why; justify solution procedures; make counter-claims ; make generalisations;
	Enacted Task Cognitive Activation	How the demands of mathematical tasks are enacted in instruction
	Overall Students' Participation in Meaning-Making and Reasoning	Overall students involvement in meaning-making and reasoning

The MQI was originally developed to measure the quality of mathematics teachers' instruction for purposes of finding correlations with teachers' mathematics knowledge for teaching (Hill, et al., 2008). Table 3.6 above summarises the MQI dimensions and sub-dimensions that I used in analysing the teachers' teaching. Mathematical quality of instruction refers to "a composite of several dimensions that characterize the rigor and richness of the mathematics lesson, including the presence or absence of mathematical errors, mathematical explanation and justification, mathematical representation, and related observables" (Hill, et al., 2008, p. 431).

The coding tool was found to be suitable for analyzing the teachers' teaching because it covers key dimensions of mathematics lessons which put together provide a comprehensive way of looking at the quality of mathematics teaching. By coding the teachers' lessons before, during and after the intervention, the tool enabled a comparative analysis of shifts in the teachers' teaching practices. The tool was originally intended for use with large samples. I used it with a small sample and so all claims that I make are supplemented with qualitative analyses of the coded practices.

The dimensions of the MQI which were used in analyzing the teachers' lessons are: Mode of Instruction; Richness of Mathematics; Working with Students and Mathematics; Errors and Imprecision; and Student Participation in Meaning-Making and Reasoning. Each dimension has sub-dimensions. Each lesson was coded in 10-minute segments, which I refer to as episodes in my analyses. Coding each sub-dimension was done by judging the extent to which each activity or phenomenon was observed in a ten-minute interval, and using the codes 'Low or None' (1); 'Mid' or Some' (2); and 'High or Most' '3' (see Appendix V). In my coding of the lessons I used the codes 'Low'; 'Mid' and 'High' for purposes of clarity and consistency. Inter-rater reliability was established through coding of the same lessons by colleagues participating in the DIPIP project.[7] For purposes of analysing shifts in the teachers' teaching, each teacher's lessons were put into three categories: Pre-Intervention; During Intervention; Post-Intervention. Details of the analyses are presented in Chapter 4.

[7] Details of establishing reliability are given in Section 3.8 below

3.7.2 Analyzing teacher identity

In analyzing data on the teachers identities I adopted the view of qualitative data analysis as a "systematic process of coding, categorizing, and interpreting data to provide explanations of a single phenomenon of interest" (McMillan & Schumacher, 2006, p. 364). Such a process is inductive in that pieces of evidence lead to a meaningful whole (Hatch, 2002; McMillan & Schumacher, 2006; Miles & Huberman, 1994). The data which was analyzed for shifts in the teachers' identities consisted of transcripts of individual and focus group interviews. I also used field notes to analyze for other aspects of teacher identity such as participation and relating with others in the community.

In analyzing the teachers' identities I drew from Wenger's (1998) view of identity as dynamic and in a state of formation and reformation. Participation and learning in the professional learning community created opportunities for the teachers to develop understandings of themselves as members of a community. To study the identities in such a context I used Wenger's (1998) conception of identity as modes of belonging to communities of practice: imagination, engagement and alignment. The three modes of belonging were found to be appropriate for developing criteria for analyzing shifts in the teachers' identities.

Imagination "refers to a process of expanding our self by transcending our time and space and creating new images of the world and ourselves" (Wenger, 1998, p. 176). Imagination is the formation of images of the world; the past and the future; the possibilities; and our selves through participation in communities of practice. In the study imagination was used to refer to the teachers' images of themselves; the past and future possibilities of the professional learning community; and their relations with others in the community. From this understanding of imagination I drew up the following as criteria for analyzing teacher identity shifts: professional roles in the school; perceptions of self within the school community; perceptions of merits of the professional learning community, both immediate and in the future; perceived roles within the professional learning community; and visions of the future of the professional learning community. In brief, the criteria captured the extent to which the teachers imagined their participation in the professional learning community as a learning trajectory extending from the

histories of their teaching experiences into the future, and how they imagined themselves in that trajectory.

Engagement involves "the ongoing negotiation of meanings; the formation of trajectories and the unfolding of histories of practice" (Wenger, 1998, p. 174). In this study engagement referred to the process of joint negotiation of new meanings about the teachers' professional practice. Through such engagement the teachers developed new understandings of both their professional knowledge and themselves. Engagement is "a mode of belonging and a source of identity" (Wenger, 1998, p. 174). From this view of engagement as a fundamental component of identity, I drew up the following as criteria for analyzing teacher identity before and after the intervention: ways of engaging with other mathematics teachers and learners; perceptions of other teachers and learners; and relationships, both social and professional, with other teachers. The criteria were meant to capture shifts in how the teachers engaged with other teachers and learners through participation in the professional learning community, and how the developing relationships with others supported the engagement.

Alignment is the process of "coordinating our energy and activities in order to fit within broader structures and contribute to broader enterprises" (Wenger, 1998, p. 174) It involves the "discourses; coordinated enterprises; and compliance" that shape our ways of belonging within communities of practice. In the study alignment referred to how the teachers related to and acted upon their experiences of the activities of the professional learning community. It is a way of looking at how the teachers saw the goals, activities and achievements of the professional learning activities as part of their practice. The criteria for purposes of analysis which I developed focused on: perceptions of learning in the community and how the teachers saw that learning as part of their professional practice; emphasis on collaboration as part of the teachers' professional work; and views of changed practice.

The criteria developed from each of the three modes of belonging were captured into a data analysis framework for analyzing shifts in the teachers' identities. Table 3.6 below shows the framework. The coding process was done using the data analysis software ATLAS Ti. Inter-rater reliability was established through coding of the same interview transcripts by four other

doctoral students who were also analyzing identity[8]. Once the coding reliability was established I then coded all the data and generated tables summarizing the coding results. In analysing shifts in each teacher's identity I compared coding of the teacher's description of himself/herself before the intervention to the coding of his/her comments about himself/herself during and after the intervention.

Table 3.7: Mathematics teacher identity analysis framework

Identity	Sources of identity	Codes	
Identity as Self-in-Community	**Imagination**	Perceived roles	(Ir)
		Self-perceptions	(Isp)
		Perceived benefits of community	(Icb)
		Vision of community	(Icv)
	Engagement	Moral responsibility	(Emr)
		Ways of engaging with other teachers	(Ewt)
		Ways of engagement with learners	(Ewl)
		Relations with others	(Ecr)
	Alignment	Learning in community	(Acl)
		Identification with community practices	(Acp)
		Achievements of community	(Aca)

Although the unit of analysis at this stage was the individual teacher, the goal of the analysis was to draw conclusions about the group in terms of how teacher participation in the professional learning community influenced and was influenced by teacher identity. Thus using the individual as the unit of analysis enabled was a way of making conclusions about the collective. These results of the analyses are presented in Chapter 5.

3.7.3 Analyzing opportunities for teacher learning

The view of teacher learning adopted in the study was from a situated learning perspective (Lave, 1993). I discussed this view of teacher learning in detail in Chapter 2. Three key principles which underpin teacher learning from a situated perspective are: learning as participation; learning as social in nature; and learning as necessary for teachers to develop

[8] Details of establishing the reliability are presented under Rigour below

professionally. These ideas highlight the characteristics of teacher learning in a community. Through active participation with others the teachers collaboratively develop new meanings about their professional knowledge. Analyzing teacher learning in a professional learning community thus entails attention to what new knowledge is developed; how such knowledge is negotiated; and what supports the development of new meanings.

In analyzing teacher learning, I used the term 'opportunities for teacher learning' rather than 'teacher learning'. The distinction between the two is important as they have different implications for claims which can be made from the analysis. The opportunities for learning which arose in the conversations were distinguishable in terms of focus on a particular domain of the teachers' professional knowledge. I use the term opportunities for learning to refer to instances in which there was substantive collaborative discussion of particular forms of teacher knowledge in the conversations of the professional learning community. In my analysis I regarded an opportunity for learning as a complete focused conversation in which there was deep and extended engagement with the teachers' understandings of the topic under discussion. An example of an opportunity for learning is when teachers talked about or analyzed the learners' thinking in error analysis. In those conversations the teachers grappled with trying to understand why particular learners made a particular pattern of errors on a test item, and what mathematics the learners were working with in making the error. In those conversations the teachers had opportunities for deepening their understanding of why learners make errors and view learner errors as reasoned and reasonable (Brodie, 2012a). The challenge in my analysis was to ascertain whether the teachers had indeed developed such an understanding of learner errors. This was not always possible from the data, hence the use of 'opportunities for learning' rather than 'teacher learning'.

The unit of analysis for the opportunities for learning was the group rather than the individual (Borko, 2004), which is consistent with the situated learning theory adopted for the study. Rather than addressing the question of what each teacher learnt, focusing on the group as the unit of analysis enabled determination of what Brodie (2011c) regards as key features of learning in a professional learning community, namely: "professional learning" that takes place "within the context of a cohesive group" and "focuses on collective knowledge" (p. 26). In my analysis the focus was on what professional knowledge was collectively developed in the professional

learning community, hence the use of the group as the unit of analysis. The domains of knowledge which were evident in the opportunities for learning included subject content knowledge, pedagogical content knowledge and knowledge of the curriculum (Shulman, 1986). Opportunities for learning needed to have clearly identifiable mathematical foci which were linked to teachers' professional knowledge. Examples of such foci are: mathematics subject content knowledge; mathematics instructional practice or pedagogy; learners' mathematical thinking; and teachers' assumptions about mathematics teaching and/or learning.

In the selection and analysis of the opportunities for learning I focused on the distinguishing features of each conversation in terms of the content of each conversation, a process referred to as content analysis (Kondracki, Wellman, & Amundson, 2002). Content analysis is a process which involves "organization of communication content in a manner that allows for easy identification, indexing, or retrieval of content relevant to research questions" (Kondracki, et al., 2002, p. 224). The components of the content include words, phases, topics, concepts or theories, which, once identified, may be analyzed qualitatively or quantitatively. According to the same authors qualitative content analysis involves examination of the "*latent* or inferred meanings of the communication under study", which allows for drawing of conclusions about "such factors as the presence or absence of particular ideas, theories, or biases; the extent of coverage of specified topics; contradictions or myths" (p. 224). In my selection and analysis of conversation episodes which constituted opportunities for learning, my focus was on: the mathematical knowledge involved; the depth of discussion; and how the developed meanings were likely to result in deepened understanding by the teachers. The conversations had to show possibilities for deepening understanding through collective questioning and reflection on knowledge or practice. Such possibilities could be identified through comments such as 'I have learnt this today'. Analyzing for deepening of understanding meant paying attention to the substance of the conversation which each opportunity for learning provided in terms of manifestation of initial teacher understanding and the subsequent negotiation of deeper understanding.

Another focus of my analysis was connecting the opportunities for learning to the teachers' teaching practices and ways of talking about themselves. Connecting the learning opportunities to shifts in the teachers' teaching practices and identities was regarded as evidence of learning on the part of the teachers. Chapter 6 focuses specifically on analyzing how specific opportunities

for learning were connected to observed shifts in the teachers' teaching practices and identities. Such a connection contributed to the development of the argument that a professional learning community can support teacher learning in ways that may result in significant changes in teachers' teaching practices and identities. As part of the analysis of teacher learning in the professional learning community, I examined how the teachers made efforts to work with the mathematical knowledge discussed in the community in their actual teaching practice. It was also necessary to analyze how the teachers made inferences to these forms of knowledge in talking about themselves in the professional learning community. Hence teacher learning from the opportunities for learning could only be inferred from how the teachers drew on the knowledge discussed in the community in both their teaching practice and ways of talking about themselves as teachers.

3.7.4 Analyzing features of the professional learning community

According to the literature successful professional learning communities have a number of features which support teacher learning. The features include: relationships of trust and confidence in the community, professional challenge of existing knowledge and assumptions, and collaborative inquiry for joint sense-making (Katz, et al., 2009). Data which was analyzed for similar features in the professional learning community were mainly the audio-recorded conversations of the professional learning community. Content analysis was the strategy used for the identification and analysis of episodes in the conversations which highlighted any of these features. For example, an episode in which one teacher challenged another teacher about an aspect of mathematical knowledge constituted evidence of relationships of trust as well as professional challenge. Using similar criteria, episodes were identified and analyzed to examine how specific features of the professional learning community developed and supported teacher participation and learning in the community. Chapter 7 presents the results of the analysis.

3.8 Rigour in the research

In research of this nature where the results are expressed in the form of claims based on qualitative evidence, the need for rigour is paramount. Rigour has to do with generating and sustaining the readers' trust and confidence (Opie, 2004). In qualitative research the researcher is the main instrument (Patton, 1990) hence the credibility of the research depends on the ability

and effort of the researcher (Golafshani, 2003). Rigour in my study was supported through a number of strategies that enhanced the validity and reliability of the findings.

3.8.1 Validity

While the most common conception of validity is the extent to which a method, a test or research tool actually measures what it is supposed to measure (Scarfe, 2004), in qualitative research validity refers to the relationships among the results of the research, the research claims and the realities of the world (Maxwell, 1992; McMillan & Schumacher, 2006). Validity in this sense is the extent to which the results of the research are consistent with reality. Research results are usually in the form of knowledge claims, which are supported by evidence from the data analysis. The validity of the findings therefore depends on the accuracy of both data collection and analysis (McMillan & Schumacher, 2006) and this is enhanced by a number of strategies.

In the study the accuracy of data collection was enhanced through the use of techniques that minimized inaccurate recording and/or failure to record some observations. Audio-recording of interviews and conversations, as well as video-recording of lesson observations, enhanced the accuracy of data recording. These techniques also minimized researcher subjectivity and bias in data collection, both of which can be threats to the accuracy of the data (Lewis, 2009). The use of open-ended questions in the semi-structured interviews allowed the teachers to elaborate answers and reduced directing respondents towards particular answers (Lewis, 2009).

The threat of reactivity, which is the effect of the researcher on what is observed (Lewis, 2009) may have been minimized by the longitudinal nature of the data collection process. Working with the same teachers for almost a year may have reduced researcher effects as the teachers became more comfortable with me as researcher, although this was difficult to determine.

The validity of data analysis was enhanced through the use a number of data collection methods that enabled triangulation of data sources in order to corroborate analysis (McMillan & Schumacher, 2006) and increase the credibility of findings. Data in the form of audio-recordings of interviews and conversations, video-recordings of the teachers' teaching practices, artefacts of the professional learning community, and researcher's field notes enabled triangulation of data in the analysis which enhanced the validity of the findings. For example in analyzing how the professional learning community activities explained observed shifts in the teachers' teaching

practices, it was necessary to analyze: how the teachers talked in the interviews and during lesson reflection about how their teaching practices had shifted; the teachers' actual teaching; and how the teachers used artefacts of teaching developed in the community.

A key aspect of data analysis was paying attention to disconfirming evidence in order to support the validity of claims. For each claim that was made from the data analysis, a thorough search was done for data that would disconfirm the claim. Any frequently occurring evidence that contradicted emerging claims could not be ignored. Tentative claims that had disconfirming evidence from the data could not be advanced as valid claims from the study. Paying attention to disconfirming evidence meant that only claims for which little or no contradictory evidence could be established from the data were presented as valid claims from the study.

3.8.2 Reliability

In quantitative research reliability refers to the consistency of research processes in producing similar results an all occasions (Scarfe, 2004). Applying such a conception to qualitative studies is problematic since qualitative research is not easily replicable. With reference to qualitative research Lincoln and Guba (1985) use the term 'dependability' instead of reliability. Dependability is closely associated with trustworthiness and "lies at the heart of issues conventionally discussed as validity and reliability" (Seale, 1999, p. 266).

During the data collection process reliability was enhanced by the collection of similar data at different points during the study. Collecting data about the teachers' teaching practices and identities before, during and after the intervention enabled the identification of recurring and non-recurring practices and responses, which enhanced the reliability of claims about shifts in teaching practices and identities. The consistency and recurrence of responses minimized chances of oversimplification or under-simplification in reporting of the data (Lewis, 2009). In the interviews asking the similar questions again at a later date in a different context, and asking same question in different formats (Lewis, 2009) enhanced the richness and reliability of the teachers' responses.

Reliability in research findings is also enhanced through consistency and accuracy in data interpretation. Analyzing the teachers' practices and identities involved coding data using the analytical tools described earlier in the chapter. To assure reliability in both cases I relied on

other doctoral students working on the DIPIP project to establish inter-rater reliability. Inter-rater or inter-coder reliability is a measure of the extent to which independent raters or coders evaluate or code the same phenomenon and reach the same conclusion (Lombard, Snyder-Duch, & Bracken, 2002). To establish inter-rater reliability in coding the teachers' lessons six lessons were coded by two other coders besides me, and percentage agreement for two coders on each lesson was calculated. The average percentage agreement for all the six lessons was 84%, which was found to be acceptable. Differences in the coding were found to be common mainly on the MQI dimension 'Errors and Imprecision'. Discussions were held and agreement was reached on the meanings of the sub-dimensions 'Imprecision in Language or Notation' and 'Lack of Clarity' and on how to code these sub-dimensions.

Inter-rater reliability for coding teacher identity was established similarly. For coding teacher identity I developed a coding framework from Wenger's (1998) theory of identity as modes of belonging. In developing the framework I held a number of meetings with my supervisor and this resulted in a number of changes to the original framework. The process of establishing inter-rater reliability with fellow doctoral students involved two coding cycles. The first cycle involved discussion of the framework, coding some data, and then discussing the coding results and the framework again. In the second cycle each coder coded two transcripts of teacher interviews and inter-rater percentages of agreement were calculated between pairs of coders on each transcript. The overall average percentage agreement was found to be 77%, which was found to be acceptable.

Once inter-rater reliability had been established the final coding of the rest of the video-lessons and interview transcripts was done by me.

3.9 Summary

In this chapter I discussed the research design of the study. I explained the research methods used, the data collection and analysis, and how ethical issues and rigour were addressed in the study. In the next four chapters I present the analysis of the data in responding to the research questions set for the study.

CHAPTER 4

THE TEACHERS' TEACHING PRACTICES

4.1 Introduction

In this chapter I analyse shifts in the teachers' teaching practices, in the understanding of, and ways of engaging with learner errors. The data consisted of video-recorded lessons which each teacher taught before, during and after the intervention, as well as the teachers' comments about their understanding of learner errors. Details of the teachers' video-recorded lessons were presented in Chapter 3. The teachers' comments about learner errors were analysed for shifts in their understanding of the nature and significance of errors. Prior to the intervention in individual teacher interviews, each teacher was asked about their understanding of learner errors. In the focus group interviews during the intervention the teachers discussed issues in relation to learner errors. In the individual teacher interviews after the intervention the teachers also responded to questions about learner errors. The teachers' comments across these data sets were analysed for shifts in understanding of learner errors and the results are presented in this chapter. Two activities of the professional learning community that were directly connected to the teachers' teaching practices were the error analysis and the concept development activities. The error analysis activity afforded the teachers the opportunity to understand the reasonableness of their learners' errors (Brodie, 2012a). Such understandings could influence how the teachers identify and respond to learner errors in their teaching of mathematics. In this chapter I present the findings of how the teachers' espoused shifts in understanding of learner errors were linked to their ways of responding to learner errors in their teaching.

The analysis of the teachers' lessons was done using the Mathematical Quality of Instruction (MQI) coding tool (Hill, 2010) (see Appendix V). The analysis focused on the following dimensions of each lesson: Mode of Instruction, Richness of the Mathematics, Working with Students and Mathematics, Errors and Imprecision, and Students' Participation in Meaning-Making and Reasoning. Details and justification of these dimensions were presented in Chapter 3. The analysis of shifts in the teachers' teaching practices was complemented by content analysis of teaching episodes from the teachers' lessons to describe and explain further the observed shifts in the teachers' teaching practices.

The main research question addressed in this chapter is:

> What shifts, if any, occurred in the teachers' teaching practices and their ways of engaging with learner errors?

The sub-research questions were:

1. On which dimensions of the mathematics lessons did the individual teachers make shifts in their teaching?
2. How did the teachers' understanding and ways of responding to learner errors shift during the intervention and in their teaching?

4.2 Overview of findings

The results show some shifts in the teachers' understanding of learner errors and teaching practices. In their comments about learner errors before and after the error analysis activity the teachers showed they had made some shifts in their understanding of errors. Before the error analysis activity the teachers blamed learners, previous teachers and parents for learner errors in mathematics. They also proposed teacher-centred teaching strategies such as explaining, remediation, using simpler examples and motivating learners as some of the ways of dealing with learner errors. After the error analysis activity the teachers' comments showed a shift towards an understanding of learner errors which is consistent with what is known in the literature, i.e. errors as a normal part of mathematics teaching and learning (e.g. Brodie, 2012a; Nesher, 1987). They highlighted the need to understand learners' reasoning as a possible strategy for dealing with errors.

In terms of shifts in the teachers' teaching practices, two teachers, Bongiwe and Janeth, made shifts on some dimensions of the MQI coding tool in their teaching of the jointly planned lessons as compared to their teaching before the intervention. For these two teachers the results show a decrease in direct instruction and an increase in engaging learners in discussing mathematical ideas. There was more remediation and responding to learner ideas as compared to their teaching before the intervention. In the jointly planned lessons students participated more than previously in explaining mathematical ideas and some significant learner reasoning was observed. Janeth struggled more than Bongiwe to hear and respond to learners' ideas and errors during the

intervention and in her lessons there were instances when she made some errors or asked questions which lacked precision and clarity. Bongiwe sustained the shifts in her teaching after the intervention. In Janeth's lessons after the intervention there was a decline in learner engagement in discussions and a slight rise in teacher direct instruction. Student participation and reasoning also declined in Janeth's post-intervention lessons.

The other two teachers, Jeffrey and Tandeka did not make shifts in their teaching on all the dimensions of the MQI coding tool although their mode of instruction differed significantly before the intervention. Jeffrey taught in a teacher-directed manner with occasional involvement of learners in mathematical discussions. He relied on mathematics textbooks for definitions of mathematical concepts and used textbook tasks for demonstrating procedures on the board. He emphasized procedural understanding in his teaching. He maintained this mode of teaching in the jointly planned lessons as well as after the intervention. Tandeka engaged learners in group discussions throughout all her lessons. Learners were put into groups and given tasks to discuss. Later she led whole class discussions in which learners presented their findings. She struggled to respond to learners' ideas in the whole class discussions and in most cases the mathematics involved in the discussions was not made explicit for the learners. She also made some errors and had instances where there was no clarity or precision in her comments or questions in response to learner ideas. This pattern of teaching was sustained in her teaching of the jointly planned lessons as well as after the intervention.

For all the teachers there was evidence of working with ideas developed in the professional learning community during the concept development activity. The observed shifts in their teaching were more in the structural aspects than in the mathematical substance of their lessons. The richness of the mathematics remained consistently low across all their lessons. The teachers showed no shift in linking mathematical concepts, using multiple representations and solution methods, and in making generalizations. Mathematical tasks which had been selected for the jointly planned lessons and which had the potential for developing learners' conceptual understanding were treated more procedurally than conceptually in the teachers' teaching. All the teachers struggled in some ways to hear and respond appropriately to learners' ideas and thinking in their teaching of the jointly planned lessons.

4.3 The teachers' perceptions of learner errors

The analysis of the teachers' perceptions of learner errors was done by focusing on three aspects of errors: the nature of errors; causes of errors; and ways of dealing with errors. Table 4.1 below presents a summary of some of the teachers' comments which reflected their perceptions of learners' errors during the individual and focus group interviews, and lesson reflection activity.

Table 4.1: Shifts in teachers' perceptions of learner errors

Aspect of Learner Errors	Pre-Error Analysis Views	Post-Error Analysis Views
Nature of errors	Errors show that learning is taking place (Je)	Errors are unavoidable (B) Teachers also make errors (B) Errors are resistant (T) Errors can be avoided through thorough preparation (Ja)
Causes of learner errors	Learners don't check accuracy of their working (T) Learners don't practice (T) Learners forget (T) Learners' negative attitudes towards mathematics (M) Learners poor background in particular topics (B, Ja, Je) Previous teachers to blame (M, Je) Learners' belief that mathematics is difficult (Ja) Lack of parental support (Ja)	Lack of content linkages when teaching which creates gaps in learners' knowledge (Ja) A result of learners interpreting information differently (Je) Failure to read questions carefully (T) Lack of clarity in teachers' teaching (Ja) Language used in test items (B) Limited teaching (B, Je) Learners think in different ways (Je)
Ways of Dealing with learner errors	Ask about possible problems from home background (T) Explain again using different examples (T) Increase teaching time (T) Inquire about learner thinking behind the error (M)[9] Motivate learners by highlighting significance of mathematics in life (M, B) Use simpler examples (M) Sometimes ignores due to time constraints (M, T) Remediation after classes (Ja) Thorough preparation by teachers (Je)	Understand learner reasoning behind an error (T, B) Remediation (Ja, B, Je) Analyze learners' working to understand the error (B) Thorough preparation to avoid errors (Ja) Ask learners to explain how they did the task (T, B, Je) Use of media (M) Analyze errors to identify learners' learning needs (B)

[9] Mandla joined the professional learning community in second term when the community was doing the error analysis activity, hence his comment in his initial interview could be attributed to his participation in this activity

The analysis involved comparison of the teachers' comments before the error analysis activity with comments made after the error analysis activity. This comparison was justified on the basis that the error analysis activity created opportunities for the teachers to develop deeper understanding of the nature of errors and learners' reasoning behind errors (Brodie, 2012a). In the table the teachers' comments are paraphrased and the initial(s) of the teacher(s) who made each comment is/are indicated in brackets.

The results show that before the error analysis activity most of the teachers did not make comments that reflected an understanding of the nature of learners' errors, except Jeffrey who saw errors as evidence of learners' learning. None of the teacher saw learner errors as part of learning mathematics. The teachers' comments after the error analysis activity showed some understanding of the nature of learner errors. Of interest was the difference in perceptions between Bongiwe and Janeth. While Bongiwe saw learner errors as unavoidable, Janeth thought that learner errors could be avoided if teachers prepared for their lessons thoroughly. Bongiwe's and Tandeka's comments were consistent with what is known about learner errors in mathematics, i.e. errors are unavoidable and resistant, and that teachers also make errors. Janeth's comment about learner errors as avoidable could suggest a different shift in her understanding of learner errors. The comment might mean that learner errors can be predicted and hence can be prepared for in advance.

On possible causes of learner errors it was evident that before the error analysis activity the teachers blamed learners to a large extent for errors, and to a lesser extent previous teachers and parents. The teachers' statements about the causes of learner errors after the error analysis activity indicate that errors can arise as a result of teaching and learners' ways of interpreting the mathematics. One teacher's statement that errors are unavoidable and that teachers can make errors could be a significant shift towards realizing that errors are reasonable and "do not signal a deficit in teaching or learning" mathematics (Brodie, 2012a, p. 4952), and therefore cannot be blamed on the learners. Such perceptions of errors are healthy for the teaching of the subject as teachers who have such an understanding of errors are likely to embrace errors rather than avoid them in their teaching (Brodie, 2012a).

Before the error analysis activity the teachers' comments about how to deal with errors in instruction highlighted teacher-centred strategies such as explaining, providing remediation, and motivating learners. There was little reference to the need for understanding the reasoning behind the errors as a precursor to helping learners deal with the errors. The following are some of the teachers' comments about learner errors during the pre-intervention teacher interviews.

Bongiwe: I think for, for, for I think because this comes because of uhm not having background information, because sometimes we find that we can ask a learner what is two minus three, he end up not giving an answer because maybe he doesn't have any background information I think most errors are done by learners because of not knowing the background information

Janeth: I think it's a background ne, the learners they don't have a background from the primary they don't know anything, we are struggling to teach them you know, and then the second thing is I think for if they are having a problem at home, if he is an orphan or he or she is living with an aunt or just the aunt or an uncle or whoever…

Tandeka: And sometimes some of the learners are lazy, they don't want to practice, maths needs practice always ... time and again

After the error analysis the responses emphasised understanding the reasoning behind errors as a way of dealing with learner errors. The following are some of the teachers' comments about learner errors after the error analysis activity.

Jeffrey: I think the template for error analysis was very much interesting because now I have realized that learners when given the knowledge, they interpret it differently. You tell them the meaning of two squared others are writing or two squared you give an example of two multiplied by two, and then you give them another example three to the power of three so they make an error giving you three plus three, so it means knowledge is being interpreted differently

Bongiwe: Ja as a teacher you are able, when you analyze a learner's error you are able to see and to know where does this learner, where does this learner need help or needs to be assisted according to how they are answering your questions, because mostly when learners have solved the problem, they know exactly what were they thinking of when they solved the

problem, but immediately when you ask as a learner why did you do that, I think that particular learner will take you back to say ... 'oh I have, I was supposed to do this' by just asking those learners why did you do this question this way

One teacher, Janeth, made a comment that highlighted the need for continuity if learner errors are to be minimized.

Janeth: I teach the learners, this grade ten in their level, so in the grade ten level, so I don't go back for it, I am not doing the pre-knowledge, so that is why I find that there is a lot of errors in this, so there is knowledge that is being missed in there, so myself I am saying highest common factor, lowest common multiple in the grade ten level, so the, the thing is I must go back from, from grade seven, eight, and nine at least so that I can reduce the errors

The teachers' comments show a shift towards an understanding which is consistent with was is known about the nature of errors. Learner errors are integral to the teaching and learning of mathematics (Borasi, 1987; Nesher, 1987). The comments highlight a need for understanding learners' thinking as a way of dealing with learner errors. The shift in the teachers' comments about learner errors can be explained by their experiences of analyzing learner errors and interviewing learners during the error analysis activity. This link is further analyzed in Chapter 6.

4.4 Shifts in the teachers' teaching practices

The results of analyzing the teachers' teaching are presented according to individual teachers, before a synthesis of the findings across all the teachers is done. As indicated in Chapter 3, the teaching of four teachers was analyzed. In the following sections the results of each teacher's teaching on the MQI are presented first, followed by some episodes from the teacher's lessons which illustrate the observed shifts on the MQI. Each lesson was coded in ten-minute episodes, using the codes: L – Low; M – Mid; H – High. The meaning of each code is explained in the MQI coding tool (see Appendix V). The results of coding each teacher's lessons are presented in tables in the relevant sections below. The lessons for each teacher were categorised according to when the lessons were taught, i.e. pre-intervention, during intervention and post-intervention. The numbers in the tables represent the frequency of each code for each dimension, in each category of lessons. The numbers in brackets represent the frequency of each code expressed as a

proportion of the total number of ten-minute episodes in each category of lessons. Proportions are provided to enable comparison of the coding for each dimension across the three categories of lessons.

4.4.1 Bongiwe's teaching

Bongiwe made more shifts in her teaching than the other teachers both during and after the intervention. Prior to the intervention, Bongiwe's teaching was teacher-directed with minimal learner involvement in discussing, explaining and reasoning. She started her lessons by giving definitions of mathematical concepts; followed by demonstration of procedures for solving tasks. She then invited one or two learners to the board to solve similar tasks, before she gave learners individual written work. In her teaching of the jointly planned lessons and after the intervention, Bongiwe gave learners group tasks, often presented on worksheets, and later she led whole class discussions in which learners from different groups presented their findings and justified their solutions. Bongiwe sustained this shift after the intervention.

Results of Bongiwe's teaching as analyzed using the MQI coding tool

Table 4.2 below shows the results of the coding of Bongiwe's lessons on the MQI tool. The table shows that Bongiwe's Mode of Instruction shifted from mostly direct instruction before the intervention to mid direct instruction during and after the intervention. This is consistent with the observed shift in her use of whole-class discussion, which shifted from low to mid. Before the intervention she dominated and controlled content delivery by giving definitions of mathematical terms and concepts and demonstrating procedures. During the intervention she engaged learners in group discussions and whole-class discussions. This shift was sustained in her teaching after the intervention.

On the overall Richness of Mathematics Bongiwe's lessons seemed to maintain a balance between low and mid, although results on the sub-dimensions indicate some shifts. Linking or connecting mathematical ideas remained consistently low. For Bongiwe there was a shift in the way she explained mathematical ideas in her lessons. Before the intervention she did most of the explaining to the learners, and her explanations were rated as mid. During the intervention learners were more involved in explaining and this was sustained after the intervention.

Table 4.2: MQI coding of Bongiwe's lessons

Dimension and sub-dimensions	Pre-Intervention (3 lessons - 14 episodes)			During Intervention (2 lessons -17 episodes)			Post-Intervention (2 lessons – 17 episodes)		
	L	M	H	L	M	H	L	M	H
Mode of Instruction									
Direct instruction	0	0	14 (1.0)	5 (0.3)	8 (0.5)	4 (0.2)	2 (0.1)	13 (0.8)	2 (0.1)
Whole-class discussion	12 (0.9)	2 (0.1)	0	2 (0.1)	10 (0.6)	5 (0.3)	8 (0.5)	5 (0.3)	4 (0.2)
Richness of the Mathematics									
Linking or Connections	14 (1.0)	0	0	17 (1.0)	0	0	14 (0.8)	3 (0.2)	0
Explanations	0	14 (1.0)	0	7 (0.4)	10 (0.6)	0	5 (0.3)	11 (0.6)	1 (0.1)
Multiple procedures or solution methods	14 (1.0)	0	0	17 (1.0)	0	0	17 (1.0)	0	0
Developing mathematical generalizations	12 (0.9)	2 (0.1)	0	16 (0.9)	1 (0.1)	0	14 (0.8)	3 (0.2)	0
Mathematical language	0	12 (0.9)	2 (0.1)	2 (0.1)	8 (0.5)	7 (0.4)	1 (0.1)	11 (0.6)	5 (0.3)
Overall richness of the mathematics	7 (0.5)	6 (0.4)	1 (0.1)	12 (0.7)	5 (0.3)	0	8 (0.5)	7 (0.4)	2 (0.1)
Working with Students and Mathematics									
Thorough Remediation of Student Errors and Difficulties	11 (0.8)	3 (0.2)	0	13 (0.8)	4 (0.2)	0	8 (0.5)	7 (0.4)	2 (0.1)
Responding to Student Mathematical Productions in Instruction	14 (1.0)	0	0	7 (0.4)	9 (0.5)	1 (0.1)	4 (0.2)	10 (0.6)	3 (0.2)
Overall working with students and mathematics	12 (0.9)	2 (0.1)	0	9 (0.5)	8 (0.5)	0	4 (0.2)	10 (0.6)	3 (0.2)
Errors and Imprecision									
Major mathematical errors or serious oversights	12 (0.9)	2 (0.2)	0	17 (1.0)	0	0	16 (0.9)	1 (0.1)	0
Imprecision in Language or Notation (mathematical symbols)	13(0.9)	1 (0.1)	0	16 (0.9)	1 (0.1)	0	15 (0.9)	2 (0.1)	0
Lack of clarity	14 (1.0)	0	0	17 (1.0)	0	0	14 (0.8)	2 (0.1)	1 (0.1)
Overall errors and imprecision	12 (0.9)	2 (0.1)	0	16 (0.9)	1 (0.1)	0	14 (0.8)	2 (0.1)	1 (0.1)
Student Participation in Meaning-Making and Reasoning									
Students provide explanations	9 (0.6)	5 (0.4)	0	6 (0.4)	11 (0.6)	0	4 (0.2)	13 (0.8)	0
Student mathematical questioning and reasoning	13 (0.9)	1 (0.1)	0	10 (0.6)	7 (0.4)	0	6 (0.4)	11 (0.6)	0
Enacted task cognitive demand	13 (0.9)	1 (0.1)	0	7 (0.4)	10 (0.6)	0	13 (0.8)	4 (0.2)	0
Overall student participation in meaning-making and reasoning	12 (0.8)	2 (0.2)	0	6 (0.4)	11 (0.6)	0	6 (0.4)	11 (0.6)	0

Although the explanations were rated as mid, there were a significant number of episodes which were rated as low, an indication that some of the teacher's and/or learners' explanations were descriptions of procedures. After the intervention explanations were rated mostly as mid, with explanations in one episode being rated as high, an indication that there was a slight improvement in the quality of teacher and/or learner explanations as compared to lessons taught during the intervention. On the use of mathematical language, Bongiwe did not shift. Her use of mathematical language was rated as consistently mid or high. What the coding results obscure is that during and after the intervention learners were more involved in the use of mathematical language and Bongiwe supported them in this endeavour. On the use of multiple representations and solution strategies Bongiwe did not show any shift; her lessons were rated as consistently low on this sub-dimension of the MQI tool. Although she occasionally made mathematical generalizations, this was also rated as consistently low throughout the observed lessons.

On Working with Students and Mathematics, there was a gradual rise from low to mid and high on the overall coding of this dimension. Remediation was rated as low before and during the intervention. After the intervention the results show an increase in instances of thorough engagement with remediation of learner errors with two episodes being rated as high on this aspect. The results also show a gradual increase in instances of responding to learner productions from her teaching before the intervention to her teaching after the intervention. Overall the results on this dimension show a shift from less engagement with learner errors and ideas to more engagement during and after the intervention.

On the dimension Errors and Imprecision the results show that all of Bongiwe's lessons were rated as low on all the sub-dimensions. Bongiwe made some errors or oversights in a few instances in her teaching. There also few instances where she was not precise and was not clear in terms of the mathematical ideas she was teaching.

On Student Participation in Meaning-Making and Reasoning the results show that Bongiwe made a significant shift on all the sub-dimensions. Learners' explanations started being mostly low but shifted to mostly mid during and after the intervention. A similar trend was observed in learners' mathematical questioning and reasoning, as well as in the enacted task cognitive demand. The fact that the shifts were mainly from low to mid indicates that Bongiwe engaged learners in explaining, justifying solutions, and reasoning in the teaching during and after the

intervention, but learners' participation in these mathematical practices could not be rated as 'High' according to the MQI criteria.

Episodes from Bongiwe's lessons

In her lessons before the intervention Bongiwe was positioned mainly at the front of the class, commanding learners' attention. She controlled learners' learning by asking them questions that mostly elicited one-word or one-phrase responses. Learners were seated in rows facing the front of the class. The following episode highlights some patterns in Bongiwe's lessons which illustrate the results of the coding presented above.

Episode 1: Pre-Intervention: Proportion

In this episode Bongiwe was teaching about direct and indirect proportion to a Grade 9 class. She introduced the topic by telling the learners that proportion consists of direct and indirect proportion before asking them what direct proportion is. She avoided telling the learners what proportion is.

Turn	Speaker	Utterance
1	Teacher	Divided into the direct proportion (*writing 'Direct Proportion' and 'Indirect Proportion' on the board*) the direct proportion and the …
2	Chorus	Indirect proportion (*writing on the board)*
3	Teacher	That is how proportion is divided, into two parts that is the direct and indirect proportion. Then who can tell me what is direct proportion, or what is the difference between the direct proportion and indirect proportion? Who can give us a clear explanation of a direct proportion and indirect proportion, before I can tell you? Anyone to help us in the direct proportion, what is the direct proportion, or what do you understand by the word direct proportion? (*Teacher pauses for a moment, but learners remain quiet).*

Realizing that none of the learners could answer her question she then used an example of eggs and cakes to highlight the concept of Direct Proportion.

4	Teacher	Okay when we talk about the direct proportion, I am just going to give you an example ne. Let's say for instance you have to bake a cake, ne, bake a cake, and for you to bake one cake you have to have two eggs, that means one cake is equivalent to two …
5	Chorus	eggs
6	Teacher	*(Writing '1 cake' and below that '2 eggs' on the board)* One cake is equivalent to
7	Chorus	Two eggs

8	Teacher	One cake is equivalent to two eggs. Then if ever one cake is equivalent to two eggs, what about two cakes? *(Some learners raise their hands but the teacher continues)* For one cake you need two eggs, if ever for one cake you need two eggs, what about two cakes? Yes papa[10] *(Calling on a learner)*
9	Johannes[11]	Four eggs
10	Teacher	For two cakes you are going to need four eggs *(writing '2' in the same row as '1 cake' and '4' just below it on the board).* What about for three cakes? *(Most learners raise their hands)* What about for three cakes? Yes, at the back
11	Michael	Six eggs
12	Teacher	Six eggs. Now the last one, what about four, four cakes? How many eggs will you need to bake four cakes? *(Learners raise their hands).* Yes papa
13	Thembani	Eight eggs
14	Teacher	Ha?
15	Thembani	Eight eggs
16	Teacher	Eight eggs, ne. Now if ever for four cakes you are going to need eight eggs what about for twelve *(writing on the board)* cakes? What about for twelve cakes? What about for twelve cakes? If ever for four cakes you are going to need eight eggs, what about for twelve cakes? How many eggs do you need? Yes, uhm
17	Johannes	Twenty four, twenty four eggs
18	Teacher	Is he correct?
19	Learners	Yes

Bongiwe's presentation on the board was such that the 'eggs' and 'cakes' were in tabular form. The use of a table to illustrate proportion was an opportunity for supporting learners' understanding of proportion as a mathematical relationship. The use of a table could also have been connected to a graphical representation of the relationship, thereby using multiple representations of the same idea. Bongiwe did not use a graph, choosing to explain the concept using the table only. This omission meant that learners' access to multiple representation of direct proportion was constrained, which in turn contributed to the low richness of the mathematics in the lesson. Bongiwe's questioning was such there was a strong learner participation and attention although the learner responses were mainly in one-word or one-phrase format. Her questions were simple and did not contribute to deepening learners' understanding of the fundamental idea of proportion as a mathematical relationship, which in this case was between two increasing variables.

[10] Not the learner's name, Bongiwe often used the term when she called on individual male learners without using their names.
[11] All learners' names are pseudonyms.

From this empirical representation of direct proportion Bongiwe then led learners into making a generalization.

20	Teacher	For twelve cakes you are going to need twenty four eggs *(writing 24 on the board)*. Now I want you to look at the number of cakes *(underlining numbers on the board)* and the number of eggs, and what can you say about these numbers? What can you say? What can you say about the number of cakes and the number of eggs? I want you to understand the direct proportion, what can you say about those numbers? For cakes we have one, two, three, four, until to twelve, for eggs we have two, four, six, eight, until to twenty four, so what can you say about those numbers of cakes and eggs? *(Learners remain silent)* What can you say? Yes Sipho?
21	Sipho	When the cakes increases the eggs increases
22	Teacher	Just clap hands your hands for her
23	All learners	*Clap their hands*
24	Teacher	When the number of cakes increases also the number of eggs increases, when the number of cakes increases also the number of cakes …
25	Learners	Increases
26	Teacher	Now that means we call this a direct proportion *(Writing on the board)* Direct proportion simply means as the value of x increases also the value of …
27	Chorus	Y increases

Although the generalization was mathematically correct it was limited in that Bongiwe did not address the issue of how the two variables were increasing. It was not clear whether the learners understood the relationship as multiplicative, or additive. The omission contributed to the low rating of the richness of mathematics.

In the following extract Bongiwe introduced indirect proportion by drawing on the earlier generalization of direct proportion as a relationship of increasing variables.

28	Teacher	That is the direct proportion. So if ever that is the direct proportion what can you say about the indirect proportion? What will the indirect proportion be if ever that is a direct proportion? We said direct proportion as the number of cakes increases the number of eggs increases. So what about the indirect proportion? What can you say about the indirect proportion? Yes papa *(Calling on a learner)*
29	Wezi	When the number of cakes decreases ah also the number of eggs decreases
30	Teacher	Say is again please, say it loud
31	Wezi	When the number of cakes are decreasing also the number of eggs decreases
32	Teacher	When the what? *(Raising her voice)*
33	Wezi	The number of cakes are increasing, I mean are decreasing, also the eggs are increasing, are decreasing
34	Teacher	He says as the number of eggs increases also the number of cakes also decreases, is he correct?

35	Learners	Yes
36	Teacher	*(Raising her voice)* Serious, is he correct?
37	Some learners	No
38	Teacher	Why do you say no? Why do you say no? Indirect proportion, why do you say no? You say no, why do you say no? Who can help him? *(Silence)*. He has already given you the answer. Yes nana
39	Sibaya	When the number of cakes, cakes increases the number of eggs decreases
40	Teacher	When the number of cakes increases, the number of eggs decreases. As the value of x increases,
41	Chorus	The value of y decreases
42	Teacher	Or as the value of x decreases the value of y
43	Chorus	Increases
44	Teacher	That is the direct
45	Learners	Indirect
46	Teacher	Indirect proportion, indirect proportion, thank you. So I want us to turn to page fifty eight *(Giving out mathematics textbooks)*

The extract highlights Bongiwe's focus on correct responses which constrained her hearing and engagement with an error. Wezi's error (T29 & T31) was obviously connected to the generalization of direct proportion developed earlier, and could have been dealt with differently. Bongiwe's apparent alteration of Wezi's response (T34) could be a slip, but it is more likely an effort to push learners towards the correct answer as evidenced by her utterance (T38). Although the correct meaning of indirect proportion was finally arrived at, Wezi's error was not significantly dealt with, which contributed to her low remediation of learner errors. Bongiwe's reaction to Wezi's error could be interpreted as a case of avoiding an error. In her comments about learner errors during the pre-intervention interview Bongiwe made no reference to errors being a normal part of teaching and learning mathematics, although Wezi's error originated in the teacher's teaching of direct proportion. Extending a limited generalization of direct proportion as an increasing relationship to indirect proportion contributed to Wezi's error. The reference to eggs and cakes to illustrate indirect proportion led to a response which did not make much sense, and Bongiwe did not pick it up. Thus Bongiwe did not go deeply into the conceptual meaning of each relationship, and the differences between direct and indirect proportion.

The episode highlights some key features of Bongiwe's teaching before the intervention. In the episode the mathematical content is delivered in a teacher-directed mode. The high amount of teacher talk and control of content meant that Bongiwe engaged in direct instruction. Learner

participation in the lesson was restricted to answering the teacher's questions which sought mostly computational responses rather than engaging learners in explaining and justifying their contributions. In line with the selected dimensions of the MQI framework, Bongiwe's teaching in the episode can be characterized as direct instruction; low in richness of the mathematics; low in working with learners' ideas and errors; and low in learner participation in meaning making and reasoning. Her responds to an error was more of avoiding the error than engaging with it, something that is consistent with her understanding of learner errors before the intervention.

Episode 2: During Intervention

In her teaching of the jointly planned lessons, Bongiwe made some significant changes in her teaching. Bongiwe taught two jointly planned lessons during the intervention, both on the topic Ratio. The following episode is from the second of the two lessons, in which Bongiwe was using a worksheet developed in the professional learning community (see Appendix P). The episode highlights some shifts in Bongiwe's teaching that were not evident in the lessons prior to the intervention. In the lesson learners were seated and worked in groups of about six learners per group. In the episode Bongiwe set up opportunities for learners to discuss mathematical ideas, firstly in their groups, and secondly through presentations to the rest of the class. In the following episode one group presented their solution to the whole class.

Explaining the meaning of a ratio

Task: If the ratio of boys to girls in a class is 2:3, what is the ratio of girls to boys in the class?

Turn	Speaker	Utterance
2	Thabo	*(Goes to the board)* Ladies and gentlemen, ladies and gentlemen as the question says the ratio of boys to girls is two to three, the question says
3	Teacher	Can you write it so we can see it on the board?
4	Thabo	Okay, ah, the ratio of boys it means that for every two girls *(writing '2 girls:3 boys')* we have three boys
5	Teacher	Are you through papa?
6	Thabo	Yes
7	Teacher	Any question? Any question? Yes papa
8	Temba	Can I ask, he says for every two girls there are three boys, in the farm or in the street? *(laughter from other learners)*
9	Teacher	Eh papa did you see the bullet carefully? *(asking Thabo)*
10	Thabo	Yes
11	Teacher	Read the first bullet, the ratio of boys to girls in a class is two as to three *(reading the task)* the ratio of boys to girls in a class is two as to three, what does that mean papa before you, what does that mean to say the ratio of boys

		to girls in a class is two as to three?
12	Thabo	That means the ratio of boys
13	Teacher	What does that mean, to say the ratio of boys to girls in a class is two as to three?
14	Thabo	It means that for every two boys there is three girls
15	Teacher	It means for every two boys we have in the class there are three girls, akere? (Isn't that so?)
16	Thabo	Yes
17	Teacher	Now the question says, did you read the question?
18	Thabo	Yes
19	Teacher	What is the ratio of girls to boys?
20	Thabo	Oh!
21	Teacher	If ever the ratio of boys to girls in a class is two as to three what is the ratio of girls to boys?
22	Thabo	Yes I did it vice versa *(changing the '2girls:3boys' to '2boys:3girls')*
23	Teacher	Then is that your answer?
24	Thabo	Yes *(after a pause)* ah no right the total is five *(writing =5)* five boys and girls
25	Some learners	Learners, five learners
26	Thabo	Okay five learners *(adding the words 'learners in a class' to have '= 5 learners in a class')*
27	Teacher	Do you align yourself with him?
28	Chorus	No
29	Thabo	*(Throws up his hands in the air in frustration and goes back to his seat)*

In the extract Bongiwe noticed Thabo's incomplete response to the task (T4) and substantially engaged in trying him to realize his omission, but did not pursue it further when Thabo appears to have given up (T29). Bongiwe asked questions seeking for conceptual understanding of ratio (T13), but missed opportunities for pushing for deeper understanding. For example when Thabo reversed the words 'boys' and 'girls' without reversing the actual numbers as well (T22), she did not ask how doing that changed the ratio. Bongiwe did not respond to Thabo's error in adding the numbers in the ratio and saying that was equal to the number of learners in the class (T26). Although she asked questions seeking for justification of responses (T49 & T59), she did not push for more comprehensive and conceptual justifications from the learners.

In comparison to Bongiwe's teaching before the intervention, the extract shows that Bongiwe had shifted to questioning that sought explanation and justification of learner responses. She also seemed less focused on the correct answer and this supported more extensive discussion of the mathematical concept. Bongiwe elicited other learners' engagement in relation to the learner's

responses. There was more engagement with a learner's error as compared to her teaching before the intervention when she ignored learner errors.

The episode continued with Bongiwe inviting another learner to answer the task.

30	Teacher	Let's hear yours, let's see yours *(calling on Mpho),* eh please, yes
31	Mpho	*(Goes to the board)* It says here the ratio of boys to girls in a class is two to three *(writes 2:3)* and the question
32	Teacher	Uhm, and what does that mean? What does that mean?
33	Mpho	Maam?
34	Teacher	What does that mean to say that the ratio of boys to girls is two as to three?
35	Mpho	It means maam we have two boys in the class to three girls
36	Teacher	We have two boys, for every two boys we have three girls akere? (Isn't that so?)
37	Chorus	Yes
38	Teacher	Then
39	Mpho	The question asks that what is the ratio of girls to boys
40	Teacher	Yes
41	Mpho	The ratio of, the ratio of girls to boys in the class is *(writes 3:2)*
42	Teacher	Is she correct?
43	Some learners	Yes
44	Teacher	Hah, is she correct?
45	Some learners	Yes
46	Unidentified learner	We are lost maam
47	Teacher	I hear no yes, is she correct?
48	Some learners	Yes/no
49	Teacher	Who are saying yes? Let me see who says yes, I want to see where, I want to see who says yes and who says no, and when you say yes explain and when you say no you have to explain
50	Unidentified learners	We are not sure
51	Teacher	Or you are not sure?
52	Some learners	Yes
53	Teacher	Is she, let me ask, is she correct?
54	Some learners	Yes
55	Teacher	Hah?
56	Chorus	Yes
57	Teacher	Those who say yes raise up your hands *(many learners raise up their hands),* so those who say yes say she is correct, akere (isn't that so?)
58	Chorus	Yes
59	Teacher	Why are you saying she is correct? Why do you say she is correct?
60	Unidentified learners	Maam
61	Teacher	Yes
62	Unidentified learners	Because the question says the ratio of girls to boys

63	Teacher	The question says what is the ratio of
64	Chorus	Girls to boys
65	Teacher	Remember you are given the ratio of boys to girls, akere? (Isn't that so?)
66	Chorus	Yes
67	Teacher	It says for every two boys we have in the class we have three girls
68	Chorus	Yes
69	Teacher	Now what is the ratio of girls to boys? That means you have three girls to
70	Chorus	Two boys
71	Teacher	Two boys, thank you, thank you, let's move on

In the above extract, although, Mpho gave the correct answer, Bongiwe engaged in extensive asking for the meanings of the ratios 2:3 and the reversed 3:2. However Bongiwe did not pay attention to the learners who indicated that they did not understand (T46), and did not follow up on disagreements (T57 & 59) which could be an indication that she was more interested in the correct answer of 3:2. She also did not ask if the two ratios had the same meaning, choosing to provide that information herself (T67 & T69).

In line with the results of coding on the MQI framework, in the episode Bongiwe engaged in direct instruction but involved learners in more substantive discussion and explanation of mathematical ideas as compared to her pre-intervention lessons. She asked questions that sought conceptual understanding but did not push for deeper meanings; hence the richness of the mathematics remained low. There was a significant change in her questioning as compared to lessons taught before the intervention. Her questioning elicited explanation and justification of answers. This afforded learners opportunities for more substantive engagement in meaning making and reasoning. Her focus on the correct answer made her miss some learner errors and opportunities for following up learner contributions.

Episode 3: Post-Intervention

Two lessons were recorded for Bongiwe after the intervention. In one of the lessons she taught Proportion from which I have extracted the following episode. This lesson was recorded in the year following the start of the intervention and Bongiwe was teaching a different class to the one she taught in the previous discussion. In the lesson learners were given tasks to solve in groups before presenting their solutions to the class. In the episode one learner presented her group's solution to the following task:

Task:

The amount of cheese that can be made is in direct proportion to the amount of milk that is used. Complete the table:

m milk (litres)		21	42	
c cheese (kg)	1	2		25

A learner from Group 1 presented the following solution as the number required to complete the first column in the table:

$$\frac{21}{2} = \frac{21}{2};$$

If c = 1, $\frac{m}{1} = \frac{21}{2}$;

m = $\frac{21}{2} \times \frac{1}{1}$;

m = $\frac{21}{2}$;

m = 10 .5 and then she wrote 10,5 in the cell above 1 in the table.

In the episode Bongiwe asked for explanation and justification of some of the steps in the solution. Initially she asked why the learner, Thenjiwe, had written $\frac{21}{2} = \frac{21}{2}$.

Turn	**Speaker**	**Utterance**
12	Teacher	Ah, I just want to know you said twenty one over two is equal to twenty one over two
13	Thenjiwe	Yes
14	Teacher	Twenty one over two, why do you say twenty one over two is equal to twenty one over two?
15	Thenjiwe	Maam I said twenty one over two gives us twenty one over two
16	Teacher	Maybe she, can you clarify that statement? Yes twenty one over two, I just want to know why you repeat it, twenty one over two. What did you want to do? Maybe you wanted to do something. *(Some learners from Group 1 try to advise Thenjiwe),* Eh leave her alone please, if you want to assist her you will assist her after answering, nana I am a bit confused you repeated twenty one over two, twenty one over two equals twenty one over two, akere? (Isn't that so?)
17	Thenjiwe	Yes

18	Teacher	Why do you repeat it? *(Inaudible)*
19	Thenjiwe	Maam *(inaudible)* ekena ku (it gets into) twenty one
20	Teacher	Eh that's what I wanted from you yes what did you do?
21	Thenjiwe	*(Inaudible)* ekena ku (it gets into) twenty one
22	Teacher	Then what is that number?
23	Thenjiwe	The number is one
26	Teacher	Eh, can you look at the first thing guys?
27	Chorus	Yes
28	Teacher	She says twenty one over two is equal to twenty one over two, what did she want to do there? She wanted to do something there, what is it? *(Teacher walks to the board)* Nana I just want to know the reason for repeating this statement twenty one over two, yes twenty one over two is equal to twenty one over two, so why did you, what did you want to do here? Let me ask you
29	Thenjiwe	I divided
30	Teacher	Hah? You divided? You divided what by what?
31	Thenjiwe	Maam I looked for a number that goes into twenty one and two
32	Teacher	And what is that number
33	Thenjiwe	That number is one, that is one
34	Teacher	Yes

At this point another learner attempted to come to the board to assist Thenjiwe but Bongiwe told her to go back and sit down. Thenjiwe then continued to explain her initial statement in the solution.

41	Thenjiwe	I used the highest common factor
42	Teacher	What is the highest common factor?
43	Thenjiwe	It's one
44	Teacher	It's one, so that means this one is already simplified *(circling* $\frac{21}{2}$ *)* there is no need of writing it again *(rubbing off '* $= \frac{21}{2}$ *' from Thenjiwe's statement)*
45	Chorus	Oh
46	Teacher	It's already simplified, so there is no need of writing it again to say twenty one over two, we know that twenty one over two is equal to twenty one over two, so there is no need to simplify it because the highest common factor is one, akere? (Isn't that so?)
47	Chorus	Yes

In the extract Bongiwe asked Thenjiwe to explain a step in the procedure used to find the value of m (litres of milk) given 1 kilogramme of cheese (c). Engaging learners in explaining their working was a shift from her initial teaching and it afforded learners the opportunity to develop an understanding of the meaning and relevance of steps in mathematical procedures. Bongiwe's

questioning however missed the critical mathematical idea behind the fraction $\frac{21}{2}$. It seems Bongiwe wanted learners to realize that the fraction was already it its lowest terms and hence there was no need to write that initial step in the solution. The more significant idea was the meaning of $\frac{21}{2}$ as the constant of variation, which is a key concept in both direct and indirect proportion. Hence she missed an opportunity to develop learners' deeper and conceptual understanding of $\frac{21}{2}$ besides it being a fraction that was already in its lowest terms. Although the solution seemed easy to get, the learner went through a number of procedures which were unnecessary, and Bongiwe did not point this out. The procedural focus could have obscured alternative approaches such as reasoning from the second column in the table.

In the subsequent conversation below Bongiwe asked about the second step in Thenjiwe's working.

48	Teacher	Then let me see, why did you equate, you say m over one is equal to twenty one over two *(pointing to Thenjiwe's working)* so why did you equate the two, why do you equate them, why do you say m over one is equal to twenty one over one? Why did you use this twenty one over one? Because I think this one helps you to get this one akere? (Isn't that so?) *(pointing to the 2nd and 3rd statements in Thenjiwe's working)*
49	Thenjiwe	Yes
50	Teacher	Why, why, what makes you maybe to use this twenty one over one? Why did you use that twenty one over two?
51	Thenjiwe	Maam ngiyetsa (I was doing)
52	Teacher	Hey mina (me) I don't understand your language
53	Thenjiwe	Because we wanted to find a number, maam because we wanted to get the number for m
54	Teacher	So my question is why did you use twenty one over two to get m, that's my question. What makes you to use that twenty one over two to get m? *(Thenjiwe remains silent)* Eh guys what makes her to use that twenty one over two? *(asking the whole class)* I think everything is right, akere (Isn't that so?)
55	Chorus	Yes
56	Teacher	But what makes you or her to use that twenty one over two to help her to get m? I just want to know, because she says m over one is equal to twenty one over two, so why? Why? Why? What do you think is the reason for her to use that twenty one over two? Because you can't just use something without a reason akere? (Isn't that so?) Yes papa
59	Thabiso	He wanted to find the value of m
60	Teacher	Ja we are looking for the value of m but why did you basically use this value,

		this one? *(Pointing at* $\frac{21}{2}$ *)* twenty one over two, why twenty one over two?
61	Thenjiwe	Because we were given in the graph
63	Teacher	Why do you laugh? She is correct, it's given in the graph eh why do you laugh? She is correct it's given in the graph. So what can you say about that twenty one over two and those other fractions? Yes it's given, you are hundred percent correct, it's given and you have to use it, akere? (Isn't that so?)
64	Chorus	Yes
65	Teacher	Hundred percent correct, why do you, why are you laughing? Definitely twenty one over two is given in the graph akere? (Isn't that so?)
66	Chorus	Yes
67	Teacher	This is the one which is going to help you to get all those values, the unknown values akere? (Isn't that so?)

In answering the teacher's question Thenjiwe's explanation showed an understanding of the step 'If c = 1, $\frac{m}{1}=\frac{21}{2}$' as nothing more than a means to getting the answer (T53). Bongiwe asked for justification of the statement (T54), which created an opportunity for discussing the mathematical idea of the constant variation in the relationship between the litres of milk and the kilogrammes of cheese in the table. The question could also have initiated a discussion of the possibility of working out the answer from first principles. Thabiso's response to the teacher's question endorsed a common understanding of the step as a means to getting the answer (T59). The subsequent discussion however missed the significant mathematical idea as the statement $\frac{m}{1}=\frac{21}{2}$ was explained by the teacher as referring to equivalent fractions (T69). It was also evident that the teacher saw the table as consisting of fractions (T63) which were equivalent. The implication was that in solving the task learners had to use equivalence of fractions rather than the constant variation which represented the mathematical relationship in the table. An understanding of the constant of variation would have created an opportunity for connecting the mathematical relationship to a graph of the same relationship, thereby developing richer mathematical understanding. In one of her utterances (T67) Bongiwe seemed to endorse the learners' understanding of $\frac{21}{2}$ as a fraction to be used in solving the task rather than as a constant which expressed a mathematical relationship. This teacher move reduced the conceptual

understanding of the algorithm to the procedural idea of working with equivalent fractions. The teacher also endorsed one learner's reference to the table as a graph (T61 & T63).

This episode shows how Bongiwe sustained the shifts in her teaching practice which were observed during her teaching of the collectively planned lessons. She created opportunities for learners to discuss mathematical ideas in groups by giving them potentially demanding and differentiated tasks. In the group presentations of solutions Bongiwe was in direct control of the mathematical ideas but asked questions that sought explanation and justification of solutions. There was more involvement of learners in discussing mathematical ideas as compared to lessons taught before the intervention. The discussion however missed the key conceptual mathematical ideas related to direct proportion. Questions that could have led to a deeper interrogation of the conceptual meaning of direct proportion resulted in responses that shifted the focus to the elementary idea of equivalent fractions. Working with equivalent fractions constrained the connection of direct proportion as a mathematical relationship to the other representations such as graphs and equations. This resulted in the reduction of the richness of the mathematics.

4.4.2 Janeth's teaching

Janeth's teaching before the intervention was characterized by a focus on mastery and recall of mathematical procedures and formulae. She was teaching a Mathematical Literacy class; hence the observed lessons were mainly on financial mathematics. She started her lessons by asking for mathematical definitions of terms such as 'profit', 'percentage profit', 'simple interest', etc. She then emphasized the formulae for solving tasks in financial mathematics, and the importance of adhering to each step in solving the tasks. Janeth was always in direct control of the mathematical content and learners participated by responding to the teacher's questions.

In her teaching of the jointly planned lessons Janeth made some shifts. She had learners working in small groups on mathematical tasks and presenting their solutions in whole class discussions. Like Bongiwe, she taught lessons on ratio in both the concept development lessons. In discussions learners explained and justified their solutions, sometimes engaging in heated mathematical arguments with their colleagues.

Results of coding Janeth's lessons using the MQI tool

Table 4.3 below presents the results of coding Janeth's lessons before, during and after the intervention.

Table 4.3: MQI coding of Janeth's lessons

Dimension and sub-dimensions	Pre-Intervention (3 lessons - 10 episodes)			During Intervention (2 lessons -20 episodes)			Post-Intervention (2 lessons – 14 episodes)		
	L	M	H	L	M	H	L	M	H
Mode of Instruction									
Direct instruction	0	0	10 (1.0)	11 (0.6)	9 (0.4)	0	5 (0.4)	7 (0.5)	2 (0.2)
Whole-class discussion	10 (1.0)	0	0	6 (0.3)	11 (0.6)	3(0.1)	4 (0.3)	4 (0.3)	6 (0.4)
Richness of the Mathematics									
Linking or Connections	10 (1.0)	0	0	18 (0.9)	2 (0.1)	0	14 (1.0)	0	0
Explanations	9 (0.9)	1 (0.1)	0	5 (0.2)	15 (0.8)	0	9 (0.6)	5 (0.4)	0
Multiple procedures or solution methods	10 (1.0)	0	0	17 (0.9)	3 (0.1)	0	14 (1.0)	0	0
Developing mathematical generalizations	10 (1.0)	0	0	20 (1.0)	0	0	14 (1.0)	0	0
Mathematical language	1 (0.1)	9 (0.9)	0	5 (0.2)	15 (0.8)	0	1 (0.1)	12 (0.8)	1 (0.1)
Overall richness of the mathematics	9 (0.9)	1 (0.1)	0	6 (0.3)	14 (0.7)	0	14 (1.0)	0	0
Working with Students and Mathematics									
Thorough Remediation of Student Errors and Difficulties	8 (0.8)	2 (0.2)	0	13 (0.7)	7 (0.3)	0	12 (0.8)	2 (0.2)	0
Responding to Student Mathematical Productions in Instruction	10 (1.0)	0	0	6 (0.3)	14 (0.7)	0	8 (0.6)	6 (0.4)	0
Overall working with students and mathematics	10 (1.0)	0	0	10 (0.5)	10 (0.5)	0	11 (0.8)	3 (0.2)	0
Errors and Imprecision									
Major mathematical errors or serious oversights	9 (0.9)	1 (0.1)	0	8 (0.4)	12 (0.6)	0	8 (0.6)	6 (0.4)	0
Imprecision in Language or Notation	10 (1.0)	0	0	8 (0.4)	11 (0.5)	1(0.1)	5 (0.4)	9 (0.6)	0
Lack of clarity	10 (1.0)	0	0	10 (0.5)	10 (0.5)	0	9 (0.6)	5 (0.4)	0
Overall errors and imprecision	9 (0.9)	1 (0.1)	0	8 (0.4)	10 (0.5)	2(0.1)	7 (0.5)	7 (0.5)	0
Student Participation in Meaning-Making and Reasoning									
Students provide explanations	5 (0.5)	5 (0.5)	0	8 (0.4)	12 (0.6)	0	8 (0.6)	6 (0.4)	0
Student mathematical questioning and reasoning	9 (0.9)	1 (0.1)	0	3 (0.1)	17 (0.9)	0	12 (0.8)	2 (0.2)	0
Enacted task cognitive demand	10 (1.0)	0	0	6 (0.3)	14 (0.7)	0	12 (0.8)	2 (0.2)	0
Overall student participation in meaning-making and reasoning	10 (1.0)	0	0	1 (0.1)	19 (0.9)	0	11 (0.8)	3 (0.2)	0

In those discussions Janeth often struggled to interpret learners' ideas and respond appropriately. In some instances she made some mathematical errors in responding to the learners ideas.

After the intervention Janeth did not sustain the shifts observed during the concept development lessons. Details of analyzing Janeth's teaching are presented below. Results of the MQI analysis are presented in Table 4.3 above and are discussed first before some episodes are presented to illustrate the observed shifts in her teaching. The results show shifts in some of the dimensions of the MQI coding tool which I will highlight in the subsequent paragraphs.

Coding results on the Mode of Instruction show that Janeth shifted in her teaching from the pre-intervention lessons to the post-intervention lessons. Before the intervention Janeth's teaching was rated as high in direct instruction and low in whole class discussions. In her teaching of the jointly planned lessons, the mode of instruction shifted to mostly low in direct instruction with some instances being rated as mid in direct instruction. Of significance is that none of Janeth's teaching episodes were rated as high in direct instruction during her teaching of the jointly planned lessons. Whole class discussions were rated as mostly mid. After the intervention the results show that Janeth sustained whole class discussions in her teaching, but there was a slight rise in episodes which were rated as high in direct instruction. There was no clear pattern in working on applied problems across all the three categories of lessons which Janeth taught.

On the Richness of the Mathematics there were shifts in Janeth's teaching on some of the sub-dimensions. Linking or connections was rated consistently low for all the observed lessons. Only two episodes during the concept development lessons were rated as mid in linking mathematical ideas. Explanations shifted from being rated as low before the intervention to low or mid during and after the intervention. These results indicate that there was a shift in the teacher's and learners' explanations of mathematical ideas from the lessons taught before the intervention to those which were taught during and after the intervention. However none of the episodes were rated as high in explanations, an indication that the explanations did not engage with deep and conceptual meanings of the mathematical ideas or procedures. Multiple procedures were rated consistently low, indicating that little effort was made in exploring alternative solutions and solution strategies to mathematical tasks. No mathematical generalizations were observed in

Janeth's lessons; the sub-dimension was rated as low for all lessons. The use of mathematical language was rated as consistently mid throughout all of Janeth's lessons. What these results obscure is that before the intervention it was mostly the teacher who explained or presented mathematical ideas, hence the mathematical language was attributed more to the teacher than to the learners. During the concept development lessons and in the post-intervention lessons learners were more involved in presenting and explaining mathematical ideas and solutions, hence the coding results apply to both the teacher's and learners' use of mathematical language. Similar shifts in use of mathematical language were observed in Bongiwe's teaching. The results for the overall richness of the mathematics show shifts from low before the intervention to mid during the concept development lessons, and then to low again in the post-intervention lessons. After the intervention only the explanations and mathematical language were rated as consistently mid, indicating shifts in these two areas as compared to Janeth's teaching before the intervention.

The coding results of the dimension Working with Students and Mathematics show some shifts in Janeth's teaching. In remediation and engaging with learner errors Janeth did not make significant shifts. This sub-dimension was rated as consistently low, with a few episodes being rated as mid. In responding to learners' mathematical productions there was a shift from low before the intervention to mostly mid during the concept development lessons. After the intervention there was a slight decline in Janeth's ways of responding to learners' productions and ideas as compared to the concept development lessons. The rating of the overall working with learners and mathematics shifted from low during pre-intervention lessons to an average of low and mid during the intervention lessons. After the intervention the rating declined to low.

Results of the coding for the dimension Errors and Imprecision show that Janeth's teaching before the intervention was free from mathematical errors, imprecision, or lack of clarity. All the sub-dimensions were rated as low. During the concept development and the post intervention lessons there were some episodes in which Janeth's teaching was rated as having some mathematical errors, and lacked precision and clarity. More than half of the episodes were rated as mid across all the sub-dimensions. The results show an increase in instances where she made major mathematical errors; was imprecise in language; and was not clear in her teaching. This shift can be linked to her involvement of learners in substantive discussions of mathematical

ideas during and after the intervention, which is something that I will show using some episodes from her lessons.

The results for the dimension Student Participation in Meaning-Making and Reasoning show some shifts in Janeth's teaching. The results show that before the intervention Janeth did not involve learners in meaning-making and reasoning although learners' explanations in some episodes were rated as mid. The rest of the sub-dimensions were rated as low, indicating that learners did not engage in mathematical questioning and reasoning, and the enacted task cognitive demand was low. During her teaching of the intervention lessons Janeth showed some shifts in all the sub-dimensions. Most of the episodes were rated as mid in learners' explanations, in learners' mathematical questioning and reasoning, in the enacted task cognitive demand, and in the overall learners' participation in meaning-making and reasoning. After the intervention there was a decline in Janeth's teaching on all the sub-dimensions.

Episodes from Janeth's lessons

In her teaching prior to the intervention, Janeth controlled content delivery and emphasized procedural understanding of algorithms for solving tasks drawn from the textbook. Learners were seated in groups of about six but there was little learner discussion of mathematical ideas within the groups. Janeth ensured learners' participation and attention by asking questions that elicited one-word, fill-in-the-blank computational answers. The following episode highlights these features of Janeth's teaching prior to the intervention.

Episode 1: Financial Mathematics – Loans

The episode was drawn from a lesson in which Janeth was teaching about Loans in Financial Mathematics. The whole lesson was a revision of previously given home-work. The questions, drawn from a mathematics textbook, asked about repayment of loans borrowed under given conditions and calculation of interest on hire-purchase agreements. Janeth was positioned at the front of the class. She asked learners to provide answers to her questions as she wrote the solutions on the board. In the episode the following task was presented to the learners.

> **Task:** Calculate the interest paid on a R1400 television set purchased under hire purchase if a 15% deposit is paid and the balance is paid through 18 monthly instalments of R73.50.

Turn	Speaker	Utterance
1	Teacher	*(Reading from textbook)* A one thousand four hundred television, a fifteen thousand deposit, then eighteen monthly repayments of seventy three rand fifty, that is question two *(writing the numbers in the question on the board)* What is the first step? What is the first step? Yes Daniel
2	Daniel	The first step is fifteen over hundred
3	Teacher	Uh uh *(disagreeing)* You can't say fifteen over hundred, I didn't teach you like that, uh uh Daniel, you can't say, stand up, fifteen over hundred, hai come on, yes Natasha
4	Natasha	Fifteen divided by hundred
5	Teacher	Come on come on Natasha, come on
6	Natasha	Maam fifteen percent
7	Teacher	Yes Linda
8	Linda	Fifteen percent divided by one thousand four hundred
9	Teacher	Fifteen?
10	Linda	Fifteen percent multiplied by one thousand four
11	Teacher	*(Interrupts)* Okay who can help *(inaudible)* yes my girl
12	Mildred	Eh we have to find fifteen percent of one thousand four hundred
13	Teacher	We have to find fifteen percent of one thousand four hundred, hau Linda stop laughing we are busy here, fifteen percent of one thousand four hundred *(writing: 15% of R1400 on the board)* so what is fifteen percent of one thousand four hundred? Don't forget we are calculating the amount of interest paid for items bought, yes
14	Unidentified learner	Fifteen over hundred
15	Teacher	So it's going to be fifteen over hundred multiply by *(writing:* $\frac{15}{100} \times R1400$*)*
16	Chorus	One thousand four hundred
17	Teacher	Final answer? Yes
18	Unidentified learner	Two hundred and ten
19	Teacher	Two hundred and ten *(writing: R210)*
20	Chorus	Yes
21	Teacher	Two hundred and ten, are you through?
22	Chorus	No
23	Teacher	Okay what is the next step? Huh? What is the next step? Hau Mandlazi
24	Mandlazi	Twelve multiply by, eh twelve multiply by seventy three comma fifty
25	Teacher	Twelve multiply by?
26	Mandlazi	Twelve multiply by seventy three comma fifty
27	Teacher	Twelve multiply by? Do we have twelve here?
28	Chorus	No
29	Teacher	No, no, no, no, you are lost, yes Vilakazi at the back, yes Vilakazi at the back, you are passive wake up, wake up, yes Vilakazi, eh
30	Vilakazi	Seventy three comma fifty
31	Teacher	Seventy two comma fifty? Eh and then?
32	Vilakazi	Times eighteen
33	Teacher	Times eighteen, then we are going to multiply this eighteen months by seventy three rand fifty six *(writing: 18 ×R73.56)* right what is the next step?

34	Some learners	Ki fifty six? Ki fifty (Its fifty)
35	Teacher	Fifty six? *(correcting the R73.56 to R73.50)*

The pattern of interaction went on until the solution to the task was written on the board by the teacher. Learners used calculators to provide answers to the interim steps of the solution. In the episode Janeth's teaching was focused largely on the steps of the procedure. Learners were limited to remembering the steps in the procedure and calculating interim answers to the solution. Janeth expected learners to be fast in providing responses to her questions as this was revision of previously taught work (T3). This expectation could explain her tendency to pass quickly over learners' incorrect and partially correct responses. In the episode Janeth frequently made slips which often went unnoticed or were corrected by learners (T1 & T33). The slips did not interfere with the mathematical goals of the lesson and were often self-corrected in subsequent steps. There was no reference to the meaning of the steps in the algorithm or of the algorithm as a whole. Only once did Janeth remind the learners about the goal of the process (T13). No meaning was given to the interim values being calculated and how such values enabled the answering of the task. Learners were kept attentive and engaged through the teacher's tendency to call upon any learner even though she often did not afford the learner enough time to respond before she called upon the next learner.

Janeth's teaching was high in direct instruction; low in the richness of the mathematics; lacked in eliciting significant learner productions; and did not engage learners in meaning-making and reasoning. The focus on the steps for getting to the answer rendered the mathematics to be mechanical in nature with few opportunities for making errors either by the teacher or the learners. The episode shows that Janeth did not expect learners to make errors and was quick to stop learners from making errors (T3 & T27). She was avoiding errors by stopping learners from making errors.

Episode 2: During Intervention

In her teaching of the jointly planned lessons Janeth showed some shifts. The following episode was drawn from her teaching of the first jointly planned lesson. Learners were seated in groups of about six. A worksheet with a set of tasks was given to each group. Each group was allocated

a different task on the worksheet to discuss and solve for about twenty minutes. A whole class discussion was then conducted in which each group presented its solution to the whole class. All the learners had access to the tasks being presented by the respective groups during the whole class discussions. During such presentations other learners were given opportunities to ask the presenting group any questions about the solution. Janeth was mainly positioned at the back of the class asking some probing questions to guide the discussions.

In the following episode one group was presenting its solution to the following task:

Task: To make 5 cans of purple paint there are 2 cans of blue for every 3 cans of red.

- There are 4 cans of blue. How much red?
- There are 9 cans of red. How much blue?
- There are 10 cans of purple paint. How much red and how much blue?

Four learners from Group 2 came to the front to present the group's answers. The presenter was Mildred, while the other three represented the paint colours. The group had used counters to answer the task empirically. In the following episode they presented their solution to the first part of the task.

Turn	Speaker	Utterance
1	Mildred	Eh here we are going to talk, we are going to explain question two, that is the one you gave us which is *(reads the task)* to make five cans of purple paint there are two cans of blue for every three cans of red. So in I will give, so they said five cans of purple paint so I will give to Siphelile, Portia and Naume *(holding counters in her hands)*
2	Teacher	So they represent what? Siphelile represents?
3	Mildred	Purple
4	Teacher	Purple, uhm
5	Mildred	Which is five *(giving 5 counters to Siphelile)* eh Portia represents two cans which is blue *(giving 2 counters to Portia)* and Naume represents three cans which is red *(giving Naume 3 counters)* So in, in our, in our question they said there are four cans of red and how much are red, so in Portia's cans they have reduced with two so I will give her two *(giving Portia 2 more counters)* so they say how much are red, so if I reduce two *(pointing at Portia)* I have to reduce in all their numbers *(pointing at the other 2 learners)*
6	Teacher	Reduce?
7	Mildred	Eh I have to add, I have to add in all their numbers, which is five and three *(giving 5 counters to Siphelile and 3 counters to Naume)* So they said to us how much are red, so we will answer all the red ones which is in a *(inaudible)* Siphelile has five add by five it gives us ten *(writing = 5+5=10 on the board)* then Portia has, eh we had two cans so we add by two to give us four *(writing =2+2=4)* Naume had three so add by three which is six

		(writing =3+3=6) Then we are going to do the ratio, so in this question I must I have to find the ratio of red which is Portia, it will be eh they gave us three which is Naume sorry its Portia, so they gave us three and we added three which is six *(writing =3:6)* which is question one answer
8	Teacher	Eh bullet one?
9	Mildred	Yes maam
10	Teacher	*(Reads the task)* If there are four cans of blue how much is red? You have the answer for bullet one?
11	Mildred	Yes that is our answer
12	Teacher	So what is the answer for red?
13	Mildred	It's six
14	Teacher	Something is not clear
15	Mildred	Then *(moving to part two of the task)*
16	Teacher	Class if you don't understand raise up your hand, ne because there is something
17	Chorus	Yes
18	Mildred	Number two
19	Teacher	Are you done with bullet one?
20	Mildred	We were able to answer the question how much are red, that is the answer *(pointing to 3:6)* three, I added, they gave us three cans of red, I added three, I added three in Naume's cans so they gave us six so I turned it into a ratio which is three as to six
21	Teacher	So they say, bullet one, there are four cans of blue, four ne
22	Mildred	Yes
23	Teacher	So you had to find how many, how much red, so its four as to something, so at the end of the day bullet one you have four as to something
24	Mildred	Eh they gave us four cans which is two cans of blue so we have to find the red ones
25	Teacher	So that you cannot be lost, four blue and then what red?
26	Mildred	And then six red *(writing 4:6)* then I reduce it eh simplify, which I will I will simplify it by two, then it will be two into four goes two times into six three times *(writing =2:3 below the ratio 4:6)* which gives us the answer of two cans of blue and three cans of red
27	Teacher	Right, bullet two

In the episode Janeth's mode of instruction had shifted from direct instruction to more of whole class discussion. Janeth created opportunities for learners to discuss mathematical ideas in groups before presenting their findings in a whole class discussion. The tasks were selected to develop learners' understanding of ratio. In the group presentations learners explained and justified their solutions to the rest of the class. Janeth asked questions which were mostly meant to seek clarification. Thus there was more learner involvement in meaning making and reasoning when compared to the lessons Janeth taught before the intervention. The use of counters to

illustrate ratios had been discussed in the professional learning community and Janeth was trying to work with this idea in the lesson.

In the episode learners used counters to obtain the required solution. However their strategy of having three learners as representing the colours of paint, including the mixture (T5 & T7) meant they worked with the ratio 2:3:5 rather than 2:5, something that was mathematically incorrect. The strategy did not show that 5 litres of the mixture was a result of adding the 2 and 3 in the ratio 2:3. Janeth sensed that something was not quite clear in the solution but was not able to identify what it was (T14). She doubted the learners' working but did not pursue it further (T14 & T16). The group correctly worked out that there were now 6 cans of red paint if the blue cans were 4 (T7), but they proceeded to give their answer as a ratio 3:6 which was an error because both 3 and 6 represented cans of red paint. The teacher identified the error but chose to guide the learner on what to write without engaging with the error (T23 & T25), which was a case of ignoring an error.

The episode highlights some shifts in Janeth's teaching. Opportunities were created for learners to discuss mathematical tasks with their colleagues, and then explain their solutions to the rest of the class. Engaging learners in the mathematical practices of reasoning, explaining and justifying solutions was a departure from Janeth's teaching before the intervention. The episode also shows how Janeth struggled to identify the mathematical inconsistencies in the learners' reasoning. While the use of counters can be used to develop the conceptual meaning of ratio, this was not achieved in the episode. Learners focused on the mechanical process of using counters to answer the task without a clear understanding of the concepts. Janeth did not engage the class in discussing the mathematics involved in solving the task using counters; she was content with the answer. The mathematical concepts underlying the practical process were therefore not brought out, thus weakening the potential richness of the mathematics in the episode. Learner errors and inconsistencies were not identified and the teacher struggled to make meaning of the learners' thinking. In short the teacher tried but struggled to work with the learners' ideas and the mathematics involved. All this contributed to muddling of the mathematics involved in answering the task. Although Janeth provided opportunities for learners to engage more in meaning-making and reasoning about mathematical ideas, she missed significant inconsistencies in learners' reasoning, and sometimes went along with mathematically incorrect statements.

Episode 3: Post-Intervention

The following episode was drawn from one of Janeth's post-intervention lessons in which she was teaching about rational numbers. The lesson content consisted of tasks from mathematics textbooks. The tasks involved converting common fractions to percentages, and vice versa. Other tasks were about converting percentages to decimals and vice versa.

Janeth introduced the lesson as a revision of work she had given the learners previously. Individual learners were invited to the board to present solutions and explain their working. In the following episode one learner presented a solution to the following task:

Task: Convert the following common fraction to a percentage: $\frac{17}{40}$

Turn	**Speaker**	**Utterance**
1	Teacher	We are going to do the remedial *(distributing a worksheet)* we are going to do the remedial, right. Who can do number one?
2	Unidentified learner	Yes
3	Teacher	Right, Thabiso will do number one for us
4	Thabiso	*(Goes to the board)*
5	Teacher	Right listen everybody, Thabo is going to do number one for us, hey, he is going to explain from one to eleven
6	Thabiso	*(Inaudible)*
7	Teacher	You are going to do number one a
8	Thabiso	Eh, as you can see page five it says change this fraction to percentage *(reading from the worksheet)* if necessary write your answer rounded off to one decimal place. So in changing this expression, sshh, there is a camera there *(laughter)* (writes $\frac{17}{40}$) so if you want to find the percentage of this fraction you must times expression, you must multiply the expression by hundred and its going to give us forty two comma five (writing out $\frac{17}{40} \times 100 = 42.5\%$)
9	Teacher	Here is a question
10	Mellisa	Be specific, how do we find the percentage?
11	Thabo	That's how we find the percentage
12	Mellisa	Whenever …
13	Thabiso	Whenever we want to find the percentage we multiply by hundred
14	Teacher	Okay number b, who can try number b?
15	Thabiso	Any questions?
16	Teacher	Are there any questions?
17	Nothando	Yes
18	Teacher	Okay

19	Nothando	Eh, eh if a percentage has a comma, is it not a decimal or is it going to remain like that *(pointing to 42.5%)* or do you have to round it off? *(Inaudible)*
20	Thabiso	This is to one decimal places, so
21	Teacher	What was the question?
22	Nothando	Change this fraction
23	Teacher	Change this fraction into a percentage, if necessary write your answer rounded off to one decimal place
24	Some learners	If necessary, if necessary
25	Teacher	So that answer is?
26	Chorus	Correct
27	Teacher	Its correct, next *(another learner comes to the board)*

The episode highlights some features of Janeth's teaching which were different from her teaching of the jointly planned lessons. Although Janeth was not at the board to write out the solutions, she was in direct control of what learners wrote on the board. She did not ask learners to explain why the algorithm worked. Thabiso's solution was justified with the statement "Whenever we want to find the percentage we multiply by hundred" (T13). Multiplying by a hundred was presented as nothing more than a necessary step to get an answer in percentage form. The conceptual meaning of the process was not followed up although this had been discussed in the professional learning community. It was not clear that learners understood the meaning of a percentage, something which Janeth could have asked the learners. The procedural nature of the content and a focus on the correct answers weakened the richness of the mathematics in the lesson.

In the lesson learners participated by presenting solutions to tasks to the rest of the class. This level of engagement with the mathematics was devoid of significant meaning-making and reasoning. Learners worked with specific algorithms which they had learnt earlier without interrogating why such algorithms worked. Of significance in this episode is Janeth's response to Nothando's question (T19). It was evident that Nothando believed that a percentage could not include a decimal fraction. Janeth did not understand Nothando's question hence she failed to deal with it properly. Hearing and interpreting learners' questions and comments helps teachers to provide appropriate responses and contributes to more substantive mathematical discussions, as well as to the richness of the mathematics

Janeth's teaching in this lesson was different from how she taught the jointly planned lesson. She maintained her approach of having learners present and explain solutions to the rest of the class. Learners were asking each other questions seeking clarification, which is something that Janeth supported during her teaching of the jointly planned lessons. However the nature of the tasks militated against learners engaging in the mathematical practices of reasoning, explaining and justifying, which were observed during the jointly planned lessons. There was an emphasis on the recall and correct application of algorithms without interrogating the meaning of the algorithms. A significant learner question was not understood by the teacher hence the possible learner misconception behind the question was not engaged with. Learner participation in meaning making and reasoning was low in this lesson, something which featured in Janeth's lessons before the intervention. The episode shows that the mechanical nature of the lesson content minimised learner errors. Thus it was difficult to decide if Janeth had shifted in her dealing with learner errors as compared to her teaching before the intervention. The episode shows that Janeth carried forward some of the shifts she had made in her teaching of the jointly planned lessons to her lessons after the intervention, while declining in some of the shifts.

4.4.3 Jeffrey's teaching

The analysis of Jeffrey's teaching showed that he did not make significant shifts on the dimensions of the MQI coding tool. Before the intervention he engaged in a mixture of direct instruction and whole class discussions. He started his lessons by informing learners of the focus of the lesson and then asking learners to define mathematical concepts. He relied on the mathematics textbook and made efforts to discuss the mathematical ideas as presented in the textbook. He often asked learners to work out some tasks either individually or in pairs. He then led the presentation of the solutions by asking individual learners to call out their solutions. Learners' errors were largely ignored by calling out for alternative answers until he got the correct solution. Jeffrey maintained this mode of teaching during his teaching of the concept development lessons, with a slight deviation in that learners worked in larger groups and for a longer time than in his pre-intervention lessons. This was an effort to engage in the teaching practice of having learners discussing solutions to mathematical tasks in groups before presenting their solutions to the rest of the class. This was the teaching approach that was agreed

upon during the joint lesson planning in the professional learning community. Instead of having learners present and justify their answers after the small group discussions he led the presentation of solutions with an emphasis on correct solutions. After the intervention Jeffrey maintained the same mode of teaching, with a decline in having learners working in small groups. Details of the results of the analysis of his teaching are presented below, starting with the results of the MQI coding and an episode from one of his lessons which illustrates his teaching.

Results of the coding of Jeffrey's lessons on the MQI tool

Table 4.3 shows the coding results of Jeffrey's lessons on the MQI coding tool. On the Mode of Instruction the results show that Jeffrey's teaching was rated as having a mixture of direct instruction and some whole class discussions. This was maintained throughout his lessons except for whole class discussions which declined in his teaching after the intervention.

The overall Richness of Mathematics in Jeffrey's lessons was rated as consistently low with some episodes being rated as mid in explanations and use of mathematical language. Linking mathematical ideas, multiple procedures or solution strategies, developing mathematical generalizations were all rated low on all Jeffrey's lessons. Jeffrey's use of mathematical language was enhanced by his adherence to the presentation of mathematical ideas as given in the textbook, as well as using textbook examples. He also tended to explain the mathematical ideas and demonstrate procedures on the board while the learners participated by chorusing one-word or one-phrase responses.

The dimension Working with Students and Mathematics was rated as consistently low in all Jeffrey's lessons. During his teaching before the intervention Jeffrey did not respond to learner errors, electing to call upon different learners until he got a correct answer. Learners were hardly involved in discussing mathematical ideas; hence there were no substantive learner productions for him to respond to. His teaching of the intervention lessons was rated as low on this dimension. This was largely due to the manner in which he handled the small group tasks which learners worked on. Instead of having learners come to the board to present and justify their solutions, Jeffrey led the learners' feedback by asking learners to call out their answers. Once a correct answer was called out and he had written it on the board, he would move on to the next task.

Table 4.4: MQI coding of Jeffrey's lessons

Dimension and sub-dimensions	Pre-Intervention (2 lessons - 11 episodes)			During Intervention (2 lessons -16 episodes)			Post-Intervention (3 lessons – 22 episodes)		
	L	M	H	L	M	H	L	M	H
Mode of Instruction									
Direct instruction	2 (0.2)	4 (0.4)	5 (0.4)	3 (0.2)	9 (0.6)	4(0.2)	8 (0.4)	8 (0.4)	6 (0.3)
Whole-class discussion	7 (0.6)	4 (0.4)	0	14 (0.9)	2 (0.1)	0	22 (1.0)	0	0
Richness of the Mathematics									
Linking or Connections	11 (1.0)	0	0	16 (1.0)	0	0	22 (1.0)	0	0
Explanations	8 (0.7)	3 (0.3)	0	13 (0.8)	3 (0.2)	0	16 (0.7)	6	0
Multiple procedures or solution methods	11 (1.0)	0	0	16 (1.0)	0	0	22 (1.0)	0	0
Developing mathematical generalizations	10 (0.9)	1 (0.1)	0	15 (0.9)	1 (0.1)	0	22 (1.0)	0	0
Mathematical language	0	10 (0.9)	1 (0.1)	0	14 (0.9)	2 (0.1)	7 (0.3)	14 (0.6)	1 (0.0)
Overall richness of the mathematics	11 (1.0)	0	0	13 (0.8)	3 (0.2)	0	22 (1.0)	0	0
Working with Students and Mathematics									
Thorough Remediation of Student Errors and Difficulties	7 (0.6)	4 (0.4)	0	14 (0.9)	2 (0.1)	0	21 (1.0)	1 (0.0)	0
Responding to Student Mathematical Productions in Instruction	11 (1.0)	0	0	12 (0.8)	4 (0.2)	0	19 (0.9)	3 (0.1)	0
Overall working with students and mathematics	9 (0.8)	2 (0.2)	0	14 (0.9)	2 (0.1)	0	22 (1.0)	0	0
Errors and Imprecision									
Major mathematical errors or serious oversights	11 (1.0)	0	0	14 (0.9)	2 (0.1)	0	18 (0.8)	4 (0.2)	0
Imprecision in Language or Notation (maths symbols)	11 (1.0)	0	0	13 (0.8)	3 (0.2)	0	12 (0.5)	10 (0.4)	0
Lack of clarity	11 (1.0)	0	0	13 (0.8)	3 (0.2)	0	18 (0.8)	3 (0.1)	1 (0.0)
Overall errors and imprecision	11 (1.0)	0	0	14 (0.9)	2 (0.1)	0	17 (0.8)	5 (0.2)	0
Student Participation in Meaning-Making and Reasoning									
Students provide explanations	6 (0.5)	5 (0.4)	0	9 (0.6)	7 (0.4)	0	22 (1.0)	0	0
Student mathematical questioning and reasoning	10 (0.9)	1 (0.1)	0	14 (0.9)	2 (0.1)	0	22 (1.0)	0	0
Enacted task cognitive demand	11 (1.0)	0	0	16 (1.0)	0	0	22 (1.0)	0	0
Overall student participation in meaning-making and reasoning	10 (0.9)	1 (0.1)	0	15 (0.9)	1 (0.1)	0	22 (1.0)	0	0

Learners who had obtained incorrect answers were not given the chance to present and justify their answers to the rest of the class. Jeffrey continued to deal with learners' errors and solutions in a similar manner in his teaching of the post intervention lessons.

Jeffrey's lessons were rated as low on all the three sub-dimensions of Errors and Imprecision, indicating that there were no or very few instances in which there were teacher errors and lack of precision in his teaching. This was attributed to Jeffrey's focus on procedures and correct solutions, with little engagement of learners in explaining and justifying their answers. He also tended to refer to mathematics textbooks during his teaching, which may have supported clear, precise mathematical language.

Jeffrey's involvement of learners in meaning-making and reasoning was rated as consistently low throughout all his lessons. Learners were hardly involved in explaining their thinking or solutions although they were occasionally involved in discussing mathematical ideas. All the lessons were rated as low on learners' mathematical questioning and reasoning. The enacted task cognitive demands in all his lessons were rated as low, indicating that the mathematical tasks which learners engaged with in his lessons were not cognitively demanding. Overall learner participation in meaning-making and reasoning was rated as low in all the lessons, indicating that there was no shift on this dimension.

Results of the coding of Jeffrey's lessons showed that he did not make any significant shifts in his teaching practice on the dimensions of the MQI framework. The coding results showed that Jeffrey consistently engaged mostly in direct instruction with some whole class discussions in his lessons. The richness of the mathematics was rated as low and procedural for all his lessons. His engagement with learner productions and errors was also rated as low. Learner participation in his lessons consisted of answering the teacher's questions; learners were not engaged in significant meaning-making and reasoning. The following two episodes from two of his lessons illustrate these features of his teaching.

Episodes from Jeffrey's lessons

In this section I present two episodes from Jeffrey's lessons to illustrate the minimal shifts he made in his teaching and in his way of dealing with learner errors. The first episode is from his

teaching of the first jointly planned lesson, and the second episode is from one of his post-intervention lessons.

Episode 1: Concept Development 1

The following episode drawn from his teaching of one of the jointly planned lessons to a Grade 7 class highlights some of the typical features of Jeffrey's teaching in all his lessons. In this lesson Jeffrey was teaching equivalent fractions, which was the critical concept for Grades 7 and 8.

Episode: The concept of equivalent fractions

In the episode Jeffrey started the lesson by asking learners what a fraction is. Most learners showed that they did not understand what a fraction is.

Turn	Speaker	Utterance
1	Teacher	Okay settle down. Today we are going to talk about fractions. What do you think is a fraction? *(Writes 'Fractions' on the board)* Okay what do you think is a fraction? What is a fraction? Fraction. What is a fraction? Rovelita
2	Roven	*(Inaudible)*
3	Teacher	What is a fraction? Please put up your hand and we will listen to you. What is a fraction?
4	Unidentified learner	*(Inaudible)*
5	Teacher	Ja okay Makwandise raise up your head *(laughter)* Okay lets listen
6	Mark	A fraction is a number that you multiply by hundred
7	Teacher	A fraction is a number that you multiply by hundred. Yes?
8	Unidentified learner	A fraction is a number that has a numerator and denominator
9	Teacher	A fraction has got a numerator and?
10	Chorus	Denominator
11	Teacher	Okay, by definition I am having one over two, ne *(writing* $\frac{1}{2}$ *on the board)* He says I must have numerator and *(writing the words numerator and denominator)*
12	Chorus	Denominator
13	Teacher	Denominator, denominator. Okay for a fraction I must have a numerator and denominator. Now I am going to move on to equivalent fractions *(Writes 'Equivalent Fractions (LO 1, ASS 4)' on the board, then proceeds to write a task for learners to do in groups)* Okay I have given you those cards so you are going to give me those fractions. You are going to draw those shapes and then you are going to report back

In this extract Jeffrey made an effort to find out how much learners knew about fractions, a move that was intended to support continuity in learners' learning by first finding out their prior knowledge of fractions. However because of his focus on correct answers, he ignored one learner's incorrect definition of a fraction, opting to move on to another learner (T7). Such an avoidance of learner errors was consistent in his teaching where he mainly focused on correct responses. Jeffrey's endorsement of a structural definition of a fraction without linking it to its conceptual meaning was a reduction of the richness of the mathematics. The meanings of a numerator and denominator in relation to parts of a whole object were not discussed.

At this point in the lesson Jeffrey gave learners a common task for them to do in groups of about eight. The teacher drew five circles on the board. The circles were each subdivided differently into equal parts. The parts of each circle which were equivalent to $\frac{1}{2}$ were shaded. Learners were given manila sheets on which they were asked to draw the same circles and then name the fraction which was shaded in each circle. Learners worked on the task for about twenty minutes before the teacher asked for feedback.

14	Teacher	Okay let us listen to groups. We want to talk about what you got, akere? (Isn't that so?)
15	Chorus	Yes
18	Teacher	So for the first part I said write the fraction for the shaded part, what is the answer for this one? *(pointing at the first circle)* Okay, yes?
19	Unidentified learner	One over two
20	Teacher	One over two *(writing* $\frac{1}{2}$ *next to the circle)*. One over?
21	Chorus	Two
22	Teacher	Number two? *(many learners raise up their hands)* Yes?
23	Unidentified learner	Two over four
24	Teacher	Two over *(writes* $\frac{2}{4}$ *next to the relevant circle)*
25	Chorus	Four
26	Teacher	Okay number three?
27	Many learners	Sir, sir *(raising up their hands)*
28	Teacher	Yes?
29	Unidentified learner	Four over eight

30	Teacher	Four over *(writing* $\frac{4}{8}$ *next to the relevant circle)*
31	Chorus	Eight

This pattern of interaction went on until all the fractions had been written next to the respective circles. Jeffrey then used the fractions to discuss the concept of equivalent fractions as shown in the following extract of the episode.

42	Teacher	Okay now, listen, listen, looking at the shaded parts, what can you tell me about all the shaded parts for all those diagrams? *(Silence)* What is it that they are called? Look at diagram, wait, look at diagram number one, diagram number two, diagram number three, diagram number four, diagram number five. Who can tell us, yes?
43	Sithabi	The fractions are almost the same
44	Teacher	Almost, okay, they are almost, the fractions are almost the same, ne
45	Some learners	Yes
46	Teacher	The fractions are almost the same, meaning that one over two is equals to two over four, is equals to four over eight, is equals to five over ten, is equals to six over twelve *(writing the statement:* ‘$\frac{1}{2}=\frac{2}{4}=\frac{4}{8}=\frac{5}{10}=\frac{6}{12}$’*)* Is that right?
47	Chorus	Yes
48	Teacher	Okay, who can prove it on the board? One over two is equal to two over four, how do we get that? *(Silence)* Okay please, how do we see that one over two is equal to two over four? Makwandise?
49	Mark	You take the half of the number
50	Teacher	You take the half of the number, yes?
51	Rovel	Two multiplied by one we get two, then two multiplied by two is four
52	Teacher	Well done! Okay you multiply, okay, the numerator and denominator have to be multiplied by the same number, akere?
53	Chorus	Yes
54	Teacher	And then Rovelita has taken two, two multiplied by the numerator is two, two multiplied by the denominator is four *(writing* ‘$\frac{1}{2}\times\frac{2}{2}=\frac{2}{4}$’*)*. Therefore one over two is equal to two over four, ne
55	Chorus	Yes
56	Teacher	And that means those are the equivalent
57	Chorus	Fractions
58	Teacher	Any question from the diagram?
59	Chorus	No
60	Teacher	Any questions
61	Chorus	No

The use of shaded parts of diagrams is one of the common approaches in most mathematics textbooks for developing learners' understanding of equivalent fractions, especially in the lower grades in primary school. For the Grade Seven class this was easy. Learners had no difficulties in correctly naming the fractions represented by the shaded parts in each of the circles. They had difficulties in deriving the concept of equivalent fractions from their answers. Jeffrey's handling of the learners' learning of the meaning of equivalent fractions from the diagrams illustrates some features of his teaching. Jeffrey's acceptance and interpretation of Sithabile's response (T43) as meaning equality could be an indication of his focus on the answer. He did not ask Sithabile what she meant by "almost the same". Writing of the fractions in a statement of equality was an appropriate teacher move that shifted the learners' attention from the diagrammatic representations of the fractions to the structure of the numerical representation of the fractions. However the discussion of the relationships among the numerical fractions was not connected to the diagrams to illustrate the multiplicative factor that represented the idea of equivalence. The meaning of equivalent fractions was reduced to the identification of a multiplicative factor that connected any two fractions, which is essentially a procedural process which can lead to a limited understanding of the concept.

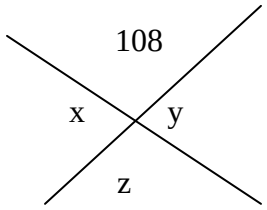
The episode shows features of Jeffrey's teaching which led to his lessons being rated low on most dimensions of the MQI coding framework. In the episode Jeffrey was in control of the content delivery. Although learners at some point worked in groups they were not engaged in significant discussions of mathematical ideas. Engaging learners in group discussions was a shift from his teaching before the intervention when no group-work was observed in his teaching. This shift could be attributed to his efforts to implement the suggested practice in the professional learning community. Learners' participation in most of the lesson was confined to answering the teacher's questions which in most cases elicited one-word or one-phrase responses. There was low learner engagement in meaning-making and reasoning. As shown above Jeffrey developed procedural rather than conceptual meanings of fractions and equivalent fractions, which effectively reduced the richness of the mathematics. Incorrect learner responses were ignored (T6 & T49), an indication that Jeffrey worked with learners' ideas and errors at a low level. Jeffrey did not afford learners who gave incorrect responses opportunities to explain

their answers and their thinking. These features of Jeffrey's teaching were consistent in all his lessons.

Episode 2: Post-Intervention Lesson 2

The following episode from Jeffrey's second post-intervention lesson illustrates how Jeffrey maintained features of his teaching that were observed in all his lessons. In this lesson he was teaching about angles to a Grade 8 class. He started by leading the definition of 'angles at a point', 'supplementary angles' and 'complementary angles'. Learners were then asked to answer tasks that he had written on the board. The tasks required learners to calculate required angles in given diagrams. Later he called the class together and then led a whole class discussion of the solutions to the tasks. Jeffrey asked learners questions and he wrote the responses on the board. His questions had a focus on the correct answer. In this episode he was leading towards the solution for the following task:

Calculate the angles x, y and z in the following diagram:



Turn	Speaker	Utterance
1	Teacher	Number d, statement, reason?
2	Thulani	Hundred and eight degrees plus x plus z plus y equals three hundred and sixty
3	Teacher	Hundred and eight plus x plus z plus y equals three hundred and sixty, akere (isn't it?)
4	Chorus	Yes
5	Teacher	That is a correct statement but it will not help us to get the values of the angles. What other thing do we know regarding the diagram? Before we can make the statement. I don't the magnitude of x, I don't know z, I don't know y, so there is something that, ja, Moeketsi
6	Moses	Hundred and eight degrees, hundred and eight plus x plus plus one hundred and eight plus x
7	Teacher	Hundred and eight plus x equals?
8	Moeketsi	Three hundred and sixty
9	Teacher	Not three hundred and sixty
10	Unidentified	*(Inaudible)*

	learner	
11	Teacher	Ja, that one is correct but we don't have the values of x, z and y, you can use other things, akere? (Isn't it) ja
12	Sphiwe	One hundred and eight degrees plus eighty plus eighty plus eighty *(inaudible)*
13	Teacher	How do we get those magnitudes? *(Inaudible)*
14	Sphiwe	Isn't it that they are the same?
15	Teacher	No, who can help us? *(Silence)* We want a statement, ja? *(Silence)* Hey, who can try? Ja?
16	Moses	One hundred and eight plus ninety plus ninety equals three hundred and sixty
17	Teacher	But how do I know that this is ninety? *(Silence)* What do you about these angles? This angle and this angle *(pointing at x and y in the diagram)* and this angle and this angle? *(pointing at z and 108 in the diagram)* ja, what do you know about those angles? *Silence* You have two lines that are crossing, akere? Two lines are crossing, what do you know about those angles? *Silence* When two lines are crossing what do we know about those angles?
18	Unidentified learner	Corresponding
19	Teacher	I hear corresponding and what? Something, ja?
20	Unidentified learner	Cross multiply
21	Teacher	No, ja
22	Naomi	*(Inaudible)*
23	Teacher	X plus? *(Silence)* Hey, when two lines are crossing what is the magnitude of these angles *(pointing at x, y and z in the diagram)* The magnitude, ja?
24	Unidentified learner	Corresponding
25	Teacher	Corresponding is when you are having maybe this angle is equal to that angle *(drawing a different diagram to show corresponding angles)* this is corresponding. We have got corresponding and what? Corresponding angles and what? Corresponding? *(Silence)* Okay, ja
26	Thulani	Vertically opposite angles
27	Teacher	Vertically opposite angles?
28	Thulani	Yes
29	Teacher	So what are vertically opposite angles here? *(pointing at the diagram)*
30	Thulani	One o eight and z
31	Teacher	One o eight and z are vertically opposite angles, akere?
32	Chorus	Yes
33	Teacher	So what do we know about vertically opposite angles
34	Thulani	They are the same
35	Teacher	They are the same, they are equal, akere?
36	Chorus	Yes
37	Teacher	Okay, my statement angle z is equal to one o eight *(writing 'z = 108'),* my reason, vertically opposite angles *(writing 'vertically opposite angles')* vertically opposite angles, akere? Then I can start, I know the magnitude of z is one o eight, akere *(writing '108' in place of z in the diagram)* Then I can get the magnitude of x and the magnitude of y, if I get the magnitude of x

		then I got the magnitude of y, akere *(pointing at x and y in the diagram)* So how can I get x or y? *(Silence)* One o eight plus? I know z, z is one o eight. What about x and y? How do I get x? Isha, make a statement, a statement x or y
38	Unidentified learner	*(Inaudible)*
39	Teacher	No. This angle and that angle we want to know *(pointing at x and 108 in the diagram)* we want to know, we want to make a statement about these angles, if I can give a clue
40	Melissa	X is equal to seventy two degrees
41	Teacher	How did you get seventy two degrees? How do we get seventy two degrees? Statement. X is equal to seventy two, but how do I get seventy two? *(Silence)* x plus? x is equal to seventy two but how did you get seventy two?
42	Moeketsi	One o eight plus one o eight divide by ninety degrees is equal to *(inaudible)*
43	Teacher	Okay who can tell us; this is a straight line, akere? *(pointing at one of the lines in the diagram)*
44	Chorus	Yes
45	Teacher	So what about angle x and what about angle one o eight? *(Silence)* Angles on a straight line add up to how much? Angles on a straight line, they add up to how much?
46	Chorus	Hundred and eighty
47	Teacher	Hundred and eighty akere?
48	Chorus	Yes
49	Teacher	They are supplementary akere?
50	Chorus	Yes
51	Teacher	So why don't you make a statement? Make a statement and say supplementary
52	Melissa	Sir one hundred and eight minus one o eight equals seventy two
53	Teacher	So seventy two is the value of x?
54	Chorus	Yes

The episode shows that Jeffrey maintained mostly direct instruction while providing learners with opportunities to solve some tasks individually in their exercise books. Allowing learners to solve given tasks individually or in small groups was consistent with his teaching of the pre-intervention and jointly planned lessons. When he invited learners to present their solutions he resorted to direct instruction. He called for answers while he wrote the learners' responses on the board. He had a focus on correct answers and quickly dismissed incorrect learner responses (T15, T21, T39 & T42). By failing to follow-up on learners' incorrect answers, Jeffrey was avoiding errors. He kept on asking different learners until he got the correct answer, and sometimes resorted to questions that led learners to the correct answer (T37, T43, T45). He hardly asked learners to justify their answers. In this episode he did it only once (T41). The

episode illustrates that Jeffrey maintained direct instruction, consistently focused on correct learner answers by not following up incorrect responses. Learners were hardly given opportunities to explain their ideas. His ways of avoiding engaging with learner errors are inconsistent with statement about learner errors as evidence of learners' learning. In his teaching errors were largely ignored, therefore learners did not learn much from errors that they made.

The two episodes show that Jeffrey did not shift in both his teaching and ways of dealing with learner errors. Involving learners in either small group discussions or individual work before engaging in discussing the solutions could be explained as efforts to implement the suggested teaching practice. However he seemed to have appropriated the form of the suggested teaching practice more than the engagement of learners in substantive discussion of mathematical ideas.

4.4.4 Tandeka's teaching

The analysis of Tandeka's lessons revealed that she did not make substantive shifts as compared to Bongiwe and Janeth. Table 4.5 shows the results of coding Tandeka's lessons on the MQI coding tool. Her teaching was different from Jeffrey's in that she consistently engaged learners in discussing tasks in groups before she led a whole discussion of the learners' solutions. She was consistent in her mode of instruction throughout her lessons. She gave out worksheets with tasks for learners to discuss in groups at the beginning of each lesson; explained the tasks to each group; and then went around monitoring progress. Learners were later invited to the board to present their solutions in whole class discussions. Learners' presentations were mainly procedural and in some cases the key mathematical ideas were not made explicit. Tandeka had problems maintaining discipline in the large class that she taught and the group activities sometimes became noisy and uncontrolled. She also had problems with identifying and following up significant learners' ideas. She was mostly satisfied with correct procedures for getting the answer.

In her teaching before the intervention and after the intervention, Tandeka gave learners tasks from the textbook which were procedural in nature and did not engage learners in substantive discussion of mathematical ideas. During the first cycle of teaching the jointly planned lessons Tandeka gave learners tasks which were in line with the planning in the community, hence learners were involved in discussing more conceptual mathematical ideas.

Results of coding Tandeka's lessons on the MQI

Table 4.5: MQI coding of Tandeka's lessons

Dimension and sub-dimensions	Pre-Intervention (2 lessons - 13 episodes)			During Intervention (2 lessons -16 episodes)			Post-Intervention (2 lessons – 17 episodes)		
	L	M	H	L	M	H	L	M	H
Mode of Instruction									
Direct instruction	8 (0.6)	5 (0.4)	0	7 (0.4)	7 (0.4)	2 (0.1)	9 (0.5)	8 (0.5)	0
Whole-class discussion	8 (0.6)	4 (0.3)	1 (0.1)	8 (0.5)	5 (0.3)	3 (0.2)	9 (0.5)	8 (0.5)	0
Richness of the Mathematics									
Linking or Connections	13 (1.0)	0	0	16 (1.0)	0	0	15 (0.9)	2 (0.1)	0
Explanations	13 (1.0)	0	0	13 (0.8)	3 (0.2)	0	12 (0.7)	5 (0.3)	0
Multiple procedures or solution methods	13 (1.0)	0	0	16 (1.0)	0	0	17 (1.0)	0	0
Developing mathematical generalizations	13 (1.0)	0	0	16 (1.0)	0	0	15 (0.9)	2 (0.1)	0
Mathematical language	2 (0.1)	11 (0.8)	1 (0.1)	0	16(1.0)	0	0	17 (1.0)	0
Overall richness of the mathematics	12 (0.9)	1 (0.1)	0	10 (0.6)	5 (0.3)	1 (0.1)	15 (0.9)	2 (0.1)	0
Working with Students and Mathematics									
Thorough Remediation of Student Errors and Difficulties	6 (0.5)	7 (0.5)	0	12 (0.7)	4 (0.3)	0	16 (0.9)	1 (0.1)	0
Responding to Student Mathematical Productions in Instruction	10 (0.8)	3 (0.2)	0	10 (0.6)	6 (0.4)	0	11 (0.7)	6 (0.3)	0
Overall working with students and mathematics	12 (0.9)	1 (0.1)	0	16 (1.0)	0	0	11 (0.7)	6 (0.3)	0
Errors and Imprecision									
Major mathematical errors or serious oversights	8 (0.6)	4 (0.3)	1 (0.1)	11 (0.7)	5 (0.3)	0	16 (0.9)	1 (0.1)	0
Imprecision in Language or Notation (mathematical symbols)	8 (0.6)	3 (0.2)	2 (0.2)	9 (0.6)	5 (0.3)	2 (0.1)	13 (0.8)	3 (0.2)	1 (0.1)
Lack of clarity	8 (0.6)	3 (0.2)	2 (0.2)	10 (0.6)	6 (0.4)	0	16 (0.9)	1 (0.1)	0
Overall errors and imprecision	8 (0.6)	3 (0.2)	2 (0.2)	12 (0.7)	4 (0.3)	0	15 (0.9)	2 (0.1)	0
Student Participation in Meaning-Making and Reasoning									
Students provide explanations	8 (0.6)	5 (0.4)	0	8 (0.5)	8 (0.5)	0	8 (0.5)	9 (0.5)	0
Student mathematical questioning and reasoning	8 (0.6)	5 (0.4)	0	8 (0.5)	8 (0.5)	0	11 (0.7)	6 (0.3)	0
Enacted task cognitive demand	13 (1.0)	0	0	8 (0.5)	8 (0.5)	0	17 (1.0)	0	0
Overall student participation in meaning-making and reasoning	13 (1.0)	0	0	11 (0.7)	5 (0.3)	0	13 (0.8)	4 (0.2)	0

In the second cycle of teaching the jointly planned lessons, Tandeka taught using a common worksheet which was developed in the professional learning community.

A common feature in Tandeka's teaching was her handling of the whole class discussions in which learners presented their solutions to the group tasks. After each group had presented their solution, she did not engage the other learners in discussing each solution and she did not highlight or summarise the mathematical ideas in the solution. She endorsed the solution if it was correct and asked the next group to make its presentation. Thus the mathematical ideas in the tasks and solutions were not further explored so that they became explicit for all the learners. This pattern of responding to learners' solutions recurred in all her lessons, and this explained the observed lack of shifts in her teaching.

The results of MQI coding Tandeka's lessons show that her mode of instruction did not change across the three categories of her lessons. Her mode of instruction was different from the other teachers. Direct instruction was consistently rated as either low or mid, indicating that she did not dominate or control content delivery in her lessons.

Whole class discussions were also rated as low or mid. Learners were involved in whole class discussions during the report-back sessions, but the discussions were low in engaging with the mathematical ideas involved. On the Richness of the Mathematics all Tandeka's lessons were rated as low. All the sub-dimensions of the Richness of the Mathematics were rated as low except for Mathematical Language which was rated as mid in some episodes of her lessons. This consistency is attributed to her handling of learners' group-work and report-backs which I described earlier. In terms of the mathematical language Tandeka was precise in her use of mathematical terms and often encouraged learners to use correct mathematical language. This explained the rating of some episodes as mid in mathematical language. The overall richness of the mathematics remained low throughout all her lessons mainly due to low engagement with the mathematical ideas involved in her responding to learners' ideas in the whole class discussions.

On Working with Students and Mathematics the results show that before and during the intervention some of the episodes were rated as mid in the remediation of learner errors and difficulties, although most of the episodes were rated as low on this aspect. After the intervention there was a decline in remediation of learner errors and difficulties. Responding to learners'

mathematical productions was rated as mostly low with some of the episodes being rated as mid. Of those episodes which were rated as mid in responding to learners' productions a larger proportion was during the teaching of the jointly planned lessons than before and after the intervention. This can be attributed to the nature of the tasks planned in the professional learning community. The tasks engaged learners in discussing conceptual meanings of mathematical concepts such as 'equivalent fractions', 'decimal fractions' and 'percentages'. Thus the discussions were richer in conceptual meanings as compared to the tasks which the learners discussed before and after the intervention. On the overall working with students and mathematics, all Tandeka's lessons were rated as low.

For Errors and Imprecision the results show that Tandeka's teaching was rated as having some episodes in which she made mathematical errors; was not precise in language or notation; and/or lacked clarity. Although most of the episodes were rated as low on these three sub-dimensions a significant number of episodes were rated as mid, and a few episodes were rated as high. The rating was consistent across all Tandeka's lessons. An episode presented below illustrates how Tandeka often asked questions that lacked clarity in her teaching.

On the dimension Student participation in Meaning-Making and Reasoning, the results show a consistent pattern in Tandeka's lessons. The sub-dimensions 'Students provide explanations' and 'Student mathematical questioning and reasoning' were rated as either low or mid in all Tandeka's lessons. This was due to her engagement of learners in discussing mathematical tasks in groups and giving them opportunities to present their solutions in whole class discussions. In those instances learners provided explanations and often asked questions that showed substantive engagement with mathematical ideas. On the 'Enacted task cognitive demand' the results show a shift from the pre-intervention lessons to the jointly-planned lessons and after the intervention. Before and after the intervention, the lessons were rated as low on this sub-dimension. During her teaching of the jointly-planned lessons there was a rise in the number of episodes which were rated as mid in the enacted task cognitive demand. Again this was explained by the nature of the tasks used during the intervention lessons. The overall participation of learners in meaning making and reasoning was consistently low, with some episodes being rated as mid.

Episodes from Tandeka's lessons

Two episodes are presented in this section to elaborate the features of Tandeka's teaching described in the above section. The episodes show how Tandeka provided learners with opportunities for discussing mathematical ideas with their peers in groups and then present their findings in whole class discussions. The first episode is from her teaching of the first jointly planned lessons. The second episode is from one of her post-intervention lessons.

Episode 1: Concept development 1

In this lesson Tandeka was teaching the first jointly planned lesson on rational numbers to a Grade 7 class.

Episode: Common Fractions and Percentages

In the lesson the teacher gave each group tasks to work on. The groups worked on different tasks that sought to develop learners' understanding of the connections among common fractions, decimal fractions and percentages. The tasks required learners to: draw and shade given fractions of shapes; convert the common fractions to percentages; given a ten by ten grid, learners were required to shade given percentages and then express those percentages as common fractions by using the grid. Learners worked on the tasks for about 30 minutes before the teacher called the class to present their findings in a whole class discussion. In the episode one group presented solutions to their tasks. The group had been working on a task in which they were required to identify what fractions represented shaded parts of given shapes and convert the fractions into percentages. In the presentation different learners from the same group take turns to talk about their solutions.

Turn	Speaker	Utterance
1	Teacher	Right you group, present what you have now. Pupils we have finished discussing, now sit down and listen to this group. Now present what you have, you will finish that after presenting what you have, so please now you present how you got this answer and what do you mean by this and that, so you can start you as a group, please listen here, please keep quiet, Presley and your group *(the group stands up)* Present from where you are, there is no space. Pupils don't forget you listen then after you ask questions
2	Sipho	Hello everybody, these are our group members. We started shading our diagram *(raising up a 10 by 10 grid)*
3	Jacob	After shading we started counting our blocks after we shaded our, our fraction,

		eh we simplify our fraction
4	Girlie	We started by *(inaudible)* then we say twenty five over hundred, divide by five is equal to five then hundred divide by five *(some learners disturb)*
5	Teacher	Hey, hey, speak
6	Mpho	Twenty five divide by five equals five and five divide by five equals one and hundred divide by five equals to twenty, twenty divide by five equals to four
7	Girlie	Our second question was three b The question said we must shade seventy five over hundred and we shaded these blocks *(raising up a 10 by 10 grid in which 75 squares had been shaded)* and we wrote seventy five over hundred *(*$\frac{75}{100}$ *was written below the grid)* Then the second question was three point b which said we must simplify the fraction. We said seventy five divide by five equals fifteen, fifteen divide by five equals three. Then hundred, hundred divide by five is equals to twenty, twenty divide by five is equal to four
8	Teacher	So all in all what is the fraction?
9	Girlie	The fraction is three over four
10	Jacob	*(Raises up a chart showing how the group had converted the fractions* $\frac{3}{5}$ *and* $\frac{7}{25}$ *to* $\frac{60}{100}$ *and* $\frac{28}{100}$ *respectively.)*
11	Thapelo	Eh our fraction is three over five, we started
12	Girle	*(raises up another chart with 5 rectangular bars of which three had been shaded)* The question says what fraction is the shaded area? The fraction of the shaded area is three over five
13	Sipho	And we simplify three over five by three times twenty, five times twenty and we got sixty over hundred
14	Teacher	Did you simplify that?
15	Chorus	Yes
16	Girlie	The real answer was three over five, that was the fraction, then we said three divide by one is equals to three and five divide by one is equal to five, then our fraction would have been three over five
17	Teacher	What does the question say?
18	Sipho	What fraction is the shaded area?
19	Teacher	And then,
20	Thapelo	The answer is three over five
21	Teacher	And then the next question says?
22	Sipho	Change the denominator to hundred
23	Teacher	So do you simplify there? Can you simplify three over five to be a simple form? Because the question says change the denominator to be hundred *(group remains silent)* Pupils listen so as to answer the questions, eh
24	Thapelo	Seven over twenty five *(moving onto the second fraction)* seven times four, twenty five times four equals twenty eight over hundred
25	Teacher	Have you finished?
26	Chorus	No, no
27	Teacher	Anyone to ask questions? If no question it means we pass
28	Moyana	How did you get the percentage?
29	Johannes	We didn't finish, we did not find the percentage

30	Teacher	You didn't finish?
31	Chorus	No
32	Teacher	So if you had managed to finish, how would you get that?
33	The Group	*(Inaudible murmurings)*
34	Teacher	Pupils, you have got twenty eight over hundred
35	Chorus	Yes
36	Teacher	Twenty eight divided by hundred, so from twenty eight over hundred how do you get the percentage? Write the percentage of that fraction
37	The Group	*(Incoherent muttering)*
38	Teacher	Write twenty eight over hundred as a percentage
39	The Group	*(Incoherent muttering)*
40	Teacher	Okay, okay let's give these few minutes to that group *(another group starts presenting its solutions)*

The episode illustrates how Tandeka made appropriate attempts in her lessons to engage learners in meaning-making and reasoning through designing mathematical tasks that had the potential for supporting the learners' conceptual understanding of mathematical ideas. Learners discussed these tasks among themselves and then in whole class discussions. In this particular task the 10 by 10 grid was an appropriate tool for developing an understanding of percentages and how percentages are connected to common fractions. The pictorial representations of fractions expressed with denominators of 100 were meant to support learners in making this connection. Another feature of Tandeka's teaching was her efforts to engage learners in discussion of the tasks in groups followed by whole class discussions of each group's findings. She invited other learners to comment or ask questions on each others' group presentations (T27). The move was meant to support whole class discussion of the mathematical ideas in each group's presentation.

Tandeka's handling of the learners' presentation in this episode highlights some features of her teaching that constrained the explicit development of the mathematical ideas embedded in the task. In the presentation there was no mention of percentages when learners were talking about the grid. The conversion of common fractions to their equivalents with a denominator of 100 (T10) could have led to discussion of percentages thereby making the connection between the two ways of representing rational numbers. One learner's question to the group about percentages could be an indication that the learner could see the connection between common fractions and percentages (T28). The teacher did not follow-up this question by asking the learner why he had asked the question, which could have led to a deeper discussion. Towards the end of the presentation the teacher asked the group how they could convert a common fraction

into a percentage, a question that remained unanswered (T36 & T38). The question was significant for goals of the task and could have been asked much earlier in the group's presentation.

The episode shows how the learners' access to the conceptual mathematical ideas was constrained by the teacher's limited scaffolding of discussions so that the conceptual meanings were made explicit. Thus learners' participation in meaning-making and reasoning did not lead to comprehensive and conceptual mathematical ideas being discussed and understood by learners. This pattern of teaching was consistent across Tandeka's lessons with little variation, hence the conclusion that she did not make any significant shifts in her teaching on the five dimensions of the MQI coding tool.

Episode 2: Post-Intervention Lesson 1: Area

In this episode Tandeka was teaching about area. Learners were first given tasks to solve in groups and then later they presented their solutions in a whole class discussion. In this episode one group was presenting their solution to the following task:

> Find the area of a rectangle whose dimensions are 50 mm by 30 mm.

The whole group was at the front and one of them presented the solution on the board.

Turn	Speaker	Utterance
1	Johannes	*(Writes 'Area = LxB', 50mmx30mm = 1500 mm^2)* Area is equal to length times breadth, fifty times thirty equals one thousand five hundred millimeters, and then
2	Teacher	One thousand five hundred millimetres?
3	Johannes	One thousand five hundred millimetres, and then you can't write two millimetre then you write it as phezulu (above) *(pointing at mm^2)*
4	Teacher	What do you mean by that as phezulu (above)?
5	Johannes	This two millimetre *(pointing at mm^2)* means ngifakile (I put) two millimetre
6	Unidentified learners	Murmurings
7	Teacher	Someone to help please
8	Thandi	It is millimetre times millimetre and it gives you two *(pointing at the 2 in mm^2)*
9	Teacher	And then tell me that answer, what is that answer please?
10	Chorus	*(Inaudible)*
11	Teacher	Eh, eh one
12	Mduduzi	One thousand five hundred millimeters *(pointing at 1500 mm^2)* plus two

		(laughter)
13	Teacher	And you? *(Referring to Sipho a member of the presenting group)*
14	Sipho	One thousand five hundred and two millimeters *(pointing at 1500 mm^2)*
15	Teacher	Another one?
16	Johannes	One thousand five hundred millimetres
17	Teacher	One thousand five hundred millimetres? On the floor is there anyone to help please? What do we mean by that answer? Anyone to help please? Someone to tell us the answer, the last step *(Silence)* No one to help? Ja, you tell us what the answer means please, tell us the last statement, the last statement
18	Nomzamo	The last statement is square millimetres
19	Teacher	Please give us the full answer, the full answer please
20	Nomzamo	Area is equal to length times breadth, fifty times thirty is equal to one thousand five hundred and the answer is one thousand five hundred square millimetres
21	Teacher	Hey boys tell us *(referring to the presenting group)*
22	Thabani	Area is equal to length times breadth, fifty millimetres times thirty millimetres equals one thousand five hundred millimetres *(pointing at 1500 mm^2)*
23	Mduduzi	It is square millimetres
24	Teacher	Millimetres? For area, millimetres? How many millimetres did you times?
25	Johannes	Millimetres? Two
26	Teacher	So why do you say millimetres, why do you say millimetres meanwhile you have two millimetres that you have times? Or multiplied?
27	Johannes, Mduduzi & Thabani *(Simultaneously)*	*(All pointing at 1500 mm^2)* One thousand five hundred square millimetres
28	Teacher	Okay, another task *(Inviting learners to proceed to the next task)*

The episode shows that Tandeka maintained her mode of instruction in which she consistently involved learners in discussing mathematical ideas. She made efforts to engage learners in explaining and justifying their answers. In the episode learners had problems with units of area. They did not understand the meaning of the 2 in mm^2. Tandeka noticed the error and made concerted efforts to engage with the learners' misunderstanding. She kept on pressing for the meaning of mm^2 until one learner gave the correct response (T18). She however made an error in her explanation of mm^2 (T24 & T26). For Tandeka the unit of area, mm^2 was the result of multiplying 'mm' by 'mm', which is an incorrect understanding of units of area.

The two episodes that Tandeka seems to have appropriated the structure of the suggested teaching practice of involving learners in group discussion of mathematical ideas and explaining

their solutions to the rest of the class. She also identified learner errors and engaged with the errors. She however struggled to deal with the mathematical concepts involved in the discussions.

4.5 Synthesis of shifts in the teachers' teaching practices

The results show that two teachers, Bongiwe and Janeth made shifts in their teaching, while Jeffrey and Tandeka did not make shifts in their teaching. Before the intervention Bongiwe, Janeth and Jeffrey taught in a teacher-directed manner. They controlled content delivery with minimal involvement of learners in explaining and justifying their ideas. The emphasis in their lessons was on mastery of procedures by learners. Jeffrey's teaching was slightly different from the others in that he often engaged learners in discussing mathematical ideas in small groups or working individually. However the discussions of the learners' solutions were dealt with in a teacher-directed manner, with Jeffrey calling out for the answers and writing the correct responses on the board. Before the intervention Tandeka taught differently as compared to the other teachers. She started her lessons by giving learners tasks to discuss in groups, followed by whole class discussions.

In the teachers' teaching of the jointly planned lessons during the intervention, shifts were observed in Bongiwe's and Janeth's teaching. They involved learners in discussing mathematical ideas in groups followed by whole class discussions in which they gave learners opportunities for explaining and justifying their solutions. There was more substantive engagement with learners' errors and productions as compared to their teaching before the intervention. In these lessons Janeth struggled to respond to learners' ideas and often made errors herself. During the intervention lessons Jeffrey maintained his mode of teaching. His teaching was teacher-directed spaced with intervals where he asked learners to discuss briefly in small groups. He would lead learners' presentation of solutions, focusing mainly on correct answers and ignoring incorrect responses. Learners shouted out their answers while he wrote the answers on the board. Learners were not given the opportunity to explain or justify their responses. Tandeka maintained the grouping of learners, but struggled to handle the whole class discussions in a mathematically productive manner. The mathematical ideas in the learners' presentations were often not made

explicit. For all the teachers the richness of the mathematics was consistently low for all their lessons.

After the intervention Bongiwe sustained the shifts in her teaching, while Janeth declined in some aspects of her teaching. Janeth declined to more teacher directed instruction although she still asked learners to explain and justify their ideas. Jeffrey and Tandeka maintained their mode of teaching and ways of handling learners' ideas in their lessons. The failure by Jeffrey to make shifts in his teaching, except in task selection, could be attributed to his confidence in teaching. In his comments about his teaching before the intervention Jeffrey described his teaching as involving learners in investigating and explaining mathematical ideas. None of these features were observed in his actual teaching. Tandeka may have felt that her teaching already resonated with the suggested teaching approach. She however seems to have appropriated the structural features of grouping learners and giving them tasks to work on, and did not think carefully about the mathematical purposes of the group discussions.

None of the teachers made shifts that qualified for the 'High' (3) code on most of the MQI dimensions, except Direct Instruction". Given that initially all of them, except Tandeka, taught in a teacher directed manner with little involvement of learners in the mathematical practices of explain and justifying their thinking, shifting to 'high' was probably not achievable within the duration of the intervention. This highlights that teacher learning and change are complex and slow processes (Borko, 2004). All the teachers made shifts in their task selection during the intervention lessons, something that can be linked to efforts to select tasks that matched the criteria discussed in the community.

Although the teachers made shifts in their espoused understanding of learner errors, not all of them made similar shifts in their actual teaching practice. Bongiwe shifted in her way of responding to, and dealing with learner errors, something that was consistent with the shifts in her espoused understanding of errors. She shifted from ignoring to more sustained engagement with learner errors. Although Janeth shifted in her ways of noticing and discussing learner errors, she continued to ignore some errors. Jeffrey consistently avoided learner errors in his teaching. He would keep on asking for alternative learner responses until he got a correct answer. This can be linked to his mode of teaching in which he hardly afforded learners opportunities for explaining their answers and his focus on correct responses. This was contrary to his comments

about learner errors, in which he expressed an awareness of learner errors as evidence of learners' learning. Tandeka consistently noticed learner errors and made efforts to engage with the errors. In most cases she however did not manage to deal with the errors successfully.

4.6 Summary

In this chapter I have presented shifts in the teachers' teaching practices before, during and after the intervention. The shifts in the teachers' teaching practices are discussed further in relation to the activities of the professional learning community in Chapters 6 and 8. In Chapter 6 I analyze how the opportunities for learning in the professional learning community were linked to the shifts in the teachers' teaching practices. In Chapter 8 I examine the relationships between shifts in teaching practice and teacher identity in relation to the opportunities for learning and features of the professional learning community

CHAPTER 5

THE TEACHERS' IDENTITIES

5.1 Introduction

In this chapter I present the development of the teachers' identities. The analysis is a step in developing the argument that the professional learning community supported shifts in the teachers' identities. The focus of the analysis was to identify any shifts in the teachers' identities before and after the professional intervention. The data that was analysed for shifts in the teachers' identities were the individual teacher interviews before, during and after the intervention, as well as the focus group interviews that were conducted during the intervention. As described in Chapter 2, Wenger's (1998) view of identity as modes of belonging was used in this study. Through continuous participation in the professional learning activities the teachers' identities were in a state of ongoing formation and reformation. Teacher identity in this context is how teachers describe themselves as members of the professional learning community. This is consistent with current literature on identity that works from interviews and self-reports (e.g. Bjuland, et al., 2007; Hodgen & Askew, 2007; Smith, 2006; Trent & Gao, 2009). This is a limitation in analysing identity shifts because identity is both what people say and do. My analysis of identity shifts was based more on how the teachers described themselves than on what they actually did. Analysing identity through what people actually do is an area that has been well-developed in the literature. In Chapter 3 I presented the teacher identity analysis framework which was developed from Wenger's view of identity as modes of belonging, namely: imagination, engagement and alignment. I also described how coding was done using the computer software ATLAS Ti.

This chapter is structured into sections. The first part of the chapter is an overview of the shifts in the teachers' identities. The second section presents an analysis of the teachers' identities before the intervention. In the third section I analyze their identities during and after the intervention. The assumption was that the teachers' identities were developing as they participated in the professional learning activities. Hence data for analyzing the teachers' identities after the intervention included the teachers' comments about themselves as well as my observations about their participation and ways of relating to each other during the intervention. An example of such

data is how the teachers described changes in who they are as teachers during the lesson reflection activity. The chapter ends with a collective analysis of shifts in the teachers' identities in relation to the teachers' teaching practices.

The chapter addresses the following research questions:

1. What shifts, if any, occurred in the teachers' identities as they participated in the professional learning community?
2. How are the shifts in teacher identity linked to the teachers' teaching practices?

5.2 An overview of shifts in the teachers' identities

The results presented in this chapter show that the teachers made some shifts in their identities as they participated in the activities of the professional learning community. The teachers shifted in their identities of belonging to communities. Before the intervention the teachers described their engagement with others as limited to consulting or working together with individual colleagues, specifically in relation to problems they experienced. In describing themselves in those contexts different identities were manifested for different teachers. Three teachers imagined themselves as working together and sharing information as equals in their teaching, which alluded to imagining themselves as belonging to a community. The three teachers had the most teaching experience among the teachers in the professional learning community. Another teacher who was not one of the three perceived his engagement with fellow teachers as creating opportunities for exploitation, preferring that teachers work as individuals. The fourth teacher described herself as learning from the others whenever she consulted them, alluding to a learner identity in her engagement with others.

During and after the intervention the teachers' comments about themselves showed shifts in their identities. Their comments reflected that they all imagined themselves as members of the professional learning community. Identities of community membership were justified in terms of the perceived learning in the professional learning community. They made comments about engaging together in activities such as lesson planning and observing each others' teaching. The teachers' visions of the future of the community showed an alignment with the practices of the professional learning community; although none of them saw it as their responsibility to ensure

the sustainability of the professional learning community. One teacher consistently imagined himself as having a dual identity: as both a mathematics teacher and a geography teacher. Another teacher imagined herself as belonging to two communities in terms of her engagement: the professional learning community and the community of teachers teaching Further Education and Training (FET) with her. Explanations for the dual identities are given in the analysis of the shifts in the individual teachers' identities.

In terms of their teaching identities the teachers shifted to imagining themselves as guides and facilitators in their teaching. The shifts were based on their alignment with the teaching practice agreed in the professional learning community and the perceived merits of such teaching practice for the learners' learning. The espoused teaching identities resonated with the observed teaching practices presented in Chapter 4.

5.3 The teachers' identities before the intervention

Two main themes were identified in relation to the teachers' identities: identity as expressed through perceptions of relations and ways of engaging with other mathematics teachers; and identity as ways of talking about the teachers' teaching practices. I refer to the former as experiences of self-in-community, and to the latter as teaching identity. Self-in-community refers to a teacher's imagination of himself/herself in his/her engagement with other teachers, as well as how the other teachers perceive him/her. It is the way in which a teacher talks about himself/herself in relation to other teachers. From the coding scheme this form of teacher identity emerged mainly through the codes: self-perceptions, perceived roles, vision of community, ways of engaging with others, relations with others, learning in community, and identification with community practices. By teaching identity I mean a teachers' perception of himself/herself in a teaching context. It is the way a teacher describes himself/herself in a classroom situation and in relation to learners. In the coding framework this form of teacher identity emerged from the codes: perceived roles, moral responsibility, ways of engaging with learners, alignment with community teaching practices, and achievements of the community. Using these two themes I first present the results for each individual teacher, and then present a synthesis of the teachers' identities before the intervention.

5.3.1 Bongiwe's identity before the intervention

Bongiwe has a Bachelor of Education Degree in Mathematics and Physical Science. She has been teaching in a number of schools for ten years and in the current school for two years. During the study Bongiwe was the acting Head of Department (HOD) for mathematics. She was teaching both mathematics and physical science. Before the intervention activities Bongiwe described herself as having been motivated to become a mathematics teacher by her high school teachers.

> Okay let me firstly say from the from the school level I had very good teachers of mathematics, so they are the ones who maybe encourage me to end up being a maths teacher.

She saw herself as a dedicated and committed mathematics teacher who loved teaching the subject.

> Oh what type of mathematics teacher, I think I ammm a committed some… mathematics teacher, I am very much dedicated, committed, I am involved in mathematics, maybe it's because I like mathematics more than any other subject, this is why all my efforts lie in mathematics, so I am a very, very dedicated *(inaudible)* teacher when it comes to mathematics.

In terms of her relations and ways of engaging with other mathematics teachers Bongiwe described herself as someone who: shared information with others; consulted a colleague when she had problems with some mathematics tasks; was not shy to ask for assistance; and believed she could learn from others. She also believed that the other teachers were like her.

> Ja I am a person who used to share information with teachers, I I that is my personality, I used to share information with teachers and whenever I come across something which maybe I, especially mathematics, maybe it can be it becomes difficult for me to solve it I am not shy to I am not shy to go to maybe the other person to say that I am struggling with this one … Whatever, whatever difficulties you come across you have to approach other people so that they can help me

In terms of her teaching identity Bongiwe said she used question and answer, and grouping learners as her teaching strategies. By question and answer Bongiwe meant that she taught by posing questions for learners to respond to. This was evident in her lessons which were observed before the intervention. Her questioning was mostly convergent and elicited one-word or one-phrase responses. In most cases learners shouted the answers in chorus. She indicated that she first explained concepts and created content linkages by asking learners' understanding of previously learnt content. This description of her teaching reflected a hybrid between traditional teaching and some learner-centred teaching approaches.

> Okay some some of the strategies I normally use question and answer method the group method … so I explain, this is my first thing I do I always explain to them maybe whenever maybe some concept that I they can be not understanding *(inaudible)* to them, so I always explain them then from there I can maybe group them or ask them some questions based on the previous lesson

Bongiwe imagined herself as empathetic towards learners who have difficulties in learning mathematics. She believed teachers have to be patient with such learners.

> And, and as a teacher you don't have to left a child who has negative attitude in mathematics, instead drive him or her to have at least a positive attitude …eh as teachers we have to have this we have to have to be long term party to these learners, you don't have to be short-tempered to say ah these learners they don't know this I leave them

So Bongiwe imagined herself as a dedicated and committed teacher who drew her love of teaching mathematics from her high school mathematics teachers. Such an identity was linked to her sense of empathy towards learners who faced challenges in learning mathematics. She indicated that she held extra lessons with such learners, which can be attributed to her identity as a dedicated teacher. With respect to her teaching identity she saw herself as being in control of content delivery through explaining mathematical ideas. She also claimed to involve her learners in group discussions. Bongiwe's espoused teaching identity resonated to some extent with her observed teaching practice before the intervention. She started her lesson by informing learners of the focus of the lesson. She then asked questions what they knew about the mathematical ideas being introduced. She then explained the mathematical ideas to the learners and

demonstrated how to solve mathematical tasks based on the explained ideas. She then invited one or two learners to come and solve similar tasks on the board before she gave learners individual written work. Contrary to her claim, no group-work was observed in any of her lessons before the intervention.

Bongiwe's sense of community was limited to associating with colleagues when they, or she, needed assistance with solving specific mathematics tasks. While such an association is a source of belonging to a community, her engagement was limited to those mathematics teachers whom she perceived to be more knowledgeable, hence leading to selective engagement with individual members of the community of mathematics teachers in the school. Limiting engagement to helping or seeking help from specific teachers constrains the development of community as there is no clearly defined practice to support such engagement, and no group learning. Thus Bongiwe's identity before the intervention could be summarized as constructed around her own sense of commitment and dedication to the profession, as well as limited engagement with particular mathematics teachers. The absence of well-defined purposes for engagement meant that Bongiwe's identity was not linked to aligning with specific community activities that could support the development of a stronger sense of belonging to the community.

5.3.2 Janeth's identity before the intervention

Janeth has a Diploma in Education with specialization in teaching at secondary school level. She also has an Advanced Certificate in Education (ACE). Her major teaching subjects are Mathematics and Physical Science. She has eleven years teaching experience in a number of secondary schools. She has been in the current school for three years. During the year of this study she was teaching Grade 11 Mathematical Literacy[12] to Grades 10 and 11 classes. She described herself as a dedicated teacher who enjoyed teaching the subject.

> I enjoy teaching mathematics, this is why you see I, I every time the school starts at eight o'clock but I start at seven o'clock and leave here till four o'clock so I am dedicated to

[12] Mathematical Literacy is an alternative mathematics subject in the South African curriculum offered to Grade 10-12 learners who do not intend to pursue a scientific career. It is meant to prepare learners for application of mathematics in everyday situations.

> my teaching maths, so I want the learners to be to be to give them extra, extra work, so it's like I am enjoying teaching maths a lot I am not getting bored

Janeth's sense of belonging to a community was limited to colleagues teaching the same grade level or subject area with her. She saw her collaboration with another teacher who was teaching Mathematical Literacy with her as teamwork.

> I am teaching maths lit with someone now, we are doing teamwork

She saw herself as willing to acknowledge weaknesses and seek assistance from colleagues. She valued consulting a colleague for help with various aspects of her teaching practice.

> If we have a problem, go there, mister J… I have a problem with this please help me, like I was, I gave them an assignment *(inaudible)* then I was struggling with the rubric, that is *(inaudible)* then I call mister J…, J… can you teach me how to …. So can you please moderate? Can you please help me?

Janeth saw herself as willing to let other teachers know about her challenges with learners so that she could get assistance.

> So instead of saying okay I have a weakness then I am going to be like that, I don't want, I want others to know that I am struggling with these learners … so if you need information, assistance or help from somewhere

She perceived some teachers as less knowledgeable than herself. She specifically mentioned one teacher as having been exploitative rather than collaborative when they taught the same grade level.

> I was teaching with mister S[13]… last year grade eight and nine, most of the time I was the one who was doing all the assessment, if he is struggling with this, maam can you please help me

Janeth perceived herself as a better teacher than those teaching lower grades. She drew this identity from her imagination of herself as experienced and dedicated. She also drew her identity from her teaching of Mathematical Literacy, a subject that is taught only in FET[14]. She

[13] This was reference to Jeffrey, one of the teachers in the professional learning community.
[14] FET is Further Education and Training, which in South Africa refers to Grades 10 to 12.

associated her teaching of FET with prestige and connotations of being more knowledgeable than those teaching in the Senior Phase. These perceptions reinforced her engagement with the only other teacher teaching Mathematical Literacy with her. Thus her sense of belonging to a community was limited to those teachers teaching the same grade level or same subject area with her. Her engagement with such teachers was, interestingly, based on relationships of trust and openness. She acknowledged her challenges to them and sought assistance from them.

In terms of her teaching Janeth said she used the question and answer technique. She saw the approach as a way of involving learners in her lessons. She began her lessons by demonstrating and explaining to the learners. She viewed mathematics teaching as the emphasis on correct application of steps in algorithms.

> I like maybe to use the question and answer method; I don't like to talk alone in class, so I want to involve those learners.
>
> … firstly I have to start with dealing with an example to show them, maybe I am teaching like in the maths I was teaching a compound, simple and compound interest, so I give them, firstly I tell them about the loan, lay-bye, the interest how do you get the interest and so on,
>
> Let me also say that in maths we move step by step … you move step by step, if that step in the middle is wrong then the answer is wrong. Sometimes you find that these steps are wrong but the answer is correct, so it means that that learner copy from somebody

Janeth's utterances above indicate a traditional mode of teaching. Traditional teaching consists of "a teacher demonstrating abstract mathematical procedures at the front of the class, followed by students practicing the procedures in short, textbook questions" (Boaler, 1998, p. 130). This description of herself in teaching resonated with her observed teaching before the intervention. In her teaching she emphasized adherence to mathematical formulae. She told learners the formula to use when solving specific mathematical problems and demonstrated how to solve the problem on the board. She expected learners to remember and show every step in a procedure in the same way she had taught it. She always reminded learners to "move step-by-step" and sometimes showed impatience with learners who forgot certain steps in procedures. No explanations were given to the mathematical procedures or formulae. Janeth was content with correct answers from

calculations and did not discuss with learners the meanings of those answers in the contexts of the original mathematical problems.

An interesting feature in Janeth's description of her teaching was how she saw herself as learning through reflection on her practice. She talked about noticing some weaknesses in her teaching and suggested some ways of motivating learners.

> … firstly when I started to teach, ne, in this department I was giving them the work *(inaudible)* I was doing something wrong so they don't understand … 'Have you finished?' 'No' 'Why?' 'We don't understand' because I was talking with the chalkboard most of the time
>
> Uh they are getting bored if you sit in front talking and talking they are getting bored, so you must come with something they can see and then you teach about that … you must come with something like eh it's something like or a tin that can show them the shape of that cylinder and you are going to take from there that from that corner to that corner it's the diameter, but if you start from the centre to that side of the…it's the radius ne eh so you can see that they enjoy it

Janeth's teaching identity before the intervention was that of a traditional teacher. This resonated with her teaching before the intervention as observed in her lessons. She made reference to some limitations in her teaching in the early stages of her teaching career, which could indicate that she reflected on her own teaching. She talked of using teaching aids as a way of motivating learners but in the observed lessons she did not use any teaching aids. While she saw herself as dominating learners' learning from a traditional style of teaching, she expressed discomfort with such teaching. This discomfort motivated her to speak about other ways of improving her teaching practice by motivating learners.

Before the intervention Janeth imagined herself as a dedicated teacher who enjoyed teaching mathematics. Janeth's teaching identity was that of having a strong control of the learners' learning through demonstrating solution procedures and emphasizing strict application of steps in mathematical procedures. She saw the limitations of such teaching and proposed using other approaches that could involve learners more in their learning. Her sense of community was limited to teachers teaching the same grade level with her. She openly acknowledged her

challenges and consulted some individual teachers for help. She was sensitive to forms of engagement that she saw as exploitative rather than collaborative, although she indicated a willingness to acknowledge challenges she was facing in her class and seek help from other mathematics teachers. Her sense of community constrained her belonging to the larger community of mathematics teachers in the school. Like Bongiwe there was no reference to a clearly defined practice that could support the development of a cohesive and inclusive community to which Janeth might belong. Hence there was no alignment to specific community practices as a source of her identity.

5.3.3 Jeffrey's identity before the intervention

Jeffrey has a Higher Diploma in Education (HDE) with Mathematics, Physical Science and Technology as his teaching subjects. He has been teaching for five years, with four of them in the current school. Jeffrey identified himself as a mathematics teacher although at college he had majored in both mathematics and physical science. He saw his teaching of physical science as temporary. He was motivated to become a mathematics teacher by the shortage of mathematics teachers in the country and his love for mathematics. He also regarded the subject as interesting.

> I see myself as a maths teacher because now in the school there was always a need for a physical science teacher and I agreed to go and help because now I did my majors in physical science and mathematics … but as soon as the school grows I will choose mathematics as one of my majors

> Ah because I love mathematics, mathematics is an interesting learning area and I like teaching mathematics more than physical science … What motivated me most was that there was a big need in the country to become ah a mathematics teacher, more maths teachers are needed in the country

In terms of his teaching identity Jeffrey imagined himself as a facilitator of learners' learning. He claimed to engage learners in exploring and investigating solutions to mathematics tasks in his lessons.

> Okay my less… my lesson is a very vast lesson, it is whereby I give learners opportunity to explore and investigate, … the abilities of the learner are discovered during exploration

> and investigating, learners can explore by themselves and get the answer by themselves instead of telling them answers

This characterization of his teaching did not correspond with his observed teaching practice before the intervention. In his teaching Jeffrey began by informing learners of the mathematical topic of the lesson. He then engaged learners in discussing the mathematical ideas sometimes by reading the explanations of the concepts presented in mathematics textbook. Jeffrey demonstrated how to solve mathematical tasks on the board. He then gave learners one or two similar tasks to solve in small groups, after which he led the discussion of the solutions by making learners call out their answers while he wrote on the board. Contrary to his claim, no engagement of learners in exploring and investigating was observed.

In terms of engagement with other mathematics teachers Jeffrey expressed his dissatisfaction with engaging with others. He preferred that individuals carry out their responsibilities. Although he perceived his relationship with other teachers as good, he saw teamwork as more exploitative than supportive because some teachers would exploit others. His engagement with the other teachers was limited to informal chatting mainly during lunch time.

> I think the type of relationship is good, sometimes you, you work with teachers that you know don't want to do their work and they want you to do their work so that they can have you, so that is the problem in most cases, where you want someone to do their own working you know, teamwork is very difficult because now someone depends on you and does no longer doing their work, so sometimes we are having teachers like that so we *(inaudible)*

> I had rather say that the individual must be given their portion of work to do, setting a question paper if we set four questions they must do two and then I can do two not depending on one person to set the whole question paper

Jeffrey's identity before the intervention was influenced more by his imagination of himself as a mathematics teacher than by his engagement with other mathematics teachers. His preference for teachers to work with little engagement with each other was influenced by his perception of being exploited by his colleagues. Thus Jeffrey has no sense of belonging to a community of mathematics teachers. He didn't imagine any benefits of collaboration in community with the

other mathematics teachers. For his teaching identity he saw himself as a facilitator of learners' learning who engaged learners in exploring and investigating. Findings from his actual teaching contradicted his espoused teaching identity. In his teaching he controlled content delivery although he often engaged learners in discussing mathematical tasks.

5.3.4 Mandla's identity before the intervention

Mandla has a Bachelor of Science with Honours degree in Mathematics and Geography. He has an Advanced Certificate in Education (ACE) in Mathematics. Mandla has the longest teaching experience among the teachers in the professional learning community. He has been teaching for fifteen years, and has been in the current school for three years. He was teaching mathematics and geography classes during this study. In describing himself he saw himself as both a geography and mathematics teacher.

> None[15], I find it difficult to answer because right now I am qualified I completed my ACE in mathematics … Uh this is why I am saying none

He felt honoured to teach mathematics because he saw the subject as challenging for learners and he was privileged to be responsible for helping learners deal with their challenges in mathematics.

> Eh I feel very much honoured because as I understand mathematics is one of the challenging learning areas, more especially to the learners, then when I teach mathematics I want those learners to acquire knowledge as much as they can, uh

Mandla described his teaching strategies as checking the learners' prior knowledge and then building on that knowledge. He also valued learners working in groups in order to help each other.

> The ways of approaching is check the learners whether do they have any background… background knowledge of what you are trying to address with them… if it's there, eh try to maximize by making it a little bit difficult for them to approach … and the other way is

[15] This was in response to the question on whether he saw himself as a mathematics teacher or as a geography teacher.

> to, to use the very same learners, group them according… let the the learners help each other as group-work

In his actual teaching, Mandla engaged mostly in direct instruction. He started his lessons by posing questions that sought to elicit learners' understanding of the mathematics topic which is consistent with his description of his teaching. He then developed his lessons mostly using question and answer, relying on chorus responses as indicators of understanding. He often called learners to the board to present answers. He often responded to incorrect learner answers with a 'No', which was a way of avoiding errors.

Mandla valued the involvement of other teachers in his teaching practice. He engaged with other teachers by consulting them when he had challenges. He found the other teachers to be supportive when he consulted them. Thus his sense of community was limited to individual mathematics teachers he relied on for assistance, when he had problems.

> Uh and try to liaise with other educators within the school, maybe trying to solve some problems if I find them difficult for me to address. As far as other educators are, I do get positive support or response from the very same educators. Like for instance Mister S[16]… and Maam M[17]… they are very much supportive

In addition to engaging with other teachers for assistance, Mandla saw engaging with other teachers as a way of enhancing linkages in teaching and learners' learning across different grade levels. He also felt consultation helped teachers in preparing their lessons.

> Ehhh in this way eh it shows, what do we call this, uhm, the relationship between the grades, and also it gives us space, space in the sense of we are able to see where the challenges might be lying maybe I am teaching grade nine and that other lady is teaching maybe grade… like Maam M[18]… is teaching grade seven, now we will be able to address or to talk together to address the problem, maybe in the case of, the problem that maybe was not addressed fully in that particular grade, now she will be able to address at that level…

[16] Refers to Jeffrey, a teacher in the professional learning community

[17] Refers to Janeth, a teacher in the professional learning community

[18] Reference to Tandeka, a teacher in the professional learning community

Before the intervention Mandla's imagined himself as both mathematics and a geography teacher, which would suggest that he belongs to more than one community. He valued engaging with other mathematics teachers as a way of getting support in his teaching. He gave a strong justification for working as a community with the other teachers, i.e. for purposes of getting assistance when he had problems and supporting continuity in learners' learning across grade levels. Thus Mandla imagined himself as a member of the community of teachers for reasons that were slightly different from the other teachers.

5.3.5 Tandeka's identity before the intervention

Tandeka holds a Senior Primary Teaching Diploma. Her major teaching subjects are Mathematics and Physical Science. She has five years teaching experience, three of them in the current school. During the year of the study she was teaching Mathematics and Natural Science to Grade 7 classes.

In the pre-intervention interview Tandeka described herself as a mathematics teacher although she was also teaching natural science. Her justification was that she found mathematics less difficult than natural science and she enjoyed teaching mathematics

> I see myself as a maths teacher, because even from the primary and high school, the one I like most it was maths. Yes and more especially I feel as if in natural science there is a lot of work than in mathematics, mathematics is just practicing. I enjoy myself when I am teaching mathematics rather than natural science

In terms of her engagement with the other mathematics teachers, Tandeka consulted individual colleagues when she had challenges. She saw herself as learning from the other teachers who she regarded as more knowledgeable than her.

> Ja, for, for our department especially, if I find that no, in this chapter I do but not so much, I manage to take Mister M[19]…, 'Excuse me please help me, how can you', and then we go to my class to explain to the learners. You find that they understand him more than what I do … Yes, or else I go to Mister M…, 'Mister M…, please teach me', and

[19] Reference to Mandla, a teacher in the professional learning community

> then we sit down. 'Here we do this and this, this, this' and then I find a way … If I find somewhere there is a trick I don't have a way to go forward, I, I ask

Tandeka was aware that none of the mathematics teachers had ever consulted her for help. When asked if any other mathematics teacher had ever consulted her, she replied "no" with laughter.

Tandeka's description of herself and her engagement with the other mathematics teachers indicates a strong self-identification as a mathematics teacher who engaged with her colleagues for purposes of learning from them. Her sense of community was constrained to the individual mathematics teachers whom she consulted for assistance when she experienced challenges.

For her teaching identity Tandeka described her teaching practice as explaining, giving examples and asking questions. Such a characterization of teaching alludes to a traditional style of teaching (Boaler, 1998).

> Sometimes I use to do charts, or else I use pupils to give examples so as to explain, just to explain, give them examples, and ask questions

Tandeka, like Janeth, was aware of the limitations of her teaching approach. She acknowledged that some learners did not understand when she explained.

> Some of them they understand, but when I look at their faces some of them just don't know, they have ignorance

Unlike Janeth, Tandeka could not suggest alternative approaches to resolving the limitations of her teaching approach. She also could not suggest alternative ways of motivating her learners.

> So when you try to convince him, or try to explain to him sometimes some of them they just say, maam how do you know this because this is difficult. And from there it's difficult to change him in order to understand because already he has this mind and he don't want to move, to change

Tandeka expressed frustration and worry when her learners struggled with mathematics, which she saw as an easy subject. Her use of the word 'powerless' indicates frustration and exasperation with her inability to deal with persistent learners' learning difficulties.

> And seems, it seems to me I, I take maths as an easy one, I feel, I feel worried, why, what should I do in order to make these learners pass, or in order to make these learners to

> understand, I feel worried, very worried … Yes sometimes when you teach and then you try to explain again, you try again, you find that no, no change, you feel powerless … Sometimes you find that you don't have a solution, or a way forward

She acknowledged ignoring some persistent learner difficulties in the interest of covering the intended mathematics content

> I can't lie, it's good to speak the truth, we rush, we are rushing, so sometimes you ignore, and you feel worried that I am going to another chapter but I left this behind

In terms of her teaching identity before the intervention Tandeka imagined herself as an empathetic teacher who gets worried when learners show lack of understanding when she had explained mathematical ideas. Her claim that she relied on explaining mathematical concepts to her learners did not correspond to her observed teaching practice before the intervention. In her teaching she put learners into groups and gave them tasks to discuss. She then asked learners to present their solutions in whole class discussions. Although she made some efforts to engage with the learners' ideas in the whole class discussions, the mathematical ideas were often not made explicit. She was aware of the limitations of her teaching which could indicate a willingness to learn. Awareness of the weaknesses of her teaching could motivate her to engage in alternative teaching approaches once she became aware of them.

Before the intervention Tandeka drew her identity as a mathematics teacher from her perception of mathematics as comparatively less challenging than natural science. From her engagement with other mathematics teachers, Tandeka saw herself as a learner who consulted the others for purposes of being taught, and was in turn not consulted by the others. Her sense of community was limited to individual colleagues whom she consulted for assistance, and in that community she located herself as a learner. In terms of her teaching practice she said she relied on explaining mathematical ideas to learners although in her actual teaching she showed a desire to engage learners in discussing mathematical ideas in groups. She struggled to help and motivate learners in class, and sometimes felt frustrated and helpless. Thus in terms of her teaching identity Tandeka struggled to engage with teaching strategies that could support learners' understanding, and was frustrated when she failed to achieve this goal. She showed empathy for learners who struggled to understand the mathematical ideas.

5.3.5 Synthesis of the teachers' identities before the intervention

The analyses above show some similarities and differences among the teachers' identities before the intervention. All teachers had strong mathematics teacher identities based on factors such as: love of the subject and enjoyment when teaching the subject; perceptions of mathematics as important or less challenging; and self-perceptions such as dedicated or committed. They imagined themselves as mathematics teachers by drawing from their experiences of learning and teaching the subject. Janeth and Tandekas' descriptions of themselves as teachers were punctuated with negative experiences about their learners' learning. They were aware that learners often had problems in understanding their explanations and they felt frustrated by such persistent learning difficulties. However these negative experiences do not seem to have affected their perceptions of themselves as mathematics teachers. One of the teachers, Mandla, also described himself as a geography teacher by citing his professional qualifications in both subject areas. In the school he was teaching more classes of geography than mathematics. Later in the professional learning community conversations Mandla kept on referring to the need to involve teachers from other subject areas in the study, and at one point he expressed a concern that he was gaining by participating in the study while other geography teachers were not gaining.

In terms of community membership none of the teachers imagined him or herself as belonging to a community of mathematics teachers. For all the teachers engagement with other mathematics teachers was limited to consulting individuals for assistance with specific challenges faced in practice. Their sense of community was limited to individuals with whom they associated regularly. None of the teachers talked about participating in community practices which they valued. Such practices could include planning lessons together or jointly reflecting on each others' lessons. It was evident from the results that there was no alignment with community practices from the way the teachers identified themselves. Alignment with community practices is important for defining both a community and practices of a community (Wenger, 1998).

One teacher, Jeffrey, saw his engagement with other teachers as being limited to informal conversations. He had a negative view of collaborating with other mathematics teachers which he justified through the fear of being exploited. Another teacher, Janeth saw herself working as a team with teachers teaching the same grade level or the same subject area as her. She also

viewed other teachers differently, depending on the school level at which the teachers were teaching. Such a view of community limited her engagement with the other mathematics teachers.

In terms of their teaching identities the teachers had different teaching identities based on their individual preferences of specific teaching strategies. Four teachers had teaching identities in which they controlled content delivery in their lessons. They valued demonstrating and explaining mathematical ideas to learners. Such teaching practices can be classified as traditional in nature (Boaler, 1998). The fifth teacher, Jeffrey described himself as a facilitator of learners' learning. He described his teaching strategies as engaging learners in investigating and exploring mathematical ideas. For all the teachers, their espoused teaching identities were not consistent with some aspects of their enacted teaching practices before the intervention. Bongiwe and Mandla claimed to use group-work as one of their teaching strategies, but in their pre-intervention lessons no group-work was observed. Janeth stated that she used teaching aids to support learners' learning and to motivate learners, but in her lessons no teaching aid was observed. Jeffrey's claim of engaging learners in investigations and explorations was not reflected in his actual teaching. Tandeka claimed that she relied on explaining mathematical concepts to learners, a feature that was not observed as part of her instructional practices before the intervention. Thus the teachers' espoused alignment with certain teaching practices was not enacted in their actual teaching.

5.4 The teachers' identities during and after the intervention

The data which was analyzed for teacher identity during and after the intervention consisted of focus group interviews, individual teacher interviews, and teachers' comments during the professional learning community meetings, especially in the lesson reflection activity. During the intervention activities two focus group interviews were held with all the teachers. In those interviews the teachers made comments which were indicative of some shifts in their identities. During the teachers' self-reflections on their teaching of the jointly planned lessons the teachers' descriptions of themselves showed some shifts in their espoused teaching identities. After the intervention a post-intervention interview was held with each teacher. Analysis of these

interviews also showed some shifts in the teachers' identities. In this section I present the results of analyzing these data for shifts in each teacher's identity during and after the intervention.

5.4.1 Shifts in Bongiwe's identity

Analysis of Bongiwe's talk during and after the intervention showed some shifts in her perceptions of both herself in community and her teaching identity. In describing how she felt about herself as a mathematics teacher Bongiwe claimed that the project had changed her. She now imagined herself as a 'proper' teacher.

> Ja, I think it has changed me a lot, Ja I think for now, I, my feeling, my feeling for now after doing this project I feel that I am a proper maths teacher, after dealing with this project I think everything, everything which I do now I feel that way, because before we were not doing the correct thing but we just realize now after this, this project[20]

Bongiwe's idea of 'proper' teacher could be an expression of her perceptions of having changed in some aspects of her practice through the project. Her comments allude to self-comparison with how she perceived herself before the intervention. Her reference to what was happening before the intervention in terms of teachers' practices could be an indication that she understood the intervention as aimed at changing teachers' practices.

During the focus group interviews it was evident that Bongiwe imagined herself as a member of the professional learning community. Her utterances reflected a commitment to, and alignment with, the activities of the professional learning community. She appreciated being in the community and saw the activities as a learning process.

> And I like this group very much. We support each other. We are, we are learning a lot…, a lot

In her articulation of the merits of working in a professional learning community Bongiwe's utterances showed that she had developed a stronger sense of belonging to the community and she saw the teachers as benefiting from the collaborative activities.

[20] I did not follow-up to find out what she meant by 'proper' teacher, which could have provided more insights about shifts in her identity.

> Ja, truly speaking team work helps a lot because sometimes you may find that other topics you are not sure, quite sure about them, but when we are busy discussing the very same topic you start to realize that but this it was, this is where I had problems and again start maybe developing somewhere somehow in it, so truly speaking team work helps a lot

An interesting shift in Bongiwe's sense of community was in her perception of the professional learning community as a context for learning from each other and helping each other to solve problems of practice. Before the intervention Bongiwe viewed consulting a colleague as a way of getting assistance in resolving problems she faced in her teaching.

> I think uhm teamwork enables us to learn from each other because sometimes you, you have problems and you don't know where to raise your problems, but when you work in a team at least everything can be solved. Working as a team because we are busy helping each other

In the following comments which she made in the post-intervention individual teacher interview Bongiwe saw the teachers as growing together through collective engagement in activities such as joint lesson planning, which, in her view, served to improve the quality of mathematics teaching.

> Ja, growing very well, and in the case where we do lesson plans because we used to do our lesson plans just haphazardly

> I think it ends up maybe making us to, everything that we do in terms of maybe mathematics, let me say so, must be of quality sake, what we have been doing has been for quality's sake, ja

Bongiwe saw the professional learning community activities as a collective learning trajectory and had a vision of the community's continuation.

> So I think this is for the, for the, this is our first time, we are not the same as people who have three years in this project, maybe after, after a year we will we will be clear about everything

> As a teacher I would love for the whole department to work as a team because I think we can go very far.

She expressed a wish for the continuation of the professional learning community because she saw it as a process of professional growth for the teachers.

> So the better way is to continue next year so that we can grow more than we are doing now

Although the above utterances indicated that Bongiwe identified herself as a member of the professional learning community in terms of her imagination, engagement and alignment, she did not develop a sense of responsibility for the sustainability of the community. She saw the continued survival of the professional learning community as dependent on what the other teachers felt rather than on her efforts to ensure the community's continuation.

> Ja I think so but it will depend on the, the, the reaction of teachers towards that … That's if ever they the teachers agree with this project, because I think it's of importance to all teachers, then I think we can go very, very far especially in our country

Bongiwe's utterances show that she developed a sense of belonging to a community which was different from her sense of community before the intervention. She now identified herself as a member of the professional learning community rather than associating with individual colleagues. She saw herself as a member of the professional learning community through her perceptions of joint learning and growth in community with others. Her expressed wish for the teachers to continue as a team was an indication of her identification and alignment with the professional learning community. Her utterances showed that she appreciated and understood the ways and goals of engagement with others in the professional learning community and regarded the process as joint learning. She had developed a sense of ownership of her own learning through engagement with others. Her understanding of the community goals supported her alignment with the community's practices, which is an important aspect in identity construction (Wenger, 1998).

Bongiwe saw the continuation of the professional learning community as dependent on the other teachers' agreement to continue. Her comment could be interpreted in two ways. The comment could indicate that she was unwilling to take responsibility for the sustainability of the

professional learning community, which in turn could imply that she had not developed a sense of ownership of the professional learning community. Another interpretation could be that she was expressing that the continuation of the professional learning community was a collective responsibility rather than individual teachers' responsibilities, an idea that is consistent with what is known about sustaining professional learning communities. Both interpretations are connected to an identity of membership in the community as fundamental for sustaining a professional learning community. Bongiwe's comment alludes to her having developed an identity as a member of the professional learning community.

In terms of her teaching Bongiwe indicated that she had shifted in her ways of engaging with learners in her lessons. She claimed that through teaching the jointly planned lessons she had learnt some aspects of how learners learn.

> I have learnt a lot based on learners that they have different styles of learning, and as a teacher you have to accommodate all those learners with the different styles, and also I have seen that, I have seen which style can best fit my learners[21]

Bongiwe indicated that she had learnt how to engage with learners in her lessons.

> What I have learnt from my learners is if you can give them work to do in groups or cooperatively, they gain, they gain a lot more than just to tell them everything
>
> Maybe let's say for instance if ever you have given learners something to do, just facilitate, monitor the work they are doing, and don't just maybe sit at the front there and not concentrating on what those learners are doing, as a teacher you have to move around these learners to see their progress and how do they help each other, I think because before I was not doing like *(laughs)* I am doing *(laughs)* ja, I think that's the the the good method of maybe presenting lessons in class.

From her utterances Bongiwe appreciated that she had shifted to a more facilitatory role in her teaching practice, something which she had not been doing before. Although Bongiwe did not see this as a significant shift in her teaching identity such an appreciation was an indication of her alignment with the agreed instructional practices in the professional learning community. In

[21] There was no discussion about learners' learning styles in the professional learning community; Bongiwe could have drawn this from her other studies that she was engaged in.

Bongiwe's case, alignment with community practices supported the development of an identity of membership to the community (Wenger, 1998).

5.4.2 Shifts in Janeth's identity

In the focus-group and post-intervention interviews as well as in the lesson reflections Janeth's description of herself indicated some shifts in her espoused identity. Janeth described some perceived changes in her teaching practices.

> Eh, there is a lot of changes ne, eh from my observation ne, I was, I was teaching just, like me for example I was, I am going to take them through an example ne, so that I they can, that example can lead them to my topic, but since we started this project eh it changed a lot ne, my teaching, my everything. It was, I have realized that when you have like a model, learners see that model, it's very easy for them to answer the questions

In terms of her teaching identity she imagined herself as a facilitator of learners' learning in which she facilitates learners' 'discovery' of mathematical ideas.

> Like they want to count, ne, how many was the ratio, so they discover for themselves, I was not the one who was telling them to, its only to give them instructions, to lead them to okay

During reflections on her teaching of one of the jointly planned lessons, Janeth described her teaching as having shifted from dominating the verbal interactions to engaging learners in more talking.

> It changed that the, I am not the one who is supposed to talk, learners must also talk, so that it's also the one that have changed … I am just a facilitator and then if they are getting lost, I, I am interfering there, okay is there any problem, if there is then I need to help. But they are the one who are going to come up with the answer

Janeth's espoused teaching identity was different from how she imagined herself before the intervention. There was a shift from an espoused teaching in which she emphasized mastery of procedures to an imagination of herself as a facilitator of learners' learning. This shift was based on an appreciation of more involvement of learners in the learning process through the use of models and giving them opportunities for discussing and explaining mathematical ideas. This

was the agreed teaching practice in the professional learning community. For Janeth, her espoused alignment with the agreed teaching practice was a source of shifts in her teaching identity. Her espoused teaching resonated with her observed teaching of the jointly planned lessons and to some extent her post intervention lessons. In her teaching of the jointly planned lessons Janeth put learners into groups and gave each group a different task to solve. The tasks were on ratio. She provided learners with counters and encouraged them to use counters to solve the mathematical tasks empirically. During the group discussions she went around monitoring progress and helping learners who had difficulties. Later she invited each group to present its solution in whole class discussions. Other learners were encouraged to ask questions to the presenting group about anything they did not understand. However, as shown in Chapter 4, in the whole class discussions she struggled to interpret the learners' mathematical ideas, and often made errors in her responding to learner ideas. T In her teaching after the intervention Janeth partly sustained this way of teaching.

In terms of community membership Janeth's imagined membership of the professional learning community was based on her appreciation of the learning that occurred in the community. In her utterances in the focus group interview she saw the professional learning community as providing opportunities for learning from each other.

> I think when we work as a team it's a good idea, ne, and we support each other, and we gain from each and every one in sharing the ideas, that is why I like teamwork
>
> Ja, we are, we gain from each other, uuhm, uuhm, this is the perfect way to do as a team
>
> We learn from other teachers, ne, we learn from other teachers, ne. Like I had problems with some of the topic, then since we had that group, and do the discussions, okay, I have realized that okay in order to get this, this is the right method

These utterances indicate that Janeth saw herself as a member of the professional learning community in which there was learning from each other. An appreciation of joint learning in the community indicated that she had a sense of ownership of the learning that took place in the community. She saw the learning in the community as shared and connected to teaching practices. Connecting the learning in the professional learning community to her teaching practice was also evidence of her alignment with the practice of the community.

> Ja, its clearer, for us to do that group discussion, we the teachers ne, aah I am telling you, aayi we are going somewhere. Because sometimes you will be having, eh maybe okay I am going to prepare the Probability, ne. Firstly at least I must sit with my group and then do the discussion, maybe I am going to give them the learners wrong information
>
> Eh, then at least if we sit down like we used to with this group, we are going somewhere. We discuss and then when we are going to give the learners at least it is something

In spite of this appreciation of learning from each other Janeth indicated that she struggled to participate in the community. In the following utterance she acknowledged her own challenges in participating with the others in the professional learning community.

> Eh ah, challenges ne, it's like uh, once you are asking questions ne M…, and then for example B… knows the answers, maybe plenty of them you are asking five questions and B… eh responds to three and then we keep quiet, it's like eeish you don't know anything *(laughter)* to me that is a challenge, it seems like we are doing nothing and we are not thinking, even if we are thinking there is nothing coming out, that's a challenge *(more laughter)*

This description of her challenges in participation resonated with my observations of her participation in the professional learning community. During the conversations Janeth sometimes appeared to be dis-engaged and uncomfortable. She did not easily volunteer her ideas and sometimes struggled to articulate her thinking. These observations were captured in my field notes. For example in the Concept Development meeting on 14 July 2010, Janeth was not comfortable with discussions about conceptual meanings of equivalent fractions. She was withdrawn and responded only when asked for a comment or input. Later she spoke about this challenge of participating equally with the others and how the challenge made her feel uncomfortable.

Janeth had a vision of the future sustainability of the professional learning community based on perceived merits of continued engagement. She imagined the community continuing in the following year and ultimately leading to better learner results.

> At least even next year I see that we are going somewhere from this year up until, I am telling you we are going to get the results. …

> We must not stop doing that, even when you are gone, uhm, we must continue because other learners are coming from primary so they need our assistance, ja and we must continue to provide it

Although Janeth expressed her wish for the professional learning community to continue in future she did not specify her responsibility in ensuring the continued sustainability of the professional learning community. Her use of 'we' could indicate an understanding that the future sustainability of the community was a collective responsibility, with her as a member of the community. An interesting feature of her comment is the connection of the sustainability of the professional learning community to learners' needs. This comment and her other comments that I have presented before underscore her appreciation of the professional learning community as serving to meet the learners' needs.

Janeth still perceived the professional learning community members differently. She saw some teachers in the professional learning community as not qualified enough to teach FET and regarded herself as worthy of learners' respect more than other teachers. She regarded herself as more disposed to work more closely with fellow mathematics teachers teaching FET with her, including one teacher who did not participate in the professional learning community. Her sense of community was still connected to colleagues teaching the same grade level or learning area with her. She also expressed an observation that the other teachers teaching the Senior Phase collaborated at that level.

> Sometimes you find that I am teaching FET ne, in this school, and then I am asking T[22]… to do that. T…, eh, she is teaching the lower grade, grade seven to nine, so I think sometimes it's going to give us problems, like eh I have realized something in this school. …
>
> Eh, the time when we were at assembly, so, so when you call eh call these learners, that they must not do any noise at assembly, because I am teaching FET they are going to listen to me

[22] Reference to Tandeka, a participant in the professional learning community

> I like to work with other teachers. Like myself and Mister M…[23], we are teaching maths literacy, we are working together. Teamwork is there but the problem is, like Mister, like T[24]… and M[25]… they won't go to FET, they didn't train for secondary, ne, ja, so that's the problem, but some, most of the time I hear that T… sometimes calls M…, meneer, here is the question paper, you said I must set from this to that, so can you moderate this paper and then you must take it to ...

From the above utterances Janeth imagined herself as belonging to two communities. She imagined herself as a member of the professional learning community through her appreciation of the learning that took place in the collaborative activities. She drew this identity from her alignment with the practices of the professional learning community and the relevance of the learning that took place for her teaching practice. Janeth also saw herself as a member of the community of mathematics teachers teaching FET. This sense of belonging did not shift from her identity before the intervention. Before the intervention Janeth saw herself as a member of the community of teachers teaching Mathematical Literacy or the same grade level with her. She was more pre-disposed to engage with these teachers than with those teaching in the Senior Phase, something that came up consistently in her description of her sense of community after the intervention. After the intervention her disposition to engage more with the community of FET teachers than with the professional learning community could be explained by her acknowledged challenge of engaging equally with others in the conversations of the professional learning community. Unstructured and informal engagement with teachers teaching FET with her may not have been as demanding for her as the interactions in the structured and goal-directed activities of the professional learning community. With respect to the professional learning community, Janeth had a sense of ownership of her own professional growth in the community but not of the professional learning community. These observations seem to indicate that comfort or discomfort experienced by individual members of a professional learning community influence their identities as members of a community. Conversely the extent to which an individual self-identifies himself/herself as a member of a community influences the comfort or discomfort the individual feels in the community.

[23] This teacher was not a participant in the professional learning community
[24] Reference to Tandeka, a teacher in the professional learning community
[25] Reference to Mandla, also a teacher in the professional learning community

Utterances about her classroom practice indicated shifts in her teaching identity. Her identity as a facilitator and 'learner' in the classroom was consistent with the professional learning community's vision of teacher in the classroom. Thus Janeth's alignment with a teaching approach advocated for in the professional learning community was a source of shifts in her teaching identity.

5.4.3 Shifts in Jeffrey's identity

Analysis of Jeffrey's utterances about himself and relationships with the other teachers in the professional learning community revealed some shifts in his identity. During the focus group interviews Jeffrey indicated that he was learning in the professional learning community. He saw his engagement in the professional learning community as a learning process.

> Okay, my own experiences are that I can also learn from other teachers how are they solving their sums, and I can gain I can go and say help me with this and then I can go and teach it with eh that methodology

Jeffrey perceived his relationships with the other teachers as having improved. He saw the professional learning community as providing opportunities for the teachers to get to know each other. This was a significant shift from his identity of disengagement with his colleagues before the intervention.

> Eh now my relationship has improved because now normally during the programme we used to communicate with other teachers and gain ideas and then see how they plan their lessons, and also during the video-taping I could see how they teach, so the relationship increases because now because we can see even more with some other teachers. I think that is helpful because you can see the teacher inside the classroom and outside the classroom which we don't get the opportunity to do that

An interesting shift was in Jeffrey's view of collaboration as a team with his colleagues. Before the intervention he saw team-work as difficult and exploitative. After the intervention he imagined himself as a member of a team collaborating to achieve significant school goals. In the post-intervention interview he was able to articulate some of the ways and benefits of collaborating with his colleagues.

> I think I have learnt human relationship, and also the curriculum, that we need to help each other when we are doing teamwork, and ah also when we are setting a test then we can do it, each and every thing that we can do we must do it together
>
> We communicate with each other, gain ideas; we need to help each other, must do everything together
>
> I think it will last because eh if we work as a team we can achieve a lot and as a school as soon as we can continue like that then we can get better results in the future

Jeffrey had a positive future vision of the professional learning community. He imagined the community continuing to engage on some of the activities which had been done already. He proposed more frequent meetings for the professional learning community in future.

> I think ah in future the team will start working on lesson preparation, because I see it was a big problem, you prepare a lesson and then it doesn't go well … So there are still some lessons that we, as a group, wanna re-teach.
>
> I think this team my wish is them to still work together next year and make some more time for the meetings, maybe twice in a week and then even we can have more time because time is always a problem

Like Bongiwe, Jeffrey apportioned the responsibility for the future sustainability of the community to the entire group of teachers rather than an individual. He however added the need for disciplined leadership which the other teachers did not mention. He saw the future sustainability as depending on the teachers' discipline and also on having a disciplined leader, but his use of the word 'discipline' was not followed up to find out what he meant.

> If, if ever we are disciplined and then appoint someone who is also disciplined and even when members are cooperating then we can still work together, I don't see the problem of us fitting[26] the programme because we have benefited a lot

Jeffrey's comment indicates that he may have developed an understanding of some of the factors necessary for the sustainability of the professional learning community. His use of 'we' alludes

[26] By 'fitting' I understood that he meant 'accommodating' the project in their daily professional work, although I did not ask what he meant.

to an identity of belonging in the community. Like Bongiwe he saw the sustainability of the community as a collective responsibility. An additional factor that he raised is the need for discipline leadership. His reference to 'discipline' can be interpreted in number of ways. It can refer to cooperation by the teachers. By 'disciplined leader', Jeffrey could have been referring to a leader who provides the necessary guidance and support for the activities of the community. Failure to find out what he meant by 'discipline' was a limitation.

In terms of shifts in his identity, Jeffrey's comments above indicate some significant shifts in terms of his sense of belonging to a community. He imagined himself as a member of the professional learning community, engaged in a process of learning with his colleagues. Such an imagination of himself was a departure from his stance before the intervention. In terms of engagement with the others Jeffrey's utterances reflect an understanding and appreciation of some ways of engaging with his colleagues as a community. Before the intervention his view of engaging with the other mathematics teachers was limited to informal conversations during non-teaching times. The use of 'we' in his comments indicates the development of an identity of belonging in community with the other teachers. He had a strong vision of the future of the community which he described in terms of joint practices with the others, such as joint lesson planning. Such a vision shows an alignment with the community activities, which is a source of identity (Wenger, 1998). He saw the future sustainability of the community as a collective responsibility, and as dependent on disciplined leadership.

In terms of his teaching identity Jeffrey did not elaborate enough to show a significant shift in his understanding of himself in the classroom. He indicated that he had gained knowledge in some aspects of his teaching.

> I have learnt some other methods, ah using models when I teach and some other methodologies, lesson planning, I think this was a good experience because I learnt that using models and group-work is much more eh effective than any other teaching style of teaching
>
> Before you came I was like this and after you came I changed some of the ways of teaching and then I have gained, so it is very much profitable and ah it is a good thing to do

> Uhm, I think I give more class-work, homework and even setting the test itself, ja, it has benefited me a lot ... Uhm, ja, because I think there is too much interaction and learners are understanding now.

The above comments show Jeffrey's appreciation of gaining in his pedagogical content knowledge. From what he said it is difficult to discern specific espoused shifts in his teaching identity. Although these comments allude to a shift in his espoused teaching identity, the espoused shifts were not observed in his actual teaching during and after the intervention. What also seems to have not changed in terms of Jeffrey's teaching identity is his espoused understanding of himself in a teaching context. He was not specific about any new ways of engaging with learners and the mathematics content in his teaching.

5.4.4 Shifts in Mandla's identity

As indicated earlier on Mandla's teaching during and after the intervention was not analyzed because he did not go through all the cycles of teaching like the other teachers. Hence in terms of analyzing his teacher identity the focus was on his sense of self-in-community. During the focus group interview and in his post-intervention individual teacher interview he made comments which showed some shifts in his identity. In the focus group interview his comments alluded to a vision of having professional learning communities being established in other subject areas. For him the activities in the current professional learning community were a learning process for teachers through which learners would excel in mathematics.

> Okay I will give you, maybe we can say we will extend, we will sell this to other learning areas, to other educators
>
> Yes us we are feeling it's working because it will be a, a recurring problem, we will be maybe excelling in mathematics but mathematics cannot be greater than or the only learning areas, what about other learning areas? Because these learners must pass all these learning areas in order to proceed to ...

Mandla's vision of having other subject-specific professional learning communities in the school was based on his identity as being a mathematics teacher and a geography teacher. This was understandable since he was teaching only one mathematics class and several geography classes

in the school. He maintained this identity in his comments during the individual teacher post-intervention interview. In the post-intervention interview Mandla kept on referring to belonging to other subject areas.

> Because we are belonging in different departments it's like I am in Social Science, I am in Geography

He identified with the professional learning community through his perceptions of the benefits of engagement in collaborative activities.

> Eh, working with other educators, planning together and having some discussions if there are some challenges
>
> Ah we are able to help each other when coming maybe for instance if I want to plan a test I can have some ideas from other, other educators around the very same test that I have set

His comments allude to an identity of belonging in the professional learning community based on benefits of engaging with the other members in activities focused on collective deepening of pedagogical knowledge. It seems Mandla drew his identity of belonging more from engagement in the practices of the professional learning community than from his imagination of himself as a mathematics teacher. He emphasized the benefits of collective engagement in the professional learning activities which he saw as a learning process.

> Ja, that's one of the things I have learnt and as I have been saying eh we plan together, we assess the learners together and we can even gauge the performance of the learners, whether we are going forward or backward

Mandla aligned himself with the teaching practice which was planned in the professional learning community. He saw such an alignment as a source of other teaching strategies that he could use.

> I am trying to implement what we have been learning. Ah putting the learners into groups and planning before you teach, and assessing those learners eh based on their performance, and what are the new strategies that I can use … ja in solving the problems or challenges that may be faced by those learners

Mandla's espoused alignment with the professional learning community practices was a source of his identity of membership in the professional learning community. He had a vision of similar professional learning communities being established in the other subject areas in the school, especially in Geography his other teaching subject. He justified this extension in terms of professional learning communities' capacity for influencing shifts in teaching practices.

> Ja, I think the project is correct, it's very good, ja, it must continue, as long as it can be extended to other learning areas. It must not just end here, let us try to extend it to other learning areas so that other educators can be exposed and change their methods of teaching

He saw professional learning communities in other subject areas as necessary for addressing the learners' learning needs in those subjects.

> But maybe in Geography these learners might be having problems in map-work … We can sit together as Geography educators … Aah the very same educators who are offering the very same learning area, ja. If we plan together, sit together and have discussions

For him it was desirable to have a school-wide culture of subject-specific professional learning communities. The establishment of other subject-specific professional learning communities would demystify the perception that mathematics was a special subject.

> I want to deal away with this misconception that those people who are doing mathematics are regarding themselves as those who are clever. If that culture goes down to these other different learning areas it will be the best. They will start to realize that even my learning area is as important as mathematics

The comments indicate that Mandla had developed a strong sense of belonging to a professional learning community. He saw subject-specific professional learning communities as a school-wide strategy for dealing with learners' learning difficulties.

The shifts in Mandla's identity as a member of a professional learning community were connected to his emphasis on the benefits of the community practices for addressing learners' needs. He valued the professional learning community practices, which he saw as beneficial to both the teachers' teaching and the learners' learning. He had a vision of himself as a member of

two professional learning communities: an identity of belonging to both the community of geography teachers and the community of mathematics teachers. A strong point emanating from his comments is the value he attached to the practices of the professional learning community in forming similar communities in the school. His vision was of such professional learning communities engaging in similar practices to those he had experienced in the current professional learning community. Mandla's comments indicate that he had shifted in his identity as a member of a community when compared to his comments before the intervention.

5.4.5 Shifts in Tandeka's identity

After the commencement of the professional learning activities Tandeka indicated some shifts in her identity. She now appreciated engaging with the professional learning community rather than individual teachers.

> Sometimes you feel that the information you get from that teacher, that colleague is not enough rather than when you are in a team. Someone can give one another and you find that you have more ideas rather than asking one person. We manage to solve more things in one time

She still saw herself learning from the others but felt now it was better to consult the professional learning community rather than individual teachers. She also saw having the facilitator as important to the learning in the professional learning community.

> Ja because you may find that there is a problem, you go to another teacher you find that no even from that teacher its difficult, but when we are here sometimes we get *(inaudible)* from you, so it helps

She appreciated learning in the community. She cited some examples of what she had learned in the professional learning community in terms of both subject content and pedagogical content knowledge.

> I suppose that one of prime factors and highest common factor, and when we came to those decimal places … so in this group I learnt a lot

> Yes because you may find that sometimes the way you express your lesson is not the same the way the other teacher does, and you find that when you are busy observing him you find that it means in this step I have to do this rather than what I have been doing

In the second focus group interview Tandeka acknowledged her learning from reflecting on other teachers' lessons.

> I think it's good because really I find that no there is this different method to solve this problem and which I wasn't aware of … From Jane's lesson I learnt that there are resources that you can use without forking out our money

Tandeka echoed Janeth's struggle in engaging actively with the others in the community.

> She is not alone, each and everybody feels that way, if you ask a question and then you find that no I don't get the answer, you feel as if … I am not here

She expressed a desire to have the professional learning community continue in future but did not show a responsibility for sustaining the community. For her the future of the community was based on having someone else leading the professional learning community. Her desire was to continue learning in the professional learning community under similar circumstances.

> We must continue … Uhm to me I can say if we can continue we learn a lot … If, even if you can leave and then someone manages to do this each week… more of this

From her utterances Tandeka showed a shift in her sense of community. She appreciated the practice of the professional learning community and imagined herself as having learnt a lot from the activities and from the facilitator. She valued engaging with the other teachers in the professional learning community rather than consulting individual teachers for assistance. What was consistent was her perception of learning from the others. Before the intervention she saw herself as learning from the individual teachers she consulted. After the intervention she still saw herself as learning jointly with the others in the professional learning community. Thus her identity of membership in the professional learning community was based on experience of the learning that went on through the joint activities more than her contribution to the learning activities.

In terms of her teaching identity, Tandeka talked about shifts in her teaching practice which were in line with the professional learning community's agreed way of engaging with learners. In reflecting on her teaching of the first jointly planned lesson, Tandeka talked having shifted from explaining mathematical ideas to having learners discussing among themselves.

> For the past I just used to explain what is about that chapter, and then, then coursework and you find out that most they didn't understand, but now you find that when they talk to one another they manage to understand

She saw engaging learners in groups as benefiting learners in terms understanding; participation and developing confidence in responding to questions.

> By these lessons they quickly understand the lesson rather than telling, you find that sometimes those who are in front is the one who are listening somewhere there they are not listening, but in groups each and everybody wants to do
>
> She don't have confidence whether the answer is right or not, but once they are in groups she has the confidence to speak

Tandeka talked about having learned about the importance of not rushing learners during her lessons. Before the intervention she acknowledged rushing in her lessons at the expense of learners' understanding.

> I have learnt that I should give them a little bit then they talk with their friends, before I used to give them more work without knowing whether what they have done is right or not

Tandeka's teaching identity after the intervention was based on her espoused alignment with the agreed teaching practice in the professional learning community. She saw the benefits of engaging learners in group discussions with their peers. Her comments did not indicate a shift in her actual teaching practice. Throughout all her observed teaching Tandeka engaged learners in group discussions followed by whole class discussions.

Tandeka's post-intervention utterances indicate some shifts in her identity. Her view of the community had changed to that of the professional learning community. She still identified herself as a learner but in the broader community than with respect to individual teachers. She

appreciated having learned in the community and had a vision of the community going forward in future under the facilitation of someone else. She had a sense of ownership of her learning in the professional learning community, but not the community itself.

5.4.6 Synthesis of shifts in the teachers' identities

Looking across the analyses of teachers' identities before and after the intervention shows some patterns in the observed shifts. As indicated above, there were two categories of teacher identity which emerged and framed the analysis of the participating teachers' identities. These are: identity as a conception of self-in-community and identity as self-in-teaching or teaching identity. These two themes emerged in the analyses of the teachers' comments about themselves. Although the two themes are related constituents of teacher identity, it was not part of my focus to analyze how they are related or how they co-shape each other in looking at teacher identity holistically. I look at them separately for purposes of analyzing the specific shifts that occurred across all the teachers.

The first part of this section responds to the first research question set out in this chapter. Analysis of the teacher identity as self-in-community was done using Wenger's (1998) view of identity as modes of belonging: imagination; engagement and alignment, which I have described in detail in Chapter 3. The shifts in the teachers' identities were linked to their imagination of themselves as members of the professional learning community. The sense of membership was linked to joint participation in the practice of the professional learning community. The teachers made frequent reference to: planning together; discussing together; joint reflection on each other's lesson; and joint visions of improvement in teaching and learners' achievement. This shared appreciation of the community's practices was a source of their developing identities as members of a community through collective engagement in the practice of the professional learning community.

The teachers expressed appreciation of their own learning through participation in the professional learning activities. Each teacher viewed his or her participation in the professional learning community as a learning process and as learning from each other. A limitation of the study was that it did not explore whether they observed and appreciated each other's learning, and from the data it was not clear whether they took responsibility for each other's learning.

Thus the teachers drew their identity as members of the professional learning community from perceptions of their own learning in the community. Wenger (1998) regards learning as identity formation; a process of becoming. Through their learning in the professional learning community the teachers saw themselves as becoming certain kinds of teachers. For example Bongiwe described herself as 'now a proper teacher'; Janeth claimed to have changed a lot although without being specific about the changes; Mandla, Tandeka and Jeffrey highlighted their learning from the community practices; and all of them referred to 'getting somewhere together'. These comments allude to an imagination of themselves as changing both individually and collectively through learning in the professional learning community. This resonates with Wenger's (1998) characterization of the work of imagination as processes that include: "defining a trajectory that connects what we are doing to an extended identity, seeing ourselves in new ways" (p. 185). Reference to learning together and achieving learner-related school goals together, indicated that the teachers were imagining themselves in new ways as members of the professional learning community. Although the teachers made comments about achieving school goals through the professional learning community, there was no evidence to suggest that school goals such as improved learner performance were being achieved. The achievement of school goals through teacher learning is something that takes time. However the teachers' awareness of the ultimate goals of participating in the professional learning community as the achievement of school goals was a source of their sense of belonging and commitment to the community. Having a shared understanding of the goals of the community supports the development of identity as self-in-community.

The teachers made different shifts in terms of their sense of belonging to the professional learning community. Before the intervention all the teachers had a sense of community that was limited to either individual teachers they consulted when they needed help, or the teachers with whom they taught the same grade level or subject. Although all the teachers shifted to a sense of community in which they saw themselves as members of the professional learning community, the shifts were based on different experiences and imagination of selves in the professional learning community. Bongiwe's shift was based on her appreciation of the professional learning community as a context for learning from each other rather than consulting one another. She characterized the learning as growing together and expressed a wish that the (mathematics)

department continue as a professional learning community together so that there could be continued growth in knowledge. Janeth saw a close connection between her learning in the professional learning community and her teaching practice. Thus her membership in the professional learning community was based on her alignment with knowledge developed in the community in her teaching practice. Jeffrey based his membership on the developing relationships with his colleagues. His emphasis was on getting to know the other teachers much more closely and appreciating that he could learn from them through collaboration in the professional learning community. Mandla's shift was based on his appreciation of the practices of the professional learning community, which were the activities that the community engaged in. Mandla emphasized his appreciation of analyzing learners' performance together; planning together; and discussing together. Although this appreciation of the practices was the source of Mandla's identity as a member of the professional learning community, they were also a source of his perceived future disengagement with the community, a point I will discuss in detail in the next paragraph. Tandeka's shift was based on her perception of the professional learning community as a better context for learning than consulting individual colleagues. Just like Jeffrey and Janeth, for Tandeka it was more about her own learning than joint learning. She emphasized learning from the others in the professional learning community rather than learning through collective sharing and development of new meanings.

The shifts in the teachers' identities of belonging to the professional learning community were uneven. For two teachers the shifts were partial. Before the intervention Mandla imagined himself as both a mathematics teacher and as a geography teacher. This perception did not change after the intervention. He still described himself as belonging to both communities. This was understandable since he was teaching both subjects. What was interesting was Mandla's future vision of professional learning communities in the school. He saw the practices of the current professional learning community as relevant for other teachers in the school. He argued for the need to have similar professional learning communities in the other subject areas in the school. For him the practices of the current professional learning community had potential to influence teachers' teaching practices and provide ways of addressing learners' learning needs. For Janeth there was a partial shift in her identity as a member of a community. Before the intervention Janeth belonged to and engaged more with the community of teachers teaching the

same grade level or Mathematical Literacy with her. After the intervention she still imagined herself as a member of that community, although she was evidently also a member of the professional learning community. The results presented above show that Janeth belonged to two communities after the intervention, indicating a partial shift in her identity.

Another feature of the teachers' identities that was common was their espoused alignment with the teaching practice suggested in the professional learning community. A description of the teaching practice which was agreed in the professional learning community was presented in Chapter 3 (Concept Development Cycle 1) as part of the concept development activity. In the lesson reflections and post-intervention descriptions of their teaching, the teachers indicated various shifts in their teaching identities. What was evident in the teachers' descriptions was their espoused alignment with the suggested teaching practice. They all expressed their appreciation of various benefits of the teaching practice. Janeth and Mandla saw the agreed teaching practice as a source of shifts in their teaching practices. Bongiwe and Jeffrey expressed the benefits of engaging in the agreed practice in teaching without being explicit about what had shifted in their teaching. Tandeka talked about a shift in her teaching practice which was connected to the agreed practice. Collectively, the teachers' alignment with the agreed practice was a source of shifts in their descriptions of themselves in teaching contexts, although the shifts were non-uniform. According to Wenger (1998) alignment with community practices is a source of identity and the creation of a community of practice.

The teachers' comments about the future of the professional learning community highlighted that they saw sustainability as a collective responsibility rather than their individual responsibility. Jeffrey and Tandeka also highlighted the importance of leadership for the sustainability of the professional learning community. Collective responsibility and leadership have been underscored in the literature as fundamental for the sustainability of professional learning communities (e.g. Hipp, Huffman, Pancake, & Olivier, 2008; Katz, et al., 2009; Stoll, et al., 2006). What was evident in the teachers' comments about the sustainability of the professional learning community was their use of 'we', which indicated that they now perceived themselves as members of a community. Such an identity was not evident in their comments about themselves before the intervention.

In responding to the second research question, there was some congruence between the teachers' espoused shifts in their teaching identity and their enacted teaching practices. During the lesson planning the teaching practice of engaging learners in group discussions of mathematical tasks and presenting their solutions in whole class discussions ascribed certain roles for the teacher. In such a teaching situation the teacher has a designated teaching identity (Sfard & Prusack, 2005). The suggested teaching approach designated for the teachers the role of guiding the learners' conversation about mathematical tasks in the groups and then mediating the learners' mathematical ideas and productions during the whole class discussions. In that role the teacher has a teaching identity of a facilitator of learners' learning rather than a presenter of mathematical concepts and skills. In their comments during and after the intervention the teachers highlighted how aligning themselves with the suggested teaching practice created some shifts in their descriptions of their teaching. Bongiwe's and Janeth's descriptions of themselves and their teaching during lesson reflection and after the intervention resonated with their actual teaching of the jointly planned lessons. Janeth's reference to herself as a learner in one of her lessons was an espoused shift in her teaching identity (Reflection on her teaching of the first jointly planned lesson), which resonated with her actual teaching. In her teaching in that lesson her role could be described as a mediator of learners' learning. For two other teachers their espoused shifts in their teaching identities did not resonate with their actual teaching. Jeffrey still maintained that he involved learners in investigation, discussion and explaining mathematical ideas, but none of these features were observed in his lessons. Tandeka expressed her appreciation of learners learning from each other, which designated to her an identity of facilitator of learners' learning. Although this resonated with her actual teaching, she did not manage to successfully guide the mathematical discussions in productive ways.

In Chapter 4 I presented an analysis of shifts in the teachers' espoused understanding of learner errors (Table 4.1). The table shows that the teachers shifted from blaming learners and previous teachers for errors to perceiving errors as a result of learners' different ways of engaging with and thinking about the mathematics in the learners' learning. They also shifted in their understanding of ways of dealing with errors, from strategies such as re-teaching, remediation, motivating, etc., to strategies that engage with learners' thinking about the mathematics such as asking learners to explain their thinking. In the teachers' comments about themselves and their

teaching identity there was little reference to learner errors, hence it was difficult to connect shifts in teachers' identities to shifts in their understanding of learner errors. This was a limitation of the study.

5.5 Summary

In the chapter I have analysed shifts in the teachers' identities and how the shifts were connected to the teachers' teaching practices. In the next chapter I analyze the observed shifts in teacher identities and teaching practices in relation to the professional learning activities of the professional learning community. In Chapter 8 I explore the relationships among teacher identity, teaching practice and learning opportunities, in developing an argument that they exist in co-evolving relationships.

CHAPTER 6

TEACHER LEARNING IN THE PROFESSIONAL LEARNING COMMUNITY

6.1 Introduction

In Chapters 4 and 5 I presented shifts in the teachers' teaching practices and identities. The analyses in those chapters constituted the first step in developing the argument that the professional learning community supported shifts in the teachers' teaching practices and identities. In this chapter I develop the argument further by accounting for the shifts through the activities and conversations of the professional learning community. In the conversations of the professional learning community my focus was on the opportunities for learning that were created, and the teachers' comments about perceived developments in their teaching practices and identities. In the learning opportunities I focused specifically on the forms of knowledge that were negotiated and how the knowledge was used in the teachers' teaching and in subsequent activities and conversations in the professional learning community. It should be noted the shifts in both teaching practices and identities cannot be accounted for by a particular activity or conversation hence accounting for particular shifts meant analysing series of conversation episodes at different stages in the intervention. Thus accounting for the shifts in this chapter is done by linking each shift to a number of conversation episodes and learning opportunities at different stages in the activities of the professional learning community.

In Chapter 3 I explained the rationale for and meaning of the term 'opportunities for learning' rather than 'teacher learning'. Opportunities for learning were episodes in the conversations of the professional learning community, in which there was substantive talk about particular forms of mathematical knowledge. The conversations formed the main feature of the activities of the professional learning community. In this chapter I use extracts from these conversations as episodes that help account for the shifts in the teachers' teaching practices and identities.

The chapter addresses the research question:

> How were the shifts in the teachers' teaching practices and identities linked to the conversations and learning opportunities created in the professional learning activities?

A key feature of the conversations that supported and constrained the depth of the discussions was facilitation. As explained in Chapter 3, I was the facilitator of the professional learning community. Due to my limited experience in facilitating professional learning community communities, my facilitation sometimes constrained discussions that could have led to significant ideas emerging. Sometimes I missed asking important follow-up questions to get clarity on teachers' contributions hence opportunities for deeper discussions were sometimes missed. The limitations of the facilitation that may be evident in the conversation extracts presented in this chapter are due to this background. Details of the effects of my facilitation as a feature of the professional learning community are presented in Chapter 7.

6.2 Overview of the findings

In accounting for shifts in the teachers' teaching practices I started by identifying conversations of the professional learning community in which the focus was on subject content and pedagogical content knowledge related to the selected mathematical topics of ratio and rational numbers. Specific conversations that can be linked to the shifts in teaching practice were on: the conceptual meanings of ratio and rational numbers; the nature of mathematical tasks that could support learners' conceptual understanding of ratio and rational numbers; the merits of engaging learners in collaborative discussion of the mathematical tasks during instruction; and reflection on teaching. In their teaching the teachers selected and implemented tasks that had the potential to develop learners' conceptual understanding and this accounted for shifts in the teachers' selection of tasks. The teachers made efforts to engage learners in collaborative discussion of the tasks and share their developing understandings in whole class discussions. As shown in Chapter 4, the teachers varied in their implementation of the planned teaching approach and the selected tasks. The conversations during the lesson reflection activity created more insights about the teachers' teaching practices, and some extracts from these conversations are presented in this chapter in accounting for the shifts in teaching practice. This chapter shows how working with the ideas discussed in the professional learning community in teaching and reflecting on the teachers' teaching can account for the shifts in the teachers' teaching practices, task selection and their teaching identities.

Through their participation in the professional learning community the teachers made shifts in their teaching identities and their identities as members of communities, as shown in Chapter 5. The shifts in teaching practice were linked to the designated teaching identity in the joint lesson planning activity, something that is elaborated in this chapter. In Chapter 5 I also showed how the teachers shifted from their perceptions as members of smaller communities based on individual perceptions of each other, to a perception of themselves as members of the professional learning community. The shift is linked to the teachers' appreciation of participating and developing new understandings about their professional practice in the professional learning community. These links are explored in detail in this chapter.

6.3 Accounting for shifts in teaching practice

In this section I analyze how the shifts in the teachers' teaching practices that were presented in Chapter 4 can be accounted for by the teachers' access to the different forms of knowledge that were talked about in the professional learning community. The following were the main observed shifts in the teachers' teaching practice:

- There was a shift in the mode of instruction from controlling content delivery and dominating the talk in the lessons to more involvement of learners in discussing, explaining and justifying mathematical ideas.
- There was a shift in task selection and implementation - from tasks that focused on mathematical procedures to tasks that had the potential to develop learners' conceptual understanding of mathematical concepts. The implementation of the tasks differed for each teacher although a common pattern was the tendency to engage with the tasks more procedurally than conceptually.
- The teachers shifted in their ways of working with and responding to learners' ideas as a result of involving learners in significant discussions of mathematical concepts.
- There was a shift in the teachers' understanding of learner errors which was linked to their ways of responding to learner errors during instruction.

It should be noted that not all the teachers made the shifts listed above as presented in Chapter 4. I will discuss each of the shifts in the next four sections, showing how each shift can be accounted for by the activities and conversations in the professional learning community.

6.3.1 Mode of instruction

The results presented in Chapter 4 showed that in their teaching before the intervention the teachers engaged in direct instruction, although to a lesser extent for Tandeka. Bongiwe, Janeth and Jeffrey controlled content delivery by demonstrating mathematical procedures and explaining the related mathematical concepts to learners. In their teaching of the jointly planned lessons and the post-intervention lessons Bongiwe and Janeth made efforts to engage learners in discussing mathematical concepts in groups followed by whole-class discussions of the learners' findings. Jeffrey continued to control content delivery with some minimal involvement of learners in small group discussions. Tandeka sustained her practice of engaging learners in discussing mathematical tasks in groups followed by whole class discussions.

The shifts in some of the teachers' mode of teaching can be accounted for by the conversations relating to the joint lesson planning and reflection on the teaching of these lessons. In Chapter 3, Section 3.5.1 under 'Concept Development Cycle 1' I briefly outlined how the lesson planning process occurred in the professional learning community. In that section I used the term 'agreed teaching practice' to refer to the practice of teaching that was negotiated and later implemented by the teachers in their teaching of the jointly planned lessons. My use of 'agreed' does not imply that negotiating the practice was a simple process of describing the practice and teachers agreeing to it. It was a process that involved extended conversations, each one lasting no less than one and half hours. The process was guided by a protocol that I had adapted from Buffet, Teoh and Martinez (2008). The first conversation was on 'Developing an Action Plan' (see Appendix O). Appendix O summarises the ideas that were discussed in the professional learning community in response to the guiding questions in the protocol. The conversation on the actual teaching practice involved responding to questions 3 and 4 in the protocol. The format of the conversation was such that the facilitator would ask for teachers' ideas before he also offered his own ideas. The following is an extract of the conversation in responding to question 3 'What are the strategies to be used?'

Episode 6.1: Deepening pedagogical content knowledge

Turn	Speaker	Utterance
1	Mandla	Report backs
2	Jeffrey	Group-work
3	Sibanda[27]	When you say report back what do you mean
4	Mandla	You will have given those learners all those assessments, and then you give report backs
5	Sibanda	Aah you are saying report backs differently from what I had thought, yes when you give learners any form of assessment you are expected to give feedback, so I think let's just tie it to assessment. Okay, any other strategy that we can use? Remember the issue is we want to see if learners understand the concepts that we identified and this is our lesson plan that we are developing ... What other strategy? (*Silence)*
6	Bongiwe	*(Inaudible, then laughter from all)*
7	Sibanda	Okay one strategy we can adopt let me put it as saying we want to engage our learners in mathematical conversations, as a strategy we want to engage our learners in mathematical conversations; we want our learners to be talking about what they are learning. When I say engage learners in mathematical conversations what am I talking about?
8	Bongiwe	You are talking about practice
9	Sibanda	I am not sure it's about practice
10	Mandla	They should be seen to be living mathematically *(laughter from all)*
11	Sibanda	That sounds high-powered, but what do you mean by that
12	Jeffrey	I think it is feedback at the end of the lesson about what they have learnt
13	Sibanda	I am not looking at it that way, I am looking at it right from the beginning throughout the lesson *(silence)*
14	Mandla	Mathematical conversations?
15	Jeffrey	Yes
16	Bongiwe	They have to have this understanding that mathematics is about applications
17	Jeffrey	It is about mathematical terms, learners giving their responses about particular mathematical terms
18	Sibanda	Remember I am saying we want our learners to have mathematical conversations
19	Jeffrey	That is when learners explain to others who do not understand, I think that is when there is a mathematical conversation
20	Sibanda	Yes, Jeffrey is partly correct, it is the explanation part of it, but it is not about explaining to those who do not understand, learners should be engaged in explaining what they are learning, for example remember we said we want to teach them about the meaning of ratio, are we just going to tell them 'Ratio means this, this?'
21	Chorus	No
22	Mandla	Reciting
23	Sibanda	We want our learners to develop an understanding of ratio though conversations, let them talk about it, what do they think ratio is

[27] Sibanda was the facilitator

24	Janeth	Yes
25	Sibanda	So it is learner talk where the learners are engaging with mathematical ideas
30	Bongiwe	That's why that lesson looks interesting *(laughter from all)*

The conversation progressed with a focus of what it means to have learners talking about mathematical ideas with the teachers expressing doubts about their learners' capacity to engage in mathematical conversations. The conversation led into the episode below in which Mandla raised the problem of learners not being able to discuss mathematics without relying on the teacher. The following episode reflects how this assumption was discussed.

Turn	Speaker	Utterance
1	Mandla	Uhm, that's the main challenge, this is a serious challenge of learning
2	Sibanda	Why do you say it's a serious challenge?
3	Mandla	Our learners cannot learn on their own, they can't learn
4	Sibanda	Why do you say that?
5	Mandla	They need a force
6	Jeffrey	Ja
7	Bongiwe	I think it's a matter of laziness, maybe that makes us say they cannot learn on their own
8	Sibanda	I mean let me hear from your experiences why you are saying your learners cannot learn on their own. Can you give us evidence?
9	Jeffrey	Ja, sure, learners are lacking the required knowledge in order to complete the task
10	Tandeka	Sometimes they don't work

The teachers' comments reflected an assumption that learners could not learn mathematical ideas without reliance on the teacher. The other teachers echoed Mandla's statements by proffering possible explanations of why they thought learners relied on the teacher for learning mathematics. The teachers assumed that learners needed constant teacher control and monitoring in order to learn. This assumption could explain the teachers' mode of instruction prior to the intervention. What was also common in the teachers' comments was the blame they put on learners, that the learners lack knowledge and don't work. The tendency to blame learners for their learning difficulties is a common feature among teachers (Turner, Warzon, & Christensen, 2011).

The facilitator challenged the assumption and asked the teachers to describe episodes from their teaching experiences that led them to believe that learners relied extensively on the teacher in their learning. Below is an extension of the above conversation in which three teachers described their teaching. Each description of teaching practice was analysed in the professional learning community in relation to whether or not learners were afforded opportunities for discussing mathematical ideas with less reliance on the teacher.

Janeth's description of her teaching practice

Turn	Speaker	Utterance
1	Janeth	I show them the method
2	Jeffrey	Ja
3	Janeth	Step by step and explain thoroughly after that, and after that I give them the work, do this on your own
4	Sibanda	Ja, is that learning…
5	Janeth	And if you have a problem you can come, they won't come
6	Sibanda	I mean lets address the issue of learners cannot learn on their own
7	Janeth	Uhm
8	Sibanda	When you doing your step by step, who is doing the learning?
9	Mandla	It all depends, the learners are passive
10	Janeth	The learners are passive.
11	Chorus	Yes
12	Sibanda	And you think they are learning?
13	Janeth	They don't do
14	Sibanda	They can't learn by watching,
15	Janeth	Yes, they have to do it practically

Janeth's description reflected direct instruction as her mode of teaching. Although she referred to providing learners opportunities to work on their own (T59), this was after she had demonstrated a procedure and learners were expected to practice the procedure. The facilitator challenged this form of engaging learners in terms of how such teaching afforded learners the opportunity to engage in collaborative discussion and learning of mathematical ideas without relying on the

teacher. Mandla's response (T65) contributed to Janeth's acknowledgement of the limitations of her teaching practice.

Tandeka's description of her teaching practice

Turn	Speaker	Utterance
1	Tandeka	I explain, when I explain, you ask questions, you do, you solve problems with the learners and then after that you give them work…
2	Sibanda	Now when you say with the learners, I want the 'with', when you say with the learners what do you mean?
3	Tandeka	For instance in multiplication you pose a question, 'two multiply by two', you ask someone 'what is the answer?', they give you answers, then after that you give them class-work, the very same
4	Sibanda	Why I don't think that, you have asked a question, one learner has given you the answer 'four', then you have moved on. What have the others learnt from that? What have the other learners learnt from that? (*Silence).* You see why it doesn't work? Because you didn't ask the learner 'how did you find four? Can you come and show us or explain to us how you got four'. You were satisfied with the answer four and you moved on, and in such contexts learners learn very little, because the others are quiet, only one learner has given the answer four, and for you that's an indicator that the learner knows the answer, but that doesn't mean the rest of the sixty learners also know how to get that four. So to me it's not a context where learners can learn on their own *(silence),* let's listen to Bongiwe *(laughter)* she wants to give us an example.

Tandeka's description reflected a question and answer style of teaching. The facilitator responded by explaining why reliance on one learner's response could not be construed as evidence of learning by all the other learners. The other teachers did not contribute in response to Tandeka's description of her teaching, probably because of the facilitator's explanation that seemed to close further dialogue on Tandeka's description of her teaching practice. The tendency to offer explanations that curtailed further discussion was a limitation of my facilitation.

Bongiwe's description of her teaching practice

Turn	Speaker	Utterance
1	Bongiwe	Okay, I was teaching about transformations ne, basically reflection and rotation, so uhm
2	Sibanda	We are all listening
3	Bongiwe	So that was this ways of demonstration, so, but, but firstly I demonstrated everything ne to them, then I said they had to draw themselves standing up first,

		each and everyone ne. They drew themselves standing up, then from standing up, remember I had just talked about the, the, the centre of rotation everything, then I just ask them to draw themselves standing up each and everyone, then from there, from standing up they have to fall down, if fact they were creating the direction of rotation and the angle there, ne, then they drew themselves falling down all of them drew like this, then I asked them 'where is the, the, the, centre of rotation?'
4	Sibanda	The foot *(laughter)*
5	Bongiwe	Then I think here it's demonstrating to show the understanding of rotation, the direction and the angle, Sibanda, uhm that's what I wanted from this one because immediately I, I gave them this activity it was… then before they can do this activity I had to demonstrate, they had to demonstrate this rotation, hore initially you were standing up but now you have fallen down, so which angle did you create there and in which direction
6	Sibanda	My question is, and I think the others will also ask, are the learners learning on their own?
7	Bongiwe	They are because they were Sibanda each and everyone was drawing and they were they were coming up with their own, with the, the, the different *(laughs extensively)*
8	Sibanda	No I am asking the others not you *(laughter)* guys do you think learners were learning on their own?
9	Bongiwe	Are they learning out of the teacher?[28]
10	Sibanda	No we are not saying, we are not saying they are not,
11	Jeffrey	I am seeing that it's a bit difficult because now you are having a protractor ne and you want learners to start measuring the angles
12	Bongiwe	No it doesn't need a protractor here
13	Sibanda	No he is giving an example
14	Bongiwe	Oh
15	Jeffrey	It's an example
16	Sibanda	You said I explained to them, what is rotation; explained centre of rotation, that's what you said isn't it?
17	Bongiwe	No, Sibanda, okay let's do it practically *(silence)* I didn't explain rotation, I asked them what is rotation, akere (isn't that so?), that's what we usually do that's what to check the baseline the learners' prior knowledge
18	Sibanda	So you start by asking them, what is rotation?
19	Bongiwe	Uhm

[28] This was not followed up to understand what she meant by 'out of the teacher'. In the context of the conversation this could mean learning through observing and listening to the teacher.

From her description, Bongiwe described an instructional approach similar to Janeth's. The description reflected her understanding that learners' learning on their own means learners engaging in practical activities in which they apply knowledge and skills that the teacher would had explained or demonstrated previously. Realizing that Bongiwe was being defensive (T98 & 100), Sibanda opted to present an alternative teaching approach which built on Bongiwe's narrated teaching practice.

Sibanda's description of an alternative teaching practice

Turn	Speaker	Utterance
1	Sibanda	If I am teaching learners so that they learn on their own I don't start with that question
2	Bongiwe	Uhm, I am listening
3	Sibanda	To me if I am teaching transformations, and I want learners to learn on their own, right, I want learners, on their own, to develop their understanding of what is a translation, what is rotation, what is a reflection, right. So I don't start by asking them what is translation, what is, because that's the concept that I want them to learn
4	Bongiwe	Uhm
5	Sibanda	Right, that's the concept that I want them to learn, so what I would do basically is to plan for learners to learn that concept on their own, right, so why don't you create tasks with diagrams, you yourself know very well that in this picture there are two diagrams where one is a translation of the other, right, in this picture, in this diagram there are two diagrams where one is a reflection of the other, right
6	Bongiwe	Uhm
7	Sibanda	And so on, then under those tasks you just pose questions, can you explain what you need to do to one of the diagrams to get the other one, right. That's a task, give them to discuss. What do you think has happened to this diagram, to this one to get that? Or how would you get this from that? How do you get A from B? Right, I haven't told them anything about translation, I haven't told them anything about reflection, and so on, right. Give them a number of tasks like that; hear their explanation of what they think has happened. If they can pick up that in this one I have just shifted, we have just moved this one to a new position, in this one we have, we have almost like put a mirror in between and what we are seeing is the other side, what appears on the other side, it's as if I am looking in a mirror, right. In this one it seems I have turned, they don't use the word rotate, they have turned, do you see what is happening there
8	Bongiwe	Eh
9	Sibanda	Those are the notions of translation, reflection and
10	Sibanda	Rotation

	& Janeth	
11	Sibanda	We, they haven't used the words as yet
12	Bongiwe	Uhm
13	Sibanda	But from the pictures the learners are learning the concepts and they are doing it on their own using the tasks that I have given them. Then later on I will supply the words, to say here this is what we call a translation, here this is what we call a, but the concept is already in
14	Bongiwe	The learners
15	Sibanda	In that case I will say learners are learning on their own because they have created an understanding of the concepts on their own. … Lets argue or agree to disagree *(laughter)*

Sibanda described a teaching practice which differed from the teachers' descriptions in a number of ways. His description was of a teaching practice in which learners were given tasks to work on in groups. The tasks would be designed in such a way that learners would develop conceptual meanings of mathematical ideas through collaborative discussions with their colleagues. The teachers' role would be to support the development of the mathematical understandings rather than providing definitions to learners.

In responding to the facilitator's description Bongiwe expressed her doubts about the learners' ability to engage in such collaborative discussions of mathematical concepts. The following extract shows that, while she appreciated the teaching approach presented by Sibanda, she was adamant that it would not work with learners in the school.

Turn	**Speaker**	**Utterance**
1	Bongiwe	Ja Sibanda everything that you said I agree hundred percent, I agree hundred percent, but when coming to our situation, sometimes to be fair and honest, uhm to be fair and honest Sibanda sometimes (*inaudible)* us like, like in the case of *(laughs)*
2	Sibanda	Here we are aware there are constraints, we are aware there are realities in any situation, that's why one school is different from another, that's why one class is different from another, right. There are always these constraints
3	Jeffrey	Sure
4	Sibanda	Right, but that should not distract us from engaging with what is good teaching
5	Bongiwe	But sometimes when we have the type of learners...
6	Sibanda	Huhm
7	Bongiwe	That we have, immediately when learners do not know what reflection, because

		reflection I think even, because they do reflection everyday but immediately when they don't know what reflection is because, maybe talking
8	Sibanda	I will leave the others to comment
9	Bongiwe	But Sibanda I like your explanation, it's very much fruitful, and I wish one day mhani, one day, one day if you can come to the class and just do demonstration, you will see
10	Janeth	You will see
11	Sibanda	I will see what?
12	Janeth	You will see its difficult
13	Bongiwe	Your, your explanation is very much fruitful
14	Sibanda	Uhm
15	Bongiwe	But the only problem is that we are, we are talking not doing actions
16	Mandla	I think we better start than never
17	Sibanda	Exactly, we are talking about a plan, remember we are planning something here, and we are saying these are some of the elements of the plan that we want to incorporate and try out

Two issues arise from the above episode. The first is related to teachers' pedagogical content knowledge about how learners learn. The second is how the teachers' participation supported or constrained access to that knowledge in the conversation. At this point I will focus on the first. In Chapter 7 I analyze the second issue by examining factors that supported or constrained teacher learning in the professional learning community.

In the episode the teachers' assumption that their learners need extensive teacher guidance created the opportunity for having the conversation. The assumption resonated with three teachers' mode of instruction before the intervention, where they dominated content delivery with learner participation being limited to answering teacher questions that elicited one-word or one-phrase answers. Only Tandeka had a different mode of teaching before the intervention. In their descriptions of their teaching the teachers' use of words such as 'I show' (T57), 'I explain' (T81), 'I demonstrate' (T93) illustrate a direct instruction mode of teaching. The descriptions of teaching which the teachers presented highlighted the assumption that learners depend on teachers in their learning of mathematics.

In the episode, descriptions of their teaching acted as resources for interrogating the teachers' assumption and also as resources for the teachers' access to an alternative approach to teaching. From the teachers' responses to Sibanda's description Bongiwe showed her appreciation of the teaching practice but resisted using it by arguing about the learners' competence. Janeth appeared to agree with Bongiwe. Jeffrey and Tandeka did not comment. Mandla's remark (T167) suggested a willingness to try the teaching approach.

The above conversations about what strategies to use in the jointly planned lessons show a process of negotiating a particular teaching approach that was suggested by the facilitator. The conversation was extended in answering question number 4 in the guiding protocol 'What will the plan look like in the classroom?' The ideas discussed in response to that question are summarised in Appendix O. In the second conversation on lesson planning the teaching approach of engaging learners in discussing mathematical ideas with their colleagues guided the designing of the lesson plans (see Appendices Q and R). All these conversations indicate how the practice was adopted for teaching the jointly planned lessons and some teachers continued to use the approach in their teaching after the intervention. It is the extended nature of negotiating the teaching approach that led me to refer to it as the agreed teaching practice in the thesis.

As the results presented in Chapter 4 show, all the teachers made efforts to work with this planned teaching practice in their actual teaching with varying degrees of success. These efforts account for the shifts in the mode of instruction during the teachers' teaching of the jointly planned lessons.

The teachers' comments about developments in the mode of teaching

The shifts in the mode of instruction can also be accounted for by the lesson reflection activity. The conversations during the lesson reflection activity were guided by a protocol (see Appendix U). The protocol consists of questions that were answered as the community reflected on each lesson. The questions guided reflection on the following aspects of each lesson: the extent to which the learners understood the conceptual meanings of ratio or equivalent fractions; how the learners' thinking about each mathematical concept was developed and the teachers' role in the lesson; how teaching materials were used; how learners developed their understandings of the concepts through discussion in groups; how the classroom organization supported learners'

engagement and learning in the lesson; and overall impressions of the lesson. In reflecting on their experiences of teaching the jointly planned lessons the teachers made comments in which they indicated what they had learned from their experiences of teaching these lessons. Similar comments were also made in the post-intervention interviews. The comments reflected an appreciation of the merits of learners' group discussions, which in turn can account for Bongiwe's engagement with the practice in the post-intervention lessons. Below I present some of the teachers' comments during the lesson reflection activity.

The teachers' comments during lesson reflection

In response to the question about the teacher's role in the lesson, some of the teachers compared their teaching of the intervention lessons to their teaching before the intervention. Such comparison could be an indication of learning from teaching practice (Kazemi & Hubbard, 2008). The following comments by Bongiwe about her teaching of the first jointly planned lesson illustrate this point. Bongiwe compared her lesson to an earlier lesson on ratio which she taught before the intervention. In the following extract of the reflection Bongiwe attributed the differences in the two lessons to the mode of teaching.

Bongiwe: You remember last time, this was the lesson I was presenting for the first time but according to, when you compare the two lessons, this is why they failed the test because the whole procedure was not the same as this one.

Sibanda: So what do you think about this one?

Bongiwe: No this one I have improved as compared to that one.

Sibanda: In what way?

Bongiwe: *(laughs)* At least I have seen that grouping these learners and working together they are able to discuss with each other and they are able to get something … this one (lesson) was based on a learner-centred approach

Bongiwe's last remark highlights her appreciation of having learners discuss mathematical ideas in groups. This was a departure from her earlier resistance to engaging learners in collaborative discussion of mathematical ideas (Episode 6.1).

In Janeth's first jointly planned lesson learners first discussed allocated tasks in groups before presenting their solutions in whole class discussions. During the whole class discussions Janeth was mainly at the back of the class asking clarification questions and managing the interactions among the learners. In justifying her role Janeth made the following comment:

Janeth: Because I think eh I was going to disturb them even like they were presenting individually in there so I thought that I must go at the back so that they can be free

When asked how such a role helped learners' learning in the lesson Janeth could not explain further, which may indicate that she had not developed an understanding of the purposes of learners' discussion of mathematical ideas in groups. This can account for her struggle to interpret and respond appropriately to learners' mathematical ideas during the whole class discussion in her lesson. After the intervention Janeth reverted to direct instruction in her teaching.

Both Tandeka and Jeffrey made comments about their lessons that showed appreciation of the merits of the learners' collaborative discussion of mathematical ideas. For example, in reflecting on her teaching of the first jointly planned lesson, Tandeka saw the practice as supporting learners' learning from each other.

Tandeka: And it might be that among the five of them (learners) there may be two who understand more and then they help the others to find the exact thing, but being alone it is difficult

Tandeka's comment reflects her appreciation of having learners discussing mathematical ideas in groups, and that can explain her consistent use of group-work as an instructional strategy throughout her lessons. What Tandeka struggled with was guiding the learners' discussions in mathematically productive ways. It would seem from the lesson planning conversations that Tandeka appropriated the structure of the lessons more than how to engage with the learners' ideas during the group and whole class discussions.

The teachers' comments about their experiences of teaching the intervention lessons showed a shift from their expressed assumption that their learners were not capable of engaging in collaborative discussion of mathematical ideas. The comments resonated with shifts in two teachers' teaching.

The teacher's comments during the post-intervention interviews

During the focus-group and post-intervention individual interviews the teachers made comments that provided further insights into their perceptions of involving learners in group discussions of mathematical ideas. The following are some of the teachers' comments about the enacted practice during the post-intervention focus group interview.

Bongiwe: This is a very, very good lesson … That's why I was talking about time frame, I think this one is the one which can make learners to understand very well … Because they are coming up with their ideas, and they are doing work on their own

Bongiwe: Ja, ja, what I have learnt from my learners is if you can give them work to do in groups or cooperatively, they gain, they gain a lot more than just to tell them everything. And again in terms of conversation based on maths language I think, uuhm, I think they have learnt a lot out of that and they have improved a lot out of that because they are able to go to the front and explain some concept or explain to their friends how to solve this, so I think in that way I have realized that which method can suit these learners and which one cannot suit

Janeth: Learners like to work on their own, they enjoy working on their own, so I have realized that you must not spoon-feed the learners, they must discover on their own

Janeth: Eeish, this method is good but it needs more time … Because you must give the learners more time to do, to to come up with the answer, you must not put, put them under pressure, to say hey time is running, so they need more time, uhm, so that they can give you the best feedback

Tandeka: By these lessons they quickly understand the lesson rather than telling, you find that sometimes those who are in front is the one who are listening somewhere there they are not listening, but in groups each and everybody wants to do

Tandeka: For the past I just used to explain what is about that chapter, and then, then coursework and you find out that most they didn't understand, but now you find that when they talk to one another they manage to understand.

Jeffrey: I think this was a good experience because I learnt that using models and group-work is much more eh effective than any other teaching style of teaching.

The teachers' comments suggest an appreciation of learners' group discussion of mathematical ideas as suggested during the planning of the joint lessons. A key point to note here is that although they all expressed this appreciation, none of them managed to engage learners in mathematically productive discussions in which rich and conceptual mathematical ideas were made explicit. All the teachers had the challenge of engaging with conceptual meanings embedded in the tasks. Engaging learners in mathematically rich and conceptual discussions could have been too much of a leap given that their teaching before the intervention was extremely procedural. Within the duration of the intervention it was difficult for the teachers to have shifted to 'High' in their teaching as described in most of the dimensions of the MQI coding tool.

The planned teaching approach had two features that were different in complexity. Grouping learners and having them discussing mathematical ideas was a structural feature that, on the surface, creates a semblance of teaching and learning mathematics in learner-centred (Brodie, Lelliott, & Davis, 2002) and reform-oriented ways (Borko, 2004). Brodie, et al. (2002) refer to this feature as the *form* of learner-centred teaching approaches such as group-work. Similarly to the teachers in Brodie, et al. (2002)[29], the teachers in my study found it relatively easy to embrace and implement the form of group-work as a mode of instruction in their teaching. The teachers' comments above emphasize the following features of learners' learning in groups: working on their own, understanding better by explaining to each other, enjoying working as a group, and full participation within the group. The features highlight the structure or form of group-work. The teachers' appreciation of these structural features can account for Bongiwe's and Janeth's shifts in the mode of instruction. For Tandeka this feature could have reinforced her continued engagement in her mode of teaching. Jeffrey made superficial attempts to implement this feature of the practice by briefly engaging learners in small group discussions, while engaging in direct instruction for most of each of his lessons.

[29] The teachers were enrolled for the Further Diploma in Education, a formal in-service professional development programme offered by Wits University to practicing Mathematics, Science and English teachers for purposes of deepening subject and pedagogical content knowledge, among other goals.

The second feature of the suggested teaching approach relates to the purposes of grouping learners and the *substance* of learner-centred teaching (Brodie, et al., 2002). According to Brodie, et al., (2002) the substance of learner-centred teaching includes "identifying learners' meanings and scaffolding their current knowledge to develop new meanings" (p. 100). From this definition the substance of group-work involves what mathematics learners learn and how teachers support learners' learning, for example engaging with learners' ideas in ways that support the development of rich and conceptual mathematics. The goal of the jointly planned lessons in the intervention was to support learners' conceptual understanding of ratio and rational numbers (see Appendix P). What is typically absent from the teachers' comments above is reference to the mathematics that learners learned in the groups and how the teachers supported the learners' learning. This was despite that all the professional learning activities in the community were underpinned by an emphasis on learners' conceptual understanding of mathematical ideas. During joint lesson planning the emphasis was on tasks and teaching strategies that would support learners' conceptual understanding of ratio and rational numbers. Lesson reflection also provided opportunities for commenting on what conceptual meanings had been developed in the lessons. The emphasis on learners' conceptual understanding is about the richness of the mathematics made available to the learners during instruction. The absence of the teachers' comments on the substance of what the learners learned in groups is explored further in accounting for the low richness of the mathematics in Section 6.3.5 below.

One aspect of the shifts in the teachers' mode of instruction that was difficult to account for from the data are the differences in the way individual teachers shifted. Bongiwe made a shift that she maintained after the intervention. Janeth shifted in her mode of teaching during the jointly planned lessons but did not maintain the shift after the intervention. Jeffrey did not make substantive shifts in his mode of teaching, besides minimal efforts to use group-work in his teaching of the jointly planned lessons, although he spoke thoughtfully about learner errors. Tandeka did not shift in the mode of teaching; she was already using group-work in her lessons. The differences among the teachers' working with ideas raised in professional development in their teaching is something that has been highlighted in the literature. Some teachers have been found to change their teaching practice more than others through professional development (Kazemi & Hubbard, 2008). The different shifts in the teachers' teaching practices in this study

can be accounted for by: how the teachers appropriated the ideas developed in the community as part of their pedagogical content knowledge; efforts to implement the planned teaching approach in their lessons; and how the teachers understood their changed roles during instruction or teaching identities. The connections among meanings developed in the community, teaching practice and teacher identity are elaborated in Chapter 8.

6.3.2 Task selection and task implementation

Another shift in the teachers' teaching was the choice and implementation of tasks which they used in their teaching. Shifts in the teachers' selection of tasks can be related to the professional learning activities of the community, especially the concept development activity. In this section I present examples of tasks that the teachers selected for their lessons during the first cycle of concept development. In this cycle the choice of tasks was left to individual teachers, although they could use tasks that were discussed in the professional learning community. All the teachers selected tasks that had the potential to support the learners' conceptual understanding of the mathematical concepts of ratio or rational numbers. The following are examples of tasks that the teachers selected for their lessons.

In her lesson Bongiwe selected tasks that were focused on developing learners' conceptual understanding of ratio as a way of comparing quantities. The following is an example of the tasks:

> Using the class you are in now write down the ratios of:
>
> a) Girls to boys
> b) Teacher to learners
> c) Boys to learners in your class

This task is relatively simple for a Grade 9 class, but it is the idea of engaging learners in talking about comparing quantities using ratio that was meant to support the learners' understanding of what ratio is. Hence the focus of the tasks was on the conceptual meaning and uses of ratio rather than the mechanics of computing quantities.

Like Bongiwe, Janeth selected word problems that were aimed at developing learners' conceptual understanding of ratio. The following was a task that one group worked on and later presented to the whole class.

At a football club there are 3 girls for every 5 boys.

a) There are 6 girls. How many boys?
b) There are 15 boys. How many girls?
c) There are 9 girls. How many boys?

This task could be solved procedurally, but it is the way that Janeth implemented the task that shows her aim to develop the learners' conceptual understanding of the algorithm for computing quantities involving ratio. Janeth emphasised the use of counters in solving this task, and similar tasks. Learners' explanations of how they had worked out the tasks using counters was a move meant to support understanding of the concept of ratio and the basic conceptual meanings of sharing quantities in given ratios. Such understandings could be used later to explain the meaning of the algorithm for sharing quantities in given ratios. Janeth's approach in implementing the tasks was linked to the conversation about the meaning of ratio that is presented in Episode 6.2 below.

Jeffrey and Tandeka taught equivalence of rational numbers. In his lesson Jeffrey had all learners working on common tasks that he had written on the board. In the first task Jeffrey drew circles of the same size. Each circle was sub-divided into a number of equal parts, partitioned differently and half was shaded. Learners were asked to write down the fraction of each circle that was shaded. From the shaded parts of each circle, learners were supposed to deduce that the fractions were equal to each other. The tasks were visual representations of equivalent fractions, and could support the learners' conceptual understanding of rational numbers.

Tandeka used tasks that were meant to develop learners' understanding of the connections among common fractions, decimals and percentages. Each group of learners worked on a different task. In one group learners were given a 10 by 10 grid. They were required to shade one quarter of the grid, and then work out the percentage and decimal fraction of the grid that was shaded. Another group was given a number of fractions that they were asked to change to equivalent fractions with a denominator of 100, and then write the fractions as percentages.

Other groups worked on similar tasks. The tasks were aimed at building connections among common fractions, percentages and decimals using visual representations that could support conceptual understanding of rational numbers.

The teachers' task selection was a shift from their teaching before the intervention when they used tasks from textbooks which emphasized the correct application of mathematical procedures. In Chapter 4 I presented an episode from each teacher's teaching of the jointly planned lessons that shows how the teacher implemented the selected tasks. The episodes show that the teachers had different successes in supporting learners' conceptual understanding of the mathematics in the tasks. Bongiwe was more successful than the others, although in some cases she struggled in making explicit the conceptual meanings of mathematical procedures (see Episode 3 of her teaching in Chapter 4). Episode 2 shows how she managed to support learners' understanding of ratio as comparing quantities. Her success can be attributed to the elementary ideas of ratio involved in the tasks. For Janeth Episode 2 from her teaching of the jointly planned lessons shows how she struggled in bringing out the mathematical concepts involved in the learners' solutions. Learners solved the tasks using counters, and in the whole class discussions the conceptual meanings of ratio were not made explicit. Jeffrey developed a limited understanding of equivalent fractions by using only fractions whose denominators were multiples of 2 (Episode 1). In Tandeka's implementation of tasks (Episode 1), she had learners work on diagrammatic representations of common fractions, decimal fractions, and percentages, as separate mathematical ideas. She struggled in supporting learners to make connections among the three concepts, which was the goal of the tasks. The results show that in implementing the tasks, the teachers experienced different successes in achieving the goals for which the tasks were selected.

In the second cycle of planning, common worksheets were designed on ratio and rational numbers. The worksheets were designed after reflections on the first cycle of teaching, where it became evident that the conceptual meanings of ratio and rational numbers had not been fully developed. The connections among the conceptual meanings and the algorithms which are commonly used with these concepts had also not been developed. Hence the tasks selected for the worksheets were meant to support the learners' learning of these aspects of ratio and rational numbers (see Appendices T and S).

In the episodes below I present opportunities for learning about ratio and rational numbers in the professional learning community, and show how the tasks that the teachers selected can be linked to these episodes. Two episodes are presented: one on ratio and the other on equivalent fractions. Bongiwe and Janeth taught lessons on ratio, while Jeffrey and Tandeka taught lessons on rational numbers.

Episode 6.2 Developing deeper understandings of ratio

In the professional learning community the conversations about the conceptual meanings of ratio focused on ratio as a way of comparing quantities and the meanings of the algorithm used for dividing given quantities in given ratios. In response to the question 'What is ratio?' the teachers showed that initially they had an understanding of ratio that was connected to the algorithm for dividing quantities in given ratios. For them ratio was 'sharing'. The following extract from the conversation highlights this understanding.

Turn	Speaker	Utterance
13	Sibanda	What is it that they understand about ratios in grade nine? What is a ratio? What is a ratio? I think let's talk about this, what is ratio?
14	Jeffrey	Is dividing in parts, in parts
19	Bongiwe	Maybe I don't explain it clearly but
20	Jeffrey	Ratio is *(inaudible)* a total
23	Bongiwe	If you say, if maybe we say you are three, and I give you twenty rand to share it, let's say for instance Jeffrey, Mister Mandla and someone
24	Sibanda	What you are saying, what you are saying Bongiwe is, that's an application of ratio, you are applying ratio in sharing contexts, but what is ratio?
25	Jeffrey	The total parts of a whole
32	Bongiwe	Isn't it sharing, akere? (Is that so?)
33	Jeffrey	Divide eight hundred in the ratio five as to three *(inaudible)* the total parts
34	Sibanda	When you say divide in the ratio so and so, I am saying that's an application of ratio, you are using ratio in a dividing context, right, but what is ratio?
40	Jeffrey	A share because now
41	Bongiwe	You share
42	Janeth	We are sharing, it's a share *(inaudible)*
45	Bongiwe	It's a way of sharing
46	Sibanda	I, I beg to differ when you say, when you say it's a way of sharing because

		we always talk, we also talk of ratio, for example what is the ratio of men to women, are we sharing?
47	Bongiwe	*(Laughs)* We are sharing but not in equal parts
49	Mandla	You are distributing
54	Sibanda	What is the ratio of men to women among the educators in this school?
55	Bongiwe	Ten to fifteen
56	Sibanda	What are we doing there?
57	Jeffrey	We are comparing

In the conversation about the meaning of the algorithm for dividing quantities in given ratios the following item from the original test was used:

> Divide R800 in the ratio 5:3.

The focus in the conversation was on the reasons for adding 5 to 3 to get the total ratio 8, the reasons for dividing the 8 into R800 and the meaning of the final step of getting the answers. It was evident that the teachers knew these steps in the algorithm but did not attach conceptual meanings to those steps. The facilitator built an explanation of the algorithm with the teachers as shown in the following extract of the conversation.

Turn	Speaker	Utterance
124	Sibanda	What it means is, for every three that I give Tandeka I must give five to Janeth, so if the ratio is five as to three, right, I will take three and give to her and five to her. The next time I give her three, I must give her five, and I must give her three and her five, until that whole thing is exhausted. That's sharing in the ratio five as to three, for every three that I give her I must give her five
125	Janeth	Do that until I finish
126	Sibanda	Exactly, the question now becomes how many times must I do that, and in the end how much does she have and how much does she have?
127	Mandla	So if I give this one three, this one five?
128	Sibanda	Exactly
129	Mandla	Okay
130	Sibanda	Now if I have to, the ratio is five as to three, for every three I give her, I must give her five, what is the minimum amount I need for that to be possible?
131	Mandla	The minimum?
132	Sibanda	The minimum amount of money or whatever I must have for that to be

		possible, for me to be able to give her three and this one five?
133	Mandla & Bongiwe	It's eight
134	Sibanda	Eight, you see where the eight comes from; you see where the eight comes from?
135	Jeffrey & Bongiwe	Yes
137	Bongiwe	So that is eight times or?
138	Sibanda	Five plus three
139	Bongiwe	No, I know where it comes from
141	Mandla	Oh, so how many times should you give?
143	Janeth	How many times?
144	Sibanda	Each time, right, each time I am releasing eight
145	Mandla	Uh, not once
146	Bongiwe	This one three, this one five?
147	Sibanda	Yes, eight, eight, eight, how many times do I have to do that if I have eight hundred?
150	Bongiwe	To dish out that eight hundred?
151	Sibanda	Yes, how many times must I do it?
152	Tandeka	Hundred times
153	Sibanda	Hundred times
154	Bongiwe	Hey aah Sibanda!
156	Jeffrey	There is a question, Sibanda, how did you get hundred times?
157	Bongiwe	Hundred times, wena (you) Tandeka?
158	Jeffrey	How do you get hundred?
159	Sibanda	Tandeka can you tell them how we get hundred?
160	Tandeka	From eight hundred we have to take out eight all the times ne, so eight hundred divide by eight what do you get? How many eights are there in eight hundred?
161	Janeth	Uuhm hundred
165	Mandla	Oh, this five plus three
166	Janeth	Eh, it's eight
167	Mandla	Oh okay hundred times
180	Sibanda	And I am coming to her hundred times, each time I am giving her three, so how much does she end up with? *(pointing to the first recipient)*
181	Mandla	Three hundred

183	Sibanda	She ends up with? *(pointing to the second recipient)*
184	Tandeka, Bongiwe & Janeth	Five hundred

The episode shows how the conversation presented an opportunity for the teachers to deepen their conceptual understanding of ratio and the algorithm for dividing quantities in given ratios. The tasks that Bongiwe and Janeth selected for their lessons during the first cycle of teaching the jointly planned lessons can be linked to this conversation. Bongiwe selected tasks that focused on ratio as a way of comparing quantities, and the selection can be linked to the first part of the conversation in which the meaning of ratio as a way of comparing quantities was emphasised (T13 to T57). Janeth selected tasks that sought to develop learners' understanding of the conceptual meaning of dividing quantities in given ratios. In task implementation Janeth provided learners with counters which they used to solve the tasks in a process similar to how the facilitator explained in this episode. Janeth's selection and way of implementing the tasks can be linked to the second part of the conversation (T124 to T184), in which reasons for the steps in the algorithm for sharing quantities in a given ratio were discussed. The explanation of sharing practically by giving out quantities successively can account for Janeth's requirement that learners use counters in solving the tasks that she had given them in groups.

Bongiwe's and Janeth's selection of these tasks can also be accounted for by the learners' struggles in explaining what ratio is in the learner interviews conducted during the error analysis activity. Four learners were interviewed about their errors on the test item: "Divide R800 in the ratio 5:3". In their explanations, three learners said they understood the word "divide" to mean the operation of division. The errors made by these learners involved efforts to divide 800 by 5, and/or by 3 separately. One learner explained that he understood "5:3" to mean "5+3", which is one of the steps in the algorithm for dividing quantities in given ratios. When challenged to explain what they understood by "... the ratio 5:3" in the question, all the learners said that they didn't know what it means. When asked to explain their understanding of "ratio", three of the learners described ratio as numbers that have to be divided without leaving a remainder. This understanding can be linked to a step in the algorithm for dividing quantities in given ratios. The learners' responses showed some understandings of parts of this algorithm without conceptual

understanding of what ratio is all about, indicating more procedural than conceptual understanding of ratio. Learners' errors in mathematics have been found to be caused by memorisation of procedures or rules without conceptual understanding, among other causes (e.g. Erlwanger, 1973). The responses were part of the evidence used in identifying ratio as one of the critical mathematical concepts, and the learners' learning needs in this topic. The two teachers' task selection can be linked to the need to develop learners' conceptual understanding of ratio.

Episode 6.3: Developing conceptual understanding of the 'common denominator'

The learning opportunity presented in this episode was part of the community's conversation about the following test item during the error analysis process:

Calculate and simplify: $\frac{15}{24} + \frac{2}{8} - \frac{1}{4}$

In the conversation the facilitator made reference to some learners' responses in the learner interviews about the errors they made on this test item, and then challenged the teachers' understanding of the lowest common denominator (lcd).

Turn	Speaker	Utterance
22	Sibanda	And if you look at what Martha *(a learner)* said in the interview, she clearly does not know what an lcd is … Now my question to you is why do we need an lcd when we are adding such fractions? Why is it necessary? *Silence*
23	Bongiwe	*Inaudible*
24	Sibanda	Why do you have to express those fractions, for example, under the denominator twenty four, each one of them for you to be able to add and subtract? *Silence*
25	Mandla	It's to write it into an equivalent form
26	Sibanda	Why is the equivalent form very necessary? *Silence*
27	Bongiwe	I think it's very necessary because when you add or subtract fractions *pauses* uhm your denominators must be the same so that you can concentrate on the numerators
30	Jeffrey	When the denominators are the same then we can add or subtract fractions
32	Bongiwe	It becomes, it makes your, your, your, your what, it, what can I say? I think it makes your working to be simpler
34	Jeffrey	We are dealing with fractions that are nearly identical
35	Sibanda	What do you mean?
36	Jeffrey	In terms of ah maybe when you are given a whole, you want to divide a whole, so

		when denominators are the same it will be easier for you to add the numerators
37	Sibanda	But my question is why do the denominators have to be the same? What are we doing when we are making the denominators the same?
40	Bongiwe	In order to make the denominators to be the same
41	Sibanda	Why do they have to be the same for us to be able to add or subtract fractions?
44	Tandeka	Kuutata *(It is difficult)*
45	Mandla	It's to bring them to the same level

The extract shows that the teachers struggled to explain the significance of the common denominator in the addition and subtraction of common fractions, with one teacher acknowledging that she found the question difficult (T44). Mandla's response (T25) was partly correct but he could not explain it further. Similarly Jeffrey's response (T34) was also partly correct, but when challenged to explain further he reverted to his earlier responses (T36). The other teachers' responses showed that they understood the common denominator merely as a means to getting the answer. Despite persistent questioning the teachers could not explain the need for, or the meaning of the common denominator, and the facilitator had to do something to move the conversation forward.

In explaining the meaning and need for the common denominator in adding or subtracting fractions the facilitator proposed the use of a model of cutting a cake. (Coincidentally a real cake had been brought to the meeting that day in celebration of one teacher's birthday.) In the episode the facilitator asked Bongiwe, to cut a quarter of the cake and then one eighth from the remaining part of the cake. He then challenged the teachers to explain what fraction of the cake had been cut off. The following extract shows how the teachers struggled to work with the physical model to understand the meaning and necessity for the common denominator in adding the fractions: $\frac{1}{4}+\frac{1}{8}$.

Turn	**Speaker**	**Utterance**
91	Sibanda	If I say give me one quarter and one eighth which parts are you going to give me?
92	Bongiwe & Janeth	This one and this one *(pointing to a quarter and an eighth)*
95	Sibanda	What amount, as a fraction of the cake, have you given me?

96	Janeth	Huh?
97	Sibanda	What fraction of the whole cake have you given me?
98	Bongiwe	Two over, one over
107	Janeth & Bongiwe	Two over eight... which is one over four
108	Sibanda	So you are saying if you give me this *(pointing to the one-quarter piece)* and this *(pointing to the one-eighth piece)* you have given me one quarter of the cake?
109	Bongiwe	If I have given what? This one will be the quarter of the cake *(pointing to the one-quarter piece)*
114	Sibanda	One quarter plus one eighth... I take one quarter and one eighth, so I take this *(pointing to both pieces)* what fraction of the cake have I taken? You can't say it's a quarter
115	Mandla	Three over...
116	Janeth & Bongiwe	Kiena (that's it) three over eight
117	Mandla	Three over eight
118	Sibanda	How did you get three over eight?
119	Mandla	You count how many parts are there, they are three
120	Sibanda	You see where the challenge is, you can't add this and that as they are because these are of two different sizes

The extract shows how the teachers struggled to visualise the addition of the fractions $\frac{1}{4}$ and $\frac{1}{8}$ using the pieces of cake. Bongiwe and Janeth initially made an error (T98 & T107) which could have been a result of counting the two pieces which had been cut off. It is only after repeated questioning that Mandla seems to have understood what the facilitator was getting at (T115), and then the other teachers seemed to have understood as well.

The above conversation can account for Jeffrey's and Tandeka's selection of tasks in their teaching of the first cycle of concept development lessons. Jeffrey selected tasks that sought to develop understanding of equivalent fractions, as described above. Tandeka selected tasks that sought to connect common fractions to percentages and decimal fractions.

After the intervention Bongiwe maintained her selection and implementation of tasks that supported conceptual understanding of mathematical ideas, something that was shown in the

analysis of her teaching in Chapter 4 (Section 4.4.1 Episode 3). The other teachers' selection of tasks declined to more procedural tasks, as shown in the episodes of the three teachers' teaching after the intervention that were presented in Chapter 4. The finding indicates that, with community support, the teachers could select tasks that could support learners' conceptual understanding of mathematics.

6.3.3 Working with and responding to learners' ideas in instruction

In Chapter 4 I discussed how Bongiwe and Janeth shifted in the way they engaged with learners' ideas in their teaching. The other two teachers, Tandeka and Jeffrey, did not make meaningful shifts in this dimension of their teaching. Before the intervention all the teachers except Tandeka controlled content delivery and explained mathematical concepts to learners. Learners were hardly afforded opportunities for explaining and justifying mathematical ideas in class. In their teaching of the jointly planned lessons all the teachers made efforts to involve learners in discussing mathematical ideas with their peers, and presented their thinking in whole-class discussions, as shown in the analyses of the teachers' teaching in Chapter 4. This shift can be accounted for by the conversations during the professional learning activities in the community. From the error analysis activity, the teachers had opportunities for developing an understanding for the need to understand the learners' thinking behind observed errors. By inquiring collectively into the possible reasoning behind learners' errors, and interviewing some learners about their errors, the teachers had opportunities for learning about the significance of engaging with learners' thinking and ideas during instruction. This is further elaborated in the next section. The other professional learning activities were underpinned by a focus on developing learners' conceptual understanding of ratio and rational numbers through selection and implementation of mathematical tasks that learners would solve in groups. The learners would then explain and justify their solutions in whole class discussions.

In their teaching during the intervention all the teachers made efforts to have learners explain their responses in class. Bongiwe and Janeth were more successful in this aspect of their teaching than Jeffrey and Tandeka. This is illustrated in episodes from their teaching of the jointly planned lessons that were presented in Chapter 4. For Bongiwe and Janeth asking learners to explain and justify their responses was a shift from their teaching before the intervention. Asking

learners to explain responses was a move that made it possible for the teachers to understand learners' thinking in making particular responses. However for all the teachers this move did not lead to rich mathematics as shown in Chapter 4, something that can be accounted for by the challenge of shifting from a focus on procedures to conceptual meanings of mathematical ideas in teaching. In their teaching before the intervention the teachers' teaching was more procedural than conceptual, hence making the shift to teaching for conceptual understanding and developing rich mathematics, could have been challenging. This is elaborated in Section 6.3.5 below.

In addition to error analysis and lesson planning activities, the lesson reflection activity can account for the shift in the teachers' ways of working with and responding to learners' ideas. In reflecting on their teaching in the professional learning community there were conversations about how the teachers had engaged with learners' ideas in their teaching. The following extract from a conversation during the community's reflection on Janeth's lesson shows how one teacher was concerned with the way Janeth had responded to a learner in the lesson.

Episode 6.4: The need to listen to learners in teaching

Turn	Speaker	Utterance
67	Sibanda	Bongiwe, you want to comment?
68	Bongiwe	No I don't have but for the first one, for, for, for the first presentation there, you remember that learner, she did explain it very well but the teacher said to the learner you didn't explain it *(laughs)* so that's where the learner becomes confused, the first one, the first one who was dealing with one, ja, who was giving, as I am giving this girl one I am giving the boy three, then, she did
69	Janeth	Makoti?
70	Bongiwe	Uhm, she did explain it clearly but the teacher said the learner didn't explain it well
71	Janeth	Uh uh I said that if the sweets were, let me tell you something *(checking her paper)*, you didn't hear it clearly *(Bongiwe laughs)* I said that if, here we have twelve, if it is fifteen
72	Sibanda	Ah okay, you wanted to extend
73	Janeth	Eh
74	Sibanda	You wanted to extend it by altering the number
75	Janeth	Eh
76	Bongiwe	So that one went back to that one of one as to three
77	Janeth	Eh, the number was now fifteen

78	Bongiwe	So I was thinking the teacher didn't hear the learner but she was but she was explaining that is why I was saying confusing *(laughter)*
87	Sibanda	In other words the point is let's listen carefully to the learners and see what they are doing, and then we can build on their thinking

In the episode Bongiwe raised her concern with the way she thought Janeth had responded to a particular learner. The concern was related to ideas discussed in the professional learning community about the need to listen and hear learners' ideas during instruction. Bongiwe's ability to pick up an instance where she thought Janeth had not heard properly a learner's explanation could be an indication that she (Bongiwe) had developed an awareness of listening carefully to learners' ideas in her teaching. Such awareness could explain the shift in her ways of working with and responding to learners' ideas in her lessons, a shift that she sustained after the intervention. Janeth's response to Bongiwe's concern was a clarification of what she (Janeth) had said in class. Conversations similar to this one in the professional learning community can account for shifts in the two teachers' ways of engaging with learners' ideas in their teaching.

6.3.4 Learner errors

In Chapter 4 I showed that there were shifts in the teachers' talk about learner errors. Before the intervention the teachers blamed learners and previous teachers for learners' errors and to a lesser extent the parents of the learners. After the teachers' participation in the error analysis activity the teachers' comments indicated a shift to an understanding of learner errors as coming from their thinking and working with mathematical knowledge. These shifts can be accounted for by the professional learning community conversations during the error analysis activity. In the activity the focus was on understanding the learners' thinking behind observed errors. In the conversations the first thing was to understand how the learner(s) made the observed error, followed by why the learner(s) would think in that way. The following is an extract of a conversation about errors on the following test item:

Change the following to a decimal number: $\frac{5}{8}$

Observed errors: 5.8; 0.85; 0.58;

In this extract the focus was the pattern of errors in which the digits 5 and 8 were appearing in the learners' answers.

Episode 6.5: Analysing a pattern of learner errors.

Turn	Speaker	Utterance
32	Sibanda	Let's look at the errors…what is the…if you look at both parts one and two there is one big misconception that is coming out
33	Jeffrey	Maybe now we had to convert a common fraction to a decimal because here we get aah five comma eight so it doesn't show five…how many times five goes into eight…oh eh…
39	Sibanda	... if you look at both one and two there is a big misconception that you can pick out easily
41	Tandeka	Decimals means he knows or she knows that we have a nu…a number before comma and a number after, so what she said or what she writes just add zero and comma because…
42	Mandla	No I think…
43	Tandeka	…and gets zero comma five eight
44	Sibanda	Yes but it's now five eight…
45	Mandla	*(Inaudible)*
46	Tandeka	…how can I do
47	Sibanda	But if you look at the digits that appear in their answers there
48	Mandla	They are the same…they are still there
51	Sibanda	Who…what is still there?
52	Mandla	The very same number, but there are problems *(inaudible)* as the that one denominator is numerator
53	Sibanda	Where one of them has zero point eight, that's right, zero point five eight, the other has zero point eight five
54	Mandla	Aahm
55	Sibanda	But the bigger observation as Mandla was saying…
56	Mandla	Ehm that one that is numerator in the expression and eight is the denominator
57	Chorus	Uuhm
58	Mandla	The learner just got rid of this sign, the division sign…
63	Sibanda	…play around with five and eight…
64	Chorus	Ja
65	Sibanda	So what is that they think?
66	Mandla	Any number any co…eh digit…eh decimal numbers have a comma and he puts a comma there between the two
71	Sibanda	So what is what is the bigger misunderstanding there?
72	Janeth	Division
73	Mandla	Huh
74	Janeth	Uya over
75	Sibanda	What is the big misunderstanding?
76	Matsose	They don't know how to…
77	Many speakers	They don't know how…just too…knowledge…division…

78	Janeth	…division line carries fifty percent *(inaudible)* any number…
79	Sibanda	Tandeka had almost got it the first time, I don't know why it has evaporated (*everybody laughs)* She had observed it, you can almost pick out a belief in the learners there
88	Jeffrey	The, I think there is the belief that ah that five over eight has to be represented in its equivalent form because now still we have the ah five comma eight…
89	Sibanda	So their belief is that?
90	Jeffrey	Five over eight has to be equally represented in its equivalent form
91	Sibanda	The digits five and eight must not disappear
95	Mandla	Uuhm *laughter from all* this
96	Sibanda	That's the bigger the big misconception… when you are converting a number whether to a fraction whether to decimal fraction or to percentages, the original digits simply cannot disappear
97	Chorus	Ja
100	Sibanda	Now what could have caused that misconception? Think about a teacher who is teaching converting common fractions to decimal fractions and uses the following examples: five, four…three over ten, twenty-four over hundred
101	Jeffrey	Ja
102	Sibanda	He is he is teaching converting common fractions to decimals and uses the set of…write down the fractions I am talking about…
103	Mandla	*(Inaudible)*
104	Sibanda	I said three over ten, and twenty let's say twenty-three over hundred, you can also think of something like a hundred and forty-three over a thousand…one hundred and forty-three over a thousand…if you convert those to decimals see what you get
105	Janeth	If you…
106	Sibanda	…Convert those to decimal fractions…
107	Jeffrey	Zero comma *(Writing down the answers)*
108	Mandla	The very same number
109	Jeffrey	Ja
110	Sibanda	The numbers are not disappearing
111	Mandla & Janeth	Ja they are not…
112	Sibanda	And those answers are correct
113	Chorus	Ja
115	Sibanda	So if you teach learners using these examples, what are you telling the learners?
118	Mandla	They they will apply to all of these…
119	Sibanda	When you are converting a common fraction to a decimal the digits will not disappear
120	Mandla	Uuhm
121	Sibanda	If you are using such examples…they are easy to use…dividing by ten or a multiple of ten is easy …dividing by ten, dividing by hundred is easy, right
122	Chorus	Uuhm
123	Sibanda	So as teachers we may go for such easy examples right…but they create a

		misconception in the learners, and the misconception is that the learners begin to think that oh when I am divi…converting to a decimal fraction then the digits…
126	Jeffrey	Must not disappear
129	Sibanda	… for us as teachers what is the critical issue there?
130	Janeth	For us teachers…
131	Sibanda	Uhm
132	Jeffrey	Eh I think eh as as we are teachers maybe we should take this example and another example where they are disappearing like that *(referring to* $\frac{5}{8}$*)* maybe they will see the difference
133	Sibanda	All we are saying is…
134	Mandla	According to this one must change…
135	Sibanda	Change the examples when teaching this

This conversation had three parts to it. In the first part the conversation focused on the learners' thinking that could have caused the error (T32 - T96). This part of the conversation was central to the teachers' understanding of the learner thinking behind the errors. In error analysis understanding the thinking behind an error helped the teachers in realising that there was some reasoning behind learner errors. Thus error analysis was an opportunity for learning about errors as reasonable for the learners. With such an understanding teachers could be expected to ask learners to explain or justify their incorrect answers during their teaching, something that could account for some of the teachers' shift in their way of dealing with learner errors during and after the intervention.

The second part of the conversation shifted to a discussion of the possible causes of the learners' incorrect thinking (T100 - T113). This part of the conversation was an opportunity for the teachers to learn that errors could result from correct mathematical thinking that is incorrectly applied to a different domain of numbers. In this case the facilitator asked the teachers to try out some common fractions whose correct answers resulted in a similar pattern to the observed learner errors. Understanding that errors can result from correct mathematical thinking could support the shift from blaming learners for errors to an understanding that errors are a normal part of learning mathematics. However in the observed teachers' teaching there was no evidence that the teachers had developed this understanding in practice. In Chapter 4, Section 4.5, I showed how all the teachers struggled in responding to, and dealing with learner errors in their teaching during and after the intervention. The episodes of the teachers' teaching before the

intervention that were presented in Chapter 4 show a focus on correct learner responses and ignoring of incorrect responses. Although the conversations in the professional learning community created opportunities for the teachers to develop new understandings of learner errors and how to engage with learner errors in teaching, the teachers did not make significant shifts in this aspect of their teaching. Making the shifts in practice could have been a challenge that could require more time. This is consistent with what is known about teacher learning in professional development and teachers' teaching practices. What teachers learn in professional development contexts has been found not to easily translate into changed teaching practices (e.g. Borko, 2004; Brodie, et al., 2002; Kazemi & Hubbard, 2008).

The last part of the conversation was an opportunity for the teachers to derive a teaching implication from the error analysis (T115 – T135). Varying examples in teaching particular mathematical ideas can support deeper understanding, although this aspect of the teachers' teaching was not analysed in the study.

In brief, the error analysis conversations can account for some of the teachers' shift in engaging with learners' thinking and errors during their teaching. The shift was more evident for Bongiwe and Janeth, and episodes of their teaching during and after the intervention that were presented in Chapter 4 highlight the shifts.

6.3.5 Richness of the Mathematics

In the previous four sections I have highlighted how the richness of the mathematics remained consistently low in the teachers' teaching. This was in spite of shifts in some aspects of their teaching. Teaching rich mathematics involves emphasising both procedural and conceptual meanings of mathematical ideas. The analyses of the teachers' teaching before the intervention in Chapter 4 show an emphasis of mathematical procedures at the expense of conceptual meanings. The professional learning activities in the community were opportunities for the teachers to deepen their conceptual understanding of some mathematical ideas, thereby supporting their teaching of rich mathematics. The episodes presented above in accounting for some of the shifts in the teachers' teaching practice indicate that conceptual meanings of mathematics were a common theme in the conversations related to the teachers' subject content and pedagogical content knowledge. In lesson planning the emphasis was on engaging learners in mathematically

productive group discussions that could support rich conceptual mathematics. In productive group discussions learners grapple with rich mathematical tasks that support deep conceptual understanding of mathematical ideas. Teachers support the learners' discussions by pushing for deeper thinking, explanations and justifications.

In spite of being exposed to the opportunities for learning that emphasised rich conceptual mathematics, the richness of the mathematics remained consistently low in the teachers' teaching. Some episodes from their teaching during and after the intervention that were presented in Chapter 4 illustrate this finding. For Bongiwe, Episode 3 of her teaching shows how she was not successful in making explicit the idea of constant variation as underpinning 'Direct Proportion'. She emphasised the procedures of computing missing values in a mathematical relationship between two variables that were in direct proportion without bringing out that the constant of variation defines the relationship, something that could have made the mathematics richer. For Janeth, Episode 2 shows how she struggled to hear and interpret some of the learners' ideas, thereby missing opportunities for scaffolding learners' thinking in ways that could have led to rich mathematics being discussed. Janeth was not successful in using learners' empirical approaches in solving tasks on ratio to develop conceptual understanding of the algorithm for sharing quantities in given ratios. For Jeffrey, Episode 1 shows how he often missed significant learner questions and contributions. He guided learners towards more procedural than conceptual understanding of equivalent fractions. Tandeka (Episode 1) was not successful in bringing out the connections among common fractions, decimals and percentages, even though learners worked on representations of these numbers that could support making connections among the numbers. These examples show how the teachers struggled to work with the conceptual meanings of ratio and rational numbers that were discussed in the community, thereby missing opportunities for developing rich mathematics in their teaching.

Several factors can account for the persistently low richness of the mathematics in the teachers' teaching. Rich mathematics places demands on teachers' subject content knowledge. Teachers need to be conversant with the conceptual meanings of mathematical ideas for them to teach rich mathematics to their learners. One observation during the conversations in the professional learning community was that the teachers were developing new conceptual understandings of mathematics that they had not thought of before. Episodes 6.2 and 6.3 above show how the

teachers struggled in the conversations on the conceptual meanings of ratio and rational numbers respectively. While these conversations were opportunities for deepening subject content knowledge, there was no evidence that the teachers learned the conceptual meanings sufficiently enough to work with that knowledge in their teaching in ways that could support the development of rich mathematics. An example from the teachers' teaching episodes in Chapter 4 is Janeth's attempts to work with an empirical approach in solving tasks on ratio, without using the approach as a way of explaining the meanings of the steps in the algorithm for sharing quantities in given ratios. Using counters to explain the ratio algorithm had been discussed in the professional learning community. Thus although the professional learning activities privileged conceptual meanings of mathematical ideas from which the teachers had opportunities to deepen their subject content knowledge, the teachers may not have developed the conceptual meanings sufficiently enough to work with that knowledge in their teaching. This is consistent with literature which characterises teacher learning as a slow, complex and uncertain process (Borko, 2004).

Another factor that can account for the low richness of the mathematics is the demand placed on the teachers' pedagogical content knowledge by teaching in ways that support rich mathematics. The professional learning activities in the community emphasised: understanding learners' thinking; engaging with learners' ideas in ways that support deeper understanding; scaffolding learners' thinking to develop conceptual understanding of mathematical ideas; and reflecting on teaching in ways that supported development of new insights about learners' learning of mathematics. These ideas permeated all the learning activities of the community. The implications of these ideas on actual teaching practice may not have been fully grasped by the teachers. Such implications include the development of teaching skills such as: hearing and interpreting learners' ideas correctly before responding in class; embracing learners' incorrect responses and using such responses as resources for deeper discussions of the mathematics; and following-up on learner contributions that have the potential for leading to the discussion of rich mathematics. Although such teaching skills were privileged in the conversations of the professional learning community, it seems to have been a challenge for the teachers to implement such skills in their teaching.

Another factor could be my facilitation of the conversations in the professional learning community, especially during reflection on teaching. In reflecting on group-work as a teaching approach the teachers' comments emphasised the form more than the substance of group-work. With hind-sight I realise I did not sufficiently engage the teachers in critically reflecting on the substance of group-work as a mode of teaching, and how they could have engaged with learners' ideas in ways that could develop rich conceptual understanding of mathematics.

In summary, the consistently low richness of the mathematics in the teachers' teaching can be accounted for by the complexity of working with knowledge developed in professional development contexts, in teaching practice. The professional learning activities exposed the teachers to opportunities for deepening their subject content and pedagogical content knowledge in relation to particular mathematical concepts. The teachers made some efforts to work with the knowledge in their teaching, but this did not lead to the development of rich mathematics. As highlighted in the literature, what teachers learn in professional development does not get easily translated into actual practice (Kazemi & Hubbard, 2008).

In the above sections I presented opportunities for learning in the professional learning community that accounted for some shifts in the following aspects of the teachers' teaching practices: mode of instruction, task selection and implementation, ways of engaging with and responding to learner errors, and understanding of the nature of learner errors. The connections among the shifts and the learning opportunities in the professional learning community serve to illuminate how teacher learning in the professional learning community supported shifts in their teaching practices. Such connections support the argument for professional learning communities as learning spaces in which teachers can improve by engaging with their peers in on-going reflective inquiry into their professional knowledge and teaching practices (Toole & Louis, 2002).

6.4 Accounting for shifts in the teachers' identities

In Chapter 5 I presented shifts in the teachers' identities from pre-intervention to post-intervention. A distinction was made between the teachers' identities as community members or modes of belonging (Wenger, 1998), and their teaching identities. The following were the observed shifts in the teachers' identities:

- Shift in identity as self-in-community – from membership in a community based on peer consultation to membership in a professional learning community
- Shift in teaching identity – from self-descriptions that portrayed the teacher as controlling content delivery and explaining mathematical ideas to self-descriptions that depicted the teacher as facilitator of learners' learning.

In the next two sections I show how these shifts can be explained by the activities and conversations in the professional learning community.

6.4.1 Identity as community membership

The results presented in Chapter 5 indicate that all the teachers shifted in their identities as members of communities. All the teachers developed a sense of membership in the professional learning community, albeit in different ways. The identities of belonging in the professional learning community were based on the joint learning in the activities of the professional learning community. The teachers imagined themselves as learning together and developing deeper understanding in the various domains of their professional knowledge. The connection between learning and identity has been explored quite extensively in the literature (e.g. Dam & Blom, 2006; Friedrichsen, Lannin, & Abell, 2008; Travers, 2000). A common theme in the literature is that learning shapes identity. Wenger (1998) regards identity as "a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities" (p. 5) i.e. learning is a form of identity construction. In their comments during the focus group and post-intervention interviews the teachers regarded their participation as a process of joint learning. Their perceptions supported the collective imagination of themselves as members of the professional learning community. In the interviews the teachers made reference to instances in which they thought they had learned, and in some cases gave specific examples of the subject content and pedagogical content knowledge they had learned. They all indicated having learnt from the joint lesson planning and lesson reflection activities. Perceptions of learning in the professional learning community supported the development of a sense of belonging together in the professional learning community, which can account for the shift in the identities as members of the professional learning community.

In their expressed future visions of the professional learning community the teachers imagined themselves as on-going members of the community. They justified their membership through their appreciation of the practices of the professional learning community. Mandla, in particular, expressed his desire to have similar professional learning communities in other subject areas in the school. He valued the relevance of community practices for the teachers' teaching practices. This finding alludes to the connection between identity and practice. The teachers' collective perception of the activities of the professional learning community as a set of practices that could form the basis for the continuation of the professional learning community was a source of their identities as on-going members of the community. Viewing the set of activities as a worthwhile practice could have supported the development of a sense of community, hence the expressed wish to continue engaging in the activities as a professional learning community. The emerging finding is that the shifts in the teachers' identities were contiguous to the development of a practice for the professional learning community.

Another link between the teachers' shifting identities and the professional learning activities was the development of relationships of trust and confidence in the professional learning community. The teachers developed trust and confidence to openly acknowledge their individual weaknesses in the professional learning community, as illustrated in Episode 6.6 below. In the episode the community was discussing the solution of the following test item:

Express $0.5\dot{4}$ as a common fraction.

Episode 6.7: Challenging each other's content knowledge

Turn	Speaker	Utterance
1	Mandla	Eh Janeth can you explain to us how to express that...
2	Jeffrey	As a common fraction
3	Janeth	Aah I don't know the recurring, it's the one Bongiwe gave to the learners; I don't give them the recurring in class *(laughter)* I don't want to lie.
4	Sibanda	Don't worry we will ask someone to go and find the solution and explain it to us in the next meeting
5	Janeth	Its zero comma five four five four, ne?
6	Mandla	Aaa, Aaa

7	Janeth	Or four four four?
8	Mandla	Four four
	Sibanda	Zero comma five four four four four four…its only the four which is recurring, not five four…if five was recurring then we would also have that sign above five
9	Janeth	But to my, no I am telling the truth, I didn't give the learners the one that have a recurring, I am telling you
10	Sibanda	No after tomorrow you should be able to give them
11	Janeth	Ja …like…but…but in grade ten, mister, we don't use the recurring
13	Sibanda	I mean I understand …probably in maths lit but in pure maths they should be able to deal with that
14	Janeth	Ja, ja maybe there
15	Mandla	These are the sums they avoid in most cases, why do you avoid them (*everybody laughs)*
16	Sibanda	No after tomorrow you should be able to give them
17	Janeth	Ja …like…but…but in grade ten we don't use the recurring

In the episode Mandla challenged Janeth to explain the solution to the item. Mandla's challenge was echoed by Jeffery, which could be an indication that both of them were not sure about how to answer the task. Mandla's challenge was based on an assumption that Janeth would not take offence at being challenged about her subject content knowledge. Janeth's response confirmed Mandla's assumption. She did not take offence and responded with an acknowledgement of her weakness in her knowledge about recurring decimals. Her acknowledgement of the weakness was an indication of feelings of safety in the community and was also tied to a desire to learn from the community, hence her persistence in seeking clarification about the meaning of the decimal fraction. Relationships of trust and confidence enable members of a community to challenge each other respectfully and acknowledge weaknesses, which are important features of productive data-informed conversations in professional learning communities (Earl & Timperley, 2008). Such relationships account for the development of a community (Koellner-Clark & Borko, 2004) and identities of belonging in the community.

Other indications of developing relations of trust and confidence included the manner in which the teachers reflected on each others' teaching without fear of being criticized. Opening up their individual teaching practice for discussion in the community was an indication that they

perceived the community as a safe environment, something that supports cohesion and the development of group identity. Prior to the intervention one teacher, Jeffrey had been resistant to collaboration with his peers. He later stated that he had learned human relations in the professional learning community. His identity shift was connected to perceptions of having more cordial relationships with his colleagues. The key emerging point is that the teachers' collective engagement in the practice of the community and the development of mutually shared perceptions of learning together account for shifts in the teachers' identities as members of a community.

6.4.2 Teaching identity

The shifts in the teachers' teaching identities that were presented in Chapter 6 can be linked to the lesson planning and lesson reflection activities. In the lesson reflection activity one aspect that was discussed was the teacher's role in the lesson. This aspect was connected to the designated teaching identity in the suggested teaching approach during the lesson planning activity. Episode 6.1 above shows how the suggested teaching practice was negotiated in the professional learning community. The practice designated a teaching identity (Sfard & Prusack, 2005) of guiding and facilitating the learners' discussion of mathematical ideas. According to Sfard and Prusack (2005) "designated identities are stories that are believed to have the potential to become a part of one's actual identity" (p. 45). In the professional learning community the lesson planning conversations presented an image of a teacher that the teachers had not previously thought possible, a teacher who could guide and mediate learner discussions of mathematical ideas; as well as respond to, and evaluate learners' contributions and thinking. In their teaching of the jointly planned lessons the teachers made efforts to enact the designated identity in their lessons, and this is related to shifts in their teaching identities. The following episode during the reflection on one of Janeth's lessons indicates how teachers talked about their changed teaching identities.

Episode 6.6: Reflection on the teacher's role in teaching

In this extract the professional learning community was reflecting on the role Janeth played in her teaching of the jointly planned lesson.

Turn	Speaker	Utterance
232	Sibanda	I don't know what you think about that type of positioning[30], what are your comments on her positioning in the lesson?
234	Mandla	But she doesn't want to cause any disturbance *(laughter)*
235	Janeth	Because I think eh I was going to disturb them even like they were presenting individually in there so I thought that I must go at the back so that they can be free
238	Sibanda	But does that help? In other words does that work? That's my question, what do you think about such an arrangement when the teacher is at the back and the learners are talking and doing the mathematics at the board for the others?
239	Mandla	It's still okay meneer[31], depending on the mood of the class, eh everybody is concentrating at the activities that are presented in the class, they are taking part, now the, the, the educator is giving latitude to the very same learners
240	Sibanda	But who is the source of the mathematical ideas there? *(silence)*
247	Jeffrey	The teacher is the source
248	Bongiwe	It's the teacher and the learners
249	Sibanda	Huh? Both?
250	Mandla	I don't understand the question, the source?
251	Sibanda	Yes
252	Bongiwe	Source of information
253	Mandla	No the source of information is from the learners
254	Bongiwe	I think
255	Mandla	Because they are the ones who are in control now
256	Sibanda	Do you all agree?
257	Mandla	I think the educator is facilitating, she is a facilitator
258	Janeth	I behaved as if I am a learner, so I gave them a chance to teach so they get the freedom of doing
259	Bongiwe	At the same time leading them to, that's why I am saying it's from both the teacher and the learners, the source of information, from both the teacher and the learner, akere? (isn't it?), akere teacher maybe if ever there is a problem somewhere she is leading learners to answers, I think
260	Sibanda	I mean you are right, that is right but I see the teacher's role as more of seeking further clarification for the benefit of the other learners, but the original ideas are coming from?
261	Chorus	From the learners

[30] By positioning I meant the role of the teacher in the lesson, e.g. a source of mathematical ideas, or a mediator of learners' mathematical productions, as well as physical positioning.
[31] The term 'meneer' is used in South Africa in reference to 'Mister'.

In the conversation the facilitator raised two questions that served as the points of discussion: how the physical position of the teacher supported the learners' learning; and who was the source of the mathematical ideas being discussed. Both questions allude to a teaching identity. Two teachers' responses to the first question (T234, T235 & T239) highlight the idea of giving learners the freedom of discussing the mathematical ideas with little interference from the teacher.

With reference to ownership of the mathematical ideas the teachers' initial responses showed a diversity of opinions. Jeffrey's response (T247) may be connected to his didactic teaching practices which can be characterized as direct instruction. Mandla's responses (T255 & T257) show an appreciation that learners were now more dominant in discussing the mathematical ideas, with the teacher assuming the identity of facilitator. Bongiwe's (T259) saw the teacher and learners as co-participants in the learning situation, although she initially could not articulate the differences in the learners' and the teacher's contributions. Sibanda's remark (T260) reflects an inclination towards a conclusion that learners were the source of the mathematical ideas.

The episode serves as an example of how reflections on the teachers' lessons in the professional learning community supported conversations about the teachers' teaching identities. In this episode there was a consensus that Janeth was a 'facilitator' in the lesson. Such an identity resonated with how Janeth positioned herself in the actual teaching of the lesson. Janeth was mainly at the back of the class while learners presented mathematical ideas at the board. The other learners' contributions were directed at the presenting learner at the board, with Janeth guiding the interactions. In the post-intervention interview Janeth made the following comment about her positioning in her lessons:

> It changed that the, I am not the one who is supposed to talk, learners must also talk, so that it's also the one that have changed … Uhm I am just a facilitator and then if they are getting lost, I, I am interfering there, okay is there any problem, if there is then I need to help. But they are the one who are going to come up with the answer

This description reflected a shift in Janeth's teaching identity from her teaching identity before the intervention. In her teaching of the post-intervention lessons Janeth did not consistently

enact this identity. She shifted to directly controlling content delivery in one of her post-intervention lessons.

The episode shows how the lesson planning and lesson reflection activities were connected to shifts in the teachers' teaching identities. The lesson planning activity designated a particular teaching identity for the teachers in teaching the jointly planned lessons. All the teachers attempted to enact that identity in their teaching, with different degrees of success. How the teachers saw themselves enacting the designated teaching identity supported shifts in their teaching identities. For two teachers, Bongiwe and Janeth, teaching identity resonated with their actual teaching practice during the intervention. For Tandeka and Jeffrey the shift in teaching identity was not successfully enacted in actual teaching. The connection between identity and teaching practice is elaborated further in Chapter 8. The main point is that the learning opportunities in the professional learning community can account for shifts in the teachers' teaching identities.

6.5 Connecting shifts and learning opportunities

In this chapter I have analyzed the connections between the shifts in the teachers' teaching practices and identities in relation to the professional learning activities in the professional learning community. I have shown how the opportunities for learning in the professional learning community can account for some of the shifts. In this section I summarise these connections.

In the teachers' teaching practices the shifts in the mode of instruction were linked to the conversations in the professional learning activities in the community. The activities emphasised the need to support learners' conceptual understanding of mathematical ideas, and various ways of engaging with learners' thinking and ideas were discussed. In lesson planning a teaching practice in which learners would discuss mathematical ideas with their peers before sharing their findings with the rest of the class in whole class discussions was discussed. The teacher's role in such a teaching practice would be to guide and mediate the development of learners' mathematical ideas. In teaching the jointly planned lessons the teachers made varied efforts to implement the planned teaching practice. For two teachers implementing the planned teaching practice became a significant shift in their mode of instruction and their teaching identities. Thus

the learning opportunities in the professional learning community can account for the shifts in some of the teachers teaching mode, and the teachers' teaching identities.

The learning opportunities privileged the deepening of subject content knowledge with respect to the conceptual meanings of ratio and rational numbers. The nature of mathematical tasks that would support the learners' access to these conceptual meanings was discussed. The teachers worked with these ideas in their teaching. In the first cycle of teaching all the teachers selected tasks that had the potential to support learning of the conceptual meanings of ratio and rational numbers. In the second cycle of teaching common worksheets were developed in the professional learning community with tasks selected carefully to deepen learners' conceptual understanding. In task selection there was a shift among all the teachers which three teachers did not manage to sustain in their post-intervention lessons. In task implementation all the teachers struggled to support learners' access to the conceptual meanings which were provided by the tasks, thereby reducing the richness of the mathematics. The teachers emphasized the procedural aspects of the tasks. The teachers' challenges in engaging with, and responding to learners ideas in ways that would support the richness of the mathematics and learners' conceptual understanding can be accounted for by the demands placed on teachers' knowledge when engaging with the conceptual meanings that explain mathematical procedures. Although this knowledge was privileged in the professional learning conversations, it was a challenge for the teachers to implement the knowledge in their teaching. Thus shifting from procedural teaching to more engagement with conceptual meanings of mathematical ideas was challenging for the teachers.

The shifts in the teachers' identities can be accounted for by the learning opportunities in the professional learning community. Shifts in identities of belonging to communities were linked to participation in the professional learning activities and perceptions of learning in the professional learning community. The teachers' experiences of learning together, planning together, and analyzing learners' errors together supported the teachers' senses of belonging in community. Relationships of trust among the teachers also fostered the development of identities of belonging to the professional learning community. Shifts in teaching identities were accounted for by the teachers' efforts to work with the planned teaching practice of engaging learners in collaborative discussion of mathematical ideas.

What the learning opportunities did not account for were the differences in the shifts of individual teachers' practices and identities. The differences can be accounted for by the nature of situated learning (Lave & Wenger, 1991). Participation is critical for learning in a professional learning community. How the teachers participated in the professional learning community could account for the differences in the shifts in teaching practices and identities. Bongiwe participated more than the others and was more assertive in her contributions. She made the most shifts in her teaching practice. Janeth was often disengaged but usually echoed Bongiwe's contributions. She frequently asked for clarification of ideas being discussed. She made some shifts in her teaching that were not sustained after the intervention. Jeffrey participated and often asked questions seeking for clarification in the community. Tandeka was reserved and contributed when invited. Both Jeffrey and Tandeka did not make substantive shifts in their teaching practices. This observation resonates with other findings in the literature which highlight how teachers make different shifts in teaching practice through professional development (Borko, 2004; Franke, Carpenter, Levi, & Fennema, 2001; Kazemi & Hubbard, 2008).

Another possible explanation for the differences in shifts in teaching practice could be the teachers' professional qualifications. Among the teachers Bongiwe was the most qualified. She had a teaching diploma and an Advanced Certificate in Education (ACE). At the time of the study she was about to complete her studies for a Bachelor of Education (Hons) Degree. Bongiwe made shifts in her teaching that she sustained after the intervention. Janeth had a teaching diploma and an ACE. She was not studying at the time of the study. She made shifts in her teaching practice during the interventions, which were partially sustained after the intervention. Jeffrey had a Higher Diploma in Education and was not studying for another qualification during the study. He did not make significant shifts in his teaching practice in the professional learning community. Tandeka had a Senior Primary Teachers Diploma. She did not make significant shifts in her teaching practice in the professional learning community. Although these observations suggest a connection between teacher qualifications and shifts made in teaching practice through the learning opportunities in the professional learning community, no data was collected in this study to substantiate the observation.

In this chapter I have analyzed how the teachers' shifts in teaching practices and identities, which were discussed in Chapters 4 and 5, were accounted for by the professional learning activities of

the professional learning community. Specific episodes from the conversations of the professional learning community were presented and analyzed as a way of accounting for the shifts in teaching practices and identities. Linking the shifts to the activities and conversations of the professional learning community provided evidence for the argument that the professional learning community supported shifts in the teachers' teaching practices and identities as community members. In the next chapter I analyze some features of the professional learning community that supported teacher participation and learning.

CHAPTER 7

FEATURES OF THE PROFESSIONAL LEARNING COMMUNITY

7.1 Introduction

Internationally, research on professional learning communities has highlighted features that support the success of such communities. In Chapter 3 (Section 2.4.3) I reviewed some of these research studies. The features include: having a shared learning focus; collaborative inquiry; the use of evidence to support inquiry; leadership; time; relationships; and norms of interaction. In this chapter I analyze some of the features that supported or constrained the success of the professional learning community in this study. Although the features were equally important for the work of the professional learning community, I have categorized them as internal or external to the actual work of the community for purposes of structuring of this chapter. Internal features are those features in that had direct influence on how the teachers interacted and learned together. These are features that were within the control of the professional learning community and include: purpose and focus of the activities; norms of interaction; and relationships of trust and confidence. External features relate to features such as time, leadership support and other school demands. These are features that were outside the control of the professional learning community.

The chapter addresses the research question:

- What features of the professional learning community supported or constrained teacher learning?

7.2 Overview of the findings

The internal features of the professional learning community were mostly linked to the activities and the teachers' participation. The structure of the professional learning activities, which is coherent and developmental, fostered perceptions of teacher learning and hence the teachers' sustained participation. The development of a shared learning focus, which is understanding learner errors how to work with learner errors in teaching, created a sense of relevance and ownership of the activities for the teachers. Perceptions of learning supported the teachers' sustained participation. Another feature was the teachers' tolerance of challenges and difficulties,

which supported their participation. Norms of interaction and relationships were other features which supported the teachers' participation and the development of community. The norms of interaction included: challenging each other respectfully, admitting weaknesses, taking responsibility for others' learning and sharing knowledge. The development of the norms of interaction was evidence of the development of relationships of trust and confidence in the professional learning community, as well as perceptions of the community as a safe and non-threatening environment.

Features that were external to the professional learning community included leadership support, systemic demands and time. The positive and consistent support from the school's administration facilitated the activities of the professional learning community. Systemic demands such as school and district policy requirements often impeded the work of the professional learning community.

Details of the features and how they affected the work of the professional learning community are presented in the rest of the chapter.

7.3 Internal features of the professional learning community

A number of features that had to do with the design and implementation of the professional learning activities supported the teachers' participation and learning in the professional learning community. The DIPIP activities are organized in a developmental and coherent structure. Details of the activities were presented in Chapter 3 (Section 3.4.1). Briefly the activities are in the following sequence: testing learners; mapping the test onto the South African mathematics curriculum; analyzing learner errors; interviewing learners; identifying critical mathematical concepts for learners; designing lessons for addressing the learners' learning needs; teaching the lessons, which are video-recorded; reflecting on the lessons; re-planning the lessons; re-teaching the lessons; and reflecting on the lessons.

7.3.1 The structure and focus of the professional learning activities

An important feature of the professional learning activities was the development of a shared learning focus (Katz, et al., 2009); to understand and work with learner errors during instruction. This focus supported the teachers' participation and learning. Analyzing their learners' errors on

tests that they had designed created a sense of ownership and relevance of the process for the teachers. In the error analysis the teachers talked about particular errors made by learners whom they knew quite well in a manner that reflected perplexity and concern for the learners. In those conversations the teachers developed a deeper understanding of learners' thinking and knowledge of their learners. The following episode shows a typical conversation during the error analysis activity.

Episode 7.1: Analyzing a pattern of learner errors

In the following episode the community was analyzing the learners' thinking behind the errors observed on a test item that involved decimals and percentages. In this episode, a pattern of learner errors on the following test item precipitated the conversation. The test item and observed pattern of errors were as follows:

Test item: Express: $\frac{5}{8}$ as i) a decimal fraction ii) a percentage

Observed Errors: i) 5.8; 0.85; 0.58; $\frac{5}{10}+\frac{8}{100}; \frac{8}{5}$

ii) 58%; 85%; 5.8%; $\frac{5\%}{8\%}$

Turn	Speaker	Utterance
32	Sibanda	Let's look at the errors, what is the, if you look at both parts one and two there is one big misconception that is coming out
33	Jeffrey	Maybe now we had to convert a common fraction to a decimal because here we get aah five comma eight so it doesn't show five, how many times five goes into eight, oh eh…
39	Sibanda	Zero comma eight five is now a decimal fraction (*laughter from all)* it's now decimal fraction right, but if you look at both one and two there is a big misconception that you can pick out easily
41	Tandeka	Decimals means he knows or she knows that we have a nu…, a number before comma and a number after, so what she said or what she writes just add zero and comma because…
42	Mandla	No I think…
43	Tandeka	…and gets zero comma five eight
47	Sibanda	But if you look at the digits that appear in their answers there

48	Mandla	They are the same
49	Jeffrey	Ja
50	Mandla	…they are still there
51	Sibanda	Who, what is still there?
52	Mandla	The very same number, but there are problems (*inaudible)* as the, that one denominator is numerator
53	Sibanda	Where one of them has zero point eight, zero point five eight, the other has zero point eight five
54	Mandla	Aahm
55	Sibanda	But the bigger observation as Mandla was saying
56	Mandla	Ehm, that one that is numerator in the expression and eight is the denominator
57	Chorus	Uuhm
58	Mandla	The learner just got rid of this sign, the division sign
65	Sibanda	So what is it that they think?
66	Mandla	Any number any co, eh digit, eh decimal numbers have a comma and he puts a comma there between the two
67	Sibanda	But if but if you look at the percentages there in part two
69	Mandla	Eh, eh part two these numbers must be expressed in percentage, then he puts the percentage sign
71	Sibanda	So what is what is the bigger misunderstanding there?
72	Janeth	Division
76	Mandla	They don't know how to
77	Many voices	They don't know how, just too, knowledge, division
78	Janeth	Division line carries fifty percent (*inaudible)* any number
79	Sibanda	Tandeka had almost got it the first time, I don't know why it has evaporated *(everybody laughs)*, she had observed it, you can almost pick out a belief in the learners there
81	Tandeka	*(Inaudible)* write it in the percentage form she knows, he knows that when we write a number in a percentage
82	Sibanda	What is the symbol?
84	Tandeka	So since we have decimals we just take the symbol and put it there
88	Jeffrey	The, I think there is the belief that ah that five over eight has to be represented in its equivalent form because now still we have the ah five comma eight
89	Sibanda	So their belief is that?
90	Jeffrey	Five over eight has to be equally represented in its equivalent form

In the conversation the teachers volunteered possible explanations for the pattern of learner errors. The conversation culminated in an understanding of how the learners might have been thinking when they made the errors. The conversation reflects a shared focus on making efforts to understand the reasoning behind the observed pattern of errors. The teachers' talk was driven by a commonly shared need to understand learners' thinking in making errors. In some cases these conversations were followed up by learner interviews to find out more information about how they made particular errors. In the interviews the teachers got to understand their learners' mathematical thinking. Learning about how to analyze their learners' errors and interviewing learners created a sense of relevance of engaging in the activities of the professional learning community. The teachers' comments about learner errors, which I reported in Chapter 4, can be linked to their experiences of analysing their learners' errors. In the focus group interviews and post-intervention teacher interviews the teachers highlighted the importance of understanding the learners' thinking behind errors (cf Table 4.1 in Chapter 4). Also in Chapter 4 I illustrated how the teachers mad some shifts in their ways of engaging with learner errors in their teaching.

In the first focus group interview the teachers made the following comments to show their understanding and relevance of the error analysis activity.

Jeffrey: Ja it was useful because it clearly gave us ah, ah a clear understanding of ah what learners are doing when the errors are occurring

Bongiwe: Yes I really found it very, very much interesting because it opens your mind about the type of learners you have, and the, the, the pace they have especially in teaching and maybe in writing exams because at least you are able maybe if you are giving them something to do, a test or any form of activity, you are able to, which we were not used to it before, we are now able to analyze each of the errors of learners, step by step to see where they went wrong, uhm, just like that

Janeth: Yes, and then, and again the analyzing of the correct response at least we know that learners are supposed to write this answer, for the analysis of errors they show us the errors that the learners do, and also the critical concepts

The teachers' comments show how they linked the error analysis activity to their learners' thinking and their own teaching. It is these perceptions of the relevance of the activities to their

professional practice that supported their participation and learning in the professional learning community. The following remark by Bongiwe during the post-intervention interview reflects the perception of the activities as specifically for improving the teachers' professional practice:

Bongiwe: I think it ends up maybe making us to, everything that we do in terms of maybe mathematics, let me say so, must be of quality sake, what we have been doing has been for quality's sake, ja

Hence a feature that supported the work of the professional learning community was a sense of relevance of the professional learning activities to the teachers' professional practice through understanding learner errors as a learning focus.

The coherent structure of the activities was another feature that supported the development of perceptions of collective and progressive learning by the teachers. Statements indicating learning through participation in the activities were common during the interviews. The following teacher comments illustrate this point.

Janeth: In the assessment standards, so I have gained a lot. And then before I was just maybe doing for, I didn't know that I must combine eh, eh like for fractions, ne, I didn't know that I must link for grade seven and eight's work

Janeth was referring to the curriculum mapping activity. Her comment indicates learning about curriculum continuity, which is significant pedagogical content knowledge for teachers. Bongiwe made the following comment about her learning in the curriculum mapping activity.

Bongiwe: I think it taught us, especially how to, how to link each test item to the assessment standards and what is required of the learners, because when you set a test you have to know what you require the learners to know and what is needed, what is needed for the learners to know before you can set the test

In the post-intervention interview Tandeka commented about learning from her experiences of teaching the jointly planned lessons.

Tandeka: Even the the the assessment, uhm, I have learnt that I should give them a little bit then they talk with their friends before I give them more work without knowing whether what they have done is right or not

Tandeka's comment indicated that she had learned about the importance of pacing learners' work. In the jointly planned lessons the main planned teaching approach was to start by giving learners mathematics tasks to discuss in groups and before leading whole class discussions in which the learners presented their ideas.

Jeffrey: I think I have learnt human relationship, and also the curriculum, that we need to help each other when we are doing teamwork, and ah also when we are setting a test then we can do it, each and every thing that we can do we must do it together

Jeffrey's comment highlighted his learning about the significance of community in the teachers' professional work.

Comments like these from the teachers indicate that they learned from participation in the professional learning community. Their comments show that their learning was supported by the coherence in the professional learning activities and the shared focus on learning about learner errors. Hence the focus and organizational structure of the professional learning activities were features that supported the teachers' participation and learning in the professional learning community.

7.3.2 Tolerance of difficulties and challenges

From the teachers' comments about their experiences of participating in the professional learning community they indicated that they often found the activities challenging, difficult and confusing. During the activities the teachers did not publicly voice these challenges, an indication that they tolerated the challenges and difficulties as they participated. The following comments highlight the development of tolerance of challenges and difficulties in the professional learning activities.

The first comments were made during the focus group interview when the teachers were reflecting on their participation in the curriculum mapping activity. The teachers reported that they found it difficult to navigate the National Curriculum Statement (NCS) (Department of Education, 2002). The following are some of the teachers' utterances indicating their struggles in the activity.

Jeffrey: Uhm I find it so very much a little bit confusing because now it has different bullets and I need to be sure which one is the right one to use, … because you need to look across the grades, you are not only concentrating on grade seven, still you can move to grade six, grade five, under that assessment standard

Janeth: It was not easy but we had to struggle first before we could get there, and the answer, you must be able to link … So you have to, you spend a lot of time matching, matching, okay which one suits here, and so on

In the post-intervention interviews Bongiwe echoed Janeth's and Jeffrey's difficulties in the curriculum mapping activity.

Bongiwe: Because even yourself you have seen that it was very much difficult for us *(laughter)* if we can be able to match this, it was very much difficult, and at least if we can repeat that one of mapping I think

In addition to voicing the difficulties faced by teachers in the curriculum mapping activity, Bongiwe suggested that the activity be done again in the following year. This was acknowledging that even though she had found the activity difficult, she perceived as a worthwhile activity. That perception could explain her tolerance of difficulties and challenges in the professional learning activities.

In the first focus group interview Janeth expressed her challenge in participating in the professional learning community. Her challenge was shared by Tandeka.

Janeth: Eh ah, challenges ne? It's like uh, once you are asking questions ne, and then for example Bongiwe knows the answers, maybe plenty of them you are asking five questions and Bongiwe, eh, responds to three and then we keep quiet, it's like eeish you don't know anything *(laughter)* to me that is a challenge, it seems like we are doing nothing and we are not thinking, even if we are thinking there is nothing coming out, that's a challenge *(more laughter)*. Uhm sometimes you feel like you are doing nothing, you are not thinking, so it's only Bongiwe or Bongiwe and Jeffrey who are responding *more laughter* so what about you, so those are challenges. You try by all means to think but there is nothing *(more laughter)*. Yes, it's like your mind is somewhere *(laughter)*

Tandeka echoed the same challenge.

Tandeka: She is not alone, each and everybody feels that way, if you ask a question and then you find that no I don't get the answer, you feel as if … I am not here.

Janeth's and Tandeka's comments indicate that the two teachers were struggling to participate equally with the others in the professional learning communities. Publicly acknowledging the challenge took some courage, which indicates their perceptions of the professional learning community as a safe environment to voice challenges and difficulties. That the two teachers persevered in the professional learning community may indicate tolerance of the challenge in the interests of learning in the community.

The teachers' comments about challenges and difficulties that they faced within the activities of the professional learning community suggest that tolerance of challenges and difficulties is an important feature in the work of the professional learning community. The challenges and difficulties could have easily led some of the teachers to withdraw from the professional learning community.

7.3.3 Norms of interaction and relationships

In the professional learning community the teachers developed some norms of interaction that supported collaboration and participation. The norms of interaction included sharing mathematical knowledge, challenging each other, and admitting weaknesses and learning. The teachers developed an understanding that they could learn from each other. They volunteered what they know about issues under discussion, in some cases owning up and acknowledging both what they didn't know and what they had learned. The following episode provides an example of the teachers explaining their understanding of the order of operations in mathematics (BODMAS). In the episode the facilitator challenged the teachers' understanding of BODMAS. Two teachers, Mandla and Bongiwe, explained the order of operations.

Explaining to each other

Episode 7.2: Teachers sharing their understanding of the Order of Operations

Turn	Speaker	Utterance

3	Sibanda	How do we understand the use of bodmas? How does bodmas work?
4	Bongiwe	It involves solving brackets first irrespective of whether the brackets contain plus or minus, or the other signs
5	Sibanda	Uhm
6	Bongiwe	And then from there, laughs, can I explain it?
7	Sibanda	Yes, yes just explain it and then the others will also join in
8	Bongiwe	Okay, uuuhm, for bodmas you have to solve the brackets first irrespective of what the sign inside the brackets is, the fact remains you have to start with the brackets, and then from there you can be able to solve everything but the first thing is you have to start with the brackets
11	Sibanda	Okay go ahead
12	Bongiwe	Then if ever maybe we don't have the brackets you have to consider your signs
13	Sibanda	That's where the issue is, how do you consider the signs?
14	Bongiwe	Uuhm if ever
15	Sibanda	Probably someone wants to take over
16	Mandla	Which sign must be dealt with first than the others, it's by considering the sign, like in the case of bodmas as maam has indicated, if there are brackets we deal with the brackets first then follow those letters as eh it's from multiplication, addition and subtraction; we follow them in that order
17	Sibanda	Do you have to follow them strictly in that order?
18	Jeffrey	If there are brackets
19	Mandla	Addition and subtraction are more or less related, and multiplication and division are related, now when the two are mixed multiplication and addition you consider the rule of bodmas, and when like addition, when, when they are mixed, the two groups are mixed and then consider the rule of bodmas, but when there is addition and subtraction you just move from left to right
22	Bongiwe	Yes left to right
23	Mandla	And also when there is multiplication and division
24	Bongiwe	Multiplication and division
25	Mandla	Those are related operations

A feature of this episode and others like it was how teachers shared their understanding of BODMAS in the community. Two teachers clarified when it was possible, or not possible to apply the operations from left to right in simplifying numerical expressions which do not include brackets. The two teachers drew upon their knowledge of BODMAS to support their colleagues' learning in the community. In this episode the facilitator was no longer the expert, which is

healthy for learning in community. Any member of the community should be confident and comfortable enough to share knowledge with the other members. Explaining mathematical ideas to each other is an important feature for the development of community (Koellner-Clark & Borko, 2004). Teachers bring different backgrounds and experiences to the community from which they draw upon to engage in collaborative knowledge sharing and meaning construction. Sharing understanding with others supports coherence and learning in the professional learning community. Later one teacher, Janeth, referred to this episode as an example of how they, as teachers, had learned from one of them.

Janeth: Sometimes you do the mistake like the one Bongiwe explained, the one of BODMAS, we have gained a lot, you still remember that argument about which one comes first, then Bongiwe gave us the way, okay you must use this method, it's fine, so at least we have learnt something when we do it like a group, eh teachers grouped like this eh we are going far.

Janeth's comment was an indication of how she appreciated and valued learning from colleagues rather than from an external expert. The teachers' sharing of knowledge was a common feature in the professional learning community and it supported the work of the community.

Challenging each other

Challenge was an important feature that supported the teachers' collaborative inquiry. In Chapter 6 I presented episodes that illustrated teacher learning opportunities. In those episodes most of the challenge was from the facilitator. An additional feature that developed in the professional learning community was teachers challenging each other. Challenging each other illuminated other important developments related to the teachers' participation in the professional learning community. The following episode shows how one teacher challenged another teacher, and in the ensuing conversation some interesting features of the teachers' participation in the professional learning community were illuminated.

Episode 7.3: Challenging each other's mathematical knowledge

The episode was initiated by the facilitator challenging the teachers' knowledge of how to express a recurring decimal fraction as a common fraction. The task was from the test that the

learners wrote at the beginning of the intervention. The conversation was part of the error analysis activity. In this instance the community was discussing how learners were supposed to answer the following test item:

Write the following as a common fraction: $0.5\dot{4}$.

(N.B.: In the decimal fraction the digit 4 is recurring.)

Turn	**Speaker**	**Utterance**
26	Sibanda	Are we all familiar with what… how they were going to express that as a common fraction
33	Mandla	Janeth can you explain to us how to express that as…?
34	Jeffrey	As a common fraction
35	Janeth	Ja … the (*inaudible)*
36	Sibanda	The first one zero comma five four…
37	Janeth	Aah I don't know the recurring, it's the one Bongiwe gave to the learners, I don't give them the recurring in class (*laughter from others)* I don't want to lie
38	Sibanda	There is a way of doing it, I think let's ask someone to go and find out and then come and explain to us
39	Jeffrey	No I can volunteer…
40	Mandla	I will find out ne…tomorrow
41	Sibanda	Okay Mandla …just find out. I think you can do it tomorrow when we… during lunch just tell us, because tomorrow we are interviewing Jeffrey's learners, so when you come for your tea just…
42	Mandla	Yes I will
43	Sibanda	But if you need more time just…
44	Mandla	You say that? (*he laughs and everyone laughs)* You are intimidating me (*laughs again)*
45	Sibanda	I am not *(everyone laughs)*
46	Tandeka	It's just to give you space
47	Sibanda	If you need more time, I know you are busy, you have a class tomorrow at seven and…
48	Mandla	No tomorrow I don't have a class
49	Sibanda	Ah okay that's fine that's fine…

50	Mandla	I will check …
51	Sibanda	So Janeth, the agreement is that Mandla will find out how that is done and he will explain to us tomorrow
52	Janeth	Eh, okay, the recurring one, ne?
53	Sibanda	Recurring one
54	Janeth	Its zero comma five four five four ne?
55	Mandla	Aha aha …
56	Janeth	Or four four four four?
57	Mandla	Four four four
58	Sibanda	Zero comma five four four four four four, it is only the four which is recurring, not five four, if five was recurring then we would also have that sign above five
59	Chorus	Uuhm, sure
60	Janeth	But to my, no I am telling the truth I didn't give the learners the one that have a recurring, I am telling you
61	Sibanda	No after tomorrow you should be able to give them
62	Janeth	Ja …like…but…but in grade ten we don't use the recurring
63	Sibanda	I mean I understand …probably in maths lit but in pure maths they should be able to deal with that
64	Janeth	Ja, ja maybe there
65	Mandla	These are the sums they avoid in most cases, why do you avoid them *(everybody laughs)*
66	Janeth	No, no, they are there but…*(everybody laughs)*
67	Sibanda	You can't avoid them…

The episode illustrates some features that supported the teachers' participation and learning in the professional learning community. Mandla's challenge to Janeth (T33) indicated that he felt comfortable to challenge his colleague's mathematical knowledge with the confidence that she would not take offence. Having such confidence is based on the development of relationships of trust. Janeth's response (T37) acknowledging a weakness indicated that she did not take offence at Mandla's challenge. She had enough confidence and trust in the professional learning community to acknowledge her weakness. Having confidence and trust to acknowledge

weaknesses is important for learning in a professional learning community (Katz, et al., 2009). Another feature of the conversation was taking responsibility for the others' learning. Jeffrey and Mandla volunteered to go and find out how to express a recurring decimal fraction as a common fraction, and then explain to the others. They both took the responsibility to find out mathematical information and share the information with the others. This was an indication of taking responsibility for others' learning, which is an important feature of successful learning communities (Katz, et al., 2009). Janeth's persistence in asking for clarification of the meaning of the decimal fraction (T54) indicates a desire to learn from the others. Seeking clarification was another common feature of the interactions in the professional learning community. Another feature of the conversation was laughter. Discussing teachers' subject content knowledge can be a sensitive issue. In this conversation laughter created a relaxed environment in which Janeth did not take offence at being challenged and felt comfortable enough to acknowledge her weakness.

The conversation highlights how relationships of trust and confidence in the professional learning community supported challenging each others' mathematical knowledge, acknowledgement of a weakness, and the willingness to take responsibility for others' learning. The whole conversation was riddled with laughter, which has been found to be an indicator of the development of community (Koellner-Clark & Borko, 2004). These features of the conversation contributed to the norms of interaction in the professional learning community, and to the success of the professional learning community.

7.3.4 Facilitation

A key feature in DIPIP is the role of facilitators in professional learning communities. In Chapter 3 I explained how I took on dual roles in the professional learning community; as a researcher and as a facilitator. The roles of a facilitator include: challenging existing knowledge and assumptions; probing for deeper thinking; noticing what the teachers, as insiders, may take for granted; and providing external expertise (Katz, et al., 2009). My role as a facilitator of the professional learning community in this study was an important feature of the community's activities. The episodes that I presented in Chapter 6 highlight my central role in the opportunities for learning. In the opportunities for learning I challenged teachers to reflect on their understandings and assumptions. For example in Episode 6.1 my challenge of the teachers'

assumption that their learners relied on the teacher to learn mathematics led to an extended conversation in which the teachers reflected on their preferred teaching practices. In Episode 6.2 I challenged the teachers' understanding of ratio, and the ensuing conversation developed into a significant learning opportunity for the teachers. As an external resource I often provided knowledge when appropriate. In Episode 6.2 I provided an explanation of the ratio algorithm when it was clear that none of the teachers could explain the algorithm.

My facilitation in this study also sometimes constrained deeper discussions and collective inquiry in the professional learning community. An analysis of some of the episodes presented in the chapters above shows some limitations in my facilitation. For example in Episode 6.6 in Chapter 6 I funnelled the teachers' thinking towards my own thinking. In that episode it was clear that I expected the teachers to come to the same conclusion as what was in my mind. Such facilitation constrained the emergence of different lines of thinking and alternative interpretations. The limitations in my facilitation can be accounted for by two factors. Firstly I had not had much experience in facilitating teacher learning in communities before the study. Secondly, there was no community of other facilitators for possible joint reflection on my facilitation in an ongoing manner, as there is now in DIPIP.

7.3.5 Use of protocols, tools and artefacts

The activities of the professional learning community were guided by protocols. Details of these protocols were presented in Chapter 3. Each activity was guided by a protocol that ensured the teachers focused on the goal of the activity. The protocols also served as a record of the deliberations of the PLC. The teacher-made tests were artefacts which were used to generate the data which formed the evidence for the inquiry process in the PLC. The jointly planned lessons were artefacts developed in the PLC which served to guide the teaching and reflection on the intervention lessons. Video-recordings of the teachers' teaching of the jointly planned lessons proved to be a viable tool for the joint reflection on the lessons.

In Section 7.3.1 I presented an extract of a conversation during the error analysis activity. The activity was guided by an error analysis protocol (see Appendix K). Table 7.1 shows an extract of the template showing the summaries of the findings from the analysis of learner errors.

Table 7.1: An Extract of a Completed Error Analysis Protocol

Test Item	Content Description	Analysis of Correct Response	Analysis of Errors	Critical Concept(s)
7. (i) Express as a decimal: $\frac{5}{8}$	-converting common fractions to decimal fractions	-learners had to use knowledge of how to convert a common fraction to a decimal fraction, i.e. divide the denominator into the numerator until exhausted. -how to introduce the decimal point.	-answers: 0.58; 5.8; 0.85 indicate a knowledge that the answer must have a decimal point, but the learners don't believe the original digits can change. - answers $\frac{8}{5}$; $\frac{5\%}{8\%}$; $\frac{5}{10}+\frac{8}{100}$: a lack of understanding of what a decimal is, or not knowing how to convert a common fraction to a decimal, or a belief that the original digits cannot change.	-equivalent forms of rational numbers.
7. (ii) Express as a percentage: $\frac{5}{8}$	-meaning of 'percentage' -converting numbers to percentages	-learners had to use knowledge of how to convert a common fraction to a percentage i.e. multiply $\frac{5}{8}$ by 100% and simplify	-answers: 58%; 85%; 5.8% indicate knowledge that the answer must include the percentage sign (%), but the learners don't believe that the original digits can change.	-equivalent forms of rational numbers.

The use of the protocol meant that the error analysis conversations followed an established sequence: discussing and noting the mathematical content and skills necessary to answer the test item (Column 2); the possible strategies and solution methods that could be used to answer the item (Column 3); analysing the observed errors to understand the possible learner thinking that could have led to each error (Column 4); and identifying the possible mathematical concept underlying the observed errors on the test item (Column 5)

The conversation in Episode 7.1 above relates to the entries in Column 4 in Table 7.1. This example shows how protocols had dual roles: there were used as tools for guiding the professional learning community conversations, and as records of the findings from the

conversations. Structuring the conversations around protocols supported maintenance of the focus of each activity and ensured that key ideas and points of agreement were recorded.

7.4 Features external to the professional learning community

There were factors that were external to the professional learning activities but that were critical for the success of the professional learning community. These factors became features that the professional learning community had to work with most of the time. The factors include support from the school leadership, other demands on the teachers that were part of their everyday professional work, and time.

7.4.1 Leadership support

A key condition for the proper functioning of a professional learning community is having a supportive leadership as well as a conducive social and physical environment (Fleming & Thompson, 2004; Katz, et al., 2009). In the study the professional learning community had the support of the school administration. Although the PLC meetings were held after school teaching times, the school administration ensured that there was minimum disturbance of the meetings by other activities. The office of the Head of Science and Mathematics was made available for PLC meetings, and it proved to be a conducive environment for holding the meetings. The school principal and deputy principal showed a lot of interest in the PLC by inquiring about the activities the PLC was engaging in. The school principal was supportive throughout the study. As a professional learning community we were able to use other school resources through her support. For example we could photocopy our documents using the school's photocopier. The structural support that she provided enhanced the work of the professional learning community. She often talked to me and asked about how the activities were progressing. Her implicit support was a feature that supported the teachers' participation in the professional learning community.

The deputy principal had participated in the first two phases of the DIPIP project (see Section 3.3.1 in Chapter 3). His familiarity with DIPIP was an important aspect of negotiating participation with the teachers and he encouraged the teachers to participate in the study. During the professional learning activities his support was a feature of the professional learning community. He often made appearances at the beginning of the meetings and chatted briefly to

the teachers to find out how they were experiencing the activities. He sometimes excused the teachers from carrying out some school duties that would interfere with the meetings of the professional learning communities, for example invigilating internal examinations. As a professional learning community we always deferred to him if we faced challenges that required the support of the administration. An example of such a challenge was when the teachers needed bigger classrooms for teaching the jointly planned lessons. Bigger classrooms enabled grouping learners and teacher movement around to monitor learners' progress. The deputy principal organized such classrooms for the teachers. From my frequent informal conversations with him, he informed me that he always chatted to individual teachers to find out their learning experiences in the study.

At one point the School Management Team (SMT) arranged a forum for one of the professional learning community members to share their experiences with the rest of the teachers in the school. There was school-wide interest in and support for the PLC and its activities. The researcher/facilitator who was an outsider was welcomed and greeted by all members of teaching and support staff in the school. The SMT and the rest of the school staff ensured the PLC held its activities in a supportive social and physical environment, which was critical for the teacher professional learning activities.

7.4.2 Systemic demands

A less positive feature of the professional learning community had to do with other school and district demands that often affected the teachers' attendance at meetings. It was common for the teachers to excuse themselves from the meetings due to usually impromptu demands from the district education office, which were conveyed through the school administration. Teachers were often informed about meetings for mathematics teachers at the district office at short notice, and that resulted one or two of them being absent from the meetings. In some cases scheduled professional learning community meetings had to be re-scheduled at short notice due to meetings organised by the district. Frequent visits by district education officers to the school often led to the postponement of meetings. The following comments by Janeth and Mandla highlight how the teachers felt pressurised by district demands.

Janeth: Because we are under pressure, the district is looking for that and that, too many activities, so that gives us a problem

Mandla: The problem with us we are programme driven, because we want to do what is expected of us during those schedules then we submit

School policy demands such as the need to complete teaching certain topics within specified time periods, marking examinations, submitting marks, maintaining professional records, were often so demanding on the teachers that they requested the postponement of professional learning community meetings. Making alternative arrangements to make up for the cancelled meetings was a feature of the professional learning community.

7.4.3 Time

Time was another feature that constrained the work of the professional learning community. The structure and programme of the activities meant that there was always an awareness of the need to complete each activity within the set time limits. Meetings were scheduled for duration of two hours. However in reality some meetings lasted less than two hours because of the demands on the teachers' time. A common feature was starting the meetings later than scheduled due to other impromptu school activities. One effect of this feature was that conversations that required more time due to the emerging ideas had to be limited to the scheduled times. Limiting the conversations to scheduled times constrained discussion of interesting ideas that required more time. During the post-intervention interview Jeffrey raised the issue of time when he expressed his wish for the professional learning community to continue the following year.

Jeffrey: I think this team my wish is them to still work together next year and make some more time for the meetings, and then even we can have more time because time is always a problem

The cancelation of meetings due to systemic demands on the teachers created more demand for time. In Chapter 3 I explained how the nationwide teachers' strike in August 2010 affected the schedule of the professional learning activities and data collection. The strike created a lot of pressure on the professional learning community when the strike ended. Hence working within limited time constraints was a feature of the professional learning community.

7.5 Discussion of features of the professional learning community

I have highlighted a number of features that supported or constrained the work of the professional learning community. The internal features of the professional learning community mainly supported the teachers' learning in the conversations. The developmental structure of the activities meant the conversations were a process of gradual learning and deepening understanding in the various domains of teacher knowledge. The structure of the activities supported internal coherence in the conversations, which in turn motivated the teachers to continue participation. The teachers frequently made comments about how much they were learning in the community. Tolerance of challenges and difficulties supported continued participation and engagement in conversations. Challenge and admitting weaknesses supported reflection on knowledge and assumptions, which is fundamental for learning in a professional learning community (Katz, et al., 2009). Other features were the development of relationships of trust and confidence in the community; and having a shared understanding of the learning focus (Fleming & Thompson, 2004; Katz, et al., 2009).

In the study these features, among others, were evident during the professional learning activities. Challenging the teachers' knowledge and assumptions during the conversations helped collective reflection of understandings and assumptions. Such reflection supported the need to deepen understanding. For example challenging the teachers to explain the conceptual meanings of the ratio and rational number algorithms created a need among the teachers for deepening their knowledge of the two concepts. The teachers also challenged each others' knowledge collegially. For example Mandla's challenge to Janeth to explain how to solve a task on recurring decimals was met with an acknowledgement of a weakness by Janeth. This created a need by all the teachers to deepen their understanding of recurring decimals and subsequent conversations addressed this need. Challenging knowledge and assumptions played a significant role in identifying the teachers' learning needs, leading to collective inquiry in order to deepen understanding. Challenge supported the teachers' learning in the professional learning community. This is consistent with literature which highlights how challenge pushes conversations in the professional learning community beyond re-cycling commonly held traditions and assumptions (Earl & Timperley, 2008; Katz, et al., 2009).

Having a shared and defensible focus is also emphasized as a key enabler of knowledge creation and sharing in professional learning communities (Brodie, 2011c; Katz, et al., 2009). What is not clear in the literature is how such a learning focus is established in a professional learning community. In the study the learning focus, which is embedded in the professional learning activities of DIPIP, was on collectively understanding learners' learning needs and ways of dealing with the identified learning needs. To establish such a learning focus the teachers tested their learners using teacher made tests and analyzed their learners' errors on these tests. The process created relevance and ownership of the learning focus, and this in turn supported the teachers' sustained engagement in the learning activities. Interviewing their learners about commonly observed errors also supported the establishment of the shared and understood learning focus as the teachers realized the prevalence of common learner errors irrespective of the grade level of the learners. Thus the acceptance of their learners' errors as a collective concern for all the teachers supported the development of the shared and defensible learning focus for the teachers. In the subsequent activities of the professional learning community it was evident that the teachers were aware of their learners' learning as the purpose and focus of their sustained engagement in the learning activities.

The teachers also developed shared values and vision of their professional learning community. They attested to this vision by highlighting their experiences of learning in the community. The teachers' comments reflect a shared value of the professional learning activities as contexts of their own learning. Having shared values and vision has been highlighted as being supportive of a professional learning community's sustainability (Fleming & Thompson, 2004).

The patterns of interaction showed the development of relationships of trust and confidence in the professional learning community. Acknowledging weaknesses and challenging each other were some indicators of the development of such relationships. Relationships of trust and confidence support teachers learning in a professional learning community (Earl & Timperley, 2008; Katz, et al., 2009). Acknowledging weaknesses is also an indication of perceptions of the professional learning community as a safe and non-threatening environment. Such perceptions are important for learning in a professional learning community (Katz, et al., 2009).

Another feature, which was evident in the teachers' comments, was tolerance of challenges and difficulties. This feature has not been highlighted in the literature on professional learning

community. The teachers made comments that indicated a tolerance of challenges and difficulties in their participation in the professional learning community. Two teachers raised the challenge of participating as much as their colleagues, which they found uncomfortable. The curriculum mapping was found to be difficult by the teachers, but they persevered with the activity. The teachers' tolerance of challenges and difficulties can be explained by their perceptions of learning through the professional learning activities.

All the factors identified above were important for the proper functioning of the professional learning community in the study. The factors are linked to shifts in the teachers' teaching practices and identities in that they (factors) created conditions of possibility for teacher learning. The opportunities for learning that I presented in Chapter 6 as accounting for shifts in the teachers' teaching practices and identities were shaped by the internal features of the professional learning community presented above. Having trust and confidence in the community supported the trialling of the planned teaching practice and share teaching experiences without fear of being criticised, which in turn is linked to shifts in the teachers' teaching practices. Having a shared and defensible learning focus supported visions of learning together as a community. Perceptions of learning together supported the development of group identity, which accounted for shifts in the teachers' identities as community members. Thus the features of the professional learning community that were presented in this chapter accounted for the shifts in the teachers' teaching practices and identities. Most of the features of the professional learning community presented above are well documented in the literature, and the study has illustrated how these factors supported the teachers' participation and learning in the professional learning community, as well as the shifts in the teachers' teaching practices and identities.

7.6 Summary

In this chapter I have analyzed the features that supported the teachers' participation and learning in the professional learning community. Although the features were discussed separately from the main concepts in the study, the features were significant to the shifts in the teachers' teaching practices and teacher identity, as well as to the opportunities for teacher learning that were discussed in Chapter 6. In Chapter 8 I explore this relationship in greater detail.

CHAPTER 8

CONNECTING PRACTICE, IDENTITY, AND LEARNING IN THE PROFESSIONAL LEARNING COMMUNITY

8.1 Introduction

In Chapters 4 and 5 I presented analyses of the teachers' teaching practices and identities, which was the first step in building the argument that the professional learning community supported shifts in those two constructs. The argument was further developed in Chapter 6 by accounting for the shifts through the teachers' participation and opportunities for learning in the professional learning community. Accounting for the shifts provided links between the teachers' teaching practices, teacher identity and the opportunities for learning in the professional learning community. In Chapter 7 I presented features of the professional learning community that had a facilitatory or constraining influence on the implementation of the professional learning activities and on teachers' learning. The features of the professional learning community provided a context in which the shifts in teaching practices and teacher identity occurred through the learning opportunities.

Although shifts in teachers' teaching practices and teacher identities were analysed separately, developing the main argument was achieved through accounting for the shifts through the learning opportunities created in the professional learning activities, and within the context of internal and external features of the professional learning community. From the analyses presented in Chapters 4, 5, 6 and 7, it is evident that the teachers shifted in some aspects of their teaching practices and identities through their participation, and the opportunities for learning that were created in the professional learning community. Linking features of the professional learning community to shifts in teaching practice, teacher identity and the opportunities for learning, provided evidence for the influence of such features on the other three constructs. Thus in the previous four chapters I developed and provided evidence for the argument that the professional learning community supported shifts in the teachers' teaching practices and identities.

In this chapter I analyse further the connections among teaching practice, teacher identity, opportunities for learning and features of the professional learning community as a way of

elaborating the idea of teacher learning in professional learning communities. Developing an understanding of the relationships among these constructs helps in explaining how the professional learning community functioned as a form of school-based and data-driven in-service teacher professional development. In this chapter I examine how the four constructs formed mutually constitutive relationships in an on-going manner. I draw from Wenger's (1998) ideas about the contiguity of identity, practice and learning, and Kazemi and Hubbards' (2008) idea of co-evolution of knowledge and practice in professional development to analyse the relationships. My focus in this chapter is to develop a framework that explains how teacher engagement in professional learning communities can support on-going shifts in knowledge, identity and practice through activities that use data from classrooms.

I begin the chapter by analyzing the relationships among the community practice, teacher identity and teaching practice using a proposed framework for explaining teacher learning in a professional learning community. I also illustrate how the key features of the professional learning community supported or constrained the co-evolution of the four constructs in the study. In the last two sections of the chapter I explore the implications of the framework for in-service teacher professional development and highlight the limitations of the study.

8.2 An overview of the connections among the research findings

Wenger's (1998) theory highlights the contiguity of learning and identity in the process of participating in a community of practice. The professional learning community in this study was a kind of community of practice whose practice was guided by structured professional learning activities. This relationship enabled me to use Wenger's theory to analyse the connections among the teachers' teaching practice, teachers' identities and the learning opportunities. I begin by revisiting Wenger's view of a community of practice with special attention to the ideas of 'practice', 'participation', 'learning' and 'identity' before I examine how these constructs co-evolved in the professional learning community.

In Chapter 2 I made a distinction between two types of practice: teaching practice and the practice of the professional learning community as constituted by the professional learning activities. In Chapter 6 I showed how shifts in the teachers' teaching practices were accounted for by the learning opportunities in the professional learning community, thus connecting

teaching practice to the opportunities for learning. The focus was to understand how in the professional learning community the teachers were able to deepen their knowledge about their classroom teaching practice and work with such knowledge in their actual teaching. The link between this type of practice and the other constructs used in the study is further explored below.

The community practice refers to the activities, tools, and artefacts which combined together reflect the process of collaborative inquiry in which the teachers engaged in the professional learning community. In the study this type of practice consisted of the DIPIP professional learning activities as well as the tools and artefacts that supported teacher participation and collaboration. Wenger (1998) refers to this type of practice as "the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action" (p. 5). In the professional learning community the teachers engaged in the DIPIP sequence of professional learning activities which when viewed together formed a continuous process that supported their collective engagement throughout the study. Collaboration is central to this type of practice. Collaboration supports collective inquiry through which new meanings are developed in the community. Through the teachers' participation and collaboration in the community practice there were opportunities for negotiating new meanings and learning from each other.

A key idea in a community of practice is the negotiation of meaning, which refers to the process of experiencing engagement in a practice as meaningful and as a way of understanding the world in which people participate with others (Wenger, 1998). In Chapter 6 I presented episodes in which new understandings of the subject knowledge and pedagogical content knowledge related to ratio and rational numbers were negotiated in the professional learning community. The teachers' participation in negotiating new meanings and their willingness to work with those meanings in their teaching practice resonates with the situated view of learning as being: grounded in daily activities; inseparable from the environments in which knowledge is applied; and a result of social processes that involve the negotiation of meanings with others (Buysse, et al., 2003; Wenger, 1998). Through participation in the community practice, opportunities were created for the teachers to negotiate new meanings relating to their professional work and develop new social relations with their peers. In my examination of the connections among identity, practice and learning below I refer to the emergent new understandings and social relations as learning or meanings.

The results in Chapter 5 show that the teachers' shifted in their identities as members of communities, as well as in talking about themselves in their teaching practice, i.e. their teaching identities. In Chapter 6 the shifts were accounted for through the opportunities for learning in the professional learning community, thereby linking teacher identity to opportunities for learning. This is in line with Wenger's (1998) view of identity as being formed through participation and learning in a community of practice, as members develop new meanings and social relations which change who they are and their personal histories. The teachers' participation in the professional learning community was thus a process of developing new identities in relation to belonging to communities and in their teaching. The connection between teacher identity and teacher participation means that identity is linked to the other constructs that I have described above.

Fig. 8.1 below is a schematic representation of the connections among teacher learning or meanings, teacher identity, community practice and teaching practice that I outlined above. The framework was developed inductively from the results of the study as a way of elaborating further the relationships among these constructs. The diagram shows the relationships in a nested representation of levels, starting from the outer-most boundary. The outer boundary refers to the social configuration and the external features of the professional learning community, which were elaborated in Chapter 7. The features include leadership support, systemic demands and time. Such features are not under the direct control of the professional learning community. The professional learning community worked within the constraints and affordances of the school leaders' support, the demands placed on the teachers through the nature of their work, and the time available. The influence of these features on the community practice is illustrated by the arrows pointing inwards from the outer boundary.

The next level in the diagram represents the community practice and the internal features of the professional learning community. As elaborated in Chapter 7, the internal features consist of the structure of the professional learning activities, the learning focus, teacher perceptions of learning, norms of interaction and relationships of trust and confidence in the professional learning community. In Chapter 7 I showed how these features supported the teachers' participation.

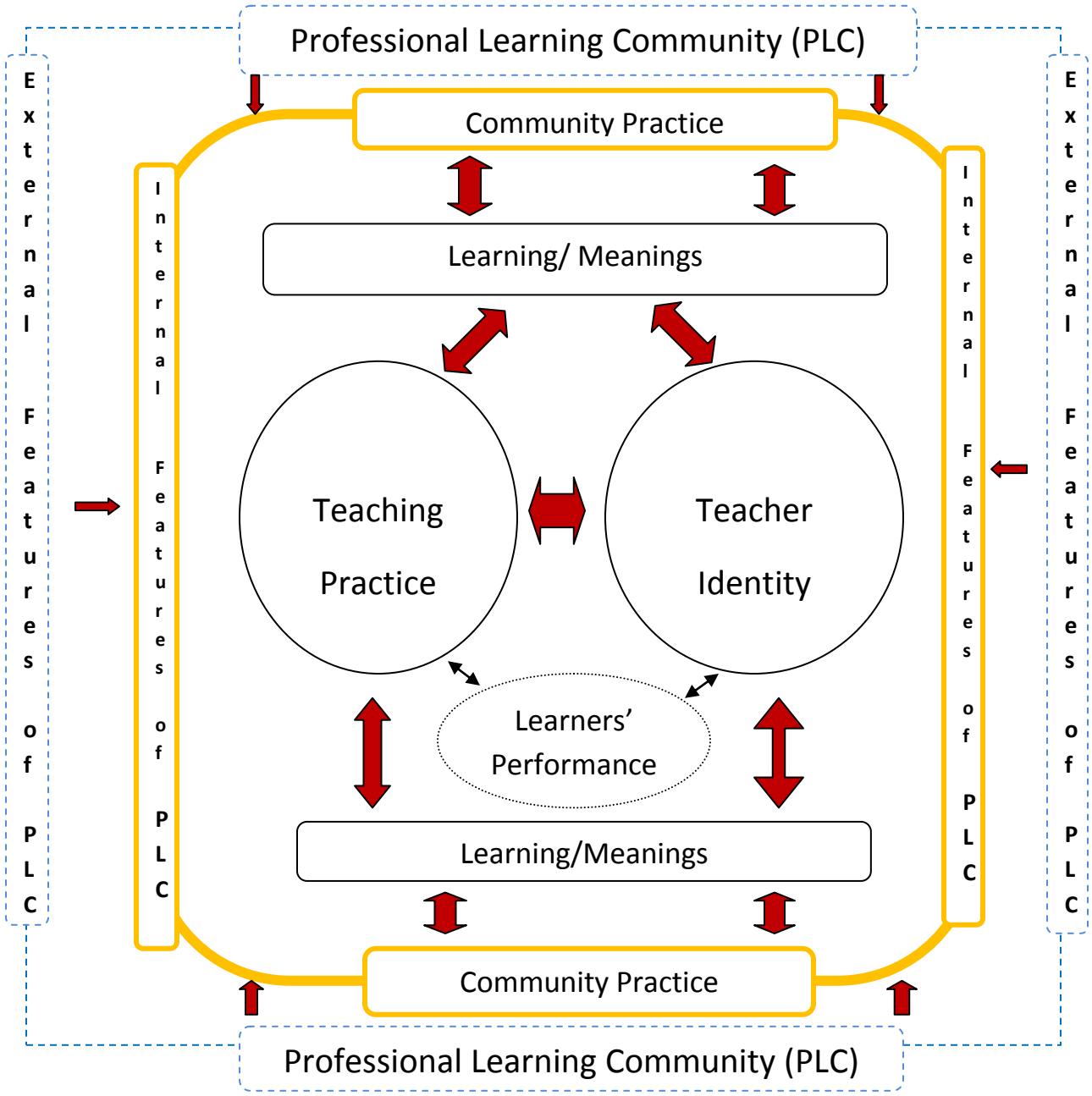


Fig. 8.1: Framework for Explaining Teacher Participation and Learning in a Professional Learning Community

Although learners' performance was not part of the focus of the study, in the diagram learners' performance is included for two purposes. Firstly it was the learners' performance in the form of the errors which the learners made in mathematics tests and the follow-up learner interviews that provided data which the teachers analyzed in the professional learning community. These data

fed into the community practice to provide a shared focus for the professional learning community (Katz, et al., 2009). This is indicated by the arrow connecting learners' performance to community practice. Secondly the ultimate goal for deepening professional knowledge and changing teaching practices is improved learner performance (Earl & Timperley, 2008). Usually evidence for improved learner performance involves testing and re-testing learners to generate quantitative data in the form of test scores that can be tested statistically for the significance of any observed differences. In the study the teachers frequently made reference to improved learners' performance as one of their expected benefits of participation in the professional learning community; however this study did not include a focus on learners' performance. In the diagram above the arrow connecting teaching practice to learners' performance is meant to represent awareness of the ultimate goal of the professional learning community's changed teaching practices as possible improved learners' performance.

The relationships among the other constructs that are represented in the rest of the framework are explained in relation to the results of the study in the next few sections. Special focus is on the following constructs: teacher learning/meanings; teacher identity; and teachers' teaching practices. In Fig 8.1 teacher learning is integral to participation in the community practice.

8.2.1 The development of meanings in the community practice

Fig 8.1 shows that meanings developed in the community practice were linked to the teachers' teaching practices and teacher identities. I will refer to some episodes which were presented in Chapter 6 to show how some of the meanings were developed and linked to the teachers' teaching practices and identities.

From the error analyses process the mathematical concepts of ratio and rational numbers were identified, among others, as underlying the mistakes made in the tests. The first step in the concept development activity was to engage the teachers in reflecting on their own knowledge of these concepts. The ensuing conversations highlighted that the teachers had algorithmic understandings of the two concepts, but could not explain the conceptual meanings behind the algorithms. They knew how to apply the ratio algorithm for dividing given quantities in given ratios but could not explain the meaning of the steps in the algorithm and how these related to the concept of ratio. They knew the algorithms for expressing common fractions as decimals, or

percentages but could not explain the conceptual connections among these forms of rational numbers. Episodes 6.2 and 6.3 in Chapter 6 show how conversations about the conceptual meanings of these concepts were opportunities for the teachers to develop deeper understandings of the concepts. Episode 6.2 was about ratio as a way of comparing quantities and the meaning of the algorithm for dividing quantities in given ratios. Bongiwe and Janeth made use of these meanings of ratio in their tasks selection and teaching during the first cycle of concept development. In Episode 6.3 the community discussed the meaning of equivalence of fractions and the meaning of 'common denominator'. Jeffrey and Tandeka made use of this knowledge in selecting tasks and teaching during the first cycle of concept development. These connections that were explored in detail in Chapter 6 illustrate the link between meanings developed in the community and the teachers' teaching practices.

Episode 6.1 in Chapter 6 is an example of a conversation about teachers' classroom pedagogies. During the lesson planning process, the suggestion to engage learners in discussing mathematical ideas with their peers in groups initiated an interesting conversation in which the teachers' assumptions about their learners and the teachers' preferred pedagogies were elaborated. The teachers initially disagreed with the suggested teaching approach of engaging learners in collaborative discussions of mathematical ideas, justifying their stance on the assumption that their learners were not capable of discussing mathematical ideas with their colleagues without the direct control of the teacher. They held a common belief that the teacher had to always explain and demonstrate mathematical procedures for learners to learn. When challenged to justify their assumption using examples from their teaching experiences, their justifications revolved around learners forgetting some steps or ideas which the teacher had explained to them. Challenging this assumption initiated a conversation about a shift in pedagogy to a teaching approach that provides learners with opportunities for discussing mathematical ideas with their peers in small groups. The conversation ended with the teachers committing to 'trying it out'. The results presented in Chapter 4 show that the teachers made efforts to implement this suggested pedagogy in their teaching of the jointly planned lessons, and this accounted for shifts in two teachers' mode of instruction as detailed in Chapter 6. In the lesson reflection and focus group interviews the teachers expressed both surprise and appreciation of how their learners had

successfully engaged in the discussions of the assigned tasks in groups and how they had come up with significant mathematical ideas.

These examples show how participation in the community practice led to the development of new meanings. Evidence of the development of new understandings by the teachers was manifested through the teachers' efforts to work with such knowledge in their task selection and teaching practices, in addition to the teachers' comments about having learnt something new.

8.2.2 Community practice and teaching practices

Shifts in the teachers' task selection and teaching practices were accounted for in Chapter 6 through the conversations about the conceptual meanings of ratio and rational numbers (Episodes 6.2 and 6.3), and a conversation suggesting an alternative teaching practice (Episode 6.1). All the teachers' shifted in their task selection during the first cycle of concept development and the shifts were linked to the conceptual meanings of ratio and rational numbers discussed in the community. Three teachers, Bongiwe, Janeth and Tandeka implemented the negotiated teaching practice of giving learners mathematical tasks to discuss in groups and then facilitating whole class discussions of learners' solutions, which was a shift in Bongiwe's and Janeth's teaching. These examples illustrate the link between meanings developed in the community practice and teaching practice. The link between community practice and teaching practice in Fig. 8.1 represents the teachers' efforts to work with meanings that were developed in the community practice, in their actual teaching. The reverse arrow linking teaching practice to community practice represents lesson reflection. During lesson reflection the teachers shared their experiences of teaching the concept development lessons in the community. As shown in Chapter 6 the teachers' comments about their teaching during lesson reflection accounted for shifts in their mode of teaching and teaching identities. Sharing their experiences of teaching the jointly planned lessons in the community by reflecting on their lessons created opportunities for developing new insights into the teachers' teaching practices, which is a process of learning in community. Thus the double arrow linking community practice and teaching practice in Fig. 8.1 represents the co-evolution of the pedagogical content knowledge developed in the community and teaching practice (Kazemi & Hubbard, 2008).

What the double arrow does not illustrate are the limitations in the opportunities for learning in accounting for some of the findings about the teachers' teaching. For all the teachers the richness of the mathematics remained consistently low. In Chapter 6 this was accounted for by the challenges faced by the teachers in working with new meanings related to the subject content and pedagogical content knowledge that were developed in the community, in their teaching practice. The other limitation is that the framework does not account for the differences in shifts in the teachers' mode of instruction through the opportunities for learning. The teachers shifted differently in their mode of teaching and only one teacher sustained the shifts after the intervention. These limitations show that the link between meanings developed in community and teaching practice does not necessarily work in similar ways for all the teachers in a professional learning community, something that should be explored through further research.

Learner errors constituted another connecting factor between learning in the community and teaching practice. In Chapter 4 I elaborated how the teachers shifted in their understanding of the meanings and significance of learner errors, and how some of the teachers shifted in their ways of dealing with learner errors in their teaching. In Chapter 6 I accounted for the shifts in teachers understanding of learner errors through the error analysis conversations. In the error analysis activity the teachers developed new meanings about learner errors, e.g. errors as a result of mathematical reasoning on the part of learners. Results in Chapter 4 show that the teachers made some shifts in their ways of engaging with learner errors, although differently. As highlighted in Chapter 6, a limitation of lesson reflection was that the community did not engage in conversations about how the teachers dealt with learner errors in their actual teaching.

In summary, the connection between teacher learning and teaching practice as illustrated by the double arrow between these two constructs in Fig. 8.1 indicates the co-constitutive nature of the meanings developed in the community practice and actual teaching practice. In this study the relationship needs to be understood in the context of the limitations highlighted above. As a feature of professional learning communities, this connection supports the co-evolution of knowledge and teaching practice across two settings (Kazemi & Hubbard, 2008), and may support more sustained changes in teaching practices (Borko, 2004; Kazemi & Hubbard, 2008), should the community continue.

8.2.3 Community practice and teacher identity

Fig. 8.1 shows the connection between teacher identity and the community practice with double arrows. The meanings that are developed through participation in the community practice influence the development of identity, as teachers re-define who they are both as members of a community and as teachers in the classroom. Identity is the negotiation of ways of belonging in a community (Wenger, 1998). The negotiation involves active participation and developing new meanings with others in community. The reverse arrow depicts the identities that individuals come with to the community and how these identities evolve through participation and learning in the community.

In Chapter 5 I showed that the teachers initially defined their membership in communities as constrained to engagement with colleagues whom they consulted for assistance, or who taught the same level with them. As they participated in the community they developed new meanings of themselves in community, and the developing identities shaped their ways of participating in the community. Later in the study the teachers talked about themselves as members of one community, learning together and improving their practice. These comments were made during the focus group and post-intervention interviews, and some of these were presented in Chapter 5.

Another dimension of the teachers' identities that shifted related to their teaching identities. Initially the teachers described themselves in their teaching as the main presenters and explainers of mathematical ideas to learners. Later in the study the teachers described themselves differently, especially after teaching the jointly planned lessons. In the lesson reflection activity each teacher described his/her role in the lessons as having shifted from how they saw their roles initially. The new descriptions portrayed a teaching identity as facilitators of learners' learning.

The main finding here was that there were shifts in the teachers' identities that were linked to their participation in the community practice. As the teachers collectively developed new meanings about themselves as teachers in the community practice, their identities shifted. Talking about their experiences of participating and teaching with others in the community was a process of learning as the teachers developed new insights into their teaching. Hence the double arrow between community practice and teacher identity in Fig 8.1 represents the development of new teacher identities and understandings in the community practice.

8.2.4 Linking teacher identity and teaching practice

The link between teacher identity and teaching practice in Fig. 8.1 represents the shifts in the teachers' understandings of themselves in teaching contexts through joint planning, teaching and reflecting on the jointly planned lessons. In accounting for the shifts in the teachers' teaching identities in Chapter 6 I explained how lesson planning designated a teaching identity that was enacted by the teachers in their teaching with varying levels of success, resulting in significant shifts in their mode of teaching. During the intervention, the designated teaching identity became Bongiwe's and Janeth's actual teaching identity. Their ways of teaching resonated with the teaching identity depicted in the lesson planning activity. Both Bongiwe and Janeth made significant efforts to mediate learners' discussions and ideas without taking control of content delivery. Episodes that illustrate these efforts were presented as part of the analysis of their teaching in Chapter 4. In reflecting on their teaching both teachers made reference to facilitating learners' learning, indicating shifts in their teaching identities from their teaching before the intervention. During lesson reflection the conversations about the role of the teacher in teaching the jointly planned lessons initiated the teachers' descriptions of their teaching identities. An example of such a conversation is Episode 6.6 in Chapter 6. In that conversation Janeth described herself as facilitating learners' learning. Thus through their teaching practice the teachers developed new understandings of themselves in teaching contexts, which illustrates the link between teacher identity and teaching practice. Discussing their teaching identities with others in the professional learning community created opportunities for further reflection on teaching and developing new meanings about teaching practice. The reflection also supported re-defining themselves as teachers in the classroom. Hence the teachers' teaching identities and teaching practice were mutually co-shaping across two settings: in the professional learning community and in the classroom.

A limitation that is not evident in Fig 8.1 is that it does not account for the non-shifts in Jeffrey's and Tandeka's mode of teaching, although both of them participated in the professional learning conversations described above.

8.2.5 Linking community practice, teaching practice, teacher identity and meanings

The positioning of community practice, teaching practice and teacher identity in Fig 8.1 signifies how the teachers' teaching practices and teachers' identities were informed by the meanings developed in the community practice. In return the teachers' teaching practices and their teaching identities influenced conversations about teaching in the community. In accounting for shifts in the teachers' teaching practices and identities in Chapter 6 I elaborated on how new meanings and understandings about ratio and rational numbers that were developed in the community were linked to the shifts in the teachers' teaching practices and teacher identities. Discussing their teaching and how they saw themselves in teaching the jointly planned lessons during lesson reflection created links among teaching practice, teaching identity and the community practice. Thus the learning opportunities in the professional learning community accounted for shifts in the teachers' teaching practices and teaching identities. At the same time some of those conversations drew on the teachers' teaching of the jointly planned lessons and the teachers' images of themselves in teaching those lessons. These connections illustrate the links among the three constructs as shown in Fig. 8.1. Teacher identity as membership in a community influenced teacher participation in the community practice. This shows two-way relationships among the three constructs. In this context community practice, teaching practice and teacher identity are viewed as interrelated elements of teacher professional development. Analyzing relationships among these elements and teaching practice is in line with studies that have investigated the relationship between professional development and teaching practice (e.g. Dunne, et al., 2000; Hollins, et al., 2004; Louis & Marks, 1998; Strahan, 2003). Such studies have sought to answer the question: 'What is the impact of participating in professional development on teachers' teaching practices?' The question indicates a one-directional analysis of the relationship between community practice and teaching practice, and does not include teacher identity in the analysis.

Of late there has been criticism of one-directional analysis of the relationship between teacher professional development and teaching practices, with arguments for a multidirectional analysis of the relationships (Kazemi & Hubbard, 2008). Kazemi and Hubbard (2008) argue for a multidirectional analysis on the basis that teacher learning occurs in and from both professional development and teaching practices, what they refer to as co-evolution. In my analysis of the

relationships among community practice, teaching practice and teacher identity in this study, I explored connections in both directions. I have shown how teacher learning through participation in a professional learning community informs, and is informed by teaching practice and teacher identity.

It is important to note that co-shaping relationships among teacher learning in the community practice, teaching practice and teacher identity occur in the context of what I have referred to as features of the professional learning community. In Fig. 8.1 these features are presented as having boundary influences on the relationships among community practice, teaching practice and teacher identity. In the study the external features had both supporting and constraining effects on the teachers' participation in the professional learning community. For example, the positive support from the school administrators motivated the teachers to sustain their engagement in the professional learning activities. On the other hand, systemic pressures on the teachers constrained their participation. Teachers often excused themselves from meetings to attend to issues having to do with their regular professional work.

The features that I have termed internal to the professional learning community mostly supported the teachers' engagement in the community practice. I have highlighted the structure of the activities as a supporting feature. The developmental nature of the activities shows progression and encompasses the various forms of teacher professional knowledge. The use of evidence from the teachers' classrooms in the form of learner errors created a direct link between the professional learning activities and what goes on in the teachers' classrooms. Teachers always worry about their learners' performance. Hence analyzing their learners' errors and developing lessons for addressing those errors was, for them, a way of improving their practice. This was evidenced by the teachers' frequent reference to learning in the professional learning community during the focus group and post-intervention individual teacher interviews. Developing relationships of trust and confidence supported the teachers' interactions in the community practice. Challenging each other and explaining mathematical ideas to each other were some of the norms of interaction that developed and supported the teachers' learning.

In this section I have summarised the connections among teaching practice, teacher identity, opportunities for learning and features of the professional learning community, as depicted in the framework in Fig. 8.1. The connections are based on the findings of the study. I have also

indicated some findings of the study that the framework does not account for. Hence the findings of the study and the proposed framework need to be regarded as contributions to knowledge about professional learning communities that can be elaborated through further studies. The findings of the study have implications for in-service teacher professional development and further research, and these are explored in the next two sections.

8.3 Implications of the findings for in-service teacher professional development and policy

The findings of this study are significant for the South African education system. The Integrated Strategic Planning Framework for Teacher Education and Development in South Africa proposes the establishment of teacher Professional Learning Communities as one form of continuing teacher professional development in schools (Department of Education, 2011b). Since the idea of professional learning communities is still novel in the South African context, this study, among others, provides some useful insights into how professional learning communities may be successfully established and sustained as a form of in-service teacher professional development.

The findings of the study showed that the professional learning community engendered some shifts in the teachers' teaching practices and identities. The shifts in teaching practices were: a decline in direct instruction to more engagement of learners in mathematical discussions; more sustained engagement with learner errors; and an increase in student participation in meaning-making and reasoning. The shifts were more pronounced for two teachers. All the teachers shifted in their identities as members of communities, all describing themselves as members of the professional learning community. The shifts in teaching practices and identities were linked to the teacher learning opportunities that I referred to as the community practice. An implication of these findings is that a professional learning community and communities of practice can support teacher learning, leading to changes in teachers' teaching practices and identities. Such changes can be supported by engaging teachers in collaborative learning activities that are guided by a clear learning focus (Katz, et al., 2009). In a study involving a community of practice of in-service mathematics in South Africa Graven (2002) observed that the teachers made gradual shifts in their teaching practices and identities through their participation in a teacher professional development programme. The shifts in teaching practice were in the

implementation of more learner-centred instructional strategies. In her analysis Graven linked the shifts to the learning activities in the teacher professional development programme.

A fundamental point to note here is that the shifts that were observed in the study in both teaching practices and identity may not be construed as sustainable changes. In my study the shifts in teaching practices were mainly limited to two teachers, and only one teacher sustained the shifts after the intervention. The shifts were in the mode of teaching, task selection and ways of engaging with learners' ideas in the lessons. In the mode of teaching the shift was from high direct instruction to more whole class discussions. In task selection the teachers shifted from selecting procedural tasks to tasks that had the potential to develop learners' conceptual understanding. In terms of engaging with learners' ideas the teachers shifted to more sustained engagement with learners' ideas in their lessons by asking for explanations and justifications; something that was not observed in their teaching before the intervention. However these shifts in teaching practice did not result in improved richness of the mathematics, which remained consistently low. In her study Graven (2002) observed that the teachers made minimal shifts on teacher questioning, verbal pupil participation with teacher and dealing with misconceptions. While findings from my study agree with Graven's findings on the richness of the mathematics, my study showed that the teachers made shifts in learner participation and teachers' working with learners' meanings, although the shifts did not result in significant improvement in the richness of the mathematics. An implication for professional development is that changing mathematics teachers' teaching practices in ways that support the richness of the mathematics is complex and may require more time.

For teacher identity, all the teachers shifted in the way they described themselves as members of a community and in teaching contexts. The teachers shifted from describing themselves as belonging to communities based on individual preferences and consultations, to describing themselves as members of the professional learning community. In terms of their teaching identities, the teachers shifted from describing themselves as controlling and explaining mathematical ideas to learners, to describing themselves as facilitators of learners' learning. In their studies, Graven (2002) and Nel (2012) observed that the teachers participating in the professional development programmes made shifts in their identities as becoming professional and competent teachers. Like in my study, the shifts were more espoused than enacted, thereby

militating against claims about the sustainability of the shifts. Since my study was limited to one year, the shifts need to be understood only as indicators of the capacity for a professional learning community to influence changes in both teaching practice and teacher identity. An implication from the study is that prolonged and sustained engagement in similar activities in a professional learning community may result in more sustainable changes in teachers' teaching practices and teacher identity, and that practice may be more difficult to shift than identity. Establishing professional learning communities requires attention to the duration of collaborative engagement in the community if sustainable changes in teaching practice are to be realised.

An important feature of professional learning communities arising from the findings of this study is the nature and ownership of the professional learning activities. The activities in the study were underpinned by a focus on teacher learning. In the study the activities were structured in a developmental and cyclic sequence. Such a design of professional learning activities enables progressive gains in knowledge for the teachers. Each activity incorporated joint inquiry and reflection on both knowledge and practice by the teachers, which supported learning in and from practice (Kazemi & Hubbard, 2008). The activities were designed around inquiring into classroom data in order to identify learners' learning needs, which in turn informed the teachers' learning needs (Timperley, 2010). The results show that the activities created significant learning opportunities for the teachers to deepen their professional knowledge, and to work with that knowledge in their teaching. The results are consistent with current literature on teacher learning in professional learning communities that highlights the importance of a shared learning focus (Katz, et al., 2009) and activities that address both the teachers' and learners' learning needs (Timperley, 2010). One concern about the professional learning activities in this study is the ownership of the activities. The activities were designed for a large research project; hence there was a possibility for the teachers to perceive the activities as for the research only; rather than as designed for their own learning, and which they could eventually take over and change to suit their needs in future. Such perceptions have implications for the sustainability of a professional learning community. In a sustainable professional learning community teachers need to be able to find their own ways of identifying their learners' and their own learning needs, and design professional learning activities that address those needs. This is important as learning needs change from time to time. Although this was not one of the goals of this study, teachers

participating in similar studies need to gradually view their participation as empowering them to take charge of their own, and their learners' learning; rather than as an end in itself. There was no evidence in this study to indicate that the participating teachers were gradually viewing the professional learning activities as building their capacity to take charge of their learners' and their own learning needs in future. The implication here is that establishing sustainable professional learning communities needs to include building the teachers' capacity to design their own professional learning activities and take ownership of the learning process. The issue of sustainability is something that is being addressed in the larger project, where after about a year and half teachers started to take ownership and suggest changes to the activities.

In the professional learning community a particular teaching approach was negotiated and the teachers made efforts to implement the practice in their teaching. The teachers' engagement with the teaching practice was initially seen as a form of experimentation. From their reflection on their teaching the teachers' comments showed appreciation of the teaching approach and its significance for learners' learning. Of significance was the capacity of the professional learning community to create an opportunity for negotiating a teaching practice which the teachers were willing to try out in their lessons. Thus through the professional learning community the teachers developed the agency to try out and reflect on the suggested practice. The results imply that changing teachers' practices through professional learning communities depends on negotiating new practices and the teachers' agency to try out new practices in their teaching. The collective negotiation of practices provides teachers with a sense of ownership of changes in their teaching practice.

Another implication for teacher professional development is the effect of features of a professional learning community that support or constrain the success of such communities. In the study a number of features were identified that had positive and negative effects on the work of the professional learning community. In the study I separated internal features from external features. Internal features that were found to support teacher participation and learning included: tolerance of difficulties and challenges, norms of interaction, challenge, and the use of protocols and artefacts. These features were found to support teacher learning and participation. External features included leadership support and other systemic demands on the teachers due to the nature of their work. Findings about the effects of these features on the professional learning

community in this study support existing literature on the influence of these and other features on the success of professional learning communities (e.g. Katz, et al., 2009; Koellner-Clark & Borko, 2004; Wood, 2007). Establishing and sustaining professional learning communities requires paying attention to features that may support or constrain the teachers' participation and learning.

The findings of my study have implications for policy; especially in the South African context where policy pronouncements indicate a move towards establishing professional learning communities in schools nationwide (Department of Education, 2011b). Several issues arising from the study may require paying attention to in designing policies on professional learning communities as an in-service teacher professional development approach. One issue relates to establishing a functional professional learning community. In this study the teachers' participation was supported by having a clear learning focus. Understanding and dealing with learner errors in instruction was the learning focus in this community. The learning focus also served as a link between the teachers' participation in the professional learning community and their classroom practices, thus creating relevance for participation. An implication for policy is that professional learning communities need to have clearly defined learning foci that have relevance for the teachers' teaching practices, and ultimately learners' learning. The learning foci can be unique to particular professional learning communities and develop over time through their community practice; hence they need not be, and in fact should not be, prescribed at policy making level.

Another issue from the findings of the study relates to the structure of the learning activities. In this study the teachers engaged in the DIPIP professional learning activities. A key feature in these activities is the focus on learners' learning needs informing teachers' learning needs (Brodie, 2011c). In this study the teachers described their engagement in the professional learning activities as a process of learning, and made comments that indicated an appreciation of the benefits of their participation for their learners' learning. Policy implications include the need for teacher learning activities that are focused on learners' and teachers' learning needs. Teachers participating in professional learning communities need to realise their participation as a process of learning; learning for them and for the benefit of their learners. This issue requires attention in

designing learning activities for professional learning communities that are responsive to the teachers' and learners' needs, especially at school-level.

Although the study did not focus directly on facilitation of professional learning communities, some insights into facilitation were produced. Facilitation was sometimes seen to support and constrain deeper analysis of issues under discussion. For deep and collaborative engagement with issues in a professional learning community, facilitation as a role must push for deeper thinking and challenge assumptions if new meanings are to be developed. This requires skilled facilitators. Brodie, et al (2012) show that policy developments on professional learning communities need to take cognisance of the role and importance of skilled facilitation that supports real learning. Katz, et.al. (2009) highlight the importance of good facilitation for successful professional learning communities. The movement towards establishing professional learning communities in schools may need to be accompanied by capacitating facilitators to lead these communities.

Successful professional learning communities are sustainable. In this study the issue of sustainability was not addressed since the study was a time-framed pilot for the current DIPIP project. However comments from the teachers indicated a desire to have the professional learning community continuing even after the researcher had left. Policies on professional learning communities may need to address issues of the sustainability of the communities and the continuity of the teachers' learning. The study reported in this thesis experienced disruptions that had an effect on the continuity of the learning activities. Such disruptions can negatively affect the teachers' participation and the sustainability of professional learning communities.

Another issue that is related to sustainability and continuity is the necessity for administrative support. In this study the professional learning community was well supported by the school's administration, and this ensured that meetings were not often disrupted. Policies on professional learning communities may need to incorporate assurances of support by administrators at school, district and national levels. This may require direct intervention strategies that serve to ensure maximum support and minimal disruptions for the activities of professional learning communities.

In raising the above policy implications of the study I recognize that this was a study of one professional learning community in one school; hence these implications need to be understood in that context. Since the study was a pilot for the current on-going DIPIP project, these implications may be further amplified in the larger study.

8.4 Implications of the findings for further research

A key outcome of the study is a proposed framework for explaining teacher learning in a professional learning community. The framework was developed from the results of the study, and it illustrates possible connections among the key constructs in the study. The connections were explained using evidence from the findings of the study. The framework needs validation through other research studies. The framework does not account for some of the results of the teachers' teaching. The differences in shifts in the teachers' teaching practices cannot be explained by the framework. Future research on teacher learning in professional learning communities needs to explore in detail how the key elements that support learning differ for different teachers. Such research could investigate why some teachers shift more than others through learning in professional learning communities, something that was not addressed in this study. The framework proposed in this thesis might support further research in this area.

One argument that was advanced in this study was that the structured activities of the professional learning community supported teacher learning in a developmental manner. These activities were developed in the larger DIPIP project. Findings from this study highlight how the teachers developed deeper understandings about their professional practice through these activities. However for sustainability, professional learning communities need to be driven by the teachers' and learners' learning needs. Teachers should gradually be able to develop their own activities that address identified learning needs. Teacher agency in developing learning activities has not received much attention in current literature on professional learning communities. Research may need to be carried out to analyse teacher learning in professional learning communities that use teacher developed activities.

In the study I was the facilitator in the professional learning community. Prior to the study I had little experience in facilitating teacher learning in a professional learning community. For me the whole period of my participation in the professional learning community was a learning

experience in terms of facilitation. Facilitation was not part of the focus of this study, yet on reflection, facilitation was a key feature for the success of the professional learning community. Facilitation has been highlighted as a crucial role for teacher learning in professional learning communities (Katz, et al., 2009). My facilitation often supported as well as constrained the development of deeper meanings in the professional learning community. Research in professional learning communities will need to include a focus on facilitation.

8.5 Limitations of the study

The study reported in this thesis involved researching an intervention on teacher learning in a professional learning community. The intervention involved engaging the teachers in a continuous sequence of professional learning activities for a period of one year. In the research I analysed shifts in teaching practice and teacher identity as the teachers participated in the intervention. There are a number of limitations of the intervention and the research. In this section I present these limitations, beginning with the limitations of the intervention.

One limitation has to do with the nature of the intervention. Implementing an intervention in a professional learning community requires on-going reflection and making decisions that may require adjustments to some aspects of the intervention. This on-going monitoring and reflection can be best achieved by having regular meetings with other facilitators as a community. The study reported in this thesis was a pilot for a bigger study. When the study was conducted there was no community of facilitators with whom I could interact regularly to reflect on the progress of the intervention and my involvement, besides my supervisor. Regular reflection with other facilitators on my facilitation could have resulted in some adjustments that could have improved some aspects of the intervention. This has been implemented in the larger project and is working well.

A second limitation of the intervention was the effect of disruptions to the continuity of the community activities. An important aspect of the functioning of a professional learning community is continuity. The activities of the professional learning community were disrupted for a month in 2010 due to a teachers' strike. The community could not hold its meetings during that month. When the meetings resumed the teachers also had a lot of pressure from their own daily work as they needed to make up for the lost time. This meant the remaining activities had

to be done in limited time, although some of the activities were completed in February 2011. Extending into the following year also meant some changes. One of the teachers was moved to teach geography, which meant he was no longer teaching mathematics although he continued participating in the professional learning community. All the teachers had changed the classes they were teaching, which meant working with learners who had not participated in the intervention before. Such disruptions can affect the smooth running of similar professional development programmes.

A third limitation of the intervention was related to my facilitation of the professional learning activities. The activities of the professional learning community depended a lot on my facilitation. Facilitating the conversations of the professional learning community was challenging for me although I had been working on a similar project for almost a year prior to the establishment of this professional learning community. On reflecting on some of my facilitation I noted that there were instances where I could have facilitated the conversations differently. There were instances in my facilitation in which I funnelled the teachers' thinking through my questioning which constrained collective inquiry. In some episodes of the professional learning community conversations I missed opportunities for following up on teachers' comments that I now realise could have led to more discussions. These features of some of my facilitation, among others, militated against collaborative inquiry.

The limitations of the research have to do with external and internal validity of the findings (McMillan & Schumacher, 2006). Since this was a case study of one professional learning community in one school, the findings may not be generalized to all professional learning communities. Although this is a limitation on the external validity of the study, the results contribute to knowledge on professional learning communities due to the design of the study. The teachers in the study participated as a subject-specific, school-based professional learning community and within the context of their daily professional work. As a case of a teacher professional learning community, the study enabled an in-depth analysis of teacher learning in the community. The duration of the study and the participant-observation status of the researcher supported the collection of detailed data over a period of a year, using a number of data collection strategies and from different sources. The data enabled in-depth analysis and triangulation to validate the findings. These features of the study mean that the findings

contribute to knowledge on subject-specific, school-based professional learning communities, in spite of the study being a case study. Such knowledge includes: establishing and implementing a professional learning community; how learning opportunities are created and supported in a professional learning community; and features that support or constrain the work of a professional learning community.

A second limitation of the research is related to how teacher identity was analysed. According to Wenger (1998) identity is both how one perceives himself/herself in relation to others and how others perceive the individual. Using identity as modes of belonging (Wenger, 1998) this would refer to how the teachers perceive their membership in the community and how the other members perceive each other in community. A limitation of the research was that data was only collected on how each teacher saw himself/herself in relation to the others in the professional learning community. No data was collected on how the teachers perceived each other as members of the professional learning community. The missing data could have provided more insight into how perceptions and identities shifted in the professional learning community.

A third limitation of the research is related to data about the teachers' views of the intervention. Although lesson reflection and interviews were used for collecting data on the teachers' perceptions of the intervention, in the collected data the teachers did not say anything negative about the study. This could have been due to my presence in both data collection contexts. The teachers may have felt reluctant to say anything negative about the study in my presence. Other data collection strategies that assure some anonymity could have helped in collecting data about the teachers' opinions about the study.

A fourth limitation of the research is the failure to account for some of the findings. The study created opportunities for the teachers to deepen their subject content and pedagogical content knowledge, related to the conceptual meanings of ratio and rational numbers. The teachers' efforts to work with this knowledge in their teaching resulted in different shifts for different teachers. No data was collected and analysed to account for the differences in shifts in the teachers' teaching practices. In her study Graven (2002) acknowledged the challenge of locating specific factors that could account for differences in the teachers' take-up of the mathematical roles implied in the teacher professional development programme. She suggested the teachers' mathematical histories, interests and understanding as possible explanations for the observed

differences in the teachers' take-up from the programme. The challenge of accounting for differences in teacher take-up from professional development is well-recognised in the literature (e.g. Borko, 2004; Kazemi & Hubbard, 2008).

8.6 Conclusion

The research study set out to investigate three fundamental aspects of professional learning communities: teacher learning; teaching practice and teacher identity. The main focus of the research was to analyse how teacher learning in the professional learning community supported shifts in teaching practice and teacher identity. Due to the complexity of teacher learning, no claims could be made about actual teacher learning, opting for episodes in the professional learning conversations in which there were opportunities for learning for the teachers. Thus the study provided evidence connecting opportunities for learning to shifts in teaching practice and teacher identity. The learning opportunities consisted of substantive teacher discussions on some of the domains of teacher professional knowledge. Analysis of the conversations highlighted the significance of features of successful professional learning communities that have been documented in the literature. The contribution of this study was in providing specific examples of what knowledge and how opportunities for deepening understanding were provided in the professional learning community.

The link between the learning opportunities created in the professional learning community and teachers' teaching practice was analysed. Existing literature on professional learning communities highlights the gap in knowledge about how teacher learning in professional learning communities is linked to teaching practice. There was evidence in the study for this link. Shifts in teaching practice were explained as a result of teachers making efforts to work with ideas discussed in the professional learning community in their practice, as well as a result of the teachers' reflections on their teaching of jointly planned lessons.

Teacher identity was studied as a way of contributing to knowledge of the centrality of identity in professional learning communities and to teaching. This was a contribution of the study since teacher identity has so far received little attention in research on professional learning communities. Two aspects of teacher identity were analysed: identity as membership in a community and teaching identity. Evidence was provided for shifts in teacher identity as

membership in communities, and how the shifts were linked to the teachers' participation in the community. That the teachers identified themselves as members of the professional learning community later in the study was a significant result that can foster the sustainability of the community.

In this chapter I explained teacher participation and learning in a professional learning community, using a framework. The framework highlights how the main concepts related to teacher learning in a professional learning community are linked, and how contextual issues influence teacher participation and learning. Although evidence of the links was provided, the framework is to be understood as a proposal based on the findings of this study. It is meant to support further research on how teacher participation and learning in a professional learning community can be explained.

In the previous paragraphs I have highlighted the contributions of the study to knowledge about teacher learning in a professional learning community. Evidence was provided in the study that teacher engagement in professional learning communities can support on-going shifts in knowledge, identity and practice through activities that use data from classrooms. Given that it was a case study and a pilot study for a bigger project, the findings of the study remain tentative and provoke ideas for further research. The study needs to be understood in the context of findings of other studies that have been carried out in South Africa on communities of practice and teacher professional development (e.g. Graven, 2002, 2004; Nel, 2012). In South Africa the study contributes to knowledge about initiating and implementing professional learning communities in schools. As a case study and pilot to Phase 3 of the DIPIP project, the findings served as indicators of the possible successes and pitfalls of professional learning communities. Hence the study should be read as part of on-going work, with possible further elaboration of the findings through the larger project.

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STUDENT NUMBER: 393817
Protocol: 2009ECE171

04 February 2010

Mr. Million Chauraya
Midlands States University
Private Bag 9055
GWWERU
ZAMBABWE

Dear Mr. Chauraya

Application for Ethics Clearance: Doctor of Philosophy

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Mathematics teacher change and identity in evidence-informed practice

Recommendation:

Ethics clearance is granted.

Yours sincerely

MMabeta
Matsie Mabeta
Wits School of Education

Cc Supervisor: Prof. K Brodie (via email)

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries : Shadrack Phele [MIRMSA]
Tel. no. : +27 11 355 0285

Monday, December 07, 2009

Mr. Million Chauraya
F08 West Campus Village
Wits University
Private Bag 3
WITS 2050

Dear Mr. Chauraya

PERMISSION TO CONDUCT RESEARCH IN GDE INSTITUTIONS

The Gauteng Department of Education hereby grants permission to conduct research in its institutions as per application.

Field of research	: "Mathematics Teacher Change and Identity in Evidence-Informed Practice."
Nature of research	: PhD.
Name of institution	: University of the Witwatersrand
Supervisor	: Prof. Karin Brodie

Upon completion of the research project the researcher is obliged to furnish the Department with a copy of the research report (electronic or hard copy).

The Department wishes you success in your academic pursuit.

Yours in Tirisano,

p.p. Martha Mashego

Ms Mmapula Kekana
Chief Director: Information Systems and Knowledge Management
Gauteng Department of Education

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Appendix C: Teacher Participation and Recording Consent Forms

Part A: Consent form for teachers' participation in the study

I, …… of……
(school) have read and understood the procedures involved in the study and what is expected of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to participate in the study.

☐ Yes ☐ No

I give consent for being interviewed.

☐ Yes ☐ No

I give consent for my lessons to be observed.

☐ Yes ☐ No

I give consent for my lesson plans and/or notes to be photocopied.

☐ Yes ☐ No

The extra copy of this form is for you to keep.

Thank you.

---------- ----------

Signature of teacher ***Date***

Please print your name

Part B: Recording Consent form for teachers

Please complete, sign and return the form below

Put a tick in the appropriate box

I give consent for being audio taped.

☐ Yes ☐ No

I give consent for being videotaped.

☐ Yes ☐ No

I give consent for audio and video tapes with me in them resulting from this study to be shown at academic conferences, workshops and seminars.

☐ Yes ☐ No

I give consent for audio and video tapes with me in them resulting from this study to be used for purposes of research and publications, teacher-education and teacher-training programmes.

☐ Yes ☐ No

I give consent for audio and video tapes with me in them resulting from this study to be kept for up to five years.

☐ Yes ☐ No

The extra copy of this form is for you to keep.

Thank you.

---------- ----------

Signature of teacher ***Date***

Please print your name

Appendix D: Consent form for learners' participation in the study

I……of……
(school) have read and understood the procedures involved in the study and what is expected of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to participate in the study

☐ Yes ☐ No

I give consent for being observed during mathematics lessons.

☐ Yes ☐ No

I give consent to being videotaped during mathematics lessons.

☐ Yes ☐ No

I give consent to being audio taped during mathematics lessons.

☐ Yes ☐ No

I give consent for video tapes with me in them resulting from this study to be shown at academic conferences, workshops and seminars.

☐ Yes ☐ No

I give consent for audio and video tapes with me in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes.

☐ Yes ☐ No

The extra copy of this form is for you to keep.

Thank you.

---------- ----------

Signature of learner ***Date***

Please print your name and surname

Appendix E: Consent (Parent/Guardians)

I, ……..…of

…….. (address) have read and understood the procedures involved in the study and what is required of my child as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to allow my child to participate in the study.

☐ Yes ☐ No

I give consent for my child being observed during mathematics lessons

☐ Yes ☐ No

I give consent for my child being videotaped during mathematics lessons.

☐ Yes ☐ No

I give consent for my child being audio taped during mathematics lessons.

☐ Yes ☐ No

I give consent for audio and video tapes with my child in them resulting from this study to be shown at academic conferences, workshops and seminars.

☐ Yes ☐ No

I give consent for audio and video tapes with my child in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes.

☐ Yes ☐ No

Name of learner: _____ ***Name of Parent/guardian*** *(Please print****:*** _____

Signature of parent/guardian *(Please print)*

Appendix F: Individual Teacher Interview Guides

Part A: Pre-Intervention

Purpose: To get details about the teachers' backgrounds; the teachers' views about their own teaching; their perceptions of themselves and other mathematics teacher; and their understandings and ways of dealing with learner errors prior to the intervention.

Questions:

1. Can you tell me about yourself?
2. Can you describe to me your mathematics teaching experience in terms of periods of time, schools and Grades that you have taught?
3. Can you describe what kind of mathematics teacher you are?
4. How would you describe yourself in relation to the other mathematics teacher in the school?
5. What are some of the teaching strategies that you use when teaching mathematics? Why do you think they are important?
6. What in your view causes learners to make errors in mathematics?
7. How do learner errors affect: i) your teaching of mathematics?

   ii) the learners' learning of mathematics?
8. How do you deal with learner errors during your teaching of mathematics?
9. What role, if any, do errors have in the teaching and learning of mathematics?
10. In general what do you think teachers need to do in order to minimize learner errors in mathematics?
11. How would you describe yourself in relation to other mathematics teachers in the school?

Part B: Individual Teacher Interview: Post-Intervention

Purpose: To find out the teachers' experiences of participation in the professional learning community.

Questions:

1. Have you changed how you think about your role as a mathematics teacher over time? In what way?
2. How can you describe yourself now in relation to other mathematics teachers?
3. Describe what you think you have learnt from the intervention, if anything.
4. What aspects of the intervention have influenced your planning and teaching of mathematics?
5. What changes in your practice, if any, can you say are attributed to your participation in the intervention?
6. Which aspects of the intervention are you likely to incorporate in your practice in future?
7. What benefits, if any, can you say you have realized from working with your fellow teachers in investigating aspects of mathematics teaching and learning?
8. What are your views about the intervention in relation to mathematics teachers' professional development in your school?
9. How do you see the future of the professional learning community in the school?

Appendix G: Focus Group Interview 1 Guide

(N.B. Similar questions were used for the second focus group interview)

Questions about the mapping activity

1. How did you find the curriculum/test mapping activity? Explain your answer.
2. Was the template which we used for mapping useful or not? In what way was it useful or not useful?
3. How did you find the National Curriculum Statements (NCS) document which we used for mapping? Was it useful? In what way was it useful?
4. Did you learn anything from the mapping activity? Explain your answer.
5. How did you find linking the Assessment Standards (ASs) with the test items? Give examples.
6. What did you learn about the test items from linking them to the ASs? Give examples.
7. How easy was it to identify the main concepts embedded in the ASs? Give examples.
8. What implications, if any, did the mapping activity have:
    i) For you when designing test items?
    ii) For your teaching?
    iii) For your understanding of the curriculum?
9. Is there anything else you want to say about the mapping activity?

Questions for the error analysis

1. How did you find the error analysis activity? Was it good or bad? Explain your answer.
2. How useful:
    i) Was the template for summarizing the learners' performance?

ii) Were the data walls?

iii) Was the error analysis template?

3. What did you learn from summarizing learners' errors on data walls? Give examples.
4. What did you learn from analyzing learners' errors using the error analysis template? Give specific examples.
5. Did you learn anything about learners' thinking from the error analysis? Explain your answer.
6. What implications, if any, did the error analysis have for:

    i) Your knowledge of mathematics?

    ii) Your teaching?

    iii) Assessment of learners?
7. Is there anything else you want to say about the error analysis activity?

Questions about collaborating with colleagues

1. Describe your experiences of working together as a team on the two activities? Give specific examples.
2. How useful was working as a team on the two activities?
3. What are the benefits, if any, of working as a team on professional development activities:

    i) For your practice as teachers?

    ii) For you as mathematics teachers?
4. What challenges, if any, did you find in working as a team so far? How can these challenges be overcome?
5. Is there anything else you want to say about working as a team on professional development activities?
6. What aspects of the current professional development activities would you want to be improved as from next term?

7.

Appendix H: MATHEMATICS TEST Grades 7 and 8

Time: I hour

Instructions:

i) Answer all questions.

ii) Do all your working in the spaces provided on the question paper.

iii) Show all working.

1. Simplify the following:

   i) 2^4

   ii) $2^2 + 3^3 + 5^3$

2. Without using a calculator express each of the following in index form and simplify

   i) $\sqrt{36}$

   ii) $\sqrt{144} + 25$

   iii) $\sqrt[3]{27}$

3. Arrange the following decimal numbers in ascending order:

   12,034; 12,403; 12,34; 12,0034; 12,304.

4. Simplify each of the following:

   i) -8 + (-3)

   ii) -15 + 5

   iii) 8 + (-3)

5. Round off 11,82528

   i) correct to 3 decimal places.

ii) to the nearest whole number.

6. Write 0,5 as a common fraction:

7. Express $\frac{5}{8}$ as a:

i) decimal.

ii) percentage.

8. Calculate and simplify:

$$\frac{15}{24} + \frac{2}{8} - \frac{1}{4}$$

9. Simplify without using a calculator:

1,2 x 2

10. Find the value of the following expression without using a calculator:

2,16 – 3,8 + 4,54

END OF TEST

Appendix I: MATHEMATICS TEST Grades 9 and 10

Time: I hour

Instructions:

i) Answer all questions.

ii) Do all your working in the spaces provided on the question paper.

iii) Show all working.

1. a) Find the highest common factor (HCF) of: 20 and 100.

b) Find the lowest common multiple (LCM) of: 15 and 20.

2. State whether each of the following is a rational number or an irrational number:

i) $\sqrt{\frac{1}{49}}$

ii) $\frac{37}{99}$

3. Write the following decimals as common fractions:

i) $0.5\dot{4}$.

ii) 0,3

iii) 0,375

4. Simplify the following ratios:

i) 6 : 5

ii) 40 min : 4 hours.

iii) 50g : 0,1kg

5. Change the following to a decimal number:

$$3\frac{4}{5}$$

6. Find 10% of 250.

7. Find the value of each of the following:

i) 260 + 75 x 2.

ii) (2,3 + 3,7) ÷ 0,6.

iii) $\frac{7}{14} + \frac{2}{7}$

iv) $2\frac{1}{3} + 3\frac{6}{5}$

8. An examination paper has 20 questions to be answered in 2 hours and has a total of 100 marks.

i) How many minutes are there in which to complete the examination?

ii) At what rate should you answer the questions in order to finish the examination within the time allowed?

9. Divide R800 in the ratio 5:3.

END OF TEST

Appendix J: Error Capturing Template

Grade:……

Test Item	Observed Error(s)	Learners' Names

Appendix K: Template for Mapping Test onto Curriculum

(AS) We know this when the learner:	**Test Item**	**Concepts needed to complete the task**	**Reason(s) for mapping test item with this Assessment Standard**	**When do you teach it?** **What other areas do you link it with, if any?**

Appendix L: Error Analysis Template

Test Item	Content Description	Analysis of Correct Response	Analysis of Errors	Critical Concept(s)

Appendix M: Learner Interview Guide

Name of Learner:……
Grade:……..

Test Item:……..

Observed Error(s):……..

Questions

1. Can you explain to me how you solved this problem?
   Answer:.....
   .....
2. Why did you…….....?
   Answer:……
3. What were you thinking about when you ……?
   Answer:……
   …….
4. Can you show me where you went wrong?
   Answer:……
   ……
   ……....
5. What should you have done instead?
   Answer:……
   ……
6. How else could you have solved the problem?
   Answer:……
   …….
7. What else do you want to say?
   Answer……..
   Thank you.

Appendix N: Guiding Questions for Readings

READINGS FOR GRADE 9 & 10

1. 'Icelandic 5th –Grade Girl's Development of Trajectories in Proportional Reasoning' by Steinthorsdottir, O. B. & Sriraman, B. (2009).

2. 'Ratios' Chapter 11, by Lamon, S. J. (1999) "Teaching Fractions and Ratios for Understanding", London: Lawrence Erlbaum Associates Publishers.

Guiding Questions

1. How do you understand the notion of 'proportional reasoning' ?

2. How is ratio linked to 'proportional reasoning'?

3. From the readings what forms of reasoning/concepts are needed by learners if they are to understand the concept of ratio?

4. Steinthorsdottir & Sriraman refer to four levels of proportional reasoning. From the error analysis and learner interviews, at what level do you think your learners are at in terms of their reasoning about ratio?

5. What are some of the strategies that can be used to develop learners understanding of ratio?

6. How the readings influence your understanding of learners' learning of ratio and your instructional practices?

READINGS FOR GRADE 7 & 8

1. 'Parts and "holes": gaps in rational number sense among children with vs. without mathematical learning disabilities' by Mazzocco, M. M. M. & Devlin, K. T. (2008) *[Ignore the statistical analysis, just focus on the theoretical concepts about rational numbers]*
2. Chapter 3: 'Fractions and Rational Numbers', by Lamon, S. J. (1999) "Teaching Fractions and Ratios for Understanding", London: Lawrence Erlbaum Associates Publishers.

Guiding Questions

1. How have the readings changed/not changed your understandings about fractions and rational numbers?

2. How are these understandings likely to affect the way you have been teaching rational numbers?

3. How the readings influence your understanding of learners' learning of rational numbers and your instructional practices?

4. What are the main concepts that learners have to understand about rational numbers and how would you sequence them into an instructional unit?

5. What strategies do you think can help learners understand the connections among rational numbers?

6. How have you found useful from the readings and in what way?

Appendix O: Concept Development Action Plan

Rationale for the Action Plan:

The aim of the session was to collaboratively develop an action plan for teaching the identified concepts, Ratio and Equivalent Forms of Rational Numbers. The aim was to sensitize the teachers about the need to focus on more broad and critical issues relating to teaching the concepts. This was to be achieved by including issues about how the plan would influence the teachers' practice and learners' learning in the long term. The discussion was guided by a set of questions.

1. **What is the unit of improvement?**

   While the concepts for teaching are ratio and equivalent forms of rational numbers, the question was meant to get specific about what is to be taught about each concept. The following were identified as constituting the unit of improvement:

   - ***Ratio:*** a conceptual understanding of the meaning of ratio; how ratio is applied in real life situation; solving problems involving ratio.
   - ***Equivalent forms of rational numbers:*** developing an understanding of a rational number and the different forms of rational numbers; developing a conceptual understanding of equivalence among the different forms of rational numbers; solving problems involving rational numbers. In this unit the focus would be on fractions only.

2. **What are the goals and expectations of the action plan?**

   The following were identified as the goals of the action plan:

   - Improving learners' performance in each of the concepts.
   - Developing the learners' conceptual understanding of the concepts.
   - Developing the learners' positive attitudes towards learning mathematics.
   - Developing the learners' thinking in solving problems related to the two concepts.

- Improving the teachers' teaching practices.
- Create 'vertical alignment' between the two concepts.

3. **What are the strategies to be used?**

   Some strategies were identified and discussed:

   - The use of models to illustrate the concepts.
   - The use of real life situations.
   - Continuous assessment in the form of oral questions, class-work, assignments, tests, etc as a way of monitoring learners' progress in the unit.
   - Engaging learners in conversations/dialogue during the lessons as a way of developing their mathematics communication skills and confidence in arguing out their ideas with their colleagues.

4. **What will the plan look like in the classroom?**

   In this part of the plan we discussed the teachers' mental images or vision of the classroom environment that would be necessary to achieve the goals of the plan. The following features of the classroom were discussed:

   - Seating learners in groups for discussion.
   - Learners to work on pre-designed tasks requiring them to discuss and solve problems.
   - Teachers providing guidance to learners and monitoring learners' progress on each concept.
   - Teachers ensuring that learners are engaged constructively in their learning.
   - Teachers guiding whole class discussions.

5. **What is the theory behind the solution strategy?**

The theory behind the action plan was discussed. The teachers were initially not clear about what such a theory is and its significance to the plan. We ended up agreeing on the theory that: 'Learner participation leads to improved learning'.

6. **How to assess progress**

   The following ways and sources of data for assessing progress were discussed:

   - Class work which will be marked and discussed later.
   - Oral questions during the lesson, especially questions that sought learners to explain/justify their thinking in discussion contexts.
   - Learners' use of models/illustrations when explaining their thinking to the rest of the class.
   - Formal written tests.
   - Homework/assignments.
   - Projects- this was suggested by one teacher and it led to a discussion of the form of projects aligned to the two selected concepts. One suggestion was that learners collect data about the school which could be used to construct meanings of ratio and fractions, e.g. ratio of boys to girls in each class.

We also discussed the indicators of progress in the action plan. The following ideas were raised:

- Correctness and meaningfulness of responses in learners' written work.
- Learner participation in class discussions and tasks.
- Learners' level of thinking manifested through originality of ideas, indications of conceptual understanding, ability to explain/justify responses during discussion contexts.
- Performance on tests and homework tasks.
- Errors committed in tests and other written tasks.

Appendix S: Worksheet on Rational Numbers: Grade 7 & 8

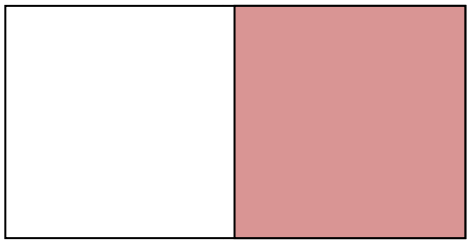
Introduction

In this worksheet you will learn about how common fractions, decimal fractions and percentages are connected. The main concept that you need to know is that of equivalent fractions. Once you know what it means to change a given common fraction into another equivalent common fraction, then you will be surprised how easy it is to convert a common fraction into a decimal fraction or percentage. Let's look at these concepts one by one, before we examine how they are connected.

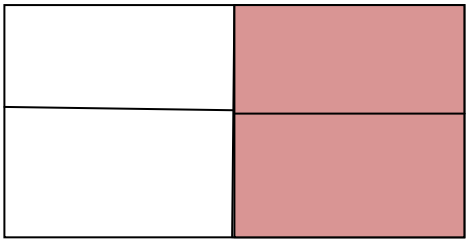
Equivalent fractions

Two fractions are said to be equivalent if they have different denominators but are of the same size. The following diagrams show this more clearly.

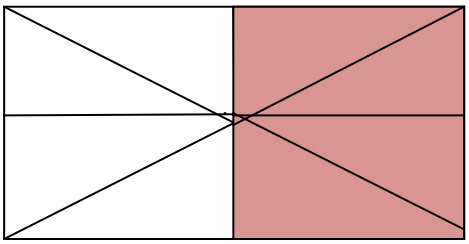
A



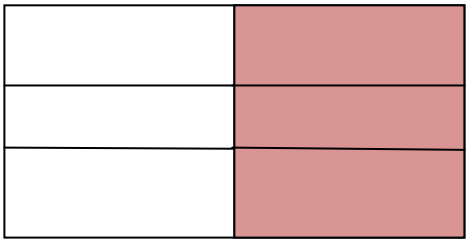
B



C



D



Task 1:

1. In each of the above shapes, what fraction of the shape is shaded?
2. What can you say about the shaded parts?
3. Write down a statement which summarizes what you notice.

You will have noticed that in each diagram the shaded part is equal to half of the shape. So your concluding statement should have been:

$\frac{1}{2} = \frac{2}{4} = \frac{4}{8} = \frac{3}{6}$

These fractions are equivalent to each other. The denominators are different but the fractions represent equal sections of the shapes.

Now if we take the first two fractions:

$\frac{1}{2} = \frac{2}{4}$

Task 2: What is the relationship between these two fractions?

You should have noticed that if we multiply the numerator and denominator of the first fraction by 2 we get the second fraction.

Task 3: Explain how the following pairs of equivalent fractions are related:

1. $\frac{1}{2} = \frac{4}{8}$
2. $\frac{1}{2} = \frac{3}{6}$
3. $\frac{3}{4} = \frac{9}{12}$
4. $\frac{2}{3} = \frac{12}{18}$
5. $\frac{5}{20} = \frac{1}{4}$
6. $\frac{7}{35} = \frac{2}{10}$

Task 4: Now try to complete the following statements:

1. $\frac{3}{4} = \frac{\quad}{16}$
2. $\frac{\quad}{36} = \frac{5}{6}$

3. $\frac{3}{10} = \frac{\quad}{100}$

4. $\frac{\quad}{100} = \frac{\quad}{20}$

5. $\frac{\quad}{48} = \frac{5}{8}$

Decimal fractions

Decimal fractions are just another way of representing fractions. They arise from 'base-ten' fractions. Base ten fractions are those common fractions whose denominator is 10 or a multiple of 10. The multiples of 10 are:

$10;\ \ 100;\ \ 1000;\ \ 10\,000;\ \ 100\,000; etc$

The following are examples of base-ten fractions:

1. $\frac{1}{10}$
2. $\frac{21}{100}$
3. $\frac{7}{10}$
4. $\frac{127}{1000}$
5. $\frac{3}{100}$

A base-ten fraction can be written as a decimal fraction. For example $\frac{1}{10}$ can be written as 0.1, i.e. $\frac{1}{10} = 0.1$

Task 5: Write each one of the above base-ten fractions as a decimal fraction.

So what does this mean if we have a common fraction which is not a base-ten fraction and we want to express it as a decimal fraction? That is now easy. All we need to do is to express that fraction in its equivalent form as a base-ten fraction first and then write it as a decimal fraction. Let's look at the following example:

Suppose we want to express $\frac{3}{4}$ as a decimal fraction. We need to first identify a multiple of 10 which can be divided by 4 without leaving a remainder.

Task 6: Which of the following multiples of 10 can be divided by 4 without leaving a remainder?

10; 100; 1000; 10 000; 100 000

You should have seen that the smallest multiple of 10 which is divisible by 4 is 100. So we can express the fraction $\frac{3}{4}$ in an equivalent form with denominator 100.

Task 7: Complete the following:

$$\frac{3}{4} = \frac{\quad}{100}$$

Once the fraction is now in base-ten form, then we can write it as a decimal. Therefore:

$$\frac{3}{4} = \frac{75}{100} = 0.75$$

Task 8: Using the above example, express the following common fractions as decimal fractions:

1. $\frac{3}{5}$
2. $\frac{4}{25}$
3. $\frac{23}{50}$
4. $\frac{1}{8}$
5. $\frac{7}{16}$

Percentages

The word 'percent' means 'out of hundred'. For example 6% means '6 out of a hundred', so 6% can be written as: $\frac{6}{100}$. In other words a percentage is another way of writing a common fraction whose denominator is 100.

If you now look back at what you have done so far you can see how easy it is to express a common fraction as a percentage. All you have to do is to first express the fraction in its

equivalent form, but this time the denominator has to be 100. For example if we want to express $\frac{1}{2}$ as a percentage, all we need to do is to express this fraction in an equivalent form with denominator 100. So we need to complete the statement:

$$\frac{1}{2} = \frac{\quad}{100}$$

Now you can easily write $\frac{1}{2}$ as a percentage.

Task 9: Using the above example, express the following fractions as percentages:

1. $\frac{2}{5}$
2. $\frac{3}{20}$
3. $\frac{1}{2}$
4. $\frac{3}{8}$
5. $\frac{13}{16}$
6. $\frac{256}{1000}$

Summary: You should have realized that once you know how to express a given common fraction as another equivalent fraction, then decimals and percentages are easy. For decimals you must express the given fraction as a base-ten fraction first. For percentages you must express the fraction with a denominator 100.

Now try to complete the following table:

Task 10: Complete the following table:

Fraction	Equivalent	Decimal	Percentage
$\frac{2}{5}$	$\frac{\quad}{10}$	0·4	
$\frac{3}{5}$	$\frac{\quad}{100}$		
$\frac{6}{48}$	$\frac{\quad}{8} = \frac{\quad}{1000}$		12.5%
$\frac{\quad}{48}$	$\frac{5}{8}$		
$\frac{\quad}{25}$	$\frac{\quad}{100}$	0·48	
$\frac{23}{50}$	$\frac{\quad}{100}$		
$\frac{1}{2}$			50%

Appendix T: Worksheet on Ratio: Grade 9 & 10

Introduction

In this worksheet you will learn about ratio. We will help you to understand what ratio is and what it means to divide a quantity in a given ratio. You must read carefully and attempt all the tasks. You should discuss with your friend all the tasks and be able to explain your answers to the rest of the class.

What is Ratio?

Ratio is a way of comparing quantities. The quantities can be in the same units or in different units. For example we can talk of the ratio of boys to girls in a class. We can also compare the number of boys in Grade 8A to the number of boys in Grade 8B using ratio.

Types of Ratio

There are two ways in which we can compare quantities using ratio. We can compare two or more parts of a whole to each other. This is called part-part comparison. We can also compare one part of a whole to the whole itself. This is called part-whole comparison. We will give examples to illustrate the difference.

Ratio as part-part comparison

When we use ratio to compare parts of a whole to each other, then the first thing is to know what the whole is. Let's take a class of learners as our whole. We can use ratio to compare various groups or categories of learners in that class. For example

- The ratio of boys to girls
- The ratio of boys who are 15 years or older to those who are less than 15 years old.
- The ratio of learners who live from Ext. 2 to those who live outside Ext. 3

Task 1

1. Using your class as the **whole** find and write down the ratios described above.
2. Form and write down other ratios about people and objects (e.g. books) in your class or school.
3. Write down the following ratios about your family:

- Boys to girls.
- Parents to children.
- Grown-ups to children.
- Bedrooms to people.
- Men to women.
- People to domestic animals.

N.B.: We can compare more than two parts of the same whole to each other using ratio. For example if a farmer has 45 cattle, 50 goats, 25 sheep, and 120 chickens, then we can compare his animals using ratio. The ratio of cattle to goats to sheep to chickens is written as: 45:50:25:120. This ratio can be simplified. Each number can be divided by 5. When we are simplifying ratios we have to divide each number by **the same number.** That number must be the highest common factor (HCF) of the numbers in the ratio. So in the above ratio we see that 5 is the highest common factor. Therefore if we divide each number by 5 the ratio is simplified as follows:

$$45:50:25:120 = 9:10:5:24$$

What does it mean to say 9:10:5:24? It means that for **every 9 cattle that the farmer has, he/she has 10 goats, 5 sheep and 24 chickens**. *This is very important. Make sure you read it and understand it.* Probably another example will help. If we say the ratio of boys to girls in a family is 1:2, what do we mean? **We mean that for every boy in the family there are two girls.** Suppose you are told that there are 12 children in that family, can you work out how many boys there are and how many girls there are? Try to answer this question with your friend and explain to the rest of the class.

Task 2

1. Explain the meaning of each of the following ratios:
    - The ratio of boys to girls in a class is 2:3.
    - The ratio of textbooks to exercise books in a class is 1:5.
    - The ratio of learners to maths textbooks is 6:1.
    - The ratio of learners to educators in a school is 60:2.

2. Try to answer the following with your friend:
    - If you share 24 biscuits among three boys, Jabulani, Sipho and Temba, how many biscuits will each one get?
    - There are 18 people in a family. The ratio of children to parents to grandparents is 3:2:1. How many are there of each category in the family?
    - Share R800 in the ratio 5:3.

3. For each of your answers in 2 above, briefly explain how you did it. Is there any other way of doing it?

4. What is the simplest way of dividing or sharing a quantity in a given ratio? Can you explain why that method works?

Ratio as part-whole comparison

The other use of ratio is for comparing one part of a whole to the whole itself. For example if we have 45 learners in a class and 25 of them are girls, then we can say the ratio of girls to the whole class is 25:45. This means 25 out of the 45 learners are girls. This can be written as 25:45 or as $\frac{25}{45}$. In its simplified form that would be 5:9 or $\frac{5}{9}$? Can you explain how we simplified this ratio?

N.B: This type of ratio is similar to common fractions.

Summary

From this worksheet you should now be able to explain what ratio is, how to simplify ratios, and what it means to divide quantities in given ratios. Our focus has been on ratio as part-part comparison. Now try the following task.

Task 3

1. **Simplify the following ratios where possible:**
    a) $9 : 12 =$

b) 18 : 30 : 42 =

c) 4 : 6 : 9 =

d) 5 : 4 =

2. Complete the following statements:

a) 3 **:** 1 = ….. **:** 3

b) 2 **:** ….. **:** 5 = 14 **:** 21 **:** 35

3. State whether each of the following statements is *true* or *false*:

a) 2 **:** 5 = 6 **:** 15 ……

b) 16 **:** 2 = 2 **:** 16 ……

c) 1**:** 3**:** 7 = 14 **:** 2 **:** 6 ……..

4. A mother shares 28 sweets between her two children, Lwazi and Thuthukani. She gives Lwazi 4 sweets for every 3 three sweets she gives Thuthukani.

How many sweets does:

i) Lwazi get?

ii) Thuthukani get?

5. A man wants to paint his house. To get the colour he wants he must mix 1 tin of red paint with 2 tins of white paint. In order to paint the whole house he needs 9 tins of paint altogether. How many tins of each colour must he buy?

Appendix U: Lesson Reflections Guide: Ratio (Rational Numbers)

Grade:…… …. **Date Taught**:…….

1. ***Unit of improvement***

   The aim of the lessons was to improve learners' conceptual understanding of ratio and what it means to divide a quantity in a given ratio.

   Did the lesson develop learners' conceptual understanding of ratio/rational numbers and what it means to divide a quantity in a given ratio? Give a justification for your answer.

   Which aspects of ratio/rational numbers were adequately dealt with in the lesson? Which aspects were not dealt with well in the lesson?

2. *Other goals of the lesson plan*

   For each of your responses provide a justification.

   How was learners' thinking about ratio/rational numbers developed in the lessons?

   What was the role of the teacher in the lessons? Was this a change from the usual way of teaching of the teacher?

   How did the teacher deal with learners' thinking in the lesson?

3. *Models and strategies used*

   Were the practical models used in the lessons useful in developing learners' understanding of ratio/rational numbers?

   To what extent did the lessons engage learners in conversations and the creation of their own understandings about ratio/rational numbers?

4. *The classroom environment*

How did the learners' seating arrangement foster learners' participation and engagement in the lessons?

What do you think about the teacher's positioning in the lesson? How did the teacher provide guidance and monitor learners' learning in the lesson?

Were there any norms used to guide the learners' learning environment? How useful were the norms?

5. *Your overall impressions of the lesson*

To what extent did the lesson improve learners' understanding of ratio/rational numbers?

What else do you think needs to be done to ensure that learners can answer questions on ratio/rational numbers?

What impressed you about the lesson? What aspects of the lesson could be improved?

Anything else you want to say about the lesson?

Appendix V: Mathematical Quality of Instruction Coding Tool

MATHEMATICAL QUALITY OF INSTRUCTION (MQI)

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This material is based upon work supported by the National Science Foundation under grant number EHR-0233456, DUR-0335411 and DRL-0918383 and work supported by the U.S. Department of Education under cooperative agreement number R305C090023.

SEGMENT CODES

Format of the Segment	
Indicate the main format in which students worked. **Please code both formats if at least one minute of each type of instruction occurs**. If class splits into two or more groups, please code all applicable formats.	
Active Instruction	Small Group/Partner/Individual Work
Teacher leads discussion or presentation of mathematical material. May be moments where students work individually to solve a problem, but these are brief interludes (under a minute) before return to whole-group work. Whole group does not necessarily imply whole class; class can be split into halves or other fractional components. Key element is extended teacher presentation of mathematical material or posing of mathematical problems to a group.	Teacher divides students into small groups or pairs for work on mathematical problem or task OR students work individually on mathematical problem or task. Typically, teacher circulates among groups or pairs, checking progress. However, teacher may be working on administrative issues, etc. during this time.

Classroom Work is Connected to Mathematics	
Code here for whether the focus is on *mathematics content* during half or more of the segment (3.5 minutes or more total).	
No	**Yes**
Focus for majority of the segment (3.5 minutes or more) is on non-mathematical topics, or student activities that have no clear connections to developing mathematical content (e.g., cutting and pasting). Examples: • Gathering or distributing materials, other administrative issues • Disciplinary issues that severely impinge upon instructional time • Students doing an activity (cutting, pasting, colouring) that is not clearly connected to mathematics ("bad reform") • Any combination of the above that sums to 3.5 minutes	Focus is on mathematical content for majority of the segment. Examples: • Teacher reviews content from a prior lesson; teacher introduces content • Students practice content • Students work on a warm-up problem while teacher takes attendance

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Note: "Majority" means 3.5 minutes or more, unless otherwise noted

Mode of Instruction

Used to code whether mathematical content is supplied in a teacher-directed manner or whether alternative methods are used to develop content. These modes are not exhaustive; that is, segments can receive a "none" for all in some cases.

Direct Instruction

Teacher is in control of delivery of mathematical content. Mathematical content can be correct or incorrect; major feature is high amount of teacher talk and/or control relative to other activities (e.g., student talking, practice, etc).

Can include, e.g., teacher going over homework, going over problems, presenting new material, reviewing, launching a task, etc. Can be in small-groups.

None	Some	Most/All
No direct instruction occurs.	This mode of instruction occurs only for part of the segment or supplements other work featured in the segment – hence, it is *not* the key feature of the segment.	This mode of instruction occurs for the majority of the segment and/or is the *key* feature of instruction featured in this segment.

Whole-Class Discussion

"The teacher is in charge of the class, just as in direct instruction. However, the teacher is not primarily engaged in delivering information or quizzing. Rather, he or she has students share their thinking, explain the steps in their reasoning, and build on one another's contributions. …. [This mode of instruction] gives students the chance to engage in sustained reasoning." (Chapin et al., 2003, p. 17) **Key feature is that students comment on mathematics of one another's contributions, not just say, "we did it another way."**

Also, most of transcript will be student voices.

Whole-class discussion is applied only to "active" instruction time.

None	Some	Most/All
No whole-class discussion.	This mode of instruction occurs only for part of the segment or supplements other work featured in the segment – hence, it is *not* the key feature of the segment.	This mode of instruction occurs for the majority of the segment and/or is the *key* feature of instruction featured in this segment.

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Working on Applied (Real-World) Problems		
Teacher and/or students work on applied (real-world) problems. Examples of applied (real-world) problems: • Figuring out among four recipes the proportion of orange juice and water that makes a mixture more orangey • Figuring out which is the best phone-call plan among three plans representing a linear, a proportional, and a stepwise function. Non-examples: • Mentioning a past contextualized problem but not working on it • Story problems used to illustrate a situation, but that are not actively worked on during the segment. Note: Short word problems from math texts DO count in this code and could result in either a mid or a high code, depending on how they are used in the segment.		
None	**Some**	**Most/All**
No work on applied (real-world) problems is featured in this segment.	This mode of instruction occurs only for part of the segment or supplements other work featured in the segment – hence, it is *not* the key feature of the segment.	This mode of instruction occurs for the majority of the segment and/or is the *key* feature of instruction featured in this segment.

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Richness of the Mathematics

This category attempts to capture the depth of the mathematics offered to students. Rich mathematics is either a) focused on the meaning of facts and procedures OR b) focused on key mathematical practices. Rich mathematics allows students to build a conceptual mathematical base and build connections within and among different components of rich mathematics.

For all, element must be substantially correct and clear to count as "mid" or "high." "Mid" constitutes good use of many of these elements; "high" constitutes extraordinary use.

Note: All codes in this category are a quality codes. A teacher can get a high, even if the aspect of instruction you are coding for occurs for only a portion of the segment.

Linking or Connections

This code refers to teachers' and students' explicit linking and connections:

- Among different representations of mathematical ideas or procedures (e.g., a linear graph and a table both capturing a linear relationship)
- Among different mathematical ideas (e.g., proportionality and linearity; fractions and ratios, etc)
- Across representations and mathematical ideas /procedures (e.g., discussing how linearity is captured in any of the following: a graph, a table, or a mathematical equation)
-

Note: If links are made but underlying representation/idea is incorrect, do not count as linking and connections.

Low	Mid	High
No linking or connections occur. Also code low when connections are **completely** pro forma, e.g. "Yesterday we did adding fractions with like denominators, today we will do subtracting fractions with like denominators."	Links or connections are present, but do not have the features included in "high," or feature these only momentarily (e.g., "You can compare ratios the same way you compare fractions" or "You can see that each step in the computation can be seen in this array model here.").	Links and connections are present with sustained, careful work on one or more of the following: • Detailed discussion of how two mathematical ideas are related to one another • Explicit linking of a representation to the underlying idea it is meant to represent • Explicit linking between multiple representations, showing how they correspond

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<table>
<tr><th colspan="3">Explanations</th></tr>
<tr><td colspan="3">Mathematical explanations explain why. This includes giving mathematical meaning to ideas or procedures, meaning of steps, or solution methods, e.g.:
• Why a procedure works
• Why a solution method makes sense
• Why an answer is true

Do NOT code "how" e.g., descriptions of steps here (first I did x, then I did y) or simply providing definitions unless meaning is also attached.

Examples: the reason for steps in simplifying fractions (dividing by 2/2, for example, is same as dividing by 1; anything divided by 1 is still itself); why particular steps in a complex problem are justified or work to achieve the solution.

Note: Do not count incorrect or incomplete explanations as explanations.</td></tr>
<tr><th>Low</th><th>Mid</th><th>High</th></tr>
<tr><td>No mathematical explanations are offered by the teacher or students or the "explanations" provided are simply descriptions of steps of a procedure.</td><td>The explanations offered by the teacher or students meet any of the following criteria:
• They meet criteria under high, but they are not detailed;
OR
• They are not generalizable (they pertain only to the specific task/problem under consideration)
• They are definitions that contain elements of "why" but that do not fully explain</td><td>The explanations offered by the teacher or students meets the following criterion:
• They move beyond particular problems (i.e., they are general explanations, not for particular problems)

AND meets one or more of the following criteria:
• They give meaning to steps and procedures
• They are detailed</td></tr>
</table>

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Multiple Procedures or Solution Methods

Multiple procedures or solution methods

- Multiple solution methods for a single problem (including shortcuts)
- Multiple procedures for a given problem type

Defined as, e.g.:

- Taking different mathematical approaches to solving a problem (e.g., comparing fractions by finding a common denominator AND comparing fractions by finding a common numerator)
- The teacher/students may solve a (word) problem using two different strategies.

If the initial strategy(ies) occurred in a prior interval, code the second (or subsequent) interval at this code (e.g., no need to go back and code the initial interval).

Note: Here you could also include teacher/student mentions multiple different procedures/solution methods.

Note: Do NOT code incorrect procedures or solution methods

Low	Mid	High
No evidence of multiple procedures/solution methods for a given problem type.	Multiple procedures/solution methods present, but do not have the features included in "high," or feature these only momentarily (e.g., "this method is easier than the other" without explicit discussion of why).	Multiple procedures or solution methods occur with special features: • Explicit comparison of multiple procedures/solution methods for efficiency, appropriateness, ease of use, or other advantages and disadvantages • Explicit discussion of features of a problem that cues the selection of a particular procedure • Explicit links between multiple procedures/solution methods (e.g., how one is like or unlike the other)

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Developing Mathematical Generalizations

Teacher and/or students **develop** mathematical generalizations by examining instances or examples, then making a general statement (e.g., drawing parabolas x^2, $2x^2$, $4x^2$ then making a generalization about shape as coefficient changes).

Examples of this activity include:

- Generalizations of mathematical facts
- Generalization of mathematical procedures
- "Building up" a mathematical definition or deriving a mathematical property after considering different examples and non-examples (e.g., defining "polygons" after considering different examples and non-examples of polygons)

Notes:

1. Requires at least two examples (either explicitly worked or referred to) from which generalization emerges.
2. Code at generalizations for only the clip in which generalization emerges / becomes explicit.
3. Do NOT code incorrect generalizations.
4. Do NOT code: When teachers *state* generalizations without first developing them from examples.

Low	Mid	High
No generalizations are developed in this segment. Also code "low" for non-mathematical generalizations (e.g., drawing a picture helps solve a word problem).	Students/teacher *develop* a generalization, but the generalization developed is not complete, clear or detailed.	Teacher and/or students *develop* a generalization. The generalization should contain the *mathematical* essence of the work done with regards to a particular task and should be complete and clear.

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Mathematical Language		
• Fluent use of technical language • Explicitness about mathematical terminology • Supporting students' use of mathematical terms		
Low	**Mid**	**High**
Teacher does not demonstrate fluency in mathematical language. Teacher uses non-mathematical terms to describe mathematical ideas and procedures AND/OR teacher talk is characterized by sloppy use of mathematical terms. If there is little mathematical language used, code here.	Teacher uses the mathematical language as a vehicle for conveying content, but has few or none of the special features listed under "high." Also code here when segment has both features of "high" but includes some linguistic sloppiness.	Teacher uses mathematical language *fluently*. May include explicitness about terminology, reminding students of meaning, pressing students for accurate use of terms, encouraging student use of mathematical language. Density of mathematical language is high during periods of teacher talk.

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Overall Richness of the Mathematics		
Depth of the mathematics offered to students. Note: This is an overall code for each segment/chapter. It is not an average of the above, but an overall estimate of richness		
Low	**Mid**	**High**
Segment is not rich in any sense, or has only a brief instance of a richness element (brief "mid" for explanation). May also be used for error-filled segments.	No major errors occur and segment offers students some opportunity to learn beyond rote memorization of rules or standard procedures. May be characterized by many "mid" codes above, one well-developed "high" along with substantial procedural focus, etc.	No major errors occur and segment offers students accurate and significant opportunities to learn mathematics as evidenced by one or more "high" codes. Two general ways: • Focus is on meaning via representations linked to one another or to underlying ideas; explanations that generalize; generalizations that are developed from specific examples • Focus is on explicit comparing of solution methods or procedures (e.g., most efficient) but without necessary focus on meaning during this discussion

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Working with Students and Mathematics

This category captures whether teachers can understand and respond to students' mathematically substantive productions (utterances or written work) or mathematical errors. By mathematically substantive productions, we mean questions, claims, explanations, solution methods, ideas, etc that contain substantial mathematical ideas. By students' mathematical errors, we mean those incorrect student productions that offer opportunities for discussing and addressing pertinent mathematical ideas.

Thorough Remediation of Student Errors and Difficulties

With this code, we mean to mark instances of remediation in which student misconceptions and difficulties with the content are *substantial*ly addressed.

Note: Can be during active instruction or student work time.

Low	Mid	High
No thorough remediation occurs for any of the following reasons: • There are no student misunderstandings or difficulties with the content • Remediation is procedural and brief or otherwise non-substantive • The teacher chooses not to remediate • The teacher remediation is confusing or off-track or not thorough	Teacher engages in thorough remediation *briefly* or *occasionally*. Also includes very *extensive* procedural remediation.	Teacher engages in thorough remediation *systematically* and *at length*. High is characterized by *conceptual* remediation: • Identifying the source of student errors or misconceptions • Discussing how student errors illustrate broader misunderstanding and then addressing those errors. It also includes teacher skill at: • Anticipating common student errors and providing instruction that helps avoid error • Parsing student productions to separate correct and incorrect thinking.

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Responding to Student Mathematical Productions in Instruction		
Student evokes new (non-routine) mathematical thought for the class, and teacher understands and responds to it during instruction in mathematically appropriate ways. Student ideas will tend to have features of student explanation/generalization/why question, or a complex description of a solution method. Teacher: • Identifies mathematical insight in specific student questions, comments, or work • Builds instruction on student ideas or methods Note: By "ideas" we do not mean simply answers to problems or pointed questions where teacher has sought a specific, bounded piece of information. They tend to be student explanation, questioning, and reasoning.		
Low	**Mid**	**High**
Routine instruction with no student productions. There are student productions, but no evidence that student ideas are "heard," taken up or used in instruction. Teacher may provide evidence that he/she does not understand student productions. Teacher uses student productions but in a way that muddles or confuses the mathematics of the lesson.	Student productions are present. Teacher may engage in features listed under "high" briefly, but instruction generally proceeds *without* strong use of student mathematical ideas. Also use in cases where there is evidence the teacher understands student thinking but chooses not to use it at that time.	Student productions are present. Teacher "hears" what students are saying, mathematically, and responds appropriately during instruction. Students' mathematical ideas are woven *at length* into the *development* of mathematical ideas during the lesson. Teacher may comment on student's mathematical ideas, elicit further student clarification of ideas, ask other students to comment on ideas, expand on and reinforce student utterances, etc. Other markers include: • Indentifying key ideas in student statement ("Mark had an interesting idea…") • Highlighting key features of student questions ("Do you see Mark asked a question about whether this would work in all cases?") • Identifying a student with an idea ("Mark's method")

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Overall Working with Students and Mathematics		
Note: This is an overall code for each segment/chapter. It is not an average of the above, but an overall estimate of the teachers' interactions with the students around the content.		
Low	**Mid**	**High**
Few substantive interactions between teacher and student or teacher may overlook information about students and/or student insight into mathematics.	A combination of strong and weak features (e.g., some high-level remediation but teacher ignores students' contributions).	Strong and significant teacher understanding and use of student ideas and errors around the content as evident by *outstanding* performance in one area or consistently solid performance in several others.

Mathematical Quality of Instruction (MQI)

Errors and Imprecision		
This category is intended to capture teacher errors or imprecision in language and notation, uncorrected student errors, or the lack of clarity/precision in the teacher's presentation of the content. Do not code errors if these errors are captured and addressed within the segment or chapter (in this case, code as "low").		
Major Mathematical Errors or Serious Mathematical Oversights • Solving problems incorrectly • Defining terms incorrectly • Forgetting a key condition in a definition • Equating two non-identical mathematical terms, etc.		
Low	**Mid**	**High**
Instruction is *clean* of major errors in spoken or written work OR errors that occur are captured and corrected within the segment.	Teacher makes *major errors* either in spoken or written work or teacher neglects to discuss key aspects of a problem (e.g., forgetting a step, forgetting to finish the problem). The errors occur in ***part*** of the segment.	Teacher makes *major errors* either in spoken or written work or teacher neglects to discuss key aspects of a problem (e.g., forgetting a step, forgetting to finish the problem). The errors occur in ***most*** of the segment.

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Imprecision in Language or Notation (mathematical symbols)		
• Errors in notation • Errors in mathematical language • Errors in general language		
Low	**Mid**	**High**
Instruction is *clean* of errors in mathematical language, general language and notation. Any errors made and quickly corrected should also be coded here.	Teacher makes a *small number* of momentary errors in notation, mathematical or general language.	Instruction is characterized of linguistic and notational *sloppiness across the segment* and/or by *major* notational and linguistic errors in even a small number of mathematical terms.

Clarification:

- ***Notation*** includes conventional mathematical symbols, such as +, -, =, or symbols for fractions and decimals, square roots, angle notation, functions, probabilities, exponents. Errors in notation might include inaccurate use of the equals sign, parentheses, or division symbol. By "conventional notation," we do not mean use of numerals or mathematical terms.
- ***Mathematical language*** includes technical mathematical terms, such as "angle," "equation," "perimeter," and "capacity." If a teacher uses these terms incorrectly, code as an error. When the focus is on a particular term or definition, also code errors in spelling or grammar.
- Teachers often use "***general language***" to convey mathematical concepts (i.e., explaining mathematical ideas or procedures in non-technical terms). General language also includes analogies, metaphors, and stories. Appropriate use of terms includes care in distinguishing everyday meanings different from their mathematical meanings. If teacher is unclear in his/her general talk about mathematical ideas, terms, concepts, procedures, code as an error.

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Lack of Clarity		

• Teacher utterances cannot be understood, e.g.:
  • Mathematical point is muddled, confusing or distorted
  • Language or major errors make it difficult to discern the point
  • Teacher neglects to clearly solve the problem or explain content
• Teachers' launch of a task/activity lacks clarity (the "launch" is the teacher's effort to get the mathematical tasks/activities in play)		

Low	**Mid**	**High**
Teacher's presentation of the mathematical content and/or launching of tasks is *clear* and *unambiguous.*	Teacher's presentation of the content and/or launching of tasks is *not clear* for *portions* of the segment.	Teacher's presentation of the mathematical content is *unclear*, *vague* or *incomplete* for most of the segment. Teacher's work is *muddled* or *confusing* and *severely distorts* the mathematical essence of the content. Also, teacher conveys mathematical tasks or problems *incompletel*y or in a *confusing* manner.
Overall Errors and Imprecision		
Note: This is an overall code for each segment/chapter. It is not an average of the above, but an overall estimate of the errors and imprecision in instruction.		
Low	**Mid**	**High**
No errors occur. Do not use this code if "mid" or "high" is marked in any category above.	Brief error or errors generally not serious enough to indicate teacher may lack mathematical knowledge.	Either multiple small errors, **consistent lack of clarity** or one large error to suggest that teacher may lack key mathematical knowledge.

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Student Participation in Meaning-Making and Reasoning

This code attempts to capture evidence of students' involvement in tasks that ask them to "do" mathematics and the extent to which students participate in and contribute to meaning-making and reasoning. During active instructional segments, this mainly occurs through student mathematical statements: reasoning, explanations, question-asking. During student work times, this mainly occurs through work on a non-routine task

Students Provide Explanations

Students provide a mathematical explanation for an idea, procedure, or solution.

Examples:

- Students explain why a procedure works
- Students explain the procedure they used to solve a particular problem by attending to the meaning of the steps involved in this procedure rather than simply listing those steps
- Students explain what an answer means
- Students explain why a solution method is suitable or better than another method
- Students explain an answer based on an estimate or other number-sense reasoning

Notes:

- Explanations could be initiated by the teacher or self-initiated; they could also be co-constructed with the teacher or constructed individually
- Explanations do not have to be complete or correct

Low	Mid	High
No student explanations are featured in the segment.	The explanations offered are: • Brief • Pertain to a specific problem/task • Do not generalize to key mathematical ideas of the content under consideration Examples: • A student explains that ¾ is larger than 3/5 because the denominator in the first fraction is smaller than the denominator in the second fraction. • A student explains that a cube net has 24 right angles because it has 6 square faces.	The explanations offered generalize past specific problems to address key mathematical ideas of the content under consideration. Examples: • A student explains that ¾ is larger than 3/5 because the denominator in the first fraction is smaller than the denominator in the second fraction and fractions with smaller denominators correspond to smaller pieces. • A student explains that a cube net has 24 right angles because it has 6 square faces and each square has 4 right angles.

Student Mathematical Questioning and Reasoning		
• Students provide counter-claims in response to a proposed mathematical statement or idea (whether from another student, the teacher, or a text) • Students ask mathematically motivated questions requesting explanations (e.g., "why does this rule work?" "What happens if all the numbers are negative?") • Students provide examples of a phenomena • Students make conjectures about the mathematics discussed in the lesson (e.g., "A triangle cannot have two obtuse angles") • Students form conclusions based on patterns they identify or on other form of evidence (e.g., "Because the sum of the angles of any triangle is 180 degrees, a triangle cannot have two obtuse angles") • Students engage in reasoning about a hypothetical or general case ("Because the sum of the angles of any triangle is 180 degrees, a triangle should have at least two acute angle") Note: Students' productions do not have to be complete or correct.		
Low	**Mid**	**High**
The segment does *not* feature any of the student behaviors related to this code.	The segment features *one or two* of the student behaviors listed under this code.	The segment features *three or more* of the student behaviors listed under this code.

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Enacted Task Cognitive Activation		
This code refers to the enactment of the task, regardless of the initial demand of the curriculum/textbook task or how the teacher sets up the task for students Notes: • Student confusion does not necessarily suggest that students are engaging with the content at a high cognitive level • Working on review tasks or on ideas discussed in previous lessons does not necessarily mean that students use lower order thinking skills • This code should not be confounded with the difficulty of the task or whether it is appropriate for a certain grade-level.		
Low	**Mid**	**High**
Students engage with the content at a *low* cognitive level. Examples of cognitively *undemanding* activities include: • Recalling and applying well-established procedures • Recalling or reproducing known facts, rules, or formulas • Listening to a teacher presentation with limited student input • Going over homework with little additional student work (e.g., reporting numerical answers) • Unsystematic exploration (i.e., students do not make *systematic and sustained progress in developing mathematical strategies or understanding*)	Students engage with content at *mixed level* of cognitive activation. May also include tasks with variable enactment (high and then low during segment).	Students engage with content at *high* level of cognitive activation. Examples of cognitively *activating* activities include when students: • Determine the meaning of mathematical concepts, processes, or relationships • Draw connections among different representations or concepts. • Make and test conjectures • Look for patterns • Examine constraints • Explain and justify

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Overall Student Participation in Meaning-Making and Reasoning		
This code attempts to capture evidence of students' involvement in "doing" mathematics and the extent to which students participate in and contribute to meaning-making and reasoning. • During ***active instruction segments***, this mainly occurs through student mathematical statements: reasoning, explanations, question-asking. • During ***student work time***, this mainly occurs through work on a non-routine task. Note: This is an overall code for each segment/chapter. It is not an average of the above, but an overall estimate of the student participation in meaning-making and reasoning.		
Low	**Mid**	**High**
There are only a few or no examples of student participation in meaning making and reasoning. Tasks are largely procedural in nature. Students might also engage in unsystematic explorations.	Students engage with content at *mixed level*. Students may provide substantive explanations or ask a mathematically motivated question. May also include tasks with variable enactment (high and then low during segment).	Students contribute substantially to the building of mathematical ideas through the activities listed in this section as "high."

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OVERALL LESSON CODES

Overall MQI and MKT		
These codes are intended to capture the overall mathematical quality of instruction (MQI) and the teacher's mathematical knowledge for teaching (MKT) as suggested by the teacher's work during the lesson.		
Overall MQI		
Low	**Mid**	**High**
Instruction is characterized by combinations of the following: • Systematic errors (mathematical errors, in notation, in language) • Student confusion or misunderstandings • Unproductive teacher-student interactions around the content (e.g., teacher cannot understand student utterances) • Lack of directionality	Instruction is relatively error-free but lacks the mathematical richness, appropriate use and discussion of procedures, and the sharp mathematical focus detailed under "high."	Instruction is characterized by combinations of the following: • Mathematical richness in terms of explanations, generalizations, use and connections of representations or multiple solutions • Appropriate use and discussion of procedures as well as of their applicability • Instruction is mostly error-free and has a clear and sharp mathematical focus and directionality that allows students develop the important mathematical ideas under consideration • Instruction is also characterized by positive teacher-student interactions around the content

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Lesson-Based Guess at MKT		
How do you think the teacher would score on our MKT assessment? Note: Differs from overall MQI in that raters may use more judgment to estimate generally what teacher MKT should be. For instance, lesson captured may be mostly practice, but there may be some evidence of very strong teacher MKT.		
Low	**Mid**	**High**
MKT is estimated as low, as suggested by combinations of the following: • Inappropriate use of representations, mathematical notation and language • Mathematical errors • Inappropriate explanations, descriptions of procedures, or discussion of student ideas and contributions • Teacher puzzlement and incorrect or distorted presentation of the content	MKT is estimated as mid as suggested by the following: • Instruction is mostly error-free but there is no evidence teacher has capacity to provide rich instruction, understands lesson material deeply, or has capacity to work with students' thinking or errors.	MKT is estimated as high, as suggested by combinations of the following: • Accurate and rich instruction • Strong use of mathematical language • Ability to follow and build on mathematical ideas • Ability to unpack the content and make it accessible to students • Ability to identify and remediate student errors and misconceptions

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Lesson Level Binary Codes
All codes should be scored as **Present** or **Not Present**
Orienting
The teacher states the lesson objectives at the beginning of the lesson in a way that is clear and understandable to the students. The teacher may not present objectives before reviewing homework from prior assignment. This can be coded present as long as the objectives are presented prior to beginning the primary instruction of the lesson.
Summarization
At the end of the lesson, the teacher (or student designate) reflects on what the class has accomplished and/or describes how the day's objectives connect to future goals (e.g., teacher provides a summary that restates or paraphrases the objective of the lesson, the work achieved during the lesson and/or previews related concepts that prepare students for the next phase of the learning process)
Checking Broadly for Understanding
Evidence suggests that teacher has systematically gathered information about student understanding in either this or a past lesson. Includes surveying a large percentage of students about answer (thumbs up/thumbs down; whiteboard), several comments on student non-verbal cues, such as puzzled looks; commenting on common student errors; reporting results of self-assessment back to students.
Differentiated Instruction
The teacher provides differentiated instruction, such that different groups of students engage in tasks focused on different content (e.g., one small group works on geometry problems while another works on solving algebraic equations), or similar tasks of differing level of difficulty (e.g., all students find the area of shapes – some shapes are more difficult to work with than others).

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Appendix P: Lesson Planning Template

GRADE(S):…….. **DATE:…….**

CONCEPT: ……..

Planned Date:…… **Actual Teaching Date:**…… **Duration:**……..

Learning Outcome:

……

Assessment Standards:

……

Knowledge, Skills, Values	Integration	Activity		Resources	Assessment and recording	Learning barriers and expanded opportunities
		Teacher's action	Learners' action			

Appendix Q: Lesson Plan on Rational Numbers grades 7 & 8

DATE: AUGUST 2010 **CONCEPT:** RATIONAL NUMBERS **Planned Date:** 11 August 2010 **Duration:** Two 35-minute lessons

Learning Outcome: LO 1: Numbers, Operations and Relationships: The learner is able to recognize, describe and represent numbers and their relationships, and count, estimates. Calculates and checks with competence and confidence in solving problems.

Assessment Standards: 7.1.5 (ii) / 8.1.5 (ii): We know this when the learner recognizes and represents the following rational numbers in order to describe and compare decimals (to at least three decimal places), fractions and percentages.

Knowledge, Skills, Values	Integration	Activity		Resources	Assessment and recording	Learning barriers and expanded opportunities
		Teacher's action	Learners' action			
-Equivalence among common fractions. -Connections among common fractions, decimals and percentages -Represent fractions, decimals and percentages in either form -Solving problems that involve equivalence of fractions, decimals and percentages. -Enjoyment -Respect for other learners' views.	Economic Management Sciences (EMS)	-Grouping learners for group tasks -Allocating group tasks or problems. -Guiding learner conversations in group tasks -Guiding group report-backs. -Clarifying learners' ideas and explaining concepts where necessary.	-Discussing and solving group tasks allocated by the teacher -Reporting and explaining group findings to the rest of the class -Doing any classwork allocated by the teacher	-Blank sheets of paper. -Work cards with group tasks -Colour pencils	-Class-work tasks -Test -Homework tasks -Learners' marks	-Language and terms associated with fractions, decimals and percentages. -More problems for those who complete work fast.

Appendix R: Lesson Plan on Ratio

GRADES 9 & 10 **DATE: AUGUST 2010**

Planned Date: 11 August 2010 **Duration:** two 35-minute lessons

Learning Outcome: LO 1: Numbers, Operations and Relationships: The learner is able to recognize, describe and represent numbers and their relationships, and count, estimates. Calculates and checks with competence and confidence in solving problems.

Assessment Standards: 4:1:10(i) / 5:1:10(i)/ 6:1:10(i): We know this when the learner solves problems that involve comparing two or more quantities of the same kind.
7:1:10: We know this when the learner solves problems that involve ratio.

Knowledge, Skills, Values	**Integration**	**Activity**		**Resources**	**Assessment and recording**	**Learning barriers and expanded opportunities**
		Teacher's action	**Learners' action**			
-Concept of a ration. -Division of quantities in given ratios -Solving problems that involve ratio -Enjoyment. -Respect for other learners' views.	-Natural Science -Business Studies	-Grouping learners for group tasks -Allocating group tasks or problems. -Guiding learner conversations in group tasks -Guiding group report-backs. -Clarifying learners' ideas and explaining concepts where necessary.	-Discussing and solving group tasks allocated by the teacher -Reporting and explaining group findings to the rest of the class -Doing any class-work allocated by the teacher	-Pre-set tasks on ratio. -Concrete materials that model ratio, e.g. Smarties - Learner generated data to be used for ratio comparisons	-Class-work tasks -Test -Homework tasks	-Language and terms associated with ratio -More problems for those who complete work fast.