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University of the Witwatersrand

Teacher perceptions of effectiveness of a mathematics teacher professional development programme

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Thesis presented in partial fulfilment for the degree of Master in Management (in the field of Public Sector Monitoring and Evaluation) to the Faculty of Commerce, Law and Management, University of Witwatersrand

March 2020

DECLARATION

I, Jaya Sojen, Student Number 579976, hereby declare that this thesis/dissertation titled "Teacher perceptions of effectiveness of a mathematics teacher professional development programme" is my own, unaided work. I have referenced and acknowledged all the sources I have used and quoted. I hereby submit it in partial fulfilment of the requirements of the degree of Master of Management (Public Sector Monitoring and Evaluation) in the University of the Witwatersrand, Johannesburg. I have not submitted it before for any other degree or examination in this or any other University.

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Jaya Sojen

Johannesburg, March 2020

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Supervisor

Johannesburg, March 2020

ABSTRACT

South African learners face serious deficits in mathematics learning at the schooling level. Low learner performance is more pronounced in the case of low-quintile schools. Several factors have been reported to contribute to low learner performance in mathematics. One of them is teacher quality. Because teachers are the only support for learning for learners from disadvantaged socio-economic backgrounds, it is imperative that teacher quality is improved in order to improve learner achievement in low-quintile schools. Eventhough several mathematics teacher professional development programmes have been implemented in South Africa to improve teacher quality, small-scale qualitative studies, in the form of classroom observation and perception studies, report that these teacher professional development programmes lack in quality and focus on content, and that they are delinked from the classroom context, thereby lacking effectiveness.

The purpose of this research was to evaluate one such mathematics teacher professional development programme, the Mathematics Teacher Professional Development Programme (MTPDP), implemented in six schools in Ivory Park in the Gauteng Province. This study intended to explore the teachers' perceptions of the effectiveness of the MTPDP through capturing the teacher experiences of participation in the MTPDP vis-à-vis exploring the teachers' perceptions of the effectiveness of the design attributes of the MTPDP, the new knowledge acquired of content and pedagogy and the change in teachers' classroom practice.

The conceptual framework proposed by Desimone (2009) for evaluating the effectiveness of teacher professional development programmes informed the conceptual framework used in this study. Desimone's (2009) framework presents an action model akin to a theory of change model (Boylan, Coldwell, Maxwell, & Jordan, 2018) to evaluate the impact of teacher professional development programmes in bringing about improved learner outcomes. The critical design attributes of a professional development programme enable positive teacher experiences of participation, thereby enabling teacher acquisition of knowledge and by extension a change in teachers' classroom practice (Desimone, 2009). This leads to impacting positively on teacher instruction and thereby improving the learner outcomes (Desimone, 2009). Thus, the model represents a connection between critical features of professional development, teacher knowledge acquisition, change in classroom practice and learner

outcomes as a continuum of change for evaluating the effectiveness of a teacher professional development programme.

This research pursued a qualitative approach with an interpretivist case study design. A sample of eight teachers was interviewed using semi-structured interviews. The thematic analysis highlighted that the teachers perceived the effectiveness of MTPDP as enabling teacher learning, enhancing teacher knowledge, improving teacher self-efficacy and bringing about transformation in teachers' classroom practice from a predominantly teacher-centred practice to a learner-centred practice. Broad design features of the MTPDP, namely the content-based workshops and the classroom-based component of MTPDP were perceived as effective and found strong resonance among the teachers. The design attributes of 'coherence', 'content coverage', 'active learning', 'sharing ideas and teacher collaboration', 'modelling classroom delivery' and 'monitoring classroom implementation' were perceived as effective by the teachers in enabling learning. The acquisition of 'knowledge of introducing subject matter' and 'knowledge of multiple strategies' were perceived as effective in enhancing teacher knowledge. The acquisition of 'knowledge of multiple strategies' garnered the maximum buy-in from the teachers and was perceived by them as the sustainable feature of the MTPDP. The acquisition of knowledge enabled by these features of the MTPDP in a safe learning environment was perceived as effective by teachers leading to improved teacher perception of self-efficacy, leading to a transformation in teachers' classroom practice from a predominantly teacher-centred practice to a learner-centred practice. Thus, the teachers' overall perceptions of effectiveness of the MTPDP along the continuum of change informed by the conceptual framework of Desimone (2009) was positive.

Though the teachers perceived the MTPDP as effective, the effectiveness would have been only at a superficial level as the low content knowledge of teachers may hinder new teacher beliefs from wholly manifesting in classroom practice.

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LIST OF ABBREVIATIONS

ACE	Advanced Certificate in Education
ANAs	Annual National Assessments
APOS	Action-Process-Object-Schema
ATP	Annual Teaching Plan
BEM	Business, Economics and Management
C2005	Curriculum 2005
CBMS	Conference Board of Mathematical Sciences
CAPS	Curriculum Assessment Policy Statements
CCSM	Common Core State Standards
CDE	Centre for Development and Enterprise
CHEC	Cape Higher Education Consortium
CK	Content Knowledge
CPD	Continuing Professional Development
CPTD	Continuing Professional Teacher Development
DBE	Department of Basic Education
DHA	Department of Home Affairs
DoE	Department of Education
ELRC	Education Labour Relations Council
GDE	Gauteng Department of Education
GDP	Gross Domestic Product

GPLMS	Gauteng Primary Language and Mathematics Strategy
HEIs	Higher Education Institutions
HSRC	Human Sciences Research Council
ICT	Information Communication Technology
IQMS	Integrated Quality Management System
MCPDPs	Mathematic Continuous Professional Development Programmes
MDI	Mathematical Discourse in Instruction
MTPDP	Mathematics Teachers Professional Development Programme
NT	Ngethemba Trust
OBE	Outcomes Based Education
OECD	The Organisation for Economic Co-operation and Development
PCK	Pedagogical Content Knowledge
PD	Professional Development
PDA	Professional Development Activity
PDP	Professional Development Programme
PEI	President's Education Initiative
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PK	Pedagogical Knowledge
PLC	Professional Learning Community
RCT	Randomised Control Trial

RME	Realistic Mathematics Education
RTOP	Reformed Teaching Observation Protocol
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
SAIRR	South African Institute of Race Relations
SET	Science, Engineering and Technology
SLP	Structured Lesson Plan
SSIP	Secondary School Intervention Project
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Third International Mathematics and Science Study
TLSI	Teacher Leadership for School Improvement
TOC	Theory of Change
TPACK	Technological Pedagogical Content Knowledge
TPL	Teacher Professional Learning
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNISA	The University of South Africa
WEF	World Economic Forum

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1. INTRODUCTION TO THE RESEARCH

This research intended to explore the teachers' perceptions of effectiveness of a mathematics teacher professional development programme, the Mathematics Teacher Professional Development Programme (MTPDP), implemented over a three-year period in six primary schools of Ivory Park, a township in Gauteng Province of South Africa. The teachers' perceptions of the effectiveness of the MTPDP are captured through exploring the teachers' experiences of participating in MTPDP, vis-à-vis the teachers' perceived effectiveness of the design features of the MTPDP, the teachers' perceived effectiveness of the MTPDP in acquisition of knowledge of content and pedagogy, and teachers' perceived effectiveness of the MTPDP in changing teachers' classroom practice. This is informed by Desimone's conceptual framework for evaluating the effectiveness of teacher professional development programmes (PDPs) (Desimone, 2009). This conceptual framework can be characterised as presenting a theory of change (TOC) model (Boylan, Coldwell, Maxwell, & Jordan, 2018) with the following major components presenting as a continuum in effecting change, namely design attributes of the PDP, enabling teacher knowledge acquisition, resulting in change in teacher beliefs and attitudes , thereby changing teachers' classroom practice and ultimately learners' outcomes. These components of the TOC model are linked to each other presenting a continuum of change intended to be brought about by the PDP to impact on learners' outcomes.

1.1. Background

This Chapter presents an introduction to the research with Section 1.1.1 briefly describing the indispensability of improving Science, Technology, Engineering, and Mathematics (STEM) education, especially mathematics education in the South African context. Economic inequality manifesting itself as inequality of mathematics performance is highlighted in the context of South Africa.

Section 1.1.2. elaborates on the necessity of improving mathematics teaching, which is a major factor affecting mathematics performance. It highlights the inequitable provision of quality mathematics teaching among various quintiles of South African public schooling system and elaborates on the mathematics teaching crisis in low-quintile schools in South Africa.

Section 1.1.3. highlights effective mathematics teacher PDPs as necessary to improve teaching of mathematics, especially in low-quintile schools, to improve mathematics performance in South Africa.

Section 1.1.4. briefly describes the MTPDP intervention and its components while Section 1.1.5 introduces the MTPDP intervention setting, namely Ivory Park. Teachers from four Quintile 2 primary schools in Ivory Park, a township in Gauteng Province of South Africa, served as the participants for this study.

Section 1.1.6 discusses the research problem statement, Section 1.1.7. describes the research purpose statement, and Sections 1.1.8 delineates the research questions, and Sections 1.1.9. and 1.1.10 deal with the delimitations of the research and justification for the research, respectively.

1.1.1. Need for improving mathematics education in the South African context

"Automatisation", "informatisation", "digitalisation" and "globalisation" has meant that STEM education, and especially mathematics education, have become indispensable for creating a workforce that is work-ready for the 21st century (Gravemeijer, Stephan, Julie, Lin, & Ohtani, 2017, p. S106; World Economic Forum (WEF), 2016). The Future of Jobs Report (WEF, 2016) warns that the lack of technology-intensive skills, namely STEM skills, demanded by the Fourth Industrial Revolution could lead to an employment crisis in the world, affecting both developed and developing countries, South Africa being no exception. This necessitates the need for improving mathematics and science education to keep pace with changing needs of the 21st century (Gravemeijer et al., 2017; WEF, 2016). le Roux (2018, p.1) predicts that occupations that are potentially automatable could displace about 35% of South African workers. Automation thus presents a risk of further widening the inequalities (Prettner & Strulik, 2019) in a country already grappling with a high Gini Coefficient of 0.63 (World Bank, 2018).

South Africa faces a skill scarcity in STEM skills, and the skills classified as "critical" are in the areas of engineering, Information Communication Technology (ICT) specialists, finance professionals and senior management professionals (Department of Home Affairs (DHA), 2014, p.12). University enrolments in courses that could address these deficits, namely Business, Economics and Management (BEM) courses and Science, Engineering and Technology (SET) courses stand at 28.1% and 29.6%, respectively, compared to enrolments for the humanities at 42.3% (Reddy, Bhorat, Powell, Visser, & Arends, 2016a, p.51). The

graduation rates too show the same trend with graduation rates standing at only 27.2% for BEM courses and 30.0% for SET courses, whereas it stands at 42.8% for humanities (Reddy et al., 2016a, p.52). The low university enrolments, combined with low graduation rates and low throughputs, contribute to STEM skill scarcity (Reddy et al., 2016a).

One of the reasons identified for these low throughputs is the deficits in mathematics and science learning at the schooling level, which makes it difficult for learners to pursue tough university courses (Fisher, 2011). Furthermore, South Africa is ranked lowest (137th) in the quality of maths and science education in the world (WEF, 2016). Thus, it becomes imperative to improve mathematics and science education, so as to improve university enrolments and throughputs in STEM fields to address the critical skill shortages.

Mathematics is a universal subject in the primary and secondary school curriculums across the world and a gateway subject for entry into Higher Education Institutions (HEIs) in the STEM fields of engineering, science and technology in South Africa. It is an integral part of the subjects tested in all the International benchmarking tests, namely Third International Mathematics and Science Study (TIMSS) (an international benchmarking test of mathematics and science for learners belonging to Grades 4 and 8 held every 4 years) (TIMSS, 2020), Programme for International Student Assessment (PISA) (PISA, 2020), and benchmarking tests administered for the nations in the African continent, namely Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) (SACMEQ, 2020). All these benchmarking tests are held periodically to compare the education standards among countries around the world and within the African continent. TIMSS and PISA all bring to the fore the disparities in learning outcomes of learners from different countries and therefore provide a window to the quality of education provided, asking us to question if the enormous investment in education is yielding results at the cognitive level (Bethell, 2016).

Empirical evidence suggests a significant relation between the performance in PISA (which tests 15-year old learners' capabilities in the subjects of mathematics, science, and reading in The Organisation for Economic Co-operation and Development (OECD) countries), as a proxy for cognitive skills, and economic prosperity of nations, as measured by the Gross Domestic Product (GDP) (Hanushek and Kimko, 2000; OECD, 2010). Every 1.5 standard deviation increase in individual scores in PISA in OECD countries is shown to have a commensurate improvement in the annual GDP growth of a country by 0.87% (OECD, 2010, p.17), and therefore is a more reliable predictor of labour quality, than length of schooling or school attainment data. Thus, it supports the assertion by Bethel (2016) that the cost of not assessing

reading, maths and science performance could have far greater implications for a nation's GDP. Considering the evidence of the link between improvement in scores in these international benchmarking tests and the impact on the economy, the South African initiative to participate in TIMSS should thus be construed as a positive step towards improving the quality of mathematics and science education in the country.

South Africa has been persistently ranked among the lowest performing countries participating in TIMSS, even after being an off-grade participant, meaning tests for Grade 4 and Grade 8 are written by South African learners from consecutive grades, Grade 5 and Grade 9, respectively (Reddy et al., 2016b). Though the average achievement of South African learners in mathematics in TIMSS increased in the period from 2003 to 2015 (from 285 to 372), still about 65.7% (Reddy et al., 2016b) of learners attain scores below 400, a scale point/benchmark below which the learner is considered a low performer. Although the percentage of learners attaining scores above 400 has steadily improved from 10.5% in 2003 to 34.3% in 2015, a majority remain categorised as low performers (Reddy et al., 2016b). Poor performance in SACMEQ III, with an average achievement score of 495, compared to other relatively economically weak African member nations participating in SACMEQ, namely Botswana (520.5), Kenya (557), Swaziland (541), Tanzania (553), and Zimbabwe (519.8), is of concern and further indicates the poor performance in mathematics among South African learners (SACMEQ, 2011). The percentage of learners who achieved at least 50% in mathematics, considered as acceptable achievement for Annual National Assessments (ANAs), for Grade 9 was a dismal 3% in 2014 (Department of Basic Education (DBE), 2014, p. 71). Thus, the consistently low learner performance in mathematics in national (ANAs), regional (SACMEQ) and international benchmarking tests (TIMSS, PIRLS) points to the low quality of mathematics education in South Africa. Considering that about 60% of the schools cater to the poorest learners attending lower quintile schools[1], namely quintiles 1 and 2 and 3, in South Africa (Department of Education (DoE), 2004), any perceptible change in learner performance in mathematics in South Africa demands that the learner performance in mathematics in these low quintile and poorly resourced schools is prioritised.

Discourses on education in South Africa cannot avoid considering educational inequality inherited from the apartheid era. Research points to the following determinants of low

[1] Quintiles 1-3 schools are no-fee schools, whereas Quintiles 4 and 5 receive a small amount of funding and charge school fees (ELRC, 1998). Quintile 1 learners belong to the poorest 20% of schools whereas the Quintile 5 learners belong to the least poor 20% of the schools (Nyanda, 2014).

performance in mathematics: classroom-level factors pertaining to the teacher namely teacher experience and age (Kunene, 2011); lack of conducive environments for learning at home, including low parental education (Visser, Juan, & Feza, 2015); language proficiency in English (Howie, 2003); accumulating knowledge deficits of learners (Spaull & Kotze, 2015); low motivation of teachers and lack of support for teachers from school management teams (Sinyosi, 2015); low content knowledge (CK) of teachers (Taylor & Vinjevold, 1999; Venkat & Spaull, 2015); underqualified teachers (Centre for Development and Enterprise (CDE), 2013, 2014). Graven (2014) and Taylor, van der Berg, & Burger (2011) point to poverty and inequality as contributing to inequality of educational opportunity in South Africa.

The inequality in mathematics performance seen among lower-quintile and higher-quintile schools is evidenced by the bimodality in the distribution of performance of learners irrespective of grade levels or subjects (van der Berg, 2007). Learners at high-quintile schools representing 25 % of schools in South Africa perform at higher levels in contrast to the learners at low-quintile schools who perform at a lower levels, with 75% of schools in South Africa catering to these poor learners (Spaull, 2013a, p. 4). This further suggests a strong relation between the socioeconomic status and the learners' mathematics performance (Spaull, 2012, 2013a). The 2014 ANA results show a similar trend in all subjects tested, with lower quintile schools performing consistently low at all grade levels tested, and the gap widening in Grades 6 and 9 (DBE, 2014).

Spaull & Kotze (2015) further reiterate the economic inequality as manifesting in mathematics performance of learners. This is evidenced by the wide learning gap between the poorest and the wealthiest learners, the gap increasing successively as the learners reach higher grade levels and reaches a point where any remedial activity cannot yield results leading to "insurmountable learning deficits" for the poorest learners (Spaull & Kotze, 2015, p.13). TIMSS' average mathematics achievement by school quintiles also show a similar trend with the lower-quintile schools having average TIMSS scores below the benchmark of 400 and Quintile 5 and independent schools, the upper-quintile schools, having average scores above 400, i.e., 423 and 477, respectively (Reddy et al., 2016b). This further reiterates educational inequality manifested in inequality in performance in the South African context.

Thus, the low learner performance in mathematics and the learning deficits seen in mathematics learners are skewed against learners belonging to lower-quintile schools, widening the inequality of educational opportunity afforded to these learners in the South African context. Considering that the socioeconomic status of learners acts as an impediment in getting after-

school learning support at home, the school teacher is the only anchor or support for learning for learners from low-quintile schools (Rammala, 2009).This situation thus demands that low-quintile schools are provided with the best quality teachers as maximum learning has to take place at the school with the teacher. Improvement in teacher quality demands provision of mathematics teacher professional development activities aimed at improving mathematics teacher quality. The present state of mathematics teaching in South Africa as it relates to teacher quality and mathematics teacher professional development is discussed below.

1.1.2. Mathematics teacher and mathematics teacher professional development

Barber & Mourshed (2007) assert teacher quality as pivotal to determining the quality of an education system. South Africa faces a severe shortage of appropriately qualified teachers in mathematics in schools in rural areas, the low-quintile schools (CDE, 2013). The extent of the problem is so acute that in about 84 rural schools mathematics is not offered as a subject in the Further Education and Training (FET) phase (South African Institute of Race Relations (SAIRR), 2013, p. 12). High teacher attrition in these schools and lack of incentives, along with the inability to attract talent to rural areas, makes the situation worse (Armstrong, 2015).

In asserting that teachers cannot impart knowledge that they themselves do not possess, Venkat & Spaull (2015) found the subject knowledge of mathematics teachers to be below par or just on par with the grade level they are teaching in mathematics in South Africa. This is the case when they are expected to possess knowledge well above the grade level they are supposed to teach (Conference Board of Mathematical Sciences (CBMS), 2001). The problem persists despite the recommendations by the studies done by President's Education Initiative (PEI) in late-1990s to enhance the CK and the conceptual knowledge of mathematics teachers to provide quality teaching (Taylor & Vinjevold, 1999). The traditional pedagogical practices and lack of a pedagogical repertoire act as a hindrance to learning for learners (Nag, Chiat, Torgerson, & Snowling, 2014). The lack of CK and pedagogical knowledge (PK) is seen as manifesting in mathematics classrooms as a lack of coherence in classroom instruction (Mhlolo, Venkat, & Schäfer, 2012; Morrison, 2013; Venkat & Adler, 2012), overtly procedural orientations in teaching mathematics (Sorto & Sapire, 2011), inability to use manipulative effectively in classrooms (Maboya, 2014). The lack of teacher knowledge in mathematics thus denies the learners the opportunity to learn (Carnoy, Chisholm, & Chilisa, 2012).

King & Newman (2001) argue that since teachers are the most directly involved in learning for the learners, it is imperative that teacher "knowledge, skills and dispositions" are improved through professional development (PD) to improve learner achievement (p. 86). Several

models of in-service and continuing teacher PDPs have been experimented with in South Africa. The cascade model (Griffin, 1999), lesson study interventions (Yoshida, 1999), mentoring (Nel and Luneta, 2017) are some of the models experimented with. While the cascade model, which was initiated for enabling implementation of curriculum reforms Curriculum 2005 (C2005), could be implemented on a larger scale and was cost-effective and time-efficient, it has been criticised for diluting the messaging midstream in the process of cascading of information and therefore the cascade model could not be sustained (Fiske & Ladd, 2004). The lesson study interventions were more collaborative and reflective and more context relevant and school-based; however, it could not be sustained due to its time-consuming nature, as the long-term and gradual approach to change did not attract the interest of teachers (Ono & Ferreira, 2010). Mentoring as a model for PD, has been found to be effective only when the training by the mentor is aligned with the context-specific and the instructional needs of individual teachers (Nel & Luneta, 2017; Owusu-Mensah, 2017). The Continuing Professional Teacher Development (CPTD) offered for in-service teachers by the Department of Education (DoE) and the professional development activities (PDAs) provided, all initiated by the employer, have been criticised for lack of focus on content and pedagogy, lack of emphasis on teacher collaboration, lack of evaluations to assess their impact on changing teachers' classroom practice and learners' learning (de Clercq & Shalem, 2014; Steyn, 2010).

Thus, it may be concluded that improvement in teacher quality in low-quintile schools is indispensable for improving and supporting learner performance in low-quintile schools. The low CK and PK of teachers impacts on teacher quality. This demands provision of PDPs for mathematics teachers that are effective in improving teacher knowledge and teacher classroom practice thereby impacting on learner outcomes. The PDPs offered to teachers are ineffective in improving teacher quality and this demands that the PDPs are evaluated for its effectiveness in improving teacher quality.

1.1.3. Evaluating the effectiveness of teacher professional development programmes

Salient features of PDPs that have the maximum impact on teachers include the location of the PD, namely classroom-based PD, PD that embeds teacher collaboration, PD that provisions for external expertise, and PD provided in a sustained manner to impact on classroom practice (Walter and Briggs, 2012). McGee, Wang, & Polly (2013) and Warnasuriya (2014) identify the effectiveness of teacher PDPs, specifically those aimed at improving the CK and PK of

teachers, as manifested as change from a predominantly teacher-centred pedagogic practice to a learner-centred pedagogic practice, and teacher collaboration.

Evidence based on empirical studies on the effectiveness of the mathematics teacher PDPs in changing teacher knowledge, and thereby teachers' classroom practice, and thereby learner achievement is scarce in South Africa. Qualitative small-scale studies in the form of classroom observation studies and perception studies are more prevalent and have found teacher PDPs to be lacking in quality, lacking focus on content, are of small duration, use a top-down approach and are delinked from classroom context (Steyn, 2010).

The intervention under study, a mathematics teacher PDP, the MTPDP, is evaluated for the teachers' perceptions of its effectiveness by capturing the teacher experiences of participation in the MTPDP vis-à-vis exploring the teachers' perception of effectiveness of the design attributes of the MTPDP, the teachers' perception of effectiveness of the MTPDP in improving the teachers' knowledge of content and pedagogy and the teachers' perceptions of effectiveness of the MTPDP in impacting on the classroom practice of the teacher.

1.1.4. The intervention: The Mathematics Teacher Professional Development Programme (MTPDP)

A mathematics teacher PDP, the MTPDP, implemented by the Ngethemba Trust (NT), was initiated in the year 2014 in six Quintile 2 Primary schools in Ivory Park, a township in the Gauteng Province.

The objective of the programme was to improve the CK and the PK of mathematics teachers so as to develop their pedagogical content knowledge (PCK), based on Shulman's (1987) theory of PCK which proposes PCK as a knowledge which is a blend of CK and PK that is a unique knowledge possessed by teachers and is an important indicator of teacher effectiveness and teacher quality. This was a comprehensive programme with both Mathematics and an ICT component, and two adjunct programmes that included teacher enrolment into The University of South Africa (UNISA) Advanced Certificate in Education (ACE) Maths Programme and the Coding Clubs Programme. This research limits its investigation to Maths Content Workshops component.

The MTPDP involved two major components, namely weekly content-based workshops for mathematics teachers in these six schools, followed by classroom-based support for teaching to the programme participants. The MTPDP programme was implemented for teachers

teaching mathematics in Grade 4 classes in all the six schools in 2014, followed by teachers of Grade 5 classes in all six schools in 2015, followed by teachers of Grade 6 classes in 2016. This implies that the learner cohort from 2014, the Grade 4 cohort, was taught by teachers trained in the MTPDP until 2016, the year in which this learner cohort reached Grade 6. A facilitator from NT conducted weekly content-based workshops in alignment with the Annual Teaching Plan (ATP) from the Intermediate Phase Curriculum Assessment Policy Statements (CAPS) document for Mathematics. The workshops laid emphasis on improving CK and PK of teachers. Another feature of the MTPDP was the classroom-based support provided by the facilitator, upon request by teachers.

The project, since its 2014 inception for the intermediate phase, Grades 4-6, has impacted 59 mathematics teachers and 4433 learners. In 2014, 22 workshops were held for teachers with average teacher attendance rate of 80%. Each Grade 4 teacher was supported in the classroom at least 15 times in 2014. In 2015, 26 workshops were held for teachers with average teacher attendance of 80%, and each Grade 5 teacher was supported in classroom at least 13 times in 2015. In 2016, 27 workshops were held for teachers with average teacher attendance of 83.2%, and each Grade 6 teacher was supported in classroom at least 11 times.

Components of the intervention relevant to this study

The MTPDP components of content-based workshops and classroom-based support are of relevance to this study. The content-based workshops were facilitated by the MTPDP facilitator. The content was delivered using PowerPoint presentations, manipulatives[2] were used for presenting lessons and the same were given to teachers to work with. Teachers were also provided with opportunities to present content strands[3]. Pre-tests were given prior to starting a new concept and post-tests were given after the concept was fully covered. This was held once in a week for a period of 2 hours after school hours at an intervention school and all the participant teachers from neighbouring intervention schools would gather at that school for the workshop.

[2] Mathematical manipulatives are physical models or resources used in mathematics teaching and used by students to learn mathematical concepts (Bartolini & Martignone, 2014).

[3] Content strands denote the content learners are expected to learn, for example, number sense, geometry, algebra, probability, statistics. The curriculum broadly describes the content to be covered under each of the content strands.

Classroom-based support was provided to teachers by the facilitator on request by the teachers. The facilitator would visit the classrooms and model the delivery of a lesson or observe the classroom delivery of a lesson by the teacher followed by facilitator's feedback.

1.1.5. Brief description of Ivory Park

Ivory Park is a township located North-East of the City of Johannesburg, in the Gauteng Province of South Africa, with an area covering 9.21 square kilometres and a population of 184 384 (Statistics South Africa Census, 2011). About 68 299 households inhabit the township, thereby registering a high population density of about 20 000 people per square kilometre (Statistics South Africa Census, 2011). According to the 2011 census, Black Africans constitute 98.82% of the population in Ivory Park (Statistics South Africa Census, 2011). The township came into existence in 1991 to accommodate informal settlers from the neighbouring townships of Alexandra and Tembisa (Omenya, 2006). Most people live in extreme poverty, and unemployment stands at 34.1% (Statistics South Africa Census, 2011). The challenges faced include dire poverty, crime and violence, overcrowding, and prevalence of social ills like drug and alcohol abuse (Omenya, 2006). Social infrastructure exists in the form of ten schools including primary and secondary schools, four public clinics, a police station and two libraries.

Four Quintile 2 primary schools in Ivory Park served as the setting for this study. These four schools are located within a 3-kilometre radius. These are Quintile 2 schools and therefore are no-fee schools, similar to other low-quintile schools in South Africa, and learners attending these schools belong to poor and low-income households (ELRC, 1998; Mestry & Ndhlovu, 2014). The unique socioeconomic challenges, namely, lack of parental support, lack of motivation, hunger, illness, poverty, the out-of-school factors, limit their ability to achieve (Bayat, Louw, & Rena, 2014).

The low education quality afforded to learners in low-quintile schools deny these learners the opportunity to learn (Stols, 2013; van der Berg & Hofmeyr, 2018) and is manifested as low curriculum coverage by teachers (Stols, 2013), lack of depth in dealing with curricular topics (Stols, 2013), setting of tasks at low cognitive demand (Stols, 2013; Taylor 2011), combined with low CK and PK of teachers (Taylor & Vinjevold, 1999; Taylor & Taylor, 2013; Venkat & Spaull, 2015). These lead to learning deficits that become more difficult to remedy as the learners reach higher grades (Spaull & Kotze, 2015).

1.1.6. Problem statement

Learners in low-quintile schools face the hurdles of under-qualified/unqualified teachers with low teaching competencies and consequently encounter "insurmountable learning deficits", owing to weak foundations in learning, culminating in learners dropping out of the schooling system (CDE, 2013, 2014; Spaull & Kotze, 2015, p. 1). Spaull & Kotze (2015) estimate that the Grade 3 learners in Quintiles 1 to 3 schools are behind their Quintile 5 peers by three years' worth of learning , growing in successive years of schooling, and by Grade 9, lag behind by 4 years' worth of learning, making remediation difficult as it reaches higher grade levels (p.26). Only 12% of those who start school enter University, with drop-out rates escalating in Grade 10 (CDE, 2013, p. 6). Thus, odds are stacked against learners in low-quintile schools, denying them the opportunity to learn.

As teachers are the sole points for learning support for learners in low-quintile schools, PD that enhances the capabilities of these teachers is of utmost priority to improve the performance of learners in the low-quintile schools. Eventhough South African teachers are provided opportunity to participate in several kinds of mathematics teacher PDPs, the provision of mathematics teacher PDPs has not resulted in improving quality of teaching (Gulston, 2010; Steyn, 2011), and the learners still demonstrate poor performance in International and National benchmarking tests in mathematics.

Indeed, PDPs for mathematics teachers have been criticised for its ineffectiveness in addressing the needs of mathematics teachers (Kaino et al., 2015; Zurub & Rubba, 1983) in relation to improved classroom practice and the learning of learners. Lack of rigorous evaluation of these PDPs to improve or redesign the PDP have also been articulated by many (Davids, 2009; Mestry, Hendrick, & Bisschof, 2009). This raises the issue on whether these PDPs are effective in contributing to improving teacher learning and responding to the context of practice and the needs of the mathematics teachers (Mestry et al., 2009).

There is a research gap in studies on effectiveness of PDPs specific to the context of Quintile 2 schools, which are characterised by a paucity of appropriately qualified teachers. Lack of appropriately qualified teachers to teach mathematics means low quality of instruction by teachers thereby resulting in poor learner outcomes. Thus, effective PDPs are essential to improving teacher quality in the context of low-quintile schools to improve quality of learning, as teachers are the sole learning support for learners from these schools.

As any improvement in learner outcomes in the context of low-quintile schools is dependent on improved quality of teaching, capturing the teachers' perceptions of the effectiveness of the PDP are of paramount importance, because if teachers perceive the PDP as ineffective, they will not bring about transformation in their practices and direct their practices towards the learning of learners (Guskey, 2000). Evaluating the effectiveness of PDPs is therefore essential to improve the design of the PDPs to improve teacher learning and thereby impacting on learner outcomes. This research thus intended to capture the teacher perceptions of the effectiveness of the MTPDP in impacting on teachers' knowledge and teachers' classroom practice. This has implications for designing effective teacher PDPs in mathematics in the context of Quintile 2 schools.

1.1.7. Purpose of the research

The research purpose revolves around exploring the teachers' perceptions of the effectiveness of the Mathematics Teachers Professional Development Programme (MTPDP) implemented in six Ivory Park Primary schools in South Africa. The effectiveness as perceived by teachers is explored around three major domains, namely features of MTPDP design that enabled teacher learning, captured vis- à -vis the experiences of the teachers participating in the MTPDP; the acquisition of new knowledge; and impact on teachers' classroom practice.

A literature review of the context of the problem and the problem under study was undertaken to accomplish the objectives of this research. Thereafter, the theoretical framework guiding this study was elaborated upon, namely Desimone's (2009) conceptual framework that set the structure for evaluating the teacher PD for its effectiveness.

Desimone's (2009) framework represents a TOC model for effecting change in learner outcomes through a continuum of change that starts with the features of teacher PDP influencing the change in teacher knowledge, which results in altered teacher beliefs and attitudes, thereby resulting in altering teachers' classroom practice, thus improving learner outcomes. Theoretical framework proposed by Desimone (2009) was compared to Guskey's (2000) theoretical framework (see Section 2.4.5.) and Desimone's framework was found to be the right fit of the conceptual framework in guiding this research. This set the base for capturing the teachers' perceptions aimed at answering research questions and ultimately achieving the purpose of this research. This led me to arrive at a research approach and research design and procedures and methods while ensuring that the aspects of validity, reliability and ethics were

taken care for. We finally arrived at themes by coding the data and concluded by identifying the major features of the MTPDP perceived as effective by teachers.

1.1.8. Research questions

Overarching research question

What is the overall perception of the teachers of the effectiveness of the MTPDP?

Sub Research Questions

SRQ1: What are the teachers' perceptions of the experiences of participation in the MTPDP vis-à-vis the effectiveness of the design attributes of the MTPDP?

SRQ2: What are the teachers' perceptions of the effectiveness of MTPDP in acquiring new knowledge?

SRQ3: What are the teachers' perceptions of the effectiveness of MTPDP in changing their classroom practice?

1.1.9. Delimitations

Owing to resource and time constraints and small-scale nature of the study, individual content strands in the CAPS curriculum will not be explored, rather an overall perception of effectiveness will be of research interest.

1.1.10. Justification for the research

Evaluation of teacher PDPs by exploring teacher perceptions of effectiveness of the teacher PDPs is necessitated by the argument that if teachers do not perceive the PDP as effective, they are unlikely to change their classroom practice (Guskey, 2000). If teacher practice is not changed, any PDP is unlikely to have any impact on learner outcomes (Desimone, 2009). Therefore, exploring the aspects of MTPDP that teachers perceive as effective has implications for designing PDPs in the context of low-quintile schools, thus justifying this research.

2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

The chapter on literature review intends to dissect the research problem, exploring evaluation frameworks for PD with theoretical underpinnings, and then identifying the conceptual framework that will be used in this research.

Databases were searched by broad topics of education, mathematics, teacher PD, and evaluation of PDPs until saturation was reached. The databases searched included Education Research Complete, ERIC, Education from SAGE, and ProQuest Central. Boolean search terms used, but not restricted to, were as follows: *mathematics education, teacher quality, high-quality professional development, theoretical frameworks for evaluating professional development programmes, knowledge for teaching mathematics, classroom practice, educational pedagogy, transformation in pedagogic practice, perception* and *evaluation*.

2.1. Progress of education in South Africa

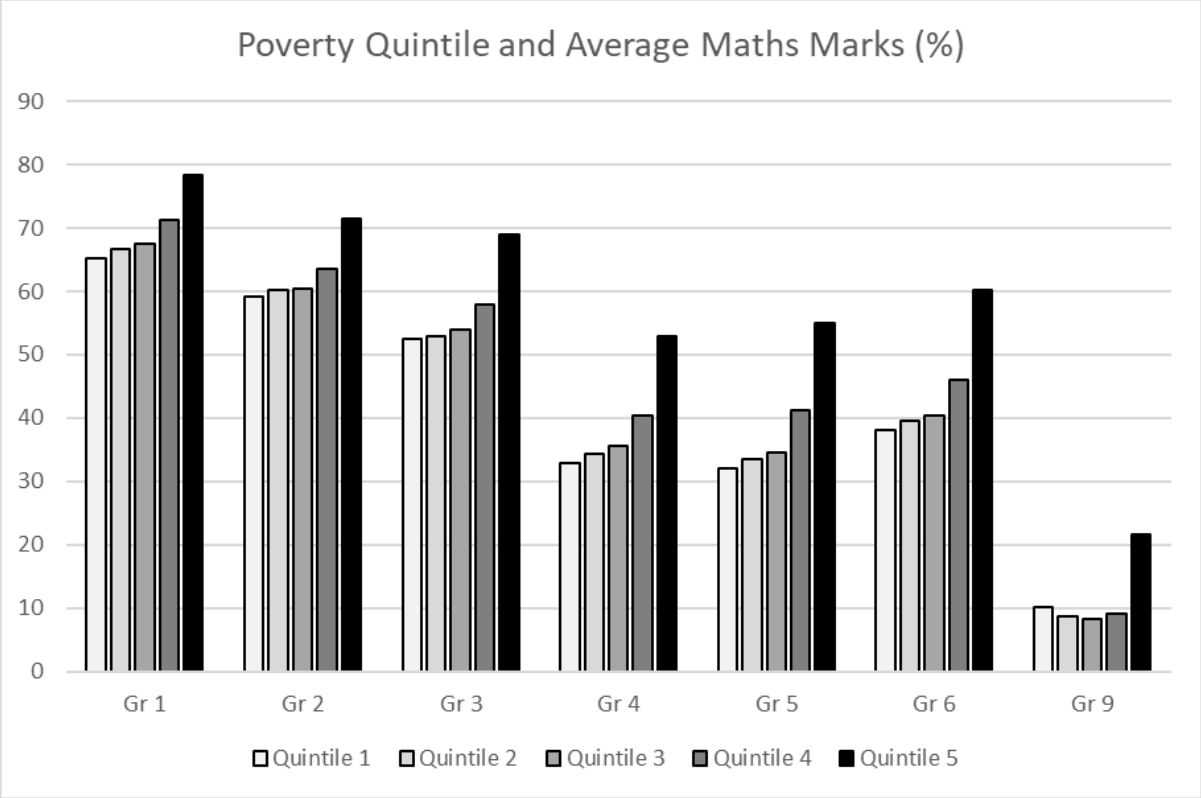
Any discourse on education in South Africa cannot ignore the inequality brought about by the apartheid system. Education was accorded priority status by the government following the end of apartheid. This continues today, as evidenced by the expenditure on education which comprises 6.014% of GDP, higher than both the world average of 4.729% of GDP and the educationally advanced nation of Singapore which is just 2.913% of GDP (World Bank, 2013). The gross enrolment rates in South Africa increased from 21% to 65% in the period from 1999 to 2011 (UNESCO, 2015), which indicates increased access to education; however, this does not seem to have improved the quality of education imparted in mathematics and science, with South Africa positioned last among 148 countries in quality of education in mathematics and science (WEF, 2014, p. 224), a cause for concern considering that mathematics and science education provide crucial skills needed for a knowledge economy.

Thus, it may be concluded that though there is improved access to education as evidenced by increase in gross enrolment rates in schools, provision of quality education, in the critical subjects of mathematics and science, remains elusive.

2.2. Disparities in mathematics performance of learners in South Africa

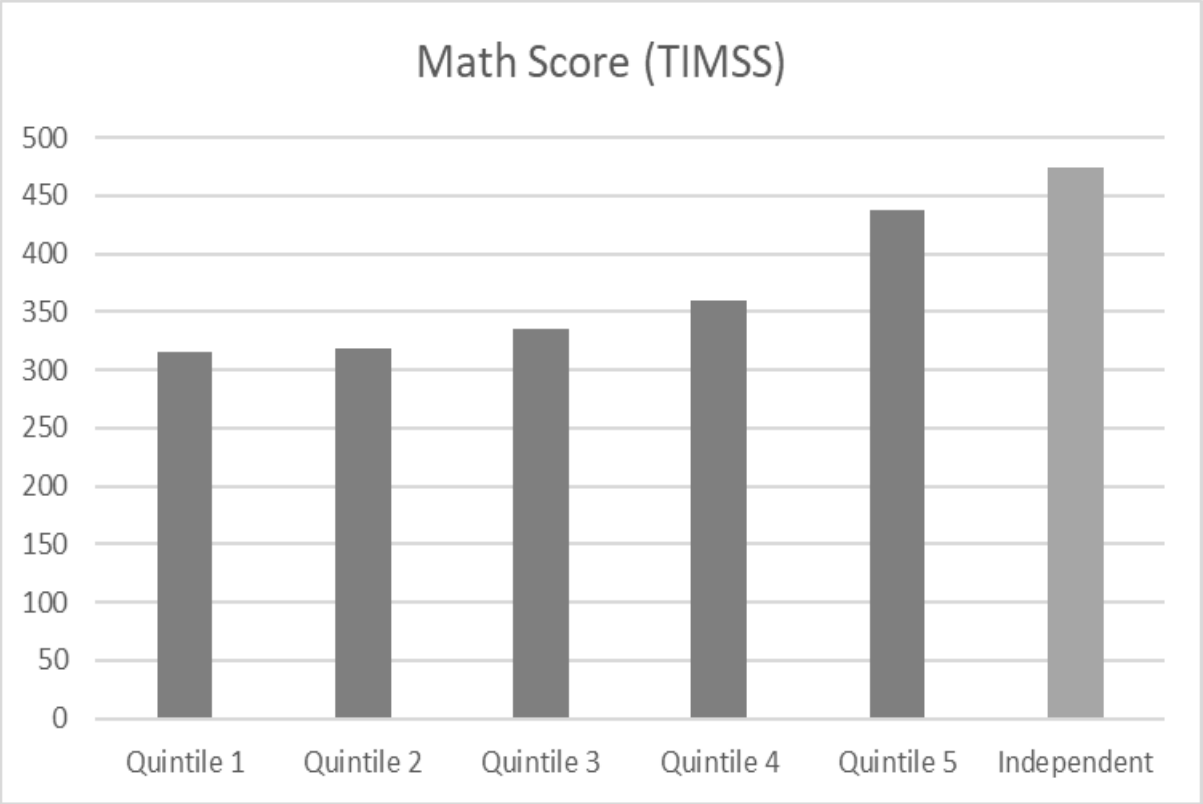
Owing to the wide disparity in the performance of learners from poor schools versus those in wealthy schools in South Africa, the average scores of the benchmarking tests, namely ANAs, SACMEQ and TIMSS, serve as a poor indicator of the nationwide performance (Spaull, 2012; Spaull, 2013a). The learners in the wealthiest school quintiles perform well, albeit underperforming by international standards, compared to the very low performance seen by learners belonging to the lower quintiles, thereby depicting a bimodal distribution of learner achievement when scores are analysed by school quintiles (Spaull, 2013a; van der Berg, 2008). This trend in wide disparities in scores of learners belonging to lower and higher quintiles is evident in the ANA 2014 and TIMSS results, with disparities widening as the grade level increases (DBE, 2014; Reddy et al., 2015) (see Figures 1 & 2).

Figure 1: ANA 2014 mathematics scores (%) by school quintiles



Source: DBE, 2014

Figure 2: TIMSS 2011 mathematics scores by school quintiles



Source: Reddy et al. (2015)

The TIMSS achievement scores highlights this disparity as only 19% of learners at low-quintile schools achieved the lowest benchmark score of 400 or above, as against 60% and 81% for the upper-quintile schools and independent schools, respectively (Reddy et al., 2016b). Between 2002 and 2011, the progress in learners scoring above 400 is only 14.5%, pointing to the lack of acquisition of basic skills in mathematics and science alike (Reddy et al., 2015). The findings of a multinomial logistic regression study by Isdale, Reddy, Juan, & Arends (2017) further reiterates the significant relationship between the scores and the disadvantaged status of the households the learners come. This is evidenced by the finding that learners scoring <350 or between 350 and 400 have high likelihood of attending poorly resourced schools coupled with low socio-economic status of the household (Isdale et al., 2017).

Considering that about 60% of schools (Quintile 1, Quintile 2, Quintile 3) in South Africa cater to the poorest learners (Nyanda, 2014, p. 113), any perceptible change in performance of learners in mathematics in South Africa demands that the performance of learners in low-quintile and poorly resourced schools is prioritised through improving teacher quality and thereby teacher effectiveness.

2.3. Mathematics teacher quality, teacher effectiveness and learner achievement in South Africa

Teachers are fundamental to the determination of school quality as the quality of instruction that they provide directly impacts the learners' performance (Hanushek and Rivkin, 2006). This is especially true in case of learners from poor schools, disadvantaged by paucity of resources, and with learners disadvantaged by poor socio-economic status, who lack parental support at home (Banerjee, 2016). Various determinants of teacher quality have been studied for their relation to learner outcomes. Teacher qualification and experience, teacher tests and teacher certification, have been used as traditional determinants of teacher quality (Hanushek and Rivkin, 2006). With the conceptualisation of Shulman's theory of PCK (Shulman, 1987), teacher subject knowledge, teacher PCK, and teacher classroom practices, and outcome-based measures have been used as measures to determine teacher effectiveness and therefore teacher quality (Guerriero, 2014; Hill et al., 2008).

Teacher effectiveness as a determinant of teacher quality links teaching to learners' learning and emphasises the characteristics of the teacher as reflective practitioners in ensuring that learning process is reflective and ensure learners' learning (Grösser, 2007). Buhl-Wiggers, Kerwin, Smith, & Thornton (2017, p.1) estimated empirically the impact of teacher effectiveness on learner outcomes based on a randomised control trial (RCT) in a school in Uganda. The impact on learner outcomes was evidenced by an increase of 1 standard deviation in teacher effectiveness leading to an increase of 0.14 standard deviation in learner achievement scores (Buhl-Wiggers et al., 2017). All these studies recognise teacher effectiveness as a determinant of teacher quality and that it effects learners' learning positively.

Rivkin, Hanushek, & Kain (2005) assert the effect of improving teacher quality to be more than the effect of reducing class size. This was evidenced by the benefit accrued from just 1 standard deviation increase in the distribution of teacher quality in a school to be more than that accrued from reducing class size by 10 (Rivkin et al., 2005). An American study (How to make a good teacher, 2016) found that the top 10% of teachers impart about three times the learning imparted by the bottom 10% of teachers in a single year of teaching, and if black learners were taught by the top quartile of teachers the achievement gap between black learners and white learners would disappear. Thus, evidence abounds that teacher quality contributes significantly to a learner's learning.

In the South African context, studies by Armstrong (2015) project teacher education and experience as positively impacting on learner performance; however, Maphoso and Mahlo (2015) found that higher teacher qualification has not been found to be related to learner outcomes when comparing qualifications of teachers from low- and high-achieving schools, thus providing a mixed result. Arends, Winaar, & Mosimege (2017), on the other hand, found certain classroom practices, namely teacher collaboration and teacher interaction with learners, to be significantly associated with mathematics outcomes in South African learners. However, Arends et al. (2017) caution against such an attribution, without taking into consideration the dual system of education in South Africa, thereby advocating for more research. Teacher tests, however, have shown much stronger relation to learner outcomes, for instance, Taylor (2011) found that only teachers who answered all the test items correctly showed a positive impact of on learner achievement. Thus, though the South African studies do not present rigorous and consistent evidence on the teacher attributes contributing to learner performance in mathematics, considering that the performance of teachers in teacher tests have shown a strong relation to learner outcomes (Taylor, 2011), teacher knowledge as a determinant of teacher quality is taken forward in this study.

2.3.1. Mathematics teacher quality and teaching crisis in low-quintile schools

Teacher quality has been of concern in schools in South Africa, more so in low-quintile schools. The varying quality of pre-service training, a paucity of teachers in the subjects of mathematics, a subject of critical importance, mathematics being taught by teachers unqualified to teach, lack of CK and PK of teachers, all amplify the crisis in the schools in mathematics teaching in South Africa (CDE, 2013). The present teacher training system is only able to meet one-third of the yearly demand for teachers, which is about 25000 (CDE, 2011, p.21) and much of the teacher population is above the age of 40 (CDE, 2011, p.15). Accentuating this problem is the issue of teachers whose qualifications are in mathematics and hence qualified to teach mathematics but are actually teaching subjects other than mathematics, when there is a general shortage of mathematics teachers (CDE, 2011). For instance, in the Eastern Cape where 16 581 teachers were qualified to teach mathematics, only about 43% of them were actually engaged in teaching mathematics and of these only about 70% had appropriate qualifications to teach mathematics (Deacon, 2010). The poor salaries and the general aversion to taking up teaching as a career in South Africa also acts as a deterrent to attracting talented learners to the profession (Armstrong, 2009). The low-quintile schools experience these issues more seriously

as evidenced by a study in Western Cape (Cape Higher Education Consortium (CHEC), 2009) which reported that Quintile 5 schools have a more teachers teaching core FET subjects (two languages of which one must be a home language, mathematical literacy or mathematics, and life orientation) than Quintiles 1-4 put together, thus highlighting the scarcity of appropriately qualified teachers in low-quintile schools.

Thus, it may be safely concluded that all odds are skewed against low-quintile schools when it comes to being equipped with appropriately qualified teachers and provision of quality teaching and therefore teacher quality. Considering that in poorly resourced low-quintile schools in South Africa, learners come from low socio-economic backgrounds and teachers are the only source of learning support for these learners, it is imperative that teacher effectiveness, and therefore teacher quality, be improved through in-service teacher PDPs.

2.4. Teacher professional development

Ganser (2000) elucidates professional development as a lifelong, continuous process of professional and personal growth of teachers through training of teachers to acquire new knowledge, skills and strategies. This conception of professional development has evolved to new form where professional development refers to the activities and techniques aimed at improving teacher effectiveness by improving teacher knowledge, thereby improving teacher instruction and eventually impacting on improving learner outcomes (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). This conception of PD is based on the evidence that teacher effectiveness contributes greatly to learner achievement (Darling-Hammond & Rothman, 2011). Thus, the transformation in the conception of PD emphasises teacher growth that links with positive learner outcomes. The much newer paradigm of PD, based on constructivism, combines all the features of lifelong learning, and linking to learner outcomes as opposed to the traditional or positivist principles seen in cascading models of PD, which dwell on the transferring of knowledge, rather than the construction of knowledge propounded by constructivism, which values teacher experiences as the foundation of PD (Pitsoe & Maila, 2012).

Thus, it may be concluded that the paradigm shift from perceiving PD as more than just transfer of knowledge to knowledge construction that values teacher experiences signals move to a more contextual approach to teacher PD attuned towards impacting positively on learner outcomes.

2.4.1. Why teacher professional development?

Studies on teacher effectiveness in Africa provide the empirical evidence that teacher training and support could explain the variation in teacher effectiveness with most-effective teachers improving more than the least-effective teachers (Buhl-Wiggers et al., 2017). As evidence abounds on teacher effectiveness as a determining factor contributing to learners' learning (Ding & Sherman, 2006; Heck, 2009), improvement in learners' learning demands commensurate learning opportunities for teachers to make an impact. Matos, Powell, Sztajn, Ejersbo, & Hovermill (2009) assert that new approaches to learning and new theories on how learning occurs, puts new demands on teaching and therefore needs PD to keep teachers on pace with the new approaches. For instance, Jovanova-Mitkovska (2010) assert that teacher PD impacts by changing teacher beliefs and practices to affect learners' learning. Thus, the different theories of how learning occurs thus support the existence of different teacher PD models.

2.4.2. Types of professional development models

Jovanova-Mitkovska (2010) categorised teacher PD into three major models, namely "standardised PTD", "purposeful PTD", and "PTD-Personal development" (p. 2923). The intervention under study fits the definition of "purposeful PD" as defined by Jovanova-Mitkovska (2010), in that it is implemented in schools usually mediated by facilitators with the purpose of improving teacher instruction to ensure curriculum goals are achieved also taking into consideration the context of teaching. Pournara, Hodgen, Adler, & Pillay (2015) acknowledge two approaches to professional development predominantly followed in mathematics PD interventions in South Africa, namely "repair approach" or "conceptual approach"[4] (p. 3). These approaches fit into the training model of PD that focuses on knowledge transmission (Kennedy, 2005) as against the practice-based model of PD that emphasises teachers' participation in practices of teaching (Matos et al., 2009, p. 167). The intervention under study however include both the components that target on improving knowledge

[4] In repair approach the emphasis is on procedural knowledge acquisition in mathematics, whereas in conceptual approach the emphasis is on acquiring conceptual knowledge through engaging in tasks through problem-solving (Pournara et al., 2015).

acquisition namely, content-based workshops and teacher practice, through classroom-based support.

2.4.3. A brief history of teacher professional development in South Africa

De Clercq & Shalem (2014) in a review of the Report of the Ministerial Committee of Teacher Education (DoE, 2005) identified various kinds of PDAs curriculum-driven, Department of Education (DoE)-driven and teacher-driven, and qualification-driven that exists for professional development in South Africa.

The end of apartheid meant that inequities in the ability to implement the new and demanding OBE curriculum C2005 were addressed at the in-service level. The criticism of OBE revolved around its implementation, which did not consider the ground realities of the lack of teacher knowledge and skill (Jansen, 1998). Criticism of OBE also revolved around the lack of a specified curriculum (Hoadley & Jansen, 2009) needed to implement it effectively, thereby finding resistance from teachers implementing it. This curriculum was introduced despite enough evidence of teachers lacking the subject knowledge required to meet the demands placed on them by C2005 (Jansen, 1998). Also, the cascade model of implementing the curriculum-driven PDAs were criticised for diluting the message by the time it cascaded down to the level of the teacher. As the trainers were themselves found to be limited in their knowledge of the OBE curriculum, the C2005 Review Report recommended the need to deepen the knowledge in learning areas, and use of textbooks and learning materials (DoE, 2000). Thus, this too fell short of improving on the subject knowledge of teachers and assessment quality though numerous challenges encountered in mathematics teacher PDPs in South Africa since apartheid also include low CK and PK of teachers (Taylor & Vinjevold, 1999).

Department-driven PDAs focused on teacher knowledge on specific learning areas and teacher-driven PDAs focused on the soft skills of classroom management (de Clercq & Shalem, 2014). However, the training lacked quality and subsequent follow-up (DoE, 2000). The persistent low performance of primary school learners led to the GDE's Strategic Plan for 2009-2014 emphasising the improvement of learner performance in primary schools by improving teacher quality through aligning the GDE system to assist towards improving the learner performance (DoE, 2005). This was to be achieved by redefining the time spent by GDE in schools for monitoring and support, resulting in a reversal of monitoring and support components from 80:20 to 20:80 (Maringe and Prew, 2014, p. 327), to ensure accountability on part of senior

management to improve teaching and learning. Thus, Post-2009 PDAs initiated by Gauteng Department of Education (GDE) focused on teaching and notable PDAs were the CAPS training, the Gauteng Primary Language and Mathematics Strategy (GPLMS) and the Secondary School Intervention Project (SSIP) and for primary and secondary schools, respectively. SSIP and GPLMS were large-scale interventions for under-performing and poorly resourced schools. The key feature of these interventions was the introduction of structured lesson plans (SLPs) (de Clercq & Shalem, 2014). These SLPs were criticised for being highly prescriptive, thereby eroding teacher autonomy with teachers being expected to be mere implementers impeding opportunity for teachers to be creative in keeping learners' learning at the forefront (de Clercq, 2013; Msibi & Mchunu, 2013).

The Integrated Strategic Planning Framework for Teacher Education and Development in South Africa (ISPFTEDSA, 2011-2025) thus outlines a comprehensive plan in order to improve the quality of teacher professional development and teacher education in South Africa, while taking into account the failure of the Integrated Quality Management System (IQMS) in assessing the needs of teachers and therefore teacher development (DBE, 2011).

The mathematic continuous professional development (CPD) programmes were, however, reported as effective in improving CK and teaching skill, teacher collaboration and collaboration with other professionals and the unpacking of challenging topics and therefore gaining confidence for the teachers to go back to the learners; however, the overcrowding and a dearth of resources posed as challenges in mathematics CPD programmes (Kaino et al., 2015).

2.4.4. Continuous Teacher Professional Development (CTPD)

Teacher CPD is widely used all over the world and is considered the most effective approach for in-service teacher development (OECD, 2019). However, in South Africa ineffectiveness of CPD have been expressed by teachers for being disconnected from the needs of the participant teachers (Johnson, Hodges & Monk, 2010). Mokhele and Jita (2010), in capturing the South African teachers' perspectives on The Mpumalanga Secondary Science Initiative (a continuing professional development initiative), argue that CPD are effective only when the teacher context, teacher motivation to participate in the programme align with the CPD intervention. CPD programmes in mathematics have been criticised for lacking content focus, for their short duration, for a lack of focus on instructional methods or pedagogy, incoherence,

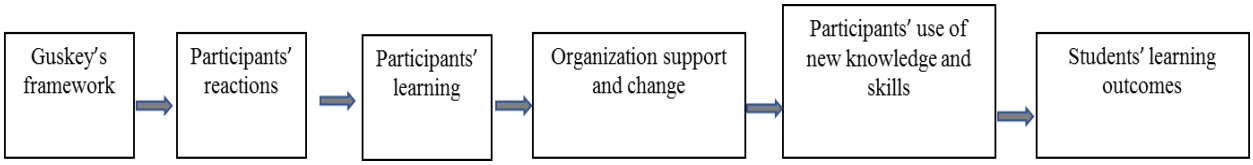
lacking evaluation on its impact, and detached from classroom practice (Nel, 2015). Nel (2015) recommends mentoring, incentivising participants, and increased intervention duration, as some steps towards improving the effectiveness of PDPs in rural areas while creating a conducive environment for developing a community of practice. Since the Ministerial Committee on Teacher Education in 2005, the approach to teacher development in South Africa has evolved from a piece-meal approach to a lifelong learning approach (DoE, 2005). Mtetwa, Chabongora, Ndemo, & Maturure (2015) reiterate that if CPD is to be effective as a lifelong learning approach, the outcomes need to be reviewed continually. However, Welch (2012) argues for context specificity and recommends learning to be viewed as an iterative process instead of as an outcome.

2.4.5. Evaluation frameworks guiding impact studies of teacher professional development programmes

Empirical studies on the impact of teacher PDPs have attempted to establish causality and attribution through linking gain in teacher knowledge to learning gains of learners using RCTs and quasi-experimental designs (Garet, Porter, Desimone, Birman, & Yoon, 2001; Pournara et al., 2015). Though it is universally acknowledged that any teacher PD must ultimately result in better learner outcomes for it to be effective, this approach to establishing causality and attribution of directly linking teacher gains in knowledge to learners' learning outcomes has been criticised for not taking into account the mediating components through which teacher change is effected and the continuum of variables that translates this change in teacher into learner outcomes (Desimone, 2009; Guskey, 2000). Opfer and Pedder (2011) assert the need to account for the complexity of the teacher change and its translation into learner outcomes. King (2014) in setting forth on designing an impact evaluation framework suggest that though this approach may not enable in establishing causality and attribution more clearly, it could provide evidence on how the teacher learning is translated into learner outcomes in a particular context, thereby enabling the design of more effective teacher PDPs. This continuum of change from teachers' participation in the PDP to how change in learner outcomes is achieved has been proposed by various frameworks.

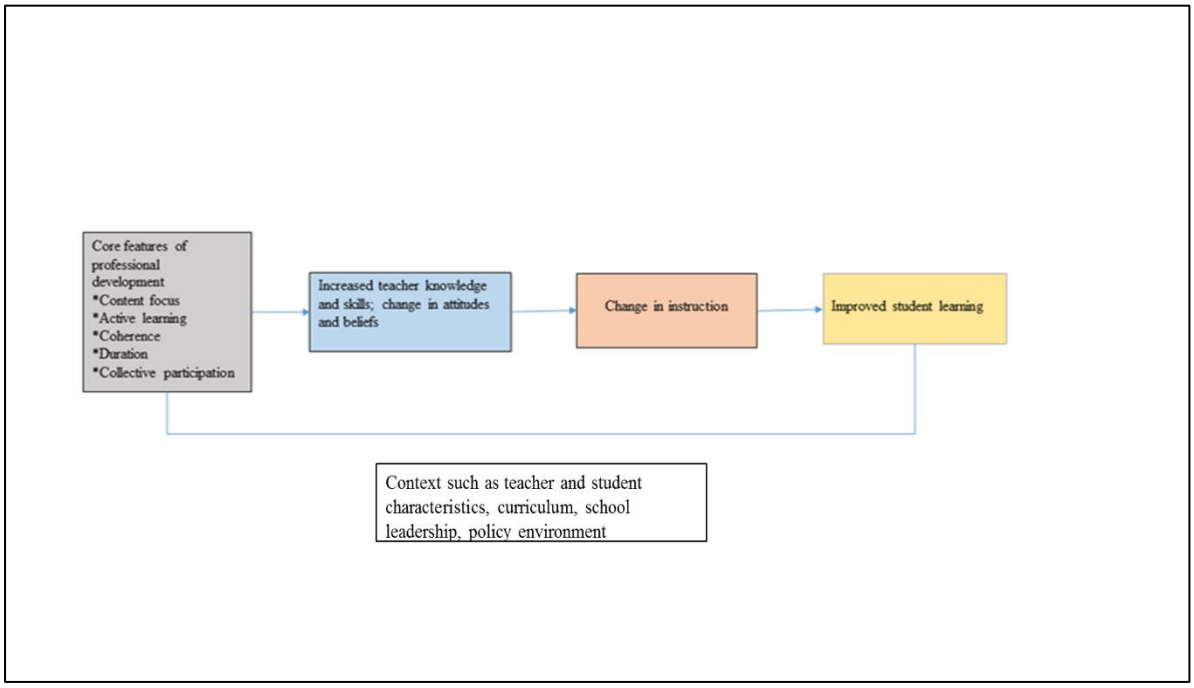
The frameworks for evaluation of teacher PDPs, proposed by Guskey (2000) and Desimone (2009), shown in Figures 3 and 4 below, follow a hierarchy of change in capturing change effected in teachers translating into change in learner outcomes.

Figure 1: Guskey's framework for the evaluation of teacher professional development programmes



Source: Guskey (2000)

Figure 2: Desimone's conceptual framework for evaluating teacher professional development programmes



Source: Desimone (2009)

These frameworks have been refined further by Bubb and Earley (2010) and King (2014). King (2014) compared the evaluation frameworks and suggested a new comprehensive evaluation framework for PD that considers the context of schools as the focus and which includes the salient features of all the frameworks above. A comparison of only Guskey's and Desimone's framework is discussed below, as the most basic frameworks, to arrive at the appropriate framework for evaluating the MTPDP intervention for its effectiveness.

Guskey (2000) proposed five levels as critical to evaluating PDPs. The levels are as follows: Level 1 deals with teachers' general perceptions of the programme design; Level 2 analyses

the acquisition of knowledge as intended by the PDP; Level 3 analyses the organisational factors that supported or enabled the change; Level 4 analyses if the new knowledge and skills acquired have been put into practice by the PDP participants and Level 5 analyses the student achievement outcomes (p. 78). Whereas, Desimone's (2009) framework proposes critical features of the PD as critical to teacher acquisition of new knowledge and skills and thereby leading to a change in attitudes and beliefs of the teacher, ultimately resulting in change teachers' classroom practice evidenced by change in teacher instruction and thereby leading to improved learner outcomes.

Guskey's (2000) framework emphasises the importance of capturing participant perceptions about the teacher PDP first, and argues for the crucial role participant perceptions plays in determining if teacher learning will be translated into practice, contending that if the teacher PDP is not perceived as useful by the teacher, the likelihood that the learning is translated into practice is remote. Guskey's argument (2000) justifies the approach of this study in respect of capturing the teacher perceptions. However, the point at which the frameworks, namely Guskey's (2000) and Desimone's (2009) frameworks deviate is in the components depicted in the continuum of change in translating teacher participation in a PDP into learning outcomes for learners. The major point of deviation is the "organisational support and change" component in the hierarchy proposed by Guskey's (2000, p. 78) framework.

In Desimone's framework (2009), the components in the continuum of change, from the features of PDP enabling teacher acquisition of knowledge to change in teachers' classroom practice, the transformation brought about in the participant, the teacher, is of interest in bringing about the change in learner outcomes. Also, this framework aligns with the objectives of the intervention of improving the teacher knowledge, namely CK and PK of the teacher. Thus, Desimone's (2009) framework serves as the conceptual basis for this research study.

In Desimone's (2009) framework the focus is on the change in the participant, the teacher, and organisational change is not a prerequisite to effect change. Thus, in contrast to Guskey's framework (2000), Desimone's framework (2009) presents an action model with TOC embedded in it, with features of PD enabling acquisition of teacher knowledge bringing about change in teachers' classroom practice by changing teacher attitudes and beliefs, which in turn translate to learner outcomes (Boylan, Coldwell, Maxwell, & Jordan, 2018). This study being a retrospective evaluation, there was no pre-existing TOC defined that guided the intervention under study (Mason & Barnes, 2007). In such a scenario, a theoretical framework of Desimone (2009) that serves as an evaluation framework for analysing the effectiveness of teacher PDPs,

with the TOC embedded in it, served as the conceptual basis for this study against which the effectiveness of the MTPDP could be interpreted. This enabled capturing the teacher perceptions of effectiveness along the TOC continuum, while still considering the context of the study.

The ensuing sections thus deal with exploring each of the components of Desimone's framework as they correspond to answering the research questions regarding the design features of effective teacher PDPs, acquisition of knowledge (CK, PK and PCK), and the final component, namely the change in classroom practice.

2.4.6. Features of effective teacher professional development programmes

Desimone (2009) and Garet et al. (2001) identify core features of teacher PD design that have been found to be effective in impacting on learner outcomes, based on empirical evidence, and are as follows: "content focus"; "active learning"; "coherence"; "duration"; and "collective participation" (p.184; p.916). As core features of the PD form the first component of the Desimone's framework, each of these features are discussed in the below paragraphs in relation to the available literature as it will enable to identify the features that are in sync with those perceived as effective in the MTPDP intervention.

Coherence

Coherence in PDPs relates to the alignment of PDAs with the goal of the school curriculum and with the state education policies and reform initiatives (Desimone, 2011, p. 69). The evidence suggests that coherent PDPs deepen the knowledge in subject areas and influences teaching practice (Firestone, Mangin, Martinez, & Plovsky, 2005; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). However, recently this understanding of coherence has widened to include coherence of PD with teachers' knowledge and beliefs along with state policies (Desimone, 2011, p.69). Evidence based on rigorous studies thus recognises coherence as a key feature of high-quality PD impacting on improving teacher classroom practice and thereby the learner outcomes. Thus, coherence is identified as a key feature of effective PDs and is identified as a salient design feature of the PDP which forms the first component of Desimone's framework for evaluating the effectiveness of teacher professional development programmes (Desimone, 2009).

Challenges to achieving coherence as an essential programme feature include the gap between theory and pedagogic practice. Segall (2002) asserts that if theory and pedagogy are not in

sync, theory remains just some knowledge without effectively translating into learning outcomes for learners (p. 157). This is echoed by Penuel et al. (2007) whose studies in PDPs in science education led them to assert that alignment to state standards by itself is ineffective if explicit guidance is not provided to teachers in structuring instruction with pedagogies that take into account the context of teaching and are directed towards achieving the curricular goals. Desimone & Garet (2015) also emphasise the need for the PD to be in sync with teachers' classroom teaching suggesting that lack of impact seen in some rigorous studies of impact of PDPs may be attributed to the disconnect between the PDP and the teachers' daily classroom practice. This supports the findings by Santagata, Kersting, Givvin & Stigler (2010) who put forward the effectiveness of pacing of instruction in achieving coherence, in reporting that a mathematics PDP, designed in a way such that a PD on a particular concept is immediately succeeded by the teachers delivering it in the classrooms, were found to be significantly effective when teachers' pacing matched with the PD as against when teachers' pacing of instruction did not match with the PD.

Thus, it may be concluded that coherence in alignment of PDPs to state policies is in itself not effective; its effectiveness is realised only when teaching practices and pedagogy are aligned to achieve curricular goals, which are in alignment with the state policies, so that learning takes place.

Content Focus

Desimone (2009) elaborates on "content focus" as the knowledge and skills essential to execute the routine or standard work in the classrooms (p.184). Desimone (2009) and Ingvarson, Meiers, & Beavis (2005) identify content focus as a core feature of effective teacher PD, impacting positively on teachers' knowledge and teachers' classroom practice. Birman, Desimone, Porter, & Garet (2000) also identify "content focus" as indispensable to effective teacher PD, arguing that teachers are expected to have an in-depth knowledge of content if they are supposed to teach to new standards (p. 29). Birman et al. (2000) found a positive relation between the content focus of a PDP and increase in knowledge and skills of teachers. Scher & O'Reilly (2009) provide empirical evidence suggesting that PDPs that focus on content and pedagogy unique to a specific subject are more effective in improving learner outcomes. However, CPTD offered for in-service teachers in South Africa are criticised for being

disconnected from the realities of teaching, for lack of focus on content and pedagogy, and lack of emphasis on teacher collaboration (de Clercq & Shalem, 2014).

Thus, it may be concluded that focus of teacher PDPs on improving teacher knowledge of content and pedagogy to improve teaching practices must be a core feature of teacher PDPs. This should be an essential feature if the teacher PDPs are to improve the teachers' classroom practice and thereby improve learners' learning outcomes.

Active learning

"Active learning" has emerged as one of the core features of effective PD (Desimone, 2009, p.184). Active learning denotes the opportunities afforded to the teacher in a PDP to actively engage in their own learning through making presentations, analysing learner work, reflection and receiving feedback, as opposed to listening to lectures as passive participants (Desimone, 2009; Desimone & Garet, 2015; Garet et al., 2001). Active learning also involves methods that engage in collaborative learning (Niemi, Nevgi, & Aksit, 2016). Considerable empirical evidence on the impact of active learning opportunities in improving professional competence have been presented (Garet et al., 2001; Ingvarson et al., 2005; Niemi et al., 2016). Cordingley, Bell & Rundell (2003) assert that active learning opportunities, perceived as effective by teachers, manifest in teacher practice by affording learners more opportunities for active learning. Teachers engaged in active learning in collaborative CPD were using less "telling" in teaching and focused on learner problems as the learning focus (Cordingley et al., 2003, p.7). However, Webster-Wright (2009) argues that active learning may not itself change practice, reflection on practice must be adhered to for authentic professional learning to occur. Reflection deals with challenging our own assumptions about learning, leading to transformative learning (Mezirow, 1990) allowing teachers to interpret their experiences in the light of new learning and thereby leading to actions that lead to bringing about transformation in practice (Webster-Wright, 2009, p.722).

Thus, it may be concluded that if active learning strategies used in PDPs, there is more likelihood that active learning opportunities will be afforded to the learners by the teacher. Using active learning strategies in PDPs exposes the teacher to a collaborative form of learning.

Sharing ideas and Collaboration

Steyn (2017) identified enhanced professional learning as indicated by participants, with emergence of communication and a sense of responsibility towards learners' learning as crucial outcomes when teachers engaged in collaborative learning (Steyn, 2017). Ronfeldt, Farmer, McQueen, & Grissom (2015) assert that teachers reap both individual and collective benefits when they engage in collaboration that they perceive as helpful and this has positive impacts on learner performance. Collective participation is identified as another core feature of effective teacher PD (Desimone, 2009, p.184), and involves teachers from same grade, or teaching same subject or from the same department participating in the PD thereby enabling them to share instructional practices and engage in active learning (Ball, 1996). Hochberg and Desimone (2010) refer to collective participation as the opportunity afforded by the PDP for teachers from the same school to be exposed to the same learning opportunities. Positive impact of collective participation on teacher classroom practice is evidenced in the empirical studies by Penuel et al. (2007) and Desimone, Porter, Garet, Yoon, & Birman (2002). Burton (2015) recognised that effective teacher collaboration occurs when the teachers share common goals and show positive interdependence, also asserting the role of school leadership in improving the effectiveness of teacher collaboration.

Duration

Duration, as another feature, refers to the duration of the PDA (Hochberg & Desimone, 2010). Empirical evidence points to the positive impact of the length of the PDA on improving teachers' knowledge and classroom practice (Heck, Banilower, Weiss, & Rosenberg, 2008).

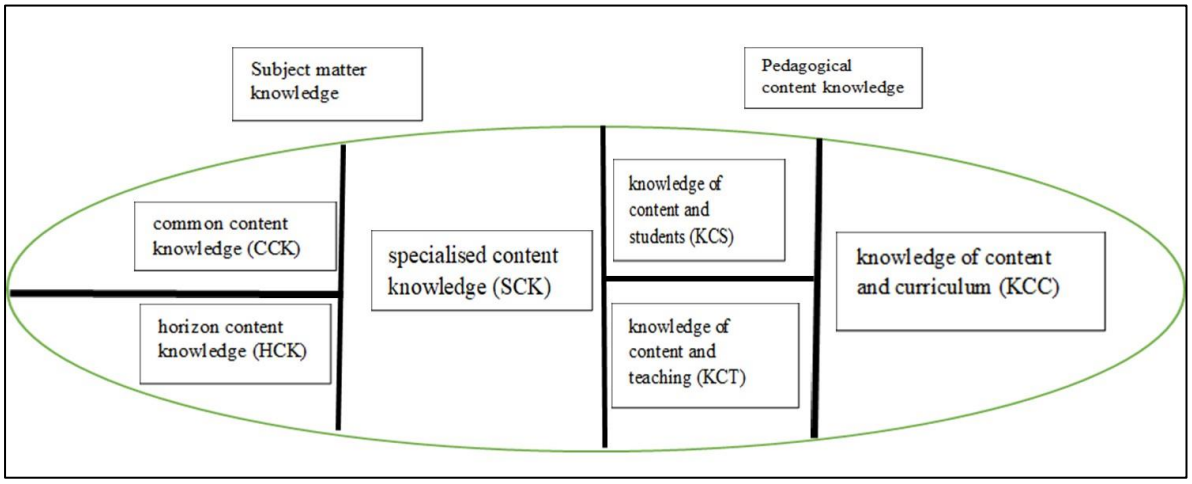
Thus, the design features of coherence, content focus, active learning, sharing ideas and collaboration, and duration of PDPs are indicative of effective PDPs, as empirical evidence on these abound. The design features of the PDP form the first component of the continuum in Desimone's (2009) framework for analysing the effectiveness of PDPs. In capturing the teachers' perceptions of the experiences of participating in the MTPDP, the emergence of these features of PDPs in the teachers' perception of effectiveness of the MTPDP is explored.

2.5. Knowledge of content, knowledge of pedagogy and pedagogical content knowledge

2.5.1. Theory of pedagogical content knowledge

Shulman (1987) proposed that there exists a kind of knowledge that is "an amalgam of content knowledge and pedagogical knowledge that is uniquely the province of teachers" and termed it the PCK (p. 8). Shulman (1987) proposes this knowledge as one that distinguishes a mathematician from a mathematics teacher, for how a mathematician holds knowledge for research is very different from a teacher who holds knowledge with the primary purpose of making it comprehensible for the learner, and this involves understanding why a learner does mathematics in a certain way and also understanding the reason behind the lingering misconceptions in a learners work. This conceptualisation of PCK not only elevated the teacher as a professional possessing knowledge unique to teaching, but also laid the tenets of effective teaching, shifting from teacher-centric to learner-centric practice (de Ponte and Chapman, 2008; Mavhunga, 2016). Shulman's concept of PCK brought about a shift in emphasis away from teacher knowledge per se to how teacher knowledge is altered into a form comprehensible to learners, that is, teacher knowledge for teaching. Empirical studies evidence a positive impact of teacher PCK on learner achievement, especially in context of learners from poor socio-economic backgrounds, in studies in Germany (Krauss, Baumert, & Blum, 2008). Hill et al. (2008) and Ball, Thames, & Phelps (2008, p. 403), based on multiple empirical studies in real classroom settings, arrived at the framework of CK and PCK termed the Mathematical Knowledge for Teaching, depicted in Figure 5.

Figure 3: Mathematical knowledge for teaching



Source: Ball, Thames, & Phelps (2008, p. 403)

The knowledge bases identified as essential for effective teaching included the components of CK categorised as "common content knowledge (CCK)" and "specialised content knowledge (SCK)" and "horizon content knowledge (HCK)" and the components of PCK include "knowledge of content and students (KCS)", "knowledge of content and teaching (KCT)", "knowledge of content and curriculum (KCC)" (Ball et al., 2008). Thus knowledge components of CK with their meaning are described as follows: CCK refers to knowledge of mathematics to be used in everyday situations, commonly held knowledge not related to teaching; SCK connotes knowledge of mathematics specific to teaching; and HCK refers to the knowledge of how mathematics topics are connected across the spectrum of the curriculum. The knowledge components of PCK with their meanings are as follows: KCS refers to the an amalgam of knowledge of mathematics and of students that enable teachers to anticipates student thinking; KCT refers to knowledge of mathematics along with knowledge of mathematical strategies for teaching; KCC, on the other hand, refers to the knowledge of curricular orientations to teaching content and knowledge of its effectiveness.

However, these components seem to be overlapping in terms of knowledge and complexity of the constructs. The Mathematics for teaching (MfT) concept put forward by Adler & Davis, (2006) as the form of knowledge of mathematics which is an amalgam of content knowledge and knowledge of mathematics-specific pedagogy presents a much simpler form for analysing the kind of knowledge acquired.

The second component in Desimone's framework for evaluating the effectiveness of teacher PDPs relates to change effected in teacher knowledge of content and pedagogy. This component also mirrors the primary purpose of the intervention under study, that is to improve the CK and PK of mathematics teachers. The assumption is that any change in CK and PK would have brought about a change in PCK, which is manifested in classroom practice, and therefore will have contributed to learners' learning in mathematics (Shulman, 1987). This research therefore intended to use Mathematical Knowledge for Teaching (Ball et al., 2008) and the Mathematics for teaching (MfT) concept (Adler, 2005; Adler & Davis, 2006) to assist in identifying the knowledge bases that teachers perceive has changed, and if PCK was developed at all. The capturing of teacher perceptions of effectiveness of the MTPDP in effecting change in the kind of knowledge base will be interpreted in light of these concepts which includes all knowledge bases for ultimately effecting change in classroom practice and hence learner outcomes.

2.6. Knowledge of content, knowledge of pedagogy and classroom practice of mathematics teachers in South Africa

2.6.1. State of content knowledge

Empirical studies reveal critical gaps in the CK held by teachers involved in teaching mathematics in South Africa (Taylor & Taylor, 2013; Taylor & Vinjevold, 1999; Venkat & Spaull, 2015). In analysing the knowledge of mathematics teachers in these studies, either the CK is tested for the same Grade band they teach (Venkat & Spaull, 2015) or CK of teachers and students are compared on similar tests (Taylor & Taylor, 2013). Irrespective of the methodology used, the findings point to majority of teachers lacking CK at the Grade level at which they are teaching (Taylor & Taylor, 2013; Venkat & Spaull, 2015). This state of CK of mathematics teachers in South Africa is in stark contrast to the need for strong CK levels, often higher than the grade the teacher is supposed to teach, advocated by Labuschagne (2016). Strong CK is considered as essential for building teacher confidence for effective teaching in the South African context (Labuschagne, 2016).

Classroom observation studies and empirical studies indicate poor knowledge of the subject manifested as errors in the content taught to the learners (Taylor & Vinjevold, 1999), inability to use manipulatives effectively in lessons (Maboya, 2014), inability to identify learner misconceptions leading to learning happening at a superficial level for the learners (Sheinuk,

2010), procedural orientations to teaching as against teaching for conceptual learning (Barnes, 2009; Long, 2005; Mogari, 2014; Sorto & Sapire, 2011).

Critical CK deficits of South African mathematics teachers thus has implications for learner outcomes (Taylor & Vinjevold, 1999) with comparative studies on teacher and learner performance on common tests pointing to learner knowledge as a reflection of teacher knowledge in the South African context (Taylor & Taylor, 2013). This lends credence to the assertion that a learner cannot be expected to have the knowledge that the teacher lacks, thus pointing towards teacher CK as crucial to improving learner knowledge.

Thus it may be concluded, based on the studies discussed above, that evidence points to the teacher subject matter knowledge as fundamental to the effective use of resources in teaching (Maboya, 2014), conveying mathematics (Venkat & Spaull, 2015), ensuring and improving learners' learning (Pournara et al., 2015), and ensuring coherence and connectedness in teaching (Venkat & Adler, 2012), in the South African context.

2.6.2. State of Pedagogical knowledge

Knowledge of mathematics pedagogy has been portrayed as critical, along with subject matter knowledge for effective teaching (Chikiwa, 2017; Taylor & Taylor, 2013). Understanding of pedagogy has evolved to include not only teaching but learning and the teaching contexts all of which interact to impact on learning (Watkins & Mortimore, 1999) indicating its complexity (Lovat, 2003). Lack of pedagogical skill development is seen as a big challenge to ensuring effective teaching (Das, 2015; Popoola & Odili, 2011). Das (2015) advocates for PDPs to address this.

Aligned with the recognition of pedagogy as a complex interaction of teaching, learning and the contexts in which teaching takes place, Anthony and Walshaw (2009) identified ten pedagogical principles[5] as evidenced by the impact on learning, which included knowledge components, learning components. Considering that the MTPDP intervention intended to improve the PK base by improving the knowledge of methods and representations emphasising on the use of manipulatives for teaching, which are akin to "tools and representations"

[5] Anthony and Walshaw (2009) outlined the following pedagogical approaches that promote effective teaching in mathematics classrooms: "ethic of care", "arranging for learning", "building on learner's thinking", "worthwhile mathematics tasks", "making connections", "assessment for learning", "mathematical communication", "mathematical language", "tools and representations", and "teacher knowledge" (p. 148).

suggested by Anthony and Walshaw (2009, p.148). A review of the studies on the use of manipulatives in mathematics teaching is discussed below.

Manipulatives in mathematics teaching in the South African context

Various studies have evidenced the positive impact of the use of manipulatives in mathematics classrooms in ensuring learner engagement (Mpewe, 2016; Naidoo, 2012) and enabling improved learning of abstract concepts (Pietersen, 2006). However, Pietersen (2006) cautions that just using manipulatives by itself does not enhance the learning, the quality of instruction when using manipulatives is a major determinant of effective learning as evidenced by the differences in scores reported in a study on the effectiveness of a numeracy development programme. This supports Clements (1999) findings who cautioned that what matters most is how manipulatives are used for instruction as against if they are used at all. In contrast to the studies that emphasise the effectiveness of use of manipulatives in learning (Clements, 1999; Naidoo, 2012; Pietersen, 2006), Moyer-Packenham (2001) in a study on the use of manipulatives by ten middle grade teachers found that the use of manipulatives was considered a distraction in classrooms where teachers themselves lacked good knowledge of mathematical concepts. This is echoed by Maboya (2014) who argues that the effective use of manipulatives requires the teacher to rely heavily on a strong CK of mathematics. In the South African context, therefore, teacher PD is advocated for effective use of manipulatives in an effort to upgrade the teachers' mathematical knowledge for teaching (Maboya, 2014; Themane & Luneta, 2016). Considering that manipulatives are not by itself have any meaning, Miranda and Adler (2010), in a study of the use of algebra tiles (a manipulative for learning algebra), advocate the need to guide teachers to make mathematical sense of the manipulatives.

A challenge faced by teachers in using manipulatives for effective learning is the gradual move from concrete objects to abstract concepts (Brown, McNeil, & Glenberg, 2009), and a disconnect between the choice of the manipulatives and the mathematical concept that was intended to be taught (Bergtun and Jakobsen, 2016) as evidenced in a study of the use of manipulatives by Malawian teachers. Miranda and Adler (2010) therefore argue that resources being not exuding meaning by itself, the resources need to be adapted to the context to make connections with their mathematical representations, and teachers needed to be guided to convey the mathematical meaning inherent in them.

Thus, it may be safely concluded that the use of manipulatives in and of itself may not ensure effective learning, unless their use is supported by a strong knowledge base on the part of teachers and teachers can make sense of the manipulatives in a mathematical way.

Considering that teachers in the MTPDP intervention were trained to use manipulatives for mathematics instruction in classrooms, the literature reviewed serves as a background to explore the teachers' perceptions of effectiveness vis-à-vis the adoption/non-adoption of use of manipulatives for mathematics instruction in classrooms in the context of Quintile 2 schools.

Pedagogical content knowledge manifested in classroom practice

Li and Oliveira (2015), frame "classroom practice" as a process involving actors and their interactions in the classroom working together as a system (p. 489). Research on classroom practice has revolved around instructional practices (Gencturk, 2012; Sinay & Nahornick, 2016), curriculum implementation (Kapenda, 2008), and teacher interaction with learners in the classroom context (Anthony & Walshaw, 2009; Brendefur & Frykholm, 2000). Kim (2004), Gess-Newsome (1999) and Tambara (2015) acknowledge that the PCK of teachers is seen as manifested in teachers' classroom practice. Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu (2008) and Davidonwitz & Rollnick (2011) further identified PCK as manifested in the use of representations, "curricular saliency", use of topic-related instructional strategies and learner interactions in science classrooms in South Africa (p. 5). The PCK Summit Consensus Model suggested by Gess-Newsome and Carlson (2013) places emphasis on teacher beliefs and prior knowledge as essential factors influencing the transformation of the teacher knowledge into classroom practice. Toerien (2013) used this model to analyse teacher classroom practice in regard to the manifestation of teacher knowledge and PCK. This model is probably more relevant in the context of South African Quintile 2 schools, in which the majority of the mathematics teachers do not possess subject-appropriate qualifications to teach mathematics (CDE, 2011), and mathematics teaching is embedded in traditional beliefs (Adler, 1997; Deacon & Parker, 2009). This demands that any reform-based PDP contributes to transforming the teacher beliefs from an instrumentalist view of mathematics to the problem-solving, dynamic view of mathematics (Ernest, 1989).

Adler (2017) proposes a framework, the Mathematical Discourse in Instruction (MDI), as a planning or reflection tool to enable effective mathematics instruction that is presented as a continuum of connected concepts thus ensuring that mathematics is available for learning (p.

129). MDI recommends the choice of proper representation for solving a problem and then subsequent manipulations across multiple representations, using transformational activity to establish connections (Adler, 2017). Venkat & Adler (2012) in emphasising the need to establish connections between problems and the chosen representations caution that the consequence of the lack of connections is the lack of meaning-making for most of the learners. Venkat (2010) also points to the linking of mathematics to everyday problems as enabling to establish mathematical coherence in instruction. Thus, it may be safely derived that the emphasis on meaning-making of mathematical instruction for learners requires connectedness in mathematics instruction.

The low performance of mathematics teachers in tasks set at higher cognitive level, led Bansilal, Brijlall, & Mkhwanazi (2014) to recommend scaffolding[6], to move teachers performing at the action level of a concept to process or object level of understanding of a concept, based on Action-Process-Object-Schema (APOS) theory (p. 48). This was recommended considering the low level of engagement with the concept at hand by teachers, usually just at the procedural level. Bansilal et al. (2014) therefore argue that the expectation that such a teacher will be able to identify the interventions needed to address learners' learning needs is flawed. In the context of poorly resourced schools, the orientation of classroom teaching towards information acquisition, rather than developing higher-order cognitive skills, is being raised as a concern since 1990 (Diphofa,1997). The poor conceptual knowledge of teachers and errors in teaching content, identified consistently in studies carried out as part of the PEI (Diphofa, 1997), is still found in the classroom observation studies till today (Hoadley, 2016).

The third component of Desimone's framework for evaluating the effectiveness of teacher PDPs thus relates to the change in classroom practice. The knowledge is manifested in the classroom practice as PCK which is evidenced in classroom instruction. Thus, change in classroom instruction demands change in CK, PK and therefore PCK.

[6] Scaffolding is defined as a "temporary, intentional and responsive support that assists learners to move towards new skills, concepts, or levels of understanding" (Gibbons, 2002, p. 15-17).

2.7. Teacher perception studies and teacher professional development programmes

2.7.1. Teacher perception studies: Purpose

Studies on teachers' perceptions have been used to analyse the effectiveness of teacher PDPs (Fennessy, 1998; McGee et al., 2013; Smith, 2015; Steyn, 2010; Williams, 2014), develop instruments to assess self-awareness of teacher CK (Bukova-Güzel, Cantürk-Günhan, Kula, Özgür, & Elçi, 2013; Fennessy, 1998) and PCK (Fennessy, 1998; Bukova-Güzel et al., 2013), to assess how the prevalent theoretical frameworks of knowledge base of teachers connect to practice (Koh, Chai, Hong, & Tsai, 2015), and also to assess the effectiveness of PDPs based on new models of teacher learning (McGee et al., 2013; Ndlovu, 2014).

Teachers' perception of effectiveness was captured for the interventions aimed at increasing teacher knowledge based on specialised pedagogy (Ndlovu, 2014; Smith, 2015) or interventions such as introducing a new curriculum (McGee et al., 2013) or existing interventions such as the in-service training and CPTD programmes in South Africa (Fennessy, 1998; Steyn, 2010). Perception scales have been developed by capturing teacher perceptions to explore how PCK is perceived by teachers (Bukova-Güzel et al., 2013) and also to explore how constructs such as TPACK frameworks is perceived by teachers as manifesting in practice (Koh et al., 2015) so that PDPs can be designed more effectively for teachers.

All these perception studies limited themselves to exploring the perceptions of teachers related to the objective of the intervention. However, the teacher perception studies by McGee et al. (2013), Nel (2015), Rimbey (2013), Smith (2015), and Warnasuriya (2014) captured the teacher perception of effectiveness of a PDP vis-à-vis the whole continuum of change, from teacher experience of participation in a PDP to knowledge acquisition by the teacher and the resulting change in classroom practice. McGee et al. (2013) captured teachers' perceptions of the impact on the teaching, learning and the change in classroom practice, as it relates to mathematics PD. Warnasuriya (2014) explored the teacher perceptions of impact on knowledge and skills following participation in a PD programme, in the context of addressing poor-performing learners. Thus, these studies that capture the teacher perceptions of effectiveness on a continuum of change are of interest as they assess the effectiveness of the PDP interventions in acquisition of knowledge, and in changing in classroom practice, which is in sync with this study.

The perceptions studies that capture the teacher perception of effectiveness of a PDP vis-à-vis the whole continuum of change, from teacher participation in a PDP to knowledge acquisition by the teacher and the resulting change in classroom practice, are scarce in the South African context. This study addresses this knowledge gap by using Desimone's (2009) conceptual framework for evaluating the effectiveness of teacher PDP, to explore how this pans out in the context of Quintile 2 schools in the South African context. Therefore, the three components that are explored for capturing the teacher perception of effectiveness of the MTPDP are the design features of the MTPDP, knowledge acquisition, and change in classroom practice.

2.7.2. Teacher perception studies: Findings

The perception studies of interest to this study are those that assesses the impact or effectiveness of the PDP interventions, and hence the findings of the studies by McGee et al. (2013), Nel (2015), Rimbey (2013), Smith (2015) and Warnasuriya (2014) are discussed below.

The findings of the studies on teacher perceptions of the respective PDs manifested as changes in teachers' knowledge and in teachers' classroom practice, as the proximal outcome, and learner achievement as the distal outcomes. The impacts on teacher outcomes on participation in PD have been consistently positive; however, in these studies no impact on learner outcomes were seen. For instance, Rimbey (2013) and Nel (2015) reported positive impact of PD on teachers' knowledge, positive impact on teachers' classroom practice but no impact on learner outcomes, thereby concluding the PD programme as only partially effective. This research study limits itself to capturing teacher perceptions in the continuum of change only upto change in classroom practice component of Desimone's framework and hence effectiveness of the MTPDP will be concluded based on teachers' perceptions of change in classroom practice, the final component in the continuum of change in the conceptual framework guiding this research study.

The major themes that emerged in these studies revolved around 'transformation'. Ross et al. (2011) report that coding of the data revealed that the teachers believed that they had transformed their 'habits of mind' in both leadership and teaching. This transformation as related to teaching manifested as shift to an inquiry-based orientation to teaching and their recognition of themselves as autonomous professionals (Ross et al., 2011). Transformation was also seen in shift in the perception of student learning as an individual responsibility to a

communal responsibility (Ross et al., 2011). In nutshell, the transformation manifested itself in both teacher thinking and teacher practice. Transformation as related to classroom practice also included perceptions of change in dispositions towards PD comprising of the emergence of following themes: positive shift in beliefs of the capabilities of at-risk students, enhanced optimism of the teacher efforts on teaching at-risk students, intention for participation in more professional development programmes (Warnasuriya, 2014). McGee et al. (2013) on the other hand indicates the ease of implementing the curriculum, as influencing teacher beliefs thereby influencing classroom practice. Thus, change in teacher beliefs emerged as an important aspect of the transformation theme in influencing positively on classroom practice. Nel (2015) identified transformation as a shift from traditional pedagogy of 'talking' to 'involving the learner', that is shifting towards facilitation. Shifts to learner-centred teaching, active learning, collective participation and collaboration were perceived as effective by the participants (Nel, 2015). The theme 'transformation' thus has emerged in the coding of data of all PDPs in various ways. Thus, emergence of this 'transformation' theme if seen in this research study thus may be construed as indicative of the MTPDP effectiveness.

The themes that emerged as regards teachers' perceptions of acquisition of new knowledge related to in-depth understanding of mathematical concepts alongwith the ability to establish connections of concepts with everyday life, improved knowledge of pedagogy, knowledge updation as regards curriculum and instruction, and enhanced awareness of curriculums of countries excelling in mathematics (Warnasuriya, 2014). The themes that emerged regarding teacher perception of enhancement of teacher skills comprised ability to apply a wide repertoire of instructional strategies to address the needs of learners with varied learning styles, enhanced ability to use technology to improve learning, teacher collaboration and integration across subjects. McGee et al. (2013) on the other hand identify learning of content and pedagogy as effective in improving knowledge and skills.

The major themes that emerged as regards teachers experiences with PD in the study by McGee et al. (2013) highlighted "teachers as learners" and "teachers as self-evaluators" (p. 21). Active learning, collective participation and collaboration were identified as effective features of the PDPs by both Warnasuriya (2014) and McGee et al. (2013).

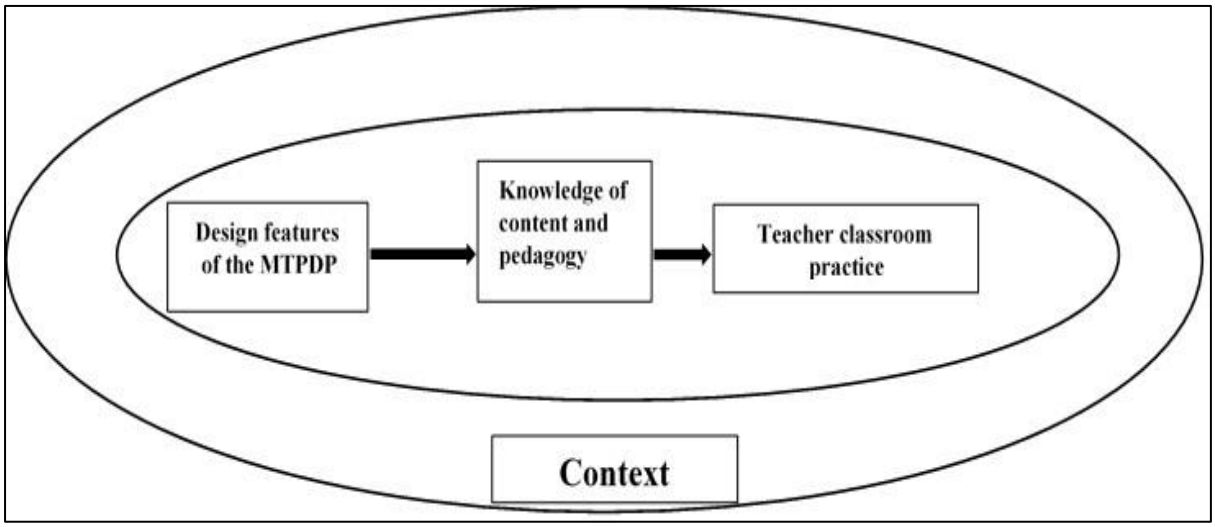
The emerging themes/sub-themes in all these studies signify the effectiveness of the PDPs as perceived by teachers vis-à-vis the effectiveness of the design features of the PD, the effectiveness of the PD in improving teacher knowledge and thereby the teacher classroom

practice. These emergent themes will be interpreted against the themes emerging from the present research study to establish the effectiveness or ineffectiveness of the MTPDP.

2.8. Conceptual framework

A visual representation of the conceptual framework is depicted in Figure 6 below. The conceptual framework for this study mirrors the components of Desimone's framework for evaluating the effectiveness of teacher PD. The first component of this conceptual framework is concerned with the design features of the MTPDP, which enable the acquisition of knowledge of content and pedagogy. The acquisition of knowledge of content and pedagogy, which is the second component of the conceptual framework, also mirrors the purpose of the MTPDP, namely, to improve the CK and PK. The third component depicts the ensuing change in classroom practice effected by the earlier two components. The teacher perceptions of effectiveness of MTPDP as regards each of these components is explored. All these components are explored in the context of low-quintile schools in South Africa.

Figure 4: The conceptual framework for this study



The conceptual framework as it relates to the research questions is discussed below. The overall teacher perception of the effectiveness of the MTPDP was captured through first capturing the teacher experiences of participation in the MTPDP vis-à-vis exploring the critical features of the MTPDP intervention design that teachers perceived as effective in an in-depth way, aided

by the sub-research question 1 (SRQ1). Desimone's framework presents an action model or TOC and therefore the teachers' perceptions of the effectiveness of the design features of the MTPDP in enabling teachers to acquire knowledge of content and pedagogy is explored vis-à-vis the second sub-research question, SRQ2. The teachers' perceptions of the effectiveness of the MTPDP intervention in changing classroom practice, enabled by the acquisition of new knowledge of content and pedagogy, is explored vis-à-vis sub-research question 3 (SRQ3). Thus, the three major components of the conceptual framework explored with regards to teacher perception of effectiveness include 'design features of the MTPDP', 'acquisition of knowledge of content and pedagogy' by the teacher and the impact on 'teacher classroom practice', all explored in the context of Quintile 2 schools.

3. RESEARCH METHODOLOGY

Chapter three elaborates the research methodology, which encompasses the research approach, the procedure and the methods, all in alignment, to accomplish the objective of answering the research questions. Section 3.1. introduces research methodology as a concept and Section 3.2. analyses the research approaches to find the best fit of the approach for this research. Section 3.3 highlights the research design guided by the literature review of similar studies, presented in Section 3.2. Section 3.4 interrogates the research methods detailing the methods and procedures for conducting the research, including validity, reliability and ethical considerations.

3.1. Research methodology

Research methodology is recognised as encompassing the component elements of research approaches, research design and methods used to scrutinise any research problem in a methodical way (Keeves, 1997). Research methodology is also interpreted as connoting the "rules and procedures" that are used to direct research which serves as a framework against which the findings of the research can be gauged (Miller and Brewer, 2003, p. 192). Thus, research methodology is seen as a systematic activity consisting of logical steps or processes undertaken to answer the research problem. Thus, research approaches, research design and methods used in this research study to answer research questions with validity and reliability are discussed in the following sections .It thus serves to define the logic and how the approaches and methods come together to answer a research problem (Kivunja & Kuyini, 2017).

3.2. Research approaches

Creswell (2014) recognises research approaches as plans for research emanating from/guided by the philosophical assumptions held by the researcher, leading to decision-making on data collection methods, data analysis and subsequent interpretation of data. Creswell (2014) thus advances three research approaches, namely, "quantitative", "qualitative", and "mixed method" (p. 4). Neuman (2007) and Bryman (2012) prefer to recognise only two approaches, namely qualitative and quantitative approaches, owing to the distinctiveness of the two

approaches. Neuman (2007) while not recognising mixed method approach puts forward the argument that a mixed method approach has implications on practice because of its complexity and time-consuming nature. The broad approaches of quantitative and qualitative research are discussed in Sections 3.2.1 and 3.2.2 for arriving at the research approach that fits this research study in terms of addressing the research problem. The fit of the research approach for this research study is elaborated in Section 3.2.3.

3.2.1. The nature of quantitative research

Quantitative research is a research approach that uses empirical data. Variables relating to the phenomenon under study are quantified and analysed using methods in statistics to test if the theory supports the phenomenon under study (Creswell, 1994). Quantitative research is thus informed by a positivist epistemology[7], emphasising the analysis of causal relationships between variables (Bryman, 2012; Creswell, 2014). Bryman (2012) and Patton (2002) put forward that the problem with use of deductive approach[8] is that it tends to ignore the experiences of the participants, and therefore the meaning that participants make of the phenomenon under study are not taken into account and thereby largely ignored.

3.2.2. The nature of qualitative research

Qualitative research is a research approach that emphasises studying phenomena in their real setting and therefore interpreting the phenomena based on the meanings people make of it (Denzin and Lincoln, 1994, p.569). Thus, qualitative research is guided by a paradigm that is interpretivist in nature (Mason, 2002). Qualitative research thus allows for in-depth exploration while trying not to restrict the responses of participants to a predetermined set of expected responses, thus enabling flexibility in responses and thereby increasing the face validity (Guest, Namey, & Mitchell, 2013).

[7] Positivist epistemology also referred to as "Positivism" is a theory with philosophical underpinnings that considers valid knowledge as that validated by the senses and hence supports the use of methods of scientific research to social research, thus emphasising collection of facts (Bryman, 2012, p.27).
[8] Deductive approach refers to a process in which theory and the hypotheses derived from it drives data collection.

3.2.3. The fit of qualitative approach over quantitative research approach for this perception study

Quantitative research approaches have been used in perception studies to capture the teacher perceptions using Likert-type scales for studying the effectiveness of PDPs (Koh et al., 2015; McGee et al., 2013). Ryan, Coughlan, & Cronin (2009) point out that this approach presumes a fixed set of responses and does not provide the space for unthought of responses. Also, the small sample sizes covered in this qualitative research study, hinder a quantitative study as low sample sizes make generalisations of the findings to the whole population problematic (Delice, 2010; Mason, 2002).

Quantitative impact studies of teacher PDPs designed to improve teacher CK and PK have tried to establish causality and attribution by trying to capture change in teacher knowledge using change in pre- and post-test teacher scores and using regression techniques and hierarchical linear modelling (Gess-Newsome et al., 2011; Kisa, 2014). These techniques are a better fit because of the clustered nature of data in education interventions, with learners clustered within classrooms, classrooms within schools, teachers within classrooms etc. (Gess-Newsome et al., 2011; Kisa, 2014). Empirical studies on the impacts of a teacher PDP on learner outcomes first explore the impact on the proximal outcome, that is, the teacher outcome, and later on attempts to establish causality or attribution of the proximal outcome to the distal outcome, namely learner achievement outcome, all guided by the TOC framework (Kisa, 2014; Schneider & Meyer, 2012; Taylor, Roth, Wilson, Stuhlsatz, & Tipton, 2016). This has been a prevalent quantitative research methodology in prospective evaluations (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

Concurrent mixed-method studies, however, find favour in the impact/evaluation studies of PDP interventions owing to the collection of quantitative and qualitative data simultaneously, thereby enhancing the credibility of research findings by compensating for the weakness of one type of data which gets nullified by the other (Creswell, 2012). Concurrent mixed-method approaches have dominated teacher perception studies of PDPs (Ndlovu, 2014; Ravhuhali, Kutame, & Mutshaeni, 2015). Ndlovu (2014), for instance, used a qualitative methodology for exploring the usefulness of the TPL as perceived by teachers and a quantitative methodology was used to test for gain in knowledge. Ravhuhali et al. (2015) initially used a survey design to encapsulate the perceptions of a large teacher population followed with the use of a qualitative study to explore in an in-depth way the teachers' perceptions of a CPD programme. Rimbey (2013) used a mixed-method study that included both quasi-experimental designs and

qualitative methods that included observation and semi-structured interviews. Smith (2015) used a concurrent mixed method study that involved both a quantitative component that analysed the change in learner test scores and a qualitative component, a survey design, that was used to capture the teachers' perceptions on change in teachers' classroom practice and teachers' attitudes.

Comparative designs, like historical cohort control designs, are being used where historical data can be accessed (Stockard, 2011; Walser, 2014).

Retrospective evaluations, such as this study, face the challenge of missed opportunities in data collection and hence teacher experiences of participation in the intervention are of interest in evaluating the intervention which dictates that qualitative methods of inquiry are resorted to (Lichtman, 2013). Therefore, a qualitative perceptions study is being carried out to explore teacher perceptions of effectiveness of the MTPDP in evaluating MTPDP. Steyn (2010) used only an in-depth explorative approach to studying the perceptions of teachers of CPD programmes in South Africa as it intended to put forward the lived experiences of the teachers, thus positioning the study in an interpretivist paradigm. This perception study thus situates itself in an interpretivist paradigm, which affords the researcher the opportunity to capture the teacher perceptions through the perspective of the lived experiences and participants' perceptions in addressing the research problem (Thanh & Thanh, 2015). Interpretivists, as Thomas (2003, p. 6) puts forward, depict a world in which reality is seen based on what meanings people make of it, accommodating the complexity and the transient nature of reality. Interpretivists, thus, predominantly apply qualitative methods (Nind & Todd, 2011; Willis, 2007).

It may be concluded that even though concurrent mixed methods are the most favoured for studying PD effectiveness to improve the validity of the findings in perception studies, owing to resource and time constraints a purely qualitative interpretivist case study design was followed.

3.3. Research design

Research design serves to provide the structure for collecting and analysing data and is dictated by priorities set in the research process (Bryman, 2012, p. 46). Creswell, Hanson, Clark and Morales (2007), identify many research designs associated with qualitative research:

"phenomenology"; "ethnography"; "case study"; "grounded theory"; and "participant action research" (p.1).

As qualitative research approach has been decided as the best fit of the research approach for this study, a research design that allows for in-depth exploration of the problem at hand is demanded. As case study design serves to explore a problem in real-life settings (Yin, 1984) and is embedded in the context of the study (Stake, 1995), a case study design aligns with the research process followed in this study. In contrast to experiments which detach from the context (Zaidah, 2007), the advantage of the case study lies in being embedded in the context of study (Stake, 1995; Yin, 1984), allowing for the use of multiple sources for gathering evidence (Yin, 1984).

As this study involved an in-depth exploration of the teachers' perceptions as regards the effectiveness of the PDPs and studied a small sample of participating teachers, a case study design is the best fit for this study.

The bounded entity of analysis in this case study were the active teacher participants of the MTPDP, which are the teachers from four Quintile 2 schools in Ivory Park, a township in Gauteng Province of South Africa. Owing to the interpretive nature of this study, where the emphasis is on the meanings the teacher participants make of the experiences of participating in the MTPDP intervention, the design is an interpretive case study.

3.4. Research method

3.4.1. Data collection and analysis

Qualitative component of mixed-methods studies and qualitative studies itself have used varied data collection instruments. Semi-structured interviews (Rimbey, 2013; Ross et al. 2011; Warnasuriya, 2014), interviews (McGee et al., 2013); classroom observations (McGee et al., 2013; Rimbey, 2013); field notes (McGee et al., 2013; Rimbey, 2013) have been used in teachers' perceptions studies of impact. These methods have been used either alone or in combination. Ross et al. (2011) and Warnasuriya (2014) used only semi-structured interviews whereas Rimbey (2013) used semi-structured interviews alongwith field notes as the qualitative component to provide support to the evidence generated by quantitative studies for classroom practice. McGee et al. (2013) used multiple qualitative instruments, namely participant interviews, field notes, leadership logs and classroom observations to collect data.

The present study being akin to summative evaluation of a retrospective nature, along with constraints to accessing data leaves semi-structured interviews as the only means available for exploring the teachers' perceptions of effectiveness of the MTPDP.

Observations, interviews and focus groups are the commonly used methods of data collection in qualitative research (Guest, Namey, & Mitchell, 2013). Interviews are of three kinds: "structured", "semi-structured", and "unstructured" (Bryman, 2012, p. 472). Structured interviews are administered verbally with predetermined questions and therefore provide little freedom to delve on questions that may need further elaboration and probing (Edwards & Holland, 2013; Gill, Stewart, Treasure, & Chadwick, 2008). On the other hand, unstructured interviews, owing to the lack of a questionnaire, are recommended only in instances where nothing much is known about the phenomenon under study (Edwards & Holland, 2013). Semi-structured interviews provide flexibility by allowing for structured questions to diverge as and when it needs elaboration or in-depth probing (Gill et al., 2008; Given, 2008).

This report presents an in-depth study of perceptions of effectiveness of an intervention, and therefore a semi-structured interview method served the purpose better as it allowed for flexibility to diverge when the situation demanded in-depth probing (Gill et al., 2008; Given, 2008). Thus, this semi-structured interview speaks to the "descriptive/interpretative typology" of semi-structured interviews where the purpose is to discover the meanings participants, as the information providers, confer to the understanding of the effectiveness of the MTPDP (McIntosh & Morse, 2015, p.3). Thus, semi-structured interviews were used to collect data for this study. Open-ended questions were subsequently followed by probing questions to get an in-depth account of the perceptions and the meaning of effectiveness the participants make of the experiences of participating in the MTPDP (Creswell, 2014). The interview guides used by the researcher for interviewing programme participants and facilitator, are presented in Appendix B and Appendix C, respectively.

Inductive analysis was used to arrive at themes for all the qualitative component of concurrent mixed-method studies (McGee et al., 2013; Rimbey, 2013) and qualitative studies (Ross et al., 2011; Steyn, 2010; Warnasuriya, 2014).

The interview data was analysed using the method put forward by McCracken (1988). In line with the method proposed by McCracken (1988) the interview was transcribed and note making was carried out on the margin and the relevant information was sieved from non-relevant information. The observation from the first stage was categorised into "descriptive" and

"interpretive" categories based on the research questions guided by Desimone's (2009) conceptual framework guiding this research. The coding of observations from the first stage served as the data for the second stage of analysis. In the third stage, the codes were analysed for connections and patterns. The codes were then assimilated into themes, which formed the fourth stage of interview analysis. Finally, the predominant themes that emerged for answering each of the research questions were analysed and was the last stage of analysis.

3.4.2. Procedure for conducting the interviews

Permissions were sought from participating teachers and principals of participating schools using a consent form that they were requested to sign. Participant consent for recording the interviews was also obtained through the consent form. The interviews were recorded using a recording device. Face-to-face interviews with each teacher were conducted individually. Each interview session lasted for 30-40 min, totalling three interview sessions with each teacher. The interviews were conducted in the school premises in a separate room. The interview times were pre-scheduled with the Head of the Department of Mathematics, who were the gatekeepers (Miller, 2000), based on the convenience of teachers, so that they were not interrupted in carrying out their duties at the school. The interview guide served as a reference for the questions to be asked.

Before beginning the interview, the teachers were first informed of the purpose of the interview (McNabb, 2013) and were asked to fill in a participant profile form, which is attached in Appendix A. Participants were assured of confidentiality and were therefore asked to use a pseudonym when completing the participant profile forms (Given, 2008). The first two interviews with each participant served to test the interview guide and to identify any missing questions that were relevant to the context (McCracken, 1988). In the first interview sessions the teachers were a bit uncomfortable and required repeated assurance of confidentiality. The purpose of the interview was presented to make them comfortable (McCracken, 1988). A brief introduction of the broad area on which interview will be based was provided (McCracken, 1988). However, from the second interview onwards they had settled in and were comfortable sharing their perceptions. The last interview was a summing up session that included all the components raised in the first two sessions. This allowed the researcher to check if any contradictory responses might have emerged and provided an opportunity to ensure that interview responses were not misinterpreted.

Qualitative studies by Ross et al. (2011) used triangulation to improve the credibility of the research by interviewing both the principal and the participants and using an iterative mechanism to remove inconsistencies, thereby adding credibility to the research findings. The present study interviewed both the participant teachers and the facilitator and triangulated the findings to add credibility to the research findings.

3.4.3. Sampling in qualitative research

In qualitative research nonprobability sampling is used as against random sampling in quantitative research (Bryman, 2012). Random sampling allows the possibility of generalising the findings to a population; this generalisation is not possible in nonprobability sampling (Bryman, 2012). The nonprobability sampling thus involves selecting the sample with the sole purpose of answering the research question and is also referred to a purposive sampling (Bryman, 2012; Neuman, 2007).

Because this study intended to evaluate the perceptions of teachers of the effectiveness of the MTPDP, it required that the sample participants have been regular participants in the MTPDP activities, namely content-based workshops and availed classroom-based support provided by an MTPDP facilitator. Participants who recorded at least 80% attendance in the MTPDP workshops were thus purposefully chosen to participate in this study. Once the participant fulfilled this criterion, consent was sought from the teacher participant to ascertain his/her willingness to participate in the interviews, which formed the next level of the criteria for deciding on the sample. Thus, this study resorted to purposive sampling (Bryman, 2012).

3.4.4. Sample size

The concept of data saturation is applied in arriving at an appropriate sample size in all qualitative studies (Bryman, 2012). This means that data is collected until no new themes emerge, also referred to as “theoretical saturation” (Bryman, 2012, p. 426). Guest, Bunce, & Johnson (2006) arrived at 12 as the optimal sample size when data saturation is achieved. This study thus identified 12 participants belonging to five of the intervention schools for this study. However, three teachers from one school abruptly discontinued after one interview session, and one teacher from another school did not stick to the prescheduled interviews cancelling them often. These teachers were probably disinterested and therefore were not pursued further;

this meant that the initial intended sample of 12 teachers had reduced to eight. Thus, this study owing to time and resource constraints decided to proceed with this sample of eight teachers.

3.4.5. Validity and reliability

Qualitative methods are often criticised for lack of generalisability and objectivity, and credibility of the data collected is often questioned (Leung, 2015; Patton, 2002). To this end, Bryman (2012) suggests adhering to the criteria of credibility, transferability, dependability and confirmability for confirming trustworthiness of findings in a qualitative research (p. 390). Whereas Lincoln and Guba (1985) advocates using the methods of prolonged engagement, persistent observation, member validation and triangulation to establish credibility in qualitative research, Bryman (2012) restricts to the methods of member validation and triangulation in establishing credibility. Korstjens & Moser (2018) however suggest that all methods may or may not be used at once and depends on the study undertaken. This study used triangulation by interviewing both the teachers and the facilitator who have been active stakeholders in the MTPDP to establish credibility.

Bryman (2012) asserts transferability as achieved by providing a detailed description of the context of the study area, which terms as "thick description" (p. 392). The similarity of the contexts will enable determining if the findings can be applied to other contexts (Korstjens & Moser, 2018). To this end, a description of the setting of the township and the context in which the intervention schools are situated is provided in Section 1.1.5. Dependability as the third criterion for establishing trustworthiness in qualitative research was ensured by keeping records of the transcribed interviews in a single document, and all the relevant documents, namely consent forms from the teachers, principals and the project, and are kept in safe custody to ensure confidentiality (p. 390). Confirmability the fourth criterion for trustworthiness equates with objectivity in quantitative research (Bryman, 2012, p. 390). This was ensured by taking care that the biases of the researcher have not influenced the findings of the study, as researcher is the only tool for research (Bryman, 2012; Cope, 2014) in this study. Triangulation of data by interviewing both the teachers and the facilitator ensured that the possible biases of the researcher that could influence the findings is reduced (Ross et al., 2011).

3.4.6. Significance of the study

In-service mathematics teacher PDPs are plenty; however, the professional support for teachers through CTPD programmes, to improve teacher quality and to ultimately improve learner outcomes, have not shown any commensurate advancement in learners' performance in mathematics in South Africa (HSRC, 2012; Reddy et al., 2016b). Evaluation studies of CTPD programmes are scare in the South African context (CDE, 2017). CDE (2017) calls for rigorous evaluations for improving the effectiveness of these PDPs so that they can be redesigned to improve teacher outcomes and ultimately, the learner outcomes. Since any reform in practice expected to be imparted through teacher PDPs must be implemented by the teacher, the perceptions of the teachers on the effectiveness of the MTPD need to be investigated. If teachers do not perceive the MTPDP as effective, it is unlikely that they will reform their practice, which has implications for learner outcomes (Guskey, 2000).

This study also gains significance in light of the context of the study, the context of Quintile 2 schools, which serve the economically disadvantaged learners and for whom teacher is the only support for learning (van der Berg, 2008). This study thus serves to explore the teachers' perceptions of the effectiveness of the MTPDP in capturing the experiences of the teachers in their perceptions of effectiveness of MTPDP along the continuum of the design features of the MTPDP, knowledge acquisition, and the change in classroom practice informed by Desimone's (Desimone, 2009) conceptual framework for evaluating the effectiveness of teacher PDPs. This study thus has implications for designing effective teacher PDPs in the context of these Quintile 2 schools.

3.4.7. Limitations of the study

This study limits itself to participant teachers of MTPDP who are engaged in teaching in the intermediate phase (Grades 4 to 6) and does not include the teachers teaching foundation phase (Grades R to 3) learners. Also, another limitation relates to generalising the findings to a population. As the participants do not constitute a random sample, the findings of the study cannot be generalised to the population.

3.4.8. Ethical considerations

Bryman (2012) identifies five major principles of ethical conduct, namely “informed consent”, “privacy/confidentiality”, “anonymity”, “voluntary participation”, and “protection from harm” (p. 143). These were adhered to and are detailed below.

Ethical clearance was first obtained from the University of Witwatersrand and was approved, thereby adhering to the ethics of research. The confidentiality of the project and the project participants was be ensured by using pseudonyms, both for the intervention and the participant teachers. The participant consent was obtained on consent forms and a detailed information letter about the research, the researcher, the interview method asking permission for the researcher to conduct the interview accompanied the consent form, thus adhering to the tenets of informed consent (Bryman, 2012, p.139). Use of appropriate language was adhered so that teacher feels confident and stress-free (McNabb, 2013).

4. PRESENTATION OF FINDINGS

This chapter presents a brief overview of the participant teacher profiles, an explanation on data preparation followed by an elaboration on the coding process. Each code, and therefore the resulting theme, was explored against the literature reviewed, to explore if the findings of the research were in alignment with, or diverged from, the literature. Extracts from transcribed interviews of the teachers served as evidence to support or contradict the findings. The transcribed interview of the facilitator was used to corroborate the findings as a triangulation exercise to improve the credibility of the research (Bryman, 2012, p. 635).

4.1 Data preparation

4.1.1. Participant teacher profiles

The details regarding the teachers participants in this study, namely, their gender, age group, teacher qualifications, experience in years of teaching mathematics, year in which the teacher attended the intervention workshops and the percentage of workshops attended, are presented in Table 1.

Table 1: Participant profiles of teachers participating in this research

Name of the Teacher	Gender	Age group	Teacher Qualification	Years of experience teaching mathematics	Year in which attended MTPDP workshop	% of MTPDP Workshops attended
Teacher A	Male	40-50	ACE (Mathematics)	22 years (Grade 6)	2014 2015 2016	100%
Teacher B	Female	40-50	ACE (Mathematics)	14 years Grades 4, 5,6	2014	100%
Teacher C	Male	40-50	BEd Honours Educational Management, Diploma and ACE Mathematics	4 years (Grade 1, 3, 5, 6)	2015 (Grade 5)	98%
Teacher D	Female	40-50	BTech Education Management ACE (Mathematics)	22 years (Grade 6)	2016 (Grade 6)	100%
Teacher E	Female	40-50	Bed (Maths and Science)	6 years (Grade 6)	2016 (Grade 6)	100%
Teacher F	Female	30-40	Senior Primary Teachers Diploma	8 years (Grade 4)	2014 (Grade 4)	100%
Teacher G	Female	20-30	PGCE (Mathematics and Accounting)	6 years (Grade 5)	2015 (Grade 5)	100%
Teacher H	Female	40-50	ACE (Mathematics and Technology)	15 years (Grade 4, 6)	2014 (Grade 4) 2016 (Grade 6)	90 %

All the eight teachers had formal qualifications to teach mathematics and had experience of teaching mathematics ranging from a period of 4 to 22 years, were experienced in teaching the intermediate phase, and were regular participants in MTPDP workshops. With the exception of two teachers, all were in the age range of 40-50 years implying that they received their schooling when South Africa was under apartheid and therefore were disadvantaged by the low quality of education. Whereas all teachers attended the MTPDP for the grades that they were teaching, one teacher, with the longest teaching experience in mathematics, attended MTPDP trainings for Grades 4, 5, and 6. All the teachers had registered more than 80% attendance in the MTPDP intervention workshops, and thus met the selection criterion for being a participant in the study. These teachers had also expressed their willingness to participate in the study, and provided consent for the same.

4.2. The coding processes

The recorded in-depth semi-structured interview was transcribed in full by the researcher herself, presenting a verbatim account of the interview. This helped the researcher to connect with the data closely (Bailey, 2008).

Each teacher's transcribed interview was given an identity code matching with the teacher's pseudonym. After each interview, the recorded interview was transcribed to check if the interview questions were answered by the participants or the interview questions needed refinement. The transcribed interview was read repeatedly by the researcher in order to acquaint and familiarise with the data thoroughly (Creswell, 2012).

The analysis of the transcribed interview formed the next step. A bottom-up, constructivist approach to thematic analysis was followed, in which the analysis was directed by the intended focus of the study (Maguire and Delahunt, 2017). Thus, three major elements that underlined the conceptual framework, and that also aligned with the three research questions to be probed, were delineated. The first element related to the 'teachers' experiences with participation in the intervention', which related to the teachers' perceptions of effectiveness of the salient attributes/design of the MTPDP intervention. The second element related to the teachers' perceptions of effectiveness of the MTPDP in 'acquisition of knowledge by the teacher'. The third element related to teachers' perceptions of the effectiveness of the MTPDP in changing 'teachers' classroom practice'. Thus, the three elements to be probed for teachers' perceptions of effectiveness are the 'salient features of the intervention', 'knowledge acquisition' and

‘teachers’ classroom practice’, which are derived from, and therefore mirror, the three major components of Desimone’s (2009) theoretical framework for evaluating the effectiveness of PDPs.

The data in the transcribed interviews was first grouped under the three elements detailed in the above paragraph. The data were analysed for recurring words, ideas and phrases across the eight interviews and recurrences were identified and assigned a descriptive code. These codes were then collapsed into themes, an outcome of coding (Saldaña, 2016). Open coding was done with no pre-set codes and codes were arrived at and refined along the coding process (Saldaña, 2016). If the recurrence was seen in three to eight teachers, the code was included in the theme or category, and if the recurrence was seen for only two teachers it was included and analysed but did not form part of the theme in research findings. This conforms to the criteria for including coded data in research findings set by Saldaña (2016), specifying that if only 25% of the participants present similar codes, it is worth analysing and including them, whereas if 75% of the participants present similar codes then that must lead to the establishment of a theme or category. Thus, as this study had a sample size of only eight teachers, if the code resonated with six to eight teachers it was considered as having strong presence (S) and therefore the feature depicted by the code was perceived as very effective. If the code resonated with three to five teachers it was considered as having moderate presence and therefore moderate effectiveness and if the codes resonated with two or fewer than two teachers, the code was included in analysis but not considered to be of enough significance to be included in the theme.

4.3. Codes, categories, subthemes and themes

The research questions intended to be answered and the intended focus of the guided the coding. As mentioned in Section 4.2., the conceptual framework served as the guide for delineating the data into three separate elements, which also mirrored the research questions. Therefore, three elements were delineated, namely the effectiveness of the design features of the MTPDP which could be captured by the teacher perceptions of experiences of participation in the MTPDP, answering question 1; the effectiveness of the MTPDP in enabling knowledge acquisition, answering question 2; and the effectiveness of MTPDP in impacting on classroom practice, answering question 3.

The transcribed interviews were analysed and data relating to each of the three elements was clustered into three respective groups. Coding was undertaken and the codes were collapsed

into themes. The codes belonging to the main components of the MTPDP, namely the content-based workshops, classroom-based support, facilitator and pre-tests and post-tests were grouped together under each of the category heads content-based workshops, classroom-based support, facilitator and pre-tests and post-tests. This was done to delineate the salient features of these components of the MTPDP that teachers perceived as effective. These categories are akin to the component features that constitute the design of the MTPDP, namely content-based workshops, pre-test and post-tests, facilitator, and classroom-based support.

All the emerging codes for each of the research questions were then reduced to themes. Thus, three main themes were identified: 'teacher as a learner'; 'teacher efficacy'; and 'transformation'. Within the theme 'teacher as a learner', two subthemes were identified, namely, 'enabling teacher learning' and 'enhancing teacher knowledge'.

Table 2 depicts the themes, sub-themes, categories and codes in rows and participant teacher names are presented in columns and the symbols used to populate the codes for each of the teachers depict if that code was perceived as effective, ineffective, or the teacher was unopinionated. The symbol 'YYY' indicated that the teacher perceived it as effective, the symbol 'III' indicated that the teacher perceived it as ineffective and if the teacher response did not feature it then the symbol '---' was used. If the code was perceived in an affirmative way by seven or eight teachers, it was interpreted as having strong resonance among the teachers and therefore was interpreted as effective and indicated by symbol 'S'. If the code was perceived in an affirmative way by three to six teachers, it was interpreted as having moderate resonance among teachers and therefore was perceived as moderately effective, denoted by 'M'. If the code was perceived in an affirmative way by only two teachers, it was interpreted as having the least resonance among teachers and was therefore perceived as least effective and denoted by symbol 'L' (Saldaña, 2016). All these outcomes of perceptions of effectiveness were depicted in the column labelled 'Outcome' in Table 2.

4.4. Thematic analysis

This section introduces the themes and subthemes. Firstly, findings relevant to each code are elaborated and analysed against the relevant literature in the paragraph titled 'Discussion' for each of the codes. Each theme is then concluded with an analysis, after all the codes for each of the themes are explored in the light of the findings and the existing literature.

Table 2: Codes, subthemes, themes and outcomes

Theme/Category/Code	Teacher Shaka	Teacher Khanyisile	Teacher Musa	Teacher Nandi	Teacher Nomvula	Teacher Sizani	Teacher Unathi	Teacher Zanele	Outcome
***Main Theme 1* : Teacher as a learner**									
Subtheme 1: Enabling teacher learning									
Category 1: Content-based workshop									
Code.: Coherence	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Code.: Content coverage	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Code: Active learning	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Code: Sharing ideas and teacher collaboration	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Category 2: Facilitator	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Category 3: Pre-tests and post-tests	III	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Category 4: Classroom-based support									
Code: Safe learning environment	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Code.: Modelling classroom lesson delivery and monitoring classroom implementation	YYY	YYY	YYY	YYY	YYY	---	YYY	YYY	S

Subtheme 2: **Enhancing teacher knowledge**									
Knowledge of introducing the subject matter	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Multiple strategies	YYY	YYY	YYY		YYY	YYY	YYY	YYY	S
Knowledge of content strands previously skipped	---	YYY	---	YYY		YYY		YYY	M
Making sense/unpacking of mathematical concepts	----	----	YYY	---	YYY	---	YYY	---	M
Main theme: Teacher self-efficacy									
Confidence	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
Main theme: Transformation									
Traditional pedagogic practice to learner-centred pedagogic practice	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S
From compliance to autonomous	---	YYY	YYY	---	---	---	YYY	YYY	M
Lesson preparation and planning	---	YYY	---	YYY	---	---	YYY	YYY	M
Classsroom management practices	YYY	YYY	YYY	YYY	YYY	YYY	YYY	YYY	S

YYY=Perceived as effective	Coded by 7 and 8 teachers= Perceived as Strongly effective
III=Perceived as ineffective	Coded by 3-6 teachers= Perceived as Moderately effective
--- =no presence	Coded by 2 teachers = Perceived as Least effective

4.4.1. Theme 1: Teacher as a learner

One of the major themes that emanated from clustering of codes and subthemes was 'teacher as a learner'. In the MTPDP, teachers assumed the role of a learner, and therefore the lived

experiences of teachers, when participating in various components of the MTPDP as learners, were captured under this theme. The features of the MTPDP that the teachers perceived as effective in enabling learning and enhancing knowledge were identified under the subthemes 'enabling teacher learning' and 'enhancing teacher knowledge' under the theme 'teacher as a learner'. 'Teacher as a learner' theme resonated with the same theme identified by McGee et al. (2013) in an analysis of change in teacher perception of effectiveness following participation in a PDP.

The experiences of teachers in regard to participation in each of the components of the MTPDP, that constituted the design of the MTPDP, namely the content-based workshops, the classroom-based support, the facilitators, and the pre-tests and post-tests, were coded under the subtheme 'enabling teacher learning', as they provided the enabling environment for teacher learning. Thus, the sub-theme 'enabling teacher learning' captured the experiences of the teachers as learners when participating in the MTPDP, capturing the teachers' perceptions of effectiveness of each of the component that constitutes the MTPDP design in enabling learning. The components of the MTPDP thus formed the categories under the subtheme 'enabling teacher learning' with 'content-based workshops' forming Category 1, 'classroom-based support' forming Category 2, 'pre-test and post-tests' forming Category 3, and 'facilitator' forming Category 4. Under Category 1, the codes 'Coherence' and 'sharing ideas and teacher collaboration', 'content coverage' and 'active learning' found strong resonance among teachers as evidenced by the strong presence of this code in the responses of all teachers.

The teacher perceptions of effectiveness of MTPDP in acquiring knowledge was captured under the subtheme 'enhancing teacher knowledge', which is also the objective of the MTPDP, namely, to improve the CK and PK. The teacher perception of the effectiveness of MTPDP in enhancing knowledge is thus captured in this subtheme.

Thus, the sub-themes 'enabling teacher learning' and 'enhancing teacher knowledge' lead to the theme 'teacher as a learner', as it captures the experiences of the teacher in the role of a learner in participating in MTPDP, in enabling teacher learning and acquiring new learning.

Subtheme 1: Enabling teacher learning

The subtheme 'enabling teacher learning' captures the teacher perceptions of the effectiveness of the major components of MTPDP, categorised into Categories 1, 2, and 3, namely 'content-

based workshop', 'pre-tests and post-tests', and 'classroom-based support', respectively. These categories represent the major components of the MTPDP that provide the framework of the design of the MTPDP. The codes identified under each of these categories capture the teachers' perceptions of effectiveness of each of these components of MTPDP design in enabling teacher learning. The categories and the respective codes for each of the categories are elaborated below.

Category 1: Content-based workshop

The emergent codes under Category 1, namely, the content-based workshops, included 'coherence', 'content coverage', 'active learning', 'sharing ideas and teacher collaboration', and 'facilitation'. These codes embody the salient aspects of the content-based workshops that the teachers experienced and therefore perceived as effective in enabling teacher learning. The codes 'coherence', 'content coverage', 'sharing ideas and teacher collaboration' and 'active learning' found strong resonance among teachers. However, the reasons underlying the perception of effectiveness for each of these codes varied among teachers.

Coherence

The teachers unanimously perceived the alignment of the content covered in each session of the content-based workshops with the ATPs, based on CAPS, as effective. The topics dealt with in the content-based workshops were immediately followed by the teachers delivering it in the classrooms, in the ensuing classroom session. Teacher Shaka succinctly elaborates:

> There was a link from what we did previously, and they were following our programme for example during this term we are supposed to be treating things like mass, temperature, and percentage and things like that and each time we have these MTPDP sessions we will be looking at the Annual Teaching Plans and treat whatever is in the plan for that term, most of the time you will find that you are dealing with a percentage today as you are meeting with MTPDP and come next week Monday you are doing percentage (interview, February 21, 2018).

The alignment of the MTPDP with the intended curriculum to be delivered by teachers ensured that teachers received the support on contents intended to be delivered according to ATPs. This

aspect of coherence was perceived as effective by Teacher Shaka as this ensured that "you don't stay very long with this knowledge you have gained before you can take it to class [thereby] trying to employ the same strategies that you acquired from the previous session" (interview, February 21, 2018).

Teacher Nomvula, on the other hand, sees coherence as effective in clarifying "what is expected, what are the outcomes of the lesson" (interview, February 14, 2018). Teacher Khanyisile perceives this aspect of coherence as effective in preparing her for the classroom in her assertion that "they prepare us before we go to class, planning and preparation is very important, before going to class. At least as a teacher I know what is it that I must do" (interview, February 21, 2018).

Findings

Thus, 'coherence', as a feature of the MTPDP, was perceived as effective in multiple ways by different teachers, varying from being perceived as enabling the application of new knowledge in classroom without much delay, in aligning MTPDP sessions to ATPs (based on CAPS), in enabling to bring clarity about the outcomes or the goal of a lesson, and in preparing the teachers before the lessons are delivered.

Discussion

The teacher perceptions of 'coherence' as an effective feature of content-based workshops in MTPDP is consonance with the findings of Firestone et al. (2005), Penuel et al. (2007), and Desimone & Garet (2015) who, based on rigorous studies, identified coherence as a core feature of effective teacher PDPs in impacting on teacher practice and learner outcomes. Enabling application of knowledge without much delay, suggests coherence in applying what is covered in the MTPDP intervention immediately in the daily practice of the teacher (Main & Pendergast, 2015). Santagata et al. (2010) also report of effectiveness of PD when PD delivered on a particular content is immediately succeeded by the teachers delivering it in the classrooms, especially in teachers whose pacing matched with that of the PD. Segall (2002) and Penuel et al. (2007) argue that coherence achieved by just aligning PD to state policies is not effective by itself, its effectiveness is only realised when the teaching practices and pedagogy are attuned to the curriculum goals intended to be achieved.

Content coverage

The continuous nature of support in the form of content-based workshops held every week was unanimously perceived as effective by teachers in covering all content strands. This contrasted with the previous experiences of attending content-based workshops, which teachers perceived as being approached in a piecemeal manner, when dealing with content, as Teacher Khanyisile puts forth:

> Every week we are being trained and then with the other ones you find we are being trained only once in a term or twice and they want to cover most of the topics within a short space of time. Whereas with MTPDP maybe once in a week we are doing a certain topic and by the end of the term we find we have covered all the topics that are supposed to be taught for that particular term (interview, February 21, 2018).

Teacher Zanele on the other hand elaborates:

> …there were some other contents in maths whereby I was dodging them sometimes I was just cutting them just like giving the learners and telling them "go do it at home", but now … I can cover each and every content strand according to the ATP (interview, February 16, 2018).

Findings

MTPDP was perceived as effective in ensuring the complete coverage of content strands intended to be delivered by teachers.

Discussion

The unanimously perceived effectiveness of MTPDP as a coherent programme, coupled with aiding coverage of all content, intended to be delivered as part of CAPS curriculum, afforded an enhanced opportunity to achieve curriculum coverage. This contrasts with the case pre-MTPDP intervention, when teachers followed the norm of skipping of content that they were not confident in, and hence can be considered significant. Thus, it may be safely derived that the opportunity to learn new content must have afforded improved opportunity to learn for the

learners (Reeves & McAuliffe, 2012) as curriculum coverage by teachers is perceived to have improved compared to pre-MTPDP intervention. Teacher Zanele articulates it thus: "every knowledge I am having, my learners are reflecting me are my reflection, my learners are displaying me so whatever they have learned they have learned from me" (interview, February 16, 2018). The content focus of the MTPDP, perceived as effective by teachers as a key feature of content-based workshops of the MTPDP, echoes the findings of Birman et al. (2000), Desimone (2009), Garet et al. (2001) and Ingvarson et al. (2005), and as a core feature of teacher PDPs in contributing to improved knowledge and improved classroom practice.

Active Learning

The involvement of teachers as active participants, actively involved in their own learning, in which they were provided with an opportunity to present the lessons, and hands-on nature of the workshops that were predominantly practical rather than theoretical, was perceived as effective by all teachers and strongly resonated with all the teachers.

Teacher Shaka articulates it thus: teachers were "more involved rather than going and listening to somebody talking…with MTPDP we were all hands-on" (interview, March 27, 2018). As the teachers were given an opportunity to "prepare a lesson…and present it to the entire group", it presented as an opportunity for teachers to "share ideas" with mathematics teachers from neighbouring schools on "various teaching approaches or method" with the MTPDP facilitator "only …there to give a direction" (interview, February 21, 2018).

Teacher Shaka commends the hands-on nature of active learning in "developing a sense of ownership as something that is yours" (interview, March 27, 2018). Teacher Nomvula on the other hand articulates that teachers were exposed to the "practical side of mathematics" in the MTPDP workshops (interview, March 23, 2018). Teacher Shaka, however, points out:

> Some teachers you know they do not feel comfortable to be presenting a lesson in front of others but they find it more comfortable to be doing with the kids and they produce very good results. But the level of confidence goes down when they see an adult around you know (interview, February 21, 2018).

Findings

The reluctance of the teachers to present thus demands that other active learning strategies, other than presenting in front of others, may be resorted to. However, the outcome of the active learning in terms of teacher exposure to mathematics as a practical subject and sharing ideas and the emergence of teacher collaboration as an offshoot of this has been widely perceived as effective, as elaborated in the below paragraph. Reflection on practices as a structured activity following content-based workshops, however, did not find mention in any of the teacher responses.

Discussion

'Active learning' is considered an important feature of effective PDPs by Desimone (2009) and Desimone & Garet (2015) impacting teacher practice and learners' outcomes. In providing presentation by teachers as an active learning strategy, MTPDP speaks to the constructivism aspect of active learning, which recognises teacher experiences as valuable resources for new learning (Trotter, 2006). This probably explains the strong resonance among teachers of the perceived effectiveness of active learning as a feature of the MTPDP to the extent of feeling a sense of ownership of the training programme among teachers. Several studies suggest that active learning by itself may not impact on teacher practice, it is necessary to reflect on the active learning methods to ensure its implementation in practice (Trotter, 2006; Webster-Wright, 2009).

Sharing ideas and teacher collaboration

Sharing ideas and the ensuing teacher collaboration was perceived as effective and found strong resonance among all the teachers.

The opportunity for active learning afforded by MTPDP methods, also referred to as "hands-on learning" (Teacher Shaka, March 27, 2018), elaborated in the above paragraph, introduced teachers to various pedagogical strategies used by teachers from neighbouring schools, thereby providing a platform for sharing of ideas on mathematical strategies, as a teacher would present it to learners in the classroom. Teacher Musa articulates that this enabled to "compare [his/her method] with that persons method [and] if maybe his or hers is better than mine then tend to

adopt the other one [thereby enabling to] select the most simplest to accommodate the slow learners (interview, February 22, 2018).

Teacher Nandi further elaborates sharing ideas as enabling to apply "whatever we were learning …so …when you leave the classroom we have grasped it practically" (interview, March 23, 2018). Teacher Nandi cites sharing ideas on strategies as enabling in replacing their own ineffective strategies with new strategies that they themselves find easy, articulating thus:

> We also have different approaches to a particular topic but you find that the way…I am doing …somehow it is difficult for the learners…another teacher … can approach this topic like this, and you know you find it easy (interview, April 17, 2018).

The willingness to put into practice tested strategies, tried by other teachers, in content that was challenging, was articulated by Teacher Shaka as "when we get back to our schools we try to employ that message that teacher said is working and is yielding results, when one feels a content is challenging for a teacher"(interview, March 27, 2018).

The organic emergence of teacher collaboration among teachers within the same school and across schools participating in MTPDP was perceived as unanimously effective by all teachers. Teacher Shaka states it thus:

> Collaborative planning and teaching…is a powerful tool that we took …because sometimes you might say to yourself you know too much and yet you tend to forget some of the things that can assist you to deliver the subject matter so we do a lot of collaboration and reflect even just orally (interview, March 27, 2018).

Collaboration also enabled communication between teachers in situations where there was no synchrony in what was being taught by three different teachers teaching the same Grade in three different classrooms. As Teacher Sizani puts it "three [teachers] were teaching three different topics so it means there was no communication there" (interview, April 17, 2018). The teamwork and synchrony in what is being implemented across classrooms of teachers, as a consequence of collaboration, was encapsulated by Teacher Khanyisile as "we work as a team… then sometimes we even set common papers" (interview, February 21, 2018). Collaboration among teachers also manifested as seeking assistance from each other on dealing with challenging content, establishing communication between teachers within schools and

between schools, and collaborating on setting assessments. Teacher Khanyisile articulates it thus:

> I am able to engage with other colleagues since we were so many there we exchanged our numbers, now we are able to help each other. We work as a team. There is something I am not clear about it I just have to phone and then sometimes we even set common papers we give our learners to write it and again there are so many strategies that I have learned there on how to approach a certain topic like division (interview, February 21, 2018).

Findings

The opportunity to share mathematical strategies afforded by teacher presentations enabled teachers to try new pedagogical strategies that the teachers felt were simpler than their own strategies. This enabled them to replace ineffective strategies with effective strategies. The presentation of strategies by other teachers, which they claimed as tried and tested, encouraged teachers to try the strategies, in contents that the teachers found challenging, in their own classrooms.

The teachers also unanimously perceived collaboration as highly effective in breaking communication barriers between teachers regarding the schoolwork, thereby discovering a new support system that exists in proximity to them. The act of seeking active assistance from within the teacher community, namely teacher collaboration, thus emerged as an unintended consequence of the project, or rather developed organically and therefore was unanimously perceived as effective by the teachers.

Discussion

The sharing of ideas and the ensuing teacher collaboration enabled teachers to augment their experiences in learning new pedagogies (Goddard, Goddard, & Tschannen-Moran, 2007). The organic emergence of collaboration probably signalled a sense of ownership of the programme by owning shared responsibility for learners' learning (Burton, 2015). Several studies identify collaboration as an indispensable feature of teacher PDPs that impacts on teacher practice and learner achievement (Burton, 2015; Ronfeldt et al., 2015).

It may however be pointed out that the interviewed teachers did not refer to the emergence of professional learning communities (PLCs), raising doubts if this collaboration was sustained

or the collaboration exists as an unstructured form of collaboration. The emergence of such PLCs is seen as necessary to sustain the seed of teacher collaboration sown by the MTPDP and reap its benefits in a sustained manner (Flores, Rodríguez, & García, 2015).

Category 2: Facilitator

Perceived effectiveness of new knowledge imparted by the facilitator, and unpacking of knowledge through allaying misconceptions, found strong resonance among teachers.

Teacher Zanele articulates that the facilitator "comes up with something very much different that grabbed our attention and then all the teachers would say "wow"' (interview, April 17, 2018). This contrasts with the "common knowledge" displayed by teachers when presenting content in content-based workshops. Teacher Zanele refers it to as "common knowledge" owing to the familiarity with that type of content presented in "workshops … attended before" (interview, April 17, 2018). Teacher Zanele further emphasises that both teachers and facilitators are learners which "was very interesting" (interview, April 17, 2018). Even though all teachers perceived the facilitator role in imparting new knowledge as effective, Teacher Shaka suggested the need for the facilitator to be an expert in all the content articulating that "they were not excellent in all the contents like for example, I remember myself and my colleague... we once assisted …the facilitator with regard to patterns, …because he came straight to us to say I don't have confidence" (interview, March 27, 2018).

Teacher Shaka notes that such situations

> …brings down… the level of confidence to teachers when you see somebody is trying to present something of which he or she does not have confidence in it and you are coming in to assist' [because] 'if somebody is 100% or more equipped with what he is coming to deliver to you then it is a motivation to you (interview, March 27, 2018).

Teacher Nomvula on the other hand articulates that "facilitators that were facilitating the workshops were very supportive, very well informed, you can attack them in any site and they will, they were well informed, and gained knowledge of practical side of mathematics and theoretical side of mathematics" (interview, March 23, 2018).

Findings

The facilitator's role in imparting new insights into mathematics teaching was perceived as effective by all the teachers. However, the need for the facilitator to be thorough in all content strands was expressed by teachers. By seeking assistance from teachers for presenting the topics the facilitator was not thorough with, the facilitator indicated a lack of confidence on his/her part of the facilitator, and therefore is a dampener on teacher learning (Linder, 2011).

Discussion

In referring both facilitators and teachers as learners, teacher probably highlights the facilitator adopting a situative perspective of learning that conceptualises learning through interaction with others, thereby structuring the learning experiences for the community. This supports Cobb's (1994) elucidation that learning should be seen as a process where knowledge is not only actively constructed at an individual level but in interaction with the wider community at large. This probably gives credence to the role performed by the facilitator in building relationships with the learning community in being a learner himself (Putnam & Borko, 2000).

Category 3: Pre-tests and post-tests

Teachers varied in their perception of effectiveness of use of pre-tests and post-tests as a measure of to ascertain gain in knowledge following participation in the MTPDP. One teacher perceived it as ineffective. Of the other seven, three teachers, though, expressed discontent at the level at which the tests were set, namely the learners' level, but found the tests effective in understanding their knowledge gaps. The remaining four perceived it as effective and were comfortable with tests set at learner level. The level of proficiency at which the tests were set, namely, at the learners' level, enabled some of the teachers to score very high on these tests, implying no new knowledge gain for these teachers, and therefore these teachers failed to find value in these tests for assessment of knowledge gain. As Teacher Shaka elaborates:

> As an experienced teacher sometimes I will feel small to be given a task that is meant for a level of a Grade 4 learner to write it [and] in the pre-test, you get 98% and come the post-test you get 90% can you see, can you see it is a question of attitude there, it should have been 90% and 98% not 98% and 90% because it is the same test, there is a difference in attitude

> [and] sometimes you will want to finish it in one minute and you are committing mistakes there and you know it makes you feel bad (interview, February 21, 2018).

Expressing remorse Teacher Shaka emphatically rejects this approach suggesting

> I should not be given something like that [and] suggests maybe the best approach from MTPDP was maybe to give us those tests and say to us how can we assist this learners to master this concept you know set in this question paper other than giving it to us to ask to write it (interview, February 21, 2018).

Teachers who perceive it as effective, on the other hand, vouch for it as "an eye-opener" in that in "the pre-test …know the level of knowledge that you are at after you are doing the post we could see great improvement…then feel that I have gained something" as articulated by Teacher Nandi (interview, March 23, 2018) . Teacher Sizani acknowledges that pre-test scores came as a shock, as her presumption that she had adequate knowledge for teaching Grade 4 was false, acknowledging that pre-tests brought to light the inadequacy of her knowledge. Teacher Sizani expresses it as shame at not being able to do the problems themselves, when in fact they are expected to teach the learners, as she articulates:

> Because I thought they are simple and when I calculated them, I did not get them right meaning that I did not know, actually it was the Grade 4 work, I got it wrong. A teacher is getting it wrong what is going to happen then in the classroom. Now you find that after that workshop now when I wrote the post-test at least I got them right, before some of the things I was failing to get them right as a teacher you know (interview, February 16, 2018).

Teacher Khanyisile, though initially sceptical of writing the tests as she felt "they were exposing me" (interview, February 21, 2018), soon feels motivated on seeing improvement in post-tests. Teacher Musa emphasises a positive attitude towards pre-test and post-test in expressing his experience:

> The mathematical problems I didn't manage to get the answers after getting them wrong I realised I have to concentrate on this and master this

> myself before you teach the learners because the teacher should be master of the subject matter (interview, February 22, 2018).

Teacher Unathi, on the other hand, sees it as a reminder of "…the need to prepare" (interview, February 16, 2018).

Findings

The use of pre-tests and post-tests as a measure of knowledge gain were not well received initially by any of the teachers. The reasons that emanated ranged from being not challenging enough, therefore ineffective in testing knowledge, to feeling insecure about being exposed on the lack of adequate knowledge. All teachers except one eventually started appreciating it, when they came to realise that the knowledge they possessed was inadequate for teaching the respective grade levels. However, one teacher was adamant in rejecting this method for the low level at which it was set.

Discussion

The general anxiety experienced by teachers when their knowledge is tested seemed to be evident in these teachers too, in their reluctance to expose their knowledge gaps and feeling insecure about the same. This demands the need of other alternative methods for testing teacher knowledge to avoid teacher insecurities experienced in writing tests. Kersting, Givvin, Thompson, Santagata, & Stigler (2012) and Kersting (2008) through The Capturing Teacher Knowledge Project, are attempting to develop a measure to capture teacher knowledge of mathematics teaching using video clips of classroom instruction.

Category 4: Classroom-based support

The other component of MTPDP the 'classroom-based support' which belongs to Category 3 under the subtheme 'enabling teacher learning' encompassed the codes 'safe learning environment', 'modelling lesson delivery' and 'monitoring classroom implementation'. The code 'safe learning environment' found strong resonance regarding its perception of effectiveness with the teachers, whereas the presence of the codes 'modelling lesson delivery'

and ‘monitoring classroom implementation’ did not find strong perception of effectiveness among teachers, with only two teachers perceiving these as effective.

Safe learning environment

The teachers’ shared a strong perception of the effectiveness of MTPDP in creating a safe learning environment.

The safe learning environment afforded by the MTPDP eliminated the anxiety previously experienced by the teachers when somebody is evaluating his/her teaching. This was exemplified by Teacher Shaka as constantly reminding oneself “I must not make a mistake because somebody is there and is going to evaluate me” (interview, March 27, 2018). Teacher Shaka articulates this insecurity because of the perception that evaluators are “fault finders” (interview, March 27, 2018). The approach of the MTPDP facilitator in creating a safe environment devoid of intimidation, was articulated by Teacher Nomvula: “when the facilitator comes in the class, he doesn’t intimidate us” (interview, February 14, 2018). Also, the willingness of the facilitator to “intervene and assist …. in delivering the subject”, articulated by Teacher Shaka (interview, March 27, 2018), when errors in teaching do occur was perceived as the most effective aspect of the classroom-based support.

Findings

The sense of freedom to ask for any kind of assistance in teaching from the MTPDP facilitator and his “willingness to assist” found strong presence among all the teachers’ shared perception of effectiveness.

Discussion

Thus, the safety experienced by teachers in airing teacher views and in expressing their ignorance regarding knowledge of some content strands, was afforded to by the facilitator. These shared perceptions of effectiveness of a safe learning environment by teachers would have enabled teacher learning. Darling-Hammond & Richardson (2009) and Graven & Pausigere (2017) attribute enhanced teaching in teachers to safe learning environments afforded by communities of practice.

Modelling classroom lesson delivery and monitoring classroom implementation

All teachers shared the perception of effectiveness of MTPDP in modelling classroom delivery and two teachers shared the added effectiveness in monitoring classroom implementation.

The facilitator's support in demonstrating the classroom delivery of certain mathematical concepts that the teachers were struggling with, was summed up by Teacher Khanyisile as follows, "it helped …… to alleviate the problems [I] used to have because some of the concepts I couldn't teach, I couldn't explain to my learners in a thorough way. Facilitators were there to do it for me" (interview, March 27, 2018).

Modelling of lesson delivery from the perspective of its effectiveness in modelling involvement of learners, and facilitator feedback on teacher lesson delivery and later reflection, found resonance among the teachers. Teacher Unathi echoes the perception of effectiveness of this aspect of classroom-based support and articulates:

> He will give you time to observe him during the lesson, he will do the lesson and he will involve the learners and you can see that he can involve the learners and when you are presenting the lesson to him he will come and sit down and then develop you according to your lesson (interview, April 17, 2018).

Implementing the CAPS scripted lesson plans exactly in the time slots allotted for each activity was challenging for teachers to replicate in a classroom situation. However, Teacher Musa acknowledges facilitator support in assisting him to conduct a mental maths session in ten minutes and reach every learner, thereby demonstrating its achievability in a classroom situation:

> Let's say we have 10 min for mental maths sometimes we say won't be able to manage the time because you won't be able to ask each and every learner the mental maths in 10 minutes time and sometimes we were asking the facilitator to show us how. And that…the facilitator will sometimes manage to ask all the learners as long as there was a mental maths (interview, April 13, 2018).

Teacher Shaka, however, presents that completing a lesson according to the time slots allocated for each activity in ATPs is difficult for teachers to achieve in the classroom situation, and even the facilitators struggle to achieve that and articulates it thus:

> There is this tendency of designing a lesson to say from until the first minute to the 60th minute, the first 10 minutes you have to be doing this, the second 20 minutes you have to be doing this the lesson will be divided into minutes but us what we have noticed as teachers is most of the time it was not possible for you to do this within an hour and we have a proof to that because even when you request the facilitators to take them through to say I want to see with you how you handle this can you start with them from the first minute up until the 60th minute, you introduce, you teach the concept and then you assess and control the books within……..I can learn from that but no one will do that (interview, March 27, 2018).

Two teachers did find classroom-based support as providing an oversight role, by ensuring that the lessons are delivered in practice as expected and according to the new learning imparted by the MTPDP. Teacher Nandi exemplifies this as:

> For me it was very important to have a facilitator in class so that he can see if we are putting into practice what we are learning every Wednesday, because if we attend and there is no one monitoring what is happening in class it was just going to be a waste of time some we are learning on Wednesday and somebody is monitoring to see if we are doing the right thing in class (interview, March 23, 2018).

Findings

The modelling of lesson delivery by facilitator also was seen as effective in various ways by teachers, whereas some teachers viewed its effectiveness from the perspective of general pedagogy, learning to involve learners in a classroom, others found the time management aspect of delivering planned content effective, and few others perceived its effectiveness in modelling delivery of content strands perceived as challenging by them. The teachers also perceived the effectiveness of classroom-based support in playing an oversight role in modelling classroom delivery.

Discussion

Darling-Hammond, Hyler and Gardner (2017) identify modelling instruction using curricular or instructional models as an effective feature of teacher PDPs to improve learner achievement. Heller, Daehler, Wong, Shinohara, & Miratrix (2012) found that in PD that focused on content that was challenging for teachers, by modelling the instruction with the help of a facilitator led to significant gains in learning for learners who were taught by teachers who participated in this PD. The role of modelling instruction in providing a "vision of practice" (Darling-Hammond et al., 2017, p. 11), on which to anchor teacher growth, has been found effective in improving learner learning achievement. Heller et al. (2012), however, propose that it is more effective when it is combined with analysis of learner work and classroom practice.

Subtheme 2: Enhancing teacher knowledge

The sub-theme 'enhancing teacher knowledge' is derived from the codes 'knowledge of introducing the subject matter', 'knowledge of multiple strategies', 'knowledge of content strands previously skipped', and 'making sense/unpacking of mathematical concepts'.

Knowledge of introducing the subject matter

The teacher perception of the effectiveness of MTPDP in enhancing the knowledge of introducing the subject matter found strong resonance among the teachers. Whereas some teachers perceive this knowledge as manifested in the ability of relating mathematical concepts to real-life or everyday situations, other teachers perceive this knowledge as manifested in using resources, variously referred to as manipulatives or models, in introducing subject matter.

Teacher Musa elaborates: "we talk about things that they see" and therefore "simplifies subject matter" and learners "derive pleasure from this" (interview, February 22, 2018). This, he adds, aids "to introduce the subject matter to the learners" (Teacher Musa, interview, February 22, 2018), and emphasises the importance of this new knowledge in learning because "if you can't relate the subject matter with the real-life situation, the subject mathematics will never make sense to the learners" (Teacher Musa, interview, April 13, 2018).

Teacher Musa cites an example of teaching angles, stating that before the MTPDP intervention when "we were teaching the angles, we were just teaching them as if they are things that are just fixed" (interview, February 22, 2018). The new knowledge of introducing subject matter by relating mathematics to everyday situations following MTPDP intervention led Teacher Musa to articulate as follows:

> But now we can use our structures, the walls and the floor, the angles that are formed there always it must be a 90 degree Celsius. The angle that is formed by the floor and the wall. And in the case of the roof we just look at different angles, the obtuses, the acute and other angles" (interview, February 22, 2018).

Teacher Nomvula finds pride in her learners understanding transformations for the first time aided by relating the topic of transformation to everyday phenomena and articulates:

> When I was doing transformations with the learners and it is my first time to see the learners they really understood the difference between reflection, translation, rotation…I used an example, Let's start with rotation, I drew the picture of a boy, this is Sikhle. Sikhle is standing... You know the angles. So, rotation 90 degrees you know the angles …, so Sikhle is sleeping now what angle is that, 90 degrees, so again from this angle to this angle and again down and in another angle, so it's like he is somersaulting" (interview, February 14, 2018).

In attributing this transformation to MTPDP she elaborates, before "we will just talk, I theorise, I theorise, I never knew that mathematics would be this practical, I theorised, I theorised" (Nomvula, interview, February 14, 2018).

The shared perception of the effectiveness of MTPDP in enhancing the knowledge of using resources resonated in multiple ways: its effectiveness in introducing the subject matter, enabling teaching for understanding, capturing learner interest in learning, and in enabling a shift away from a theoretical approach to teaching to a practical approach to teaching.

Teacher Shaka perceives it effectiveness in also capturing the interest of learners in stating that "use of resources [is] very important in that even learners who are not interested they are akin to be contributing and you know they like this doing part… The more they use these resources the more they develop interest" (interview, February 27, 2018).

The impact is seen, as Teacher Shaka states, "when they respond to a formal assessment task", "even if the instruction did not require them to make… drawing…, some of them respond to the questions even using the drawings and stuff like that even though it is time consuming to them, … but its yielding results" (interview, February 27, 2018).

Teacher Musa, on the other hand, perceives it as effective in introducing the subject matter and therefore ensuring that "they just don't theorise, it is a practical thing" (interview, April 13, 2018). This is further echoed by Teacher Shaka:

> As kids get engaged into that subject matter… it also maximises the performance of the learner even those who are average and below average they become keen you know it arouses their interest and they want to know more or they want to do more and in as much as they do more, in as much as they are engaged they get to benefit more (interview, February 21, 2018).

This further reiterates that "they like this doing part" (Teacher Shaka, February 27, 2018) or the practical part in enhancing learning. The practical aspect of the use of resources in teaching for learners' learning, and in addressing the needs of learners as they "need concrete things to see", is put forward by Teacher Khanyisile (interview, February 21, 2018).

The power of resources in engaging learners is exemplified by Teacher Nomvula as follows:

> Once you take out the resources, the tools for teaching maths, every learner would be interested, they would focus you see, they are ready to see what the teacher is going to do because they love catching things, they love working, they love constructing, so it draws a lot of attention from the learners side (interview, February 20, 2018)

Teacher Nandi sees it as impacting on pacing of finishing tasks by learners in that "they were a bit quicker to finish tasks than before" (interview, February 20, 2018). Attributing this new knowledge to the MTPDP, Teacher Khanyisile elaborates: "before when we talk, about half our learners did not understand it up until they have seen it on the fraction wall and also by using those pieces of fractions" (interview, February 27, 2018).

Perception of the facilitator

The facilitator agreed on the new knowledge of the use of resources acquired by the teachers in assisting in conceptual understanding for learners, "coming to fractions it was the use of resources and the understanding, understanding the model drawing, because I still remember there was a challenge like drawing…… so the conceptual understanding we drilled a lot in the teachers" (interview, February 26, 2018)

The facilitator emphasises the use of manipulatives across all content strands "helped in conceptual understanding of everything" (interview, March 05, 2018). The facilitator, however, notes that the teacher dependency on manipulatives as having detrimental effects on learners as "some teachers would take much time on manipulatives and that would disturb the learners if they did not have them in the exams" (interview, March 05, 2018).

Findings

The teachers thus perceive the effectiveness of MTPDP in enhancing knowledge in new ways of introducing subject matter, both by relating to everyday life and using resources/manipulatives/models, in multiple ways, positively. The perception of effectiveness is seen as emanating from better learner engagement in classroom when using concrete objects/resources, in providing an opportunity for teachers to teach for understanding rather than theorising, by using concrete things, thereby also improving their teaching skills. The augmentation of available resources and making available new resources for teaching by the MTPDP has been acknowledged unanimously by the teachers.

Discussion

The teachers' perception of effectiveness of manipulatives in introducing the subject matter and thereby facilitating better learner engagement echoes the findings by Naidoo (2012). The prevalence of the use of models, as answers to tasks in assessments by learners, establishes that "manipulatives were what were effective" (interview, March 05, 2018), as quoted by the facilitator. Though it is appreciable as creating an impact, the restrictive impact to just introducing the subject matter probably signals the inability to lead to abstract learning in the concrete-representational-abstract pathway (Ketterlin-Geller, Chard, & Fine, 2008). This

challenge of moving gradually from concrete objects to abstract concepts in using manipulatives for effective learning was echoed by Brown et al. (2009). The use of resources does not automatically lent meaning unless it can guide the learner from concrete to abstract learning (Szendrei, 1996; Brown et al., 2009). The benefits of concrete-representational-abstract approach of mathematical instruction for struggling learners or low achievers has been reported extensively (Butler, Miller, Crehan, Babbit, & Pierce, 2003; Flores, 2010; Maccini & Hughes, 2000). This probably signals the need for more teacher development on guiding/facilitating learners' learning from concrete to abstract.

Thus, although the role of manipulatives in introducing the concept behind a content cannot be diminished, the lack of mathematical sense making from the use of manipulatives will hinder the move to abstract learning (Miranda & Adler, 2010).Using a manipulative should ultimately enable the learner to make connections between a concrete object and its abstraction to aid learners' learning. Kamina & Iyer (2009) suggest using a socio-mathematical routine that involves scaffolding, exploration and abstraction which they continued using till it became a mathematical norm. Future efforts in implementing the MTPDP should thus be directed at enhancing knowledge of using manipulatives by establishing the link between the concrete objects and the abstract concepts to establish mathematical meaning to using manipulatives.

Knowledge of multiple strategies

The perception of teachers regarding the effectiveness of MTPDP in accumulating knowledge of multiple strategies found strong resonance among teachers. The teachers articulated the possession of knowledge of only one or limited pedagogical strategies pre-MTPDP intervention. The new knowledge of multiple strategies was perceived as effective in varied ways.

Teacher Zanele elaborates the effectiveness of MTPDP in acquiring knowledge of strategies that are easier to remember: "I have learnt some of the strategies that are easy and friendly that are not even easy to forget and if I do not forget it easily that means learners will also not forget" (interview, February 16, 2018). Teacher Zanele sees the knowledge of multiple strategies as being effective in enabling to address the needs of the weak and strong learners alike as she puts it:

> I can … go to the level of Grade 4, I can … go to the level of Grade 6, and the Grade 6 ones the intelligent ones they can grab easily and with the ones

> that are very slow with those ones that have got the barriers in learning I can take that method I am teaching the grade 4s (interview, February 16, 2018).

Teacher Musa echoes the same perspective on effectiveness of multiple strategies:

> I used different methods to teach one thing so that I accommodate each and every learner, there are slow learners, the average and the gifted ones. All of them derive pleasure because we introduce things in a simple and then we start from the simple and then move from the simplest to the complex (interview, February 22, 2018).

Teacher Musa also exemplifies the knowledge of multiple strategies in simplifying learning:

> Long division is a problem to the learners,….They take a long time to understand it whenever you write a clue on the other side you write that method and then you make use of the arrows to show how you get to the answer and the learner tend to realise that this thing is easy (interview, February 28, 2018) .

Teacher Nomvula also echoes the same advantage of simplifying the subject matter: "I was also struggling in teaching division, long division, but …facilitator … has shown me a very very simple method which the learners also enjoy" (interview, February 14, 2018).

Teacher Nandi exemplifies its effectiveness in accommodating different types of learning styles of learners, providing the flexibility to the learner to choose the method he/she is comfortable with: "it gives you a number of methods to use, the learner will be the one to choose which one is easy for him/her" (interview, March 23, 2018). Teacher Khanyisile echoes the flexibility afforded by multiple strategies in providing learners an opportunity to work with the strategy they are comfortable with. Teacher Sizani elaborated thus: "most of the time we used to have one method to teach them and if maybe we can come up with another method some learners can grasp the other method and get the correct answer and if you are sticking to

one method you find that some of them they don't understand" (interview, February 16, 2018)
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Teacher Shaka on the other hand though considers multiple strategies as effective in assisting "that child …who might be comfortable with approaches or methods brought by MTPDP like the breakdown method … we were not using that you see" (interview, March 27, 2018), but Teacher Musa expresses concern over its "time consuming" (interview, February 22, 2018) nature, implying lack of mathematical efficiency. Teachers Shaka and Khanyisile expressed concern over these multiple strategies as causing confusion among the learners, thereby causing them to mix up the strategies. This, despite the learners being given the freedom to use any method they like.

Teacher Shaka articulates it thus:

> MTPDP has taught us a number of strategies on how to deal with multiplication, as multiplication has been a problem for our kids. Now the strategies are good when you look at them as an adult but then with learners it tends to confuse them because you will find that you are having four different approaches to multiplication, there is the breakdown methods, there is this column … and our learners … tend to mix all these methods in trying to solve one problem (interview, February 21, 2018).

The facilitator echoes the teacher perceptions and acknowledges the knowledge of methods as a significant contribution by the MTPDP as compared with the knowledge of content itself. He elaborates thus: "Something I can significantly say the benefit to the teachers actually it was more of methods than the content because you know the knowledge itself it differs from one teacher to the other" (interview, February 26, 2018).

Findings

The knowledge of multiple strategies was perceived as effective by teachers in enabling teachers in accommodating learners of all abilities, the weak, average and the strong performers.

Discussion

The teacher perception of effectiveness of the MTPDP in gaining knowledge of multiple strategies signals building up of a pedagogical repertoire or pedagogical knowledge base considered as essential for learners' learning (Anthony and Walshaw, 2009; Guerriero, 2014; Hoadley, 2016).This perception of effectiveness could also probably be explained by the knowledge of multiple strategies enabling the teachers to differentiate instruction thus addressing the learning needs of the learners with varying learning styles (Gentry, Sallie, & Sanders, 2013; Small & Lin, 2010). Barrows (1986) suggests the integration of multiple strategies for teaching as pivotal to improving teaching and learning practices. Umugiraneza, Bansilal, & North (2017) advocate for increasing the repertoire of both teaching and assessment strategies in PDPs and identify it as the key factor affecting learner outcomes. Stein, Engle, Smith, & Hughes (2008), however, caution that simply sharing the multiple strategies with learners is ineffective if the teacher is not able to establish mathematical connections between them through comparing or contrasting. Mixing of strategies by learners is prevalent in classrooms, as perceived by teachers, and it is suggested that it may prove detrimental to struggling learners by confusing them (Lynch and Star, 2014).

Knowledge of content strands previously skipped

The teacher perception of the effectiveness of the MTPDP in acquiring knowledge of content strands that were previously skipped by teachers, due to lack of adequate knowledge on how to deliver it to learners or due to lack of CK itself, found moderate resonance among teachers. Teacher Zanele puts it as "there was some other contents in maths whereby I was dodging them sometimes I was just cutting them just like giving the learners and telling them to go do it at home". Teacher Nandi exemplifies it as follows:

> I did not understand the time zone, I didn't understand the content very well and they would ask and I would feel to say I don't know how to answer them, then I will say no we will continue tomorrow (interview, February 20, 2018).

Teacher Khanyisile elaborates, "Before we never used to complete the curriculum…because we were … not sure of the content …since MTPDP came now I am telling you we are able to cover everything within the term" (interview, February 21, 2018).

The lack of CK pertaining to some content strands probably would have dictated that the teachers had no recourse but to skip the content. The coverage of all the contents is supported by the facilitator elaborating thus:

> Generally, we treated all the topics, all the topics in the Grade 4,5,6 curriculum starting from whole numbers, their properties going to fractions, going to shapes, special shapes also looking at time and other measurements topics, volume and so on (interview, February 28, 2018).

Findings

The lack of content knowledge on certain content strands on the part of teachers made the teachers to skip content, thereby denying the opportunity to learn to the learners. Complete curriculum coverage was ensured such that all content is covered and made available to the learners.

Discussion

Stols (2013) identified the following opportunity to learn measures, namely, number of activities, coverage of content, coherence and the cognitive level at which the activities were set, to be highly correlated with performance of Grade 12 learners in mathematics in under-performing schools in South Africa. The content coverage and emphasis on certain topics, namely numbers and measurement, observed in the study by Reeves and Muller (2005), indicate that certain topics, namely numbers and measurement, were favoured at the expense of others. Floden (2003) cautions that this poses the danger of learners mastering a topic at the expense of others. The opportunity to learn, therefore, must be available for all topics. This brings to focus the lack of knowledge as the reason for skipping the content, as articulated by teachers, and not lack of teacher accountability, because the teachers are limited by the lack of knowledge and express a desire to improve it. This gives support to the argument by Spaull (2015) that in the South African context, teacher capacity improvement, to deliver learning in classrooms, must precede expectations of accountability.

Making sense/unpacking of mathematical concepts

The way teachers held the knowledge in mathematics was influenced to a great extent by the manner in which they were taught in schools, which emphasised rote learning and therefore lack of a conceptual base to their understanding. Teacher Khanyisile articulates: "I used to have only one approach of teaching the learners, the one that I was taught long time ago" (interview, February 21, 2018). The teacher perception of effectiveness of MTPDP in unpacking of mathematical concepts appeared in the responses of only three teachers, Teacher Musa, Teacher Nomvula and Teacher Unathi, and therefore registered moderate presence.

The effectiveness of MTPDP in unpacking the concepts underlying the mathematical content strands was expressed by Teacher Musa thus: "while I was still a learner, I wasn't aware that fractions is a division. I didn't know that half is equal to one whole divided by two equal parts" (interview, February 22, 2018). The MTPDP enabled making sense of fractions for Teacher Musa and Teacher Nomvula. Teacher Musa elaborates, "Now that I can see that this sign which is found between one over two that sign means division. I even tell the learners whenever they see the numerators denominators, they must know that this is a division" (interview, February 22, 2018).

This implies learner knowledge as a reflection of teacher knowledge. Teacher Unathi elaborates:

> Before [MTPDP] we were just adding because of the rule, we say 4 plus 9, 13 you write down 3 and carry 1, we didn't know it is for units, 4 and 9, it is 30 and 80 and it is 200 and 400, now we know they are place values (interview, February 20, 2018).

The perception of the facilitator

The facilitator echoes the lack of conceptual understanding of content strands by teachers:

> They were doing the procedures without understanding what is really happening…the concept of place values was not there, they could subtract to say we borrow it … but they did not know is it a one or a ten, so the skill

> of teaching the conceptual understanding was not there (interview, February 26, 2018).

Findings

Teachers held the knowledge of mathematics in a way they were taught in, and the effectiveness of MTPDP intervention in unpacking some of the mathematical concepts at a conceptual level enabled the teachers to impart that knowledge to the learners.

Discussion

Kilpatrick, Swafford, & Findell (2001) describe five strands of mathematical proficiency, namely, "conceptual understanding", "procedural fluency", "strategic competence", "adaptive reasoning", and "productive disposition" (p. 10). Whereas procedural fluency involves executing the procedures in an accurate manner in an efficient manner, conceptual understanding includes the understanding of why the procedures work (Skemp, 1986; Labuschagne 2016). This emphasises conceptual understanding as aiding in constructing knowledge that is interconnected, so when one part of the idea is recalled all the other connected parts are simultaneously recalled (Kilpatrick et al., 2001). Whereas the debate on which of these is more important than the other persists, Kilpatrick et al.'s (2001) argument that a good grasp of the concepts behind the procedures enable remembering the procedures easily and therefore enabling to make sense of the procedures probably explains the teachers perception of effectiveness of the MTPDP in unpacking mathematical concepts.

4.4.2. Teacher self-efficacy

The confidence in teaching acquired by participation in MTPDP has found strong resonance among the teachers.

Confidence

The teacher confidence in delivering the lessons has found strong resonance among the teachers. The confidence has been demonstrated variously as 'ability to respond to learner queries', 'unafraid of any mathematical problem', and confident about content to be delivered.

Teacher Musa expresses confidence in presenting to the learners: "whenever I go to present to the learners, I master almost everything. Whenever the learner asks the question, I know I know the answer. I am confident" (interview, February 28, 2018). Also, the confidence is expressed by Teacher Musa as "I am not afraid of any mathematical problem and if there is …I can encounter a problem, I directly tell the learners I will find a solution for them. I don't lie to them" (interview, February 28, 2018).

Teacher Shaka on the other hand talks of upliftment of confidence as follows:

> There are topics that one might find himself not a very comfortable to offer and yet you are sceptical of requesting some assistance from other teachers, you know so the confidence is now there in all subject matters in all concepts, in all mathematical concepts, when you go there to class to face these learners you are now confident of what we are doing because of what MTPDP has impacted on (interview, February 21, 2018) .

Teacher Khanyisile, on the other hand, sees confidence emanating from "the way they are helping us…in terms of content training" and "prepare us before we go to class", acknowledging "planning and preparation" as "very important before going to class" expressing that "at least as a teacher I know what is it that I must do" (interview, February 21, 2018). This was echoed by Teacher Nomvula.

Teacher Zanele, sees the confidence emanating from the ability to cover all the contents for the learners that were being dodged before:

> The confidence I have gained it boosted me in a way that there was some other contents in maths whereby I was dodging them sometimes I was just cutting them just like giving the learners and telling them 'go do it at home but now I am confident I can cover each and every content strand according to the ATP, that is the confidence I have gained (interview, February 16, 2018).

Perception of the facilitator

The teacher confidence is seen in teachers asking to be given higher grades. The facilitator articulates: "I heard from the Principal, they are confessing to me to …you can give me grade 7 because they are now confident" (interview, March 05, 2018).

Findings

The confidence acquired in teaching, owing to participation in MTPDP, is symptomatic of teacher self-efficacy, as a renewed confidence in themselves and in their perceived ability to teach towards better outcomes and expected goals.

Discussion

Self-efficacy points to the teachers' perceptions of the ability of the teacher to influence learners' learning outcomes (Bandura, 1997). Chacon (2005) acknowledges teachers' sense of self-efficacy as instrumental in creating a quality classroom environment by planning lessons directed at improving learning and actively engaging them in learning. Gabriele and Joram (2007) and Guskey (1988) also specify teacher self-efficacy as determining the inclination and the persistence to adopt new instructional practices. This is in sync with the perceptions of the teachers on the effectiveness of the MTPDP in enabling teacher preparation and enhancing knowledge and thereby impacting on teacher self-efficacy.

4.4.3. Transformation (in teacher classroom practice)

The codes leading to the theme 'transformation' include 'teacher-centred to learner-centred pedagogic practice', 'compliance to autonomous in implementing ATPs', and 'classroom management'. All the codes are detailed below. The shared perception of the effectiveness or ineffectiveness for each of the codes is highlighted, followed by the evidence relating to the same in the form of teacher responses. This is followed by the facilitator's perception of the same as a triangulation of data to affirm credibility. This is followed by an analysis of the code in relation to the existent literature and the findings of the study for that code. The theme 'transformation' resonated with the same theme identified in a study by Ross et al. (2011).

Teacher-centred to learner-centred pedagogic practice

The effectiveness of MTPDP in transforming teachers' classroom practice from a predominantly teacher-centred to learner-centred classroom practice found strong resonance among the teachers, though in varied ways.

Teacher Khanyisile sees a transformation in her practice, as she involves learners actively in their own learning unlike before when learners were passive participants in her class. Teacher Khanyisile elaborates the before and after scenarios by noting that before, learners would "just sit and listen to the teacher…and [teacher] doing everything", highlighting teacher talk as the dominant form of pedagogy, and "now the learners are the ones that are more involved, they are the ones doing everything" (interview, February 21, 2018), altering the role played by learners as active recipients of knowledge as opposed to passive recipients (Mtika and Gates, 2010). The MTPDP intervention, as Teacher Nandi articulates, enabled the teacher learning that "you don't tell learners what to do, you give them the challenge, let them do it then they discover for themselves" (interview, February 14, 2018). Teacher Nandi cites the example of teaching 2D shapes:

> I may say draw me a square, draw me rectangle for example, they do it and from there you go , let's do the properties, let's look at the differences between these two shapes, they will tell you this one is like this, this one is like this , they are giving you answers you never told them then after that we are telling them [the] …difference between a square and a rectangle, these are the similarities, they discover themselves like you just gave them ….they draw, look at these shapes , so what is the difference so already they are going to tell you before you can tell them (interview, March 23, 2018).

Teacher Nandi thus elaborates on taking learners through an exploratory learning process.

This shift in the practice involving learners, enabled "learners to think independently", and as more time is devoted to practice, their "minds is always busy", thereby making it the "most interesting subject" (Teacher Khanyisile, interview, February 21, 2018)). Teacher Nandi also expressed frustration at her previous practice of teacher talk, "I will be talking alone, they are

not hearing me at all, and I will become frustrated to say how do I make these learners to understand me" (interview, February 20, 2018).

This reflects limitations in her ability to reach the learners as she articulates a disconnect between teacher's teaching and learners' learning. She further elaborates, "I would become frustrated…when…they don't perform, how come because I taught these learners" (Teacher Khanyisile, interview, February 27, 2018). This implies that the teaching is not translating into learning. This depicts a sense of helplessness among teachers in effecting positive learner outcomes and pre-MTPDP teacher classroom practice as unhelpful in achieving the teacher objective of positive learner outcomes.

The role of MTPDP in effecting the realisation of the shift from teacher at the centre of learning to bringing forth the learner at the centre of learning, through its manifestation in classroom practice, is articulated by Teacher Shaka as follows:

> If I may cite an example with three-dimensional objects and two-dimensional shapes, you know sometimes when you feel like you are more experienced you don't need to be using it….it is a teachers individuals feeling to say, I do not be using models to deliver this subject matter because of my experience…in essence that is wrong because you are doing it for yourself and you are no longer doing it for kids but if you have to do it for kids you want to make sure that kids get engaged into that subject matter (interview, February, 21, 2018).

Findings

Teachers' experienced a transformation in classroom practice, from a traditional teacher centred pedagogic practice to learner-centred pedagogic practice. This transformation, perceived as effective, included a shift from direct transmission method of teacher talk to involving learners by facilitating exploration, from reliance on single pedagogical strategy to use of multiple pedagogical strategies, and from attitude of compliance towards ATPs to bringing autonomy in decisions on lesson planning'.

Discussion

Mtika and Gates (2010) construe learner-centred pedagogy as an active construction of knowledge as against being passively assimilating knowledge, thus supporting the teacher perceptions of transformation to learner-centred pedagogy in actively engaging learners in their own learning. Stephan (2014) also supports the need for active role by learners in taking-up problem solving, with the role of the teacher mainly as a facilitator in guiding towards problem solving, thus emphasising the need for teachers and learners to construct knowledge together. The use of multiple pedagogical strategies by teachers as a learner-centred practice is supported by findings of Connell, Donovan, & Chambers (2016) asserting that active learning pedagogies are learner-centred pedagogic strategies that improve learners' learning.

From compliance to autonomous (From an attitude of compliance to autonomous nature regarding implementing ATPs)

The teachers unanimously perceived as effective the shift from strict compliance to ATPs to bringing in some autonomy in teacher's lesson planning. The teachers perceived this shift as enabling them in addressing the learning needs of the learners belonging to these Quintile 2 schools, majority of whom face learning deficits.

The frustration among teachers on encountering learners who lacked grade-appropriate skills was elaborated by Teacher Zanele:

> To assume that in Grade 6, the learners in Grade 6 are supposed to know this and this and this and we go there and make sure you deliver or just give the learners the work and when you have to mark then this one is wrong, this one is wrong, this one is wrong (interview, February 16, 2018).

Teacher Khanyisile echoes the same issue "I would become frustrated …when … they don't perform" prompting the teacher to ask, "how come because I taught these learners" (interview, February 27, 2018). Teacher Musa expresses his dismay with ATPs in that the "teaching plan it accommodates the gifted ones because we are supposed to teach this in this period, if maybe in 10 min time there are learners who don't understand division" (interview, April 13, 2018). This brings to fore the dissociation of the ATPs from the context of classrooms and learners in low-quintile schools, faced with "insurmountable learning deficits" (Spaull & Kotze, 2015,

p.1). As Teacher Musa aptly puts it: “sometimes we have to bend the rules, otherwise those learners are going to be left out” (interview, April 13, 2018). This indicated a shift from teacher-centredness to learner-centredness because of a shift from an attitude of ‘compliance’ to ‘autonomous’ nature in dealing with ATPs with learners’ learning as the focus, as teachers perceive ATPs as not attuned to the needs of these learners.

Teacher Khanyisile expressed it thus “I think we are sticking too much to the work schedule. We are focusing only on the work schedule we are not exposing learners” (interview, February 27, 2018).

Findings

The inclination to adhere strictly to ATPs signalled an attitude of compliance (Singh, 2015). Rigid adherence to ATPs did not yield results as regards learners’ learning as the context of classrooms in which the lesson plans were to be delivered or the assumptions on which the ATPs were designed did not match the context in which it was supposed to be implemented.

Discussion

The knowledge of multiple strategies and the knowledge of introduction of the subject matter while unpacking teacher knowledge (detailed above) would have provided the teachers with a pedagogical repertoire of strategies that could accommodate the learners of all abilities and engage learner interest. Thus, the knowledge imparted by MTPDP intervention would have provided the much-needed confidence to move away from ‘compliance’, which was characteristic of teacher-centredness, to adjusting the lesson plans according to learner needs so that learning happens, and learners of all abilities are accommodated. Findings by Singh (2015) that the need expressed by teachers to be treated as autonomous professionals (who value learners’ learning as of utmost priority) in enacting CAPS curriculum emerges from the blind compliance the teachers are expected to follow which is at times contrary to their beliefs. Thus, the shift from compliance to autonomous nature seen in teachers participating in this intervention signifies their belief in putting learner at the centre of learning rather than blindly complying.

Lesson preparation and planning

The teacher perception of the effectiveness of MTPDP in assisting in transforming lesson preparation and planning for effective delivery of lesson found moderate resonance among teachers.

Teacher Khanyisile pointed out that, "We are able to plan as a group, yes we are able to help each other on how to approach a certain topic and the resources, also with the help of [MTPDP]" (interview, February 21, 2018).

Teacher Sizani echoes this aspect of collaboration in sharing approaches and methods that could prove effective for learners and articulates:

> We meet together …… about that topic maybe you find that [teacher] …..understand something better than I understand so once we meet together I learn from [that teacher], [that teacher] learn something from me so we help each other and also maybe we also have different approaches to a particular topic but you find that the way maybe I am doing it sometimes somehow it is difficult for the learners…another teacher I say that how we can approach this topic like this, you know you find it easy (interview, April 17, 2018).

Emphasising the planning of the lesson in such a way as to accommodate the varied learning styles of learners, implies taking into context the learner, as Teacher Khanyisile reiterates:

> There is a huge change because now like when I plan a lesson I make sure that it caters all the learners in the class with their different learning styles so I plan according to that way because some learners they learn best by taking them from concrete to abstract, while there are some just giving them abstract things they are able to do it, so I take them through all that stages (interview, February 27, 2018).

As part of lesson preparation, structuring the lessons, implying allocating time for each aspect to be covered, was put into practice as articulated by Teacher Musa. Emphasising the importance of time management in lesson delivery Teacher Musa articulates, "…because dividing time is very important. Unfortunately, the teaching time it accommodates the gifted

ones most…because we are supposed to teach this at this period, if maybe in 10 min time there are learners who do not understand division" (interview, April 13, 2018).

This reiterates that lesson preparation and lesson structuring aided in responding to accommodate the needs of underperforming learners too. Teacher Musa and Teacher Khanyisile also state using adaptive strategies (Baroody & Dowker, 2009) in mathematics teaching, enabling to cover more content thereby improving efficiency of lesson delivery. Teacher Khanyisile puts it as follows:

> Before like when I go to class, I am going to do division, I just stick to division and that is it. Whereas now since the training …, I link division and multiplication, because they are the inverse of each other. They do division and they have to prove for me whether the answer is correct or not and by proving that they will be using multiplication, so we are able to cover more now unlike before (interview, February 27, 2018).

Teachers expressed that their attitude to lesson preparation has changed post-intervention, and they take lesson preparation seriously, as Teacher Nomvula articulates:

> Because I was lazy to plan and I got stuck sometimes and I would say the learners don't even know that I am stuck but after the project, my conscience has changed very much I prepare, plan my lesson, I cover the teaching aids you provided us, I even ask my learners to make some other teaching aids so that they can help and assist in the lesson (interview, February 14, 2018).

Teacher Nandi conveys that planning lessons in a structured manner impacted on the pacing of learners as follows:

> Now I see the pacing of the learners is different from before so now they finish the work quickly meaning before when you give them mental maths they would take 30 min to write mental maths by that time you haven't reached the content of that lesson, but now they can do mental maths between 10-15 minutes, they are done we are doing correction we are done with mental maths and by the time we go on class activity it is like there is

> more time they can do the class activity and the homework within that period of time unlike before we did not do homework because the time was against us leave the classroom before finishing everything (interview, February 20, 2018).

Findings

Lesson preparation and planning, according to teachers, assumed a collaborative form after the intervention as against preparing alone, pre-intervention. Lesson planning that took into consideration the varied learning styles of all the learners, especially underperforming learners ensured that the context of learning of the learners was taken into account while also ensuring pacing of learners.

Discussion

Clarity in presentation and well-structured lessons are crucial aspects of "direct instruction" and have shown positive impact on learner outcomes (OECD, 2009, p. 89). Van Driel, Verloop, and de Vos (1998) emphasise the need for both knowledge of content and context as necessary to transfer the knowledge of subject in a specific context. Ramaligela (2012), in a study of student' teachers, found that the lack of action-orientated knowledge impeded the implementation of lesson plan in real classroom situations, thus emphasising lesson preparation as impacting classroom lesson delivery and therefore affecting the classroom practice. Ramaila & Ramnarain (2014) acknowledged that collaborative lesson planning in communities of practice among physical science teachers aided in reducing planning time and served as a platform for sharing creative and innovative practices thus enabling teachers to face the challenges of implementing the curriculum. This agrees with the teacher perceptions of effectiveness of collaboration, as articulated by MTPDP teacher participants. Thus, it may be concluded that lesson preparation and lesson planning as providing immense pedagogical value for teachers. Ramaila and Ramnarain (2014) emphasise that writing a lesson plan has immense pedagogical value in that it provides an opportunity to plan deliberately for the challenges anticipated to occur in implementing the curriculum and therefore enables development of reflective teacher practitioners.

Classroom management practices

Teachers perceived the effectiveness of MTPDP in enabling better classroom management, and this found strong resonance among the teachers. The introduction of group work in classrooms, with well-performing learners grouped with low-performing learners enabled involving well-performing learners to assist learning of low-performing learners with peer support as it enables the "learners to understand quicker" as "whenever a learner assists other learners that learner at the same time is revising" (Teacher Musa, interview, February 22, 2018). Group work also aids in moderating teacher dominance as Teacher Khanyisile puts it:

> I give them sums in groups then I take those who perform above average to assist those and I instruct them to give each one a chance within the group to try some of the sums then it becomes better that way unlike me doing everything (interview, February 27, 2018) .

This addresses the "need to accommodate all the learners, sometimes when you teach you don't consider other learners, you will find that other learners are lagging behind" (Teacher Musa, interview, April 13, 2018).

Working collaboratively in groups afforded the opportunity for learners to learn with and from their peers and in the process generate their own knowledge.

The facilitator corroborates the perception of effectiveness of teachers in improving lesson preparation and planning and classroom management geared towards learners' learning. The facilitator articulates thus:

> I can't say 100%, but 90% have the knowledge of preparing a lesson. A lesson that you will be able to involve the learners in their classrooms. Then there is time management to say during the lesson because when we started with them, sometimes they could do corrections only, the whole period, no concept developed. So, time management was a challenge and also that had an impact on the what you call it on the class activity (interview, February 26, 2018).

Findings

The introduction of group work in classrooms ensured peer learning as low-performing learners were grouped with well-performing learners.

Discussion

Classroom management is critical to creating a classroom environment where teaching and learning can happen and the responsibility for this rests with the teacher. Protheroe (2007) advocates sharing ideas through group work aids in mathematics learning and is an indication of an effective mathematics classroom.

4.5. Conclusion

'Teacher as a learner' theme resonated in its effectiveness among teachers strongly in 'enabling teacher learning' and 'enhancing teacher knowledge'. Teacher learning was perceived as enabled through the features of 'coherence', 'content coverage', 'active learning', and 'sharing ideas and teacher collaboration', and perceived as derived from participation in the content-based workshops. The MTPDP design components depicted as 'categories' namely content-based workshops, the facilitator, pre-tests and post-tests, and classroom-based support were strongly perceived as effective. However, the unanimous perception of effectiveness shared by teachers on the design features of the MTPDP that 'enabled teacher learning' emerged from the 'content-based workshops' component and hence emerged as the most effective component of the MTPDP intervention. The teacher perception of effectiveness of the 'classroom-based support' component derived from the provision of a 'safe learning environment' and 'modelling classroom delivery and monitoring classroom implementation'. The 'safe learning environment' was perceived strongly as effective, and 'modelling classroom delivery and monitoring classroom implementation' was perceived as effective though not unanimously.

Teacher knowledge was perceived as enhanced through the acquisition of 'knowledge of introducing the subject matter', 'multiple strategies', 'knowledge of content strands previously skipped' and 'making sense/unpacking of mathematical concepts'. The learning was perceived as supported by the safe learning environment enabled by facilitator support in both content-based workshops and classroom-based support by modelling classroom lesson delivery. The 'knowledge of introducing the subject matter' and knowledge of 'multiple strategies' were unanimously perceived as effective in enhancing knowledge by the teachers and therefore perceived as strongly effective, whereas 'knowledge of content strands previously skipped' and

‘making sense /unpacking of mathematical concepts’ was not unanimously perceived as effective and hence perceived as moderately effective. The teachers perceived all these features as contributing to improved self-efficacy in the form of improved confidence to deliver mathematical content in classrooms.

All this led to a transformation in classroom practice highlighted by change from ‘teacher-centred to learner-centred pedagogic practice’, ‘change in attitude of compliance to an autonomous nature in implementing ATPs’, ‘structured lesson preparation and planning’, and change in teachers’ ‘classroom management practices’ indicating the transformation from teacher-centred to learner-centred practice geared towards learning of learners.

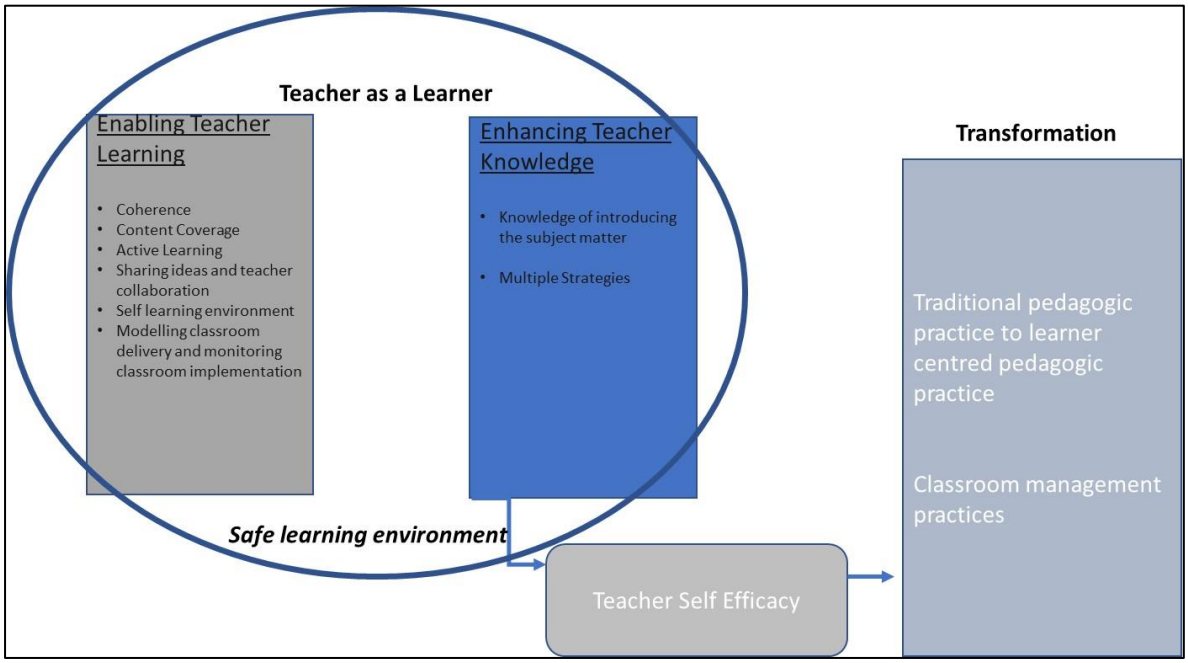
The overall strong resonance among teachers of the perception of effectiveness, despite the differences in teacher qualifications and experience in teaching mathematics, probably derives from the adult learning theory underlining the MTPDP intervention that speaks to reflection and collaboration as its key features (Gregson & Sturko, 2007). Strong perceptions of effectiveness of MTPDP in enabling acquisition of ‘knowledge of multiple strategies’ speak to the MTPDP feature of focusing on content-specific pedagogy more than general pedagogy. All these features of the MTPDP speak to job-embedded features of PD (Althauser, 2015; Middlehurst, Cross, & Jeannin, 2018), that responded to the individual and context-specific needs of the teachers, and is probably from where this strong perception of effectiveness emanates, thereby leading to a transformation in classroom practice.

The teacher perception of effectiveness of the MTPDP, in enhancing knowledge and transforming classroom practice enabled by the design features of the MTPDP also speak to new paradigm of PD based on constructivism that values teacher experiences, teachers’ context of practice, and teacher collaboration thereby improving teacher effectiveness (Pitsoe & Maila, 2012).

5. INTERPRETATION OF THE FINDINGS IN REGARD TO THE CONCEPTUAL FRAMEWORK

This chapter presents the interpretation of the findings in light of the conceptual framework, based on Desimone's (2009) framework for analysing the effectiveness of teacher PD. The conceptual framework as manifested in the MTPDP intervention is depicted in Figure 7.

Figure 5: Conceptual framework as manifested in the MTPDP intervention



5.1. Interpretation of the themes identified with reference to the conceptual framework

5.1.1. Theme 1: Teacher as a learner

The theme 'teacher as a learner' has been derived from two sub-themes namely 'enabling teacher learning' and 'enhancing teacher knowledge'. The teacher assumes the role of an adult learner when participating in a teacher PDP. The first component of Desimone's framework, which encompass the design features of the PD, speaks to the subtheme 'enabling teacher learning'. The core features of the MTPDP perceived as effective in enabling teacher learning, identified by the MTPDP participants, included 'coherence', 'content coverage', 'active learning' and 'sharing ideas and teacher collaboration'. These agree with the design features of

the conceptual framework for effective PD based on rigorous empirical studies (Desimone, 2009; Garet et al., 2001). These were identified as the core features deriving from the 'content-based workshops' component of the MTPDP. Features of 'safe learning environment', and 'modelling lesson delivery and classroom implementation', which were perceived as effective by teachers were derived from the 'classroom-based component' of the MTPDP.

The teacher perception of effectiveness usually varies among teachers as the teachers themselves differ in their teaching experience, subject knowledge, and attitudes to PD (Torff & Sessions, 2008). However, the shared perceptions among teachers of the effectiveness of the MTPDP in enabling learning, inspite of inherent differences among them cited above, probably could be explained by the key features of design of the MTPDP that speaks to the principle of adult learning guiding the MTPDP where teacher experiences are valued (Trotter, 2006). The shared perceptions of effectiveness are thus noteworthy, considering that the teachers participating in the MTPDP intervention differed in their age, teaching experience, and qualifications. Gregson & Sturko (2007) suggest that when teachers' PD experiences are built upon principles of adult learning, there is emergence of teacher collaboration, reflection on practice, thereby enabling knowledge construction with other teachers. This probably explains teachers' shared perceptions of the effectiveness of MTPDP in enabling learning in that the teacher collaboration emerged among the MTPDP participant teachers in a very organic manner and was neither teacher-directed nor MTPDP-directed, as one of the teachers Teacher Shaka articulates:

> Collaborative planning and teaching, that is what I would say is a powerful tool that we took from ORT because sometimes you might say to yourself you know too much and yet you tend to forget some of the things that can assist you to deliver the subject matter so we do a lot of collaboration and reflect even just orally…in my view these training sessions to me were another way of collaborating collaborative planning for teachers and when we get back to our schools we try to employ that message that [the other teacher] said is working and is yielding results (interview, February 27, 2018).

The collaboration usually takes the form of PLCs (Flores et al., 2015); however, the organic emergence of collaboration among MTPDP teacher participants in the three-year period did

not result in any PLCs as structures of life-long learning in the schools. Even though Welch (2012) identifies teacher-led PD initiatives such as PLCs as crucial to maximising the benefits of teacher PD, his emphasis that their creation must not be directed provides support to the teachers perceptions of effectiveness of the MTPDP in enabling the organic emergence of collaboration in planning and teaching. The emergence of collaboration as a powerful tool further supports the evidence of the need for applying basic principles of adult learning theory in PDPs to improve the effectiveness of teacher PDPs dramatically (Beavers, 2009). This emergence of collaboration as effective, in the shared perceptions of the teachers on the effectiveness of MTPDP in enabling teacher learning, is further supported by the situation that they share the same contexts and therefore the same challenges in achieving the goals of learners' learning (Steyn, 2017). The active learning strategies (Cordingley et al., 2003) adopted by the MTPDP placed teacher at the centre of learning, in which their experiences were valued by providing them opportunities to present lessons to their peers in the content areas they were confident in. This probably set the tone for exchange of ideas on how to tackle issues that are common to their context of teaching. The facilitator's role was limited to facilitation and providing support in learning and not as a dominant authoritative entity, thereby creating a safe learning environment, which was echoed by all teachers alike. This safe learning environment was afforded by the support and motivation provided by the facilitator (Linder, 2011) thereby providing support to the perception of effectiveness of the MTPDP. This support, they perceived, was in sharp contrast to their previous experiences of attending teacher PDPs in intimidating environments. Therefore, it may be safely concluded that MTPDP was effective in enabling collaboration, teacher exchange of ideas on tackling issues of common interest concerning learners' learning and enabling the discovery of a support system that exists within their proximity, namely the teacher community. However, when teachers responded on the sustainability aspect of the MTPDP, namely the feature of MTPDP that teachers perceive as effective and would sustain even when the MTPDP intervention period ends, teacher collaboration did not find mention by any of the teachers, thereby projecting the need for formation of PLCs to sustain the collaboration.

The sub-theme 'enhancing teacher knowledge' captured the teachers' perceived effectiveness of the MTPDP in enhancing knowledge of content and knowledge of pedagogy, which aligned with the purpose of the MTPDP. The objective of the MTPDP was to improve the CK and PK to develop the PCK (Shulman, 1987) of the teachers. Desimone's (2009) conceptual framework delineates the core design features of the PD as enabling the acquisition of enhanced teacher

knowledge and skills, resulting in improved knowledge, which in turn impacts on changing teacher attitudes and beliefs, thereby impacting learners' learning. Thus, Desimone's framework is valued for its action model and the TOC model embedded in it (Boylan et al., 2018).

Since the improved knowledge was intended to be achieved through the amalgam of CK and PK, resulting in developing PCK, the researcher will interpret this subtheme using the the PCK components proposed by Ball et al. (2008). The subtheme 'enhancing teacher knowledge' was formed by the codes 'knowledge of introducing the subject matter', 'making sense/unpacking of mathematical concepts' and 'knowledge of content strands previously skipped'. The codes 'knowledge of introducing the subject matter' and 'knowledge of multiple strategies' garnered the maximum buy-in from teachers as regards the shared perceptions of effectiveness of the MTPDP in enhancing teacher knowledge. The knowledge of introducing the subject matter was enabled by the knowledge of the use of resources or manipulatives and the knowledge of relating mathematics to everyday things. The knowledge of multiple strategies was perceived as enabling the teachers to reach learners of all abilities. As Teacher Khanyisile articulates, the limitation pre-MTPDP intervention was that: "it was a one size fits all…only few learners who make it in class instead of many learners" (interview, February 21, 2018). The teachers unanimously agreed on the knowledge of multiple strategies as enabling them to provide the learners with multiple strategies, thus giving them the freedom to choose the method that best suits them. As the teachers were limited by their knowledge of strategies, the poor-performing learners were not catered for, thus garnering strong buy-in from all the teachers in that multiple strategies enabled them to "accommodate each and every learner, there are slow learners, the average and the gifted ones." (Teacher Musa, interview, February 22, 2018).

All the codes that make up the subtheme incline towards the PK, except 'knowledge of content strands previously skipped'. The teachers perceived the effectiveness of the MTPDP in improving PK, by improving knowledge of use of multiple representations, models, resources, manipulatives. This speaks to the KCT component of the PCK proposed by Ball et al. (2008) and as the pedagogy is specific to the content, and it also resonates with the knowledge-specific pedagogy component of Mft (Adler & Davis, 2006). This probably must be seen as teachers finding the teaching practice becoming more meaningful, evidenced by the teachers acknowledging its impact on learner engagement, and their ability to reach learners of all abilities (Westbrook et al., 2013), thereby leaning towards learner-centred practices (Maboya, 2014). The inclination of the teachers' perceptions of the effectiveness of the MTPDP more

towards enhancing PK with low emphasis on CK was confirmed by the facilitator, "…benefit to the teachers actually it was more of methods than the content because you know the knowledge itself it differs from one teacher to the other" (interview, February 26, 2018). Maboya (2014) argues that effective use of manipulatives demands a strong grounding in mathematical CK. Considering that CK of mathematics was not developed, it is unlikely that PCK would have developed among the teachers (Shulman, 1987). The unanimous and shared perception of effectiveness of pedagogical strategies thus may derive from the first encounters they experienced in using manipulatives or resources, which they refer to as 'knowledge of introducing the subject matter'. The perception of effectiveness may also derive from the first steps in transition from predominantly direct transmission pedagogy, which teachers practiced pre-intervention (limited by knowledge of strategies and the knowledge of the use of resources/manipulatives) and that is teacher-centred, to a learner-centred pedagogy. These factors probably explain the strong buy-in for the PK, in teacher responses to the question in the interview guide. The impactful aspect, as evidenced by teacher responses on the sustainability aspect of MTPDP, is that all teachers unanimously vouch for using multiple strategies in classrooms even if the MTPDP intervention period comes to an end. Thus, the knowledge of multiple strategies was perceived as the sustainable component of the MTPDP as perceived by the teachers. The strong perception of effectiveness of the MTPDP intervention among teachers may be interpreted in the context of low-quintile schools where teachers have to encounter learners with severe learning deficits (Spaull & Kotze, 2015). The knowledge of multiple strategies, in this context, enables teachers to be responsive to learners of all levels (Gentry et al., 2013) and therefore has been acknowledged by the participant teachers of this study. The context-responsive nature of the new knowledge acquired of the pedagogies might have been the reason for its strong perception of effectiveness. This is supported by Pausigere (2016) who advocates for pacing and sequencing of pedagogies according to the context in which learning is happening so that the pedagogies are of relevance to the disadvantaged learners too.

5.1.2. Theme 2: Teacher self-efficacy

Teacher self-efficacy and beliefs are the third component of Desimone's conceptual framework (2009). Teachers perceive knowledge, planning and preparation as improving confidence and therefore signal an improved self-efficacy. Fox (2014) reported teacher PK and self-efficacy as strongly positively correlated as regards mathematics teaching. The self-efficacy is seen as

manifested in teachers' actions (Bowles & Pearman, 2017) in the form of persistent effort and resilience to improve practice (Fox, 2014). Planning and preparation that teachers have been doing post-MTPDP intervention were collaborative in nature. Thus, peer collaboration, and success in activities that relates to them personally may be the source of motivation. The knowledge of pedagogy enabling the accumulation of a pedagogical repertoire, that teachers perceived as enabling learner engagement and accommodating learners of all abilities, could also have been the source of motivation. Thus, all these speak to the "vicarious experiences"[9]and "mastery experiences"[10] as the source of self-efficacy (Bowles & Pearman, 2017, p. 102). Considering that the MTPDP was not directed at building self-efficacy, the emergence of confidence as a sign of self-efficacy signals the vicarious experiences and mastery experiences as contributing to self-efficacy.

5.1.3. Theme 3: Transformation

The teachers' perceptions of the effectiveness of the MTPDP in enabling a shift from the traditional practice of 'teacher talk', characteristic of a teacher-centred practice, to a learner-centred practice (Kim, 2004; Opdenakker & Van Damme, 2006) is the crux of the theme 'transformation'. Any change in teacher knowledge must manifest in classroom practice to impact on learners' learning. Various ways knowledge is manifested in classroom practice have been proposed, namely how PCK is manifested in classrooms, namely in use of representations, use of topic-related instructional strategies, and use of learner interactions, in the South African context (Davidowitz & Rollnick, 2011). The context of low-quintile schools, which is the context of this study, is beset with issues of low CK of teachers and unqualified or underqualified teachers teaching mathematics (CDE, 2013; CDE, 2014), and following direct transmission as the predominant form of practice (Arends et al., 2017) . This demands that any PD designed for these schools aids in reforming teacher beliefs from an instrumentalist view of mathematics which views mathematics as a collection of facts to the dynamic view of mathematics which is a problem-solving view of mathematics which sees mathematics as a set

[9] Vicarious experiences, as contributing to self-efficacy, refer to experiences where peer interaction promotes learner beliefs thereby supporting implementation (Bowles & Pearman, 2017)

[10] Mastery experiences, as contributing to self-efficacy, refer to experiences where motivation plays a key role in achieving success and satisfaction (Bowles & Pearman, 2017)

of connected concepts and processes (Ernest, 1989). The teacher perception of effectiveness of the MTPDP in enabling transformation from a teacher-centred practice to learner-centred practice emerged from the following codes: 'traditional pedagogic practice to learner-centred pedagogic practice', 'from compliance to autonomous', 'lesson preparation and planning', and 'classroom management practices'. This indicates reformation in teacher beliefs to effect change in practice (Ball et al., 2008; Ernest, 1989).

'Traditional pedagogic practice to learner-centred pedagogic practice' and 'classroom management practices' was perceived as effective and found strong resonance among teachers, whereas the other two, namely 'from compliance to autonomous' and 'lesson preparation and planning' found moderate resonance among the teachers on perception of effectiveness. The special context of the low-quintile school classrooms in which teachers encounter learners lacking foundational knowledge in mathematics demands instruction that accommodates the needs of learners at all levels of the learning curve. The teachers perceive the knowledge of multiple strategies as effective in accommodating the needs of all learners, and teacher self-efficacy manifested as confidence in reaching the learners. However, considering that these teachers have been practicing a direct transmission pedagogy for a long time, an immediate transition to learner-centred pedagogic practice to be effective needs much more training. As Teacher Khanyisile suggested, "Twice but the same time so that we can be very very clear and sure" (interview, March 27, 2018) implies the need to concretise the learning to practice (twice here means to increase frequency from one session per week to two sessions per week) and in suggesting that the classroom practice "has changed a little bit" suggests that a lot more training is needed before change in practice can be concretised.

Thus, though beliefs may have changed in being more responsive to learner needs and aided in overcoming the attitude of compliance to autonomous in taking decisions aimed at improving learners' learning, there should be still a gap between beliefs and practice as the need for more training has been proposed by the teachers.

5.2. Conclusion

The teachers' strong perceptions of the effectiveness of the design features of the MTPDP, despite teacher differences in experience, age and qualifications, probably derives its strength from being grounded in adult learning theories that support collaboration and reflection, thus supporting the 'teacher as a learner' theme; teacher here is treated as an adult learner. These

features of the MTPDP enabled the acquisition of knowledge in content-specific pedagogy and general pedagogy. The knowledge of introduction of subject matter using multiple representations and multiple strategies enabled teachers to accommodate the learners of all abilities. The teachers appreciated the use of resources and manipulatives and also the aspect of connecting mathematics to everyday day life as engaging learner interest. This also provided enough freedom to learners to choose any of the strategies that suited their learning styles.

The enhanced knowledge was perceived as pivotal and manifested in improved confidence and higher teacher self-efficacy. As any change in knowledge manifests in classroom practice, the knowledge was perceived as enabling a shift from an overtly teacher-centred practice to a learner-centred practice. This involved both general classroom management, which is an aspect of general pedagogy and the use of multiple strategies in classrooms as compared to the pre-intervention use of a single strategy in classroom, limited by teacher knowledge.

Considering that teachers were experiencing the first exposure to learner-centred pedagogic practices, and because it was perceived as effective by teachers, their beliefs might have inclined towards learner-centred learning. However, in the light of the low CK of teachers which was not impacted upon, it is possible a conflict between beliefs and practice may emerge. Also it is more likely that the PCK has not developed in light of the low CK, which teachers perceive as not impacted upon much, as a strong CK is fundamental to building PCK suggested by numerous studies (Hill, Rowan & Ball, 2005). Sustaining the momentum towards learner-centred pedagogic practices need more concretisation of the methods and in-depth knowledge of content to establish connections between concepts. Low levels of CK manifest as disconnections in mathematics classrooms and lack of coherence in classroom instruction (Mhlolo et al., 2012; Morrison, 2013), procedural orientations to mathematics teaching (Sorto & Sapire, 2011), and inability to effective use of manipulatives in classrooms (Maboya, 2014) as evidenced in classroom practice. Therefore, it may be concluded that although teacher perceptions of effectiveness are very strong, the impact of the MTPDP may have been only at the level of a first encounter with new knowledge and pedagogical practices. Thus, the impact may have occurred at a very superficial level, as teachers themselves demand more training and improved CK and PK for the gains to be concretised.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This chapter is organised by providing conclusions on each chapter, followed by recommendations for future interventions, which is then followed by recommendations on future research. The chapter concludes by summarising the research purpose and the salient findings of the research undertaken.

6.2. Conclusions

The research purpose was to explore the teachers' perceptions of the effectiveness of a mathematics teacher PDP, the MTPDP, implemented over a three-year period in six Quintile 2 Primary schools in Ivory Park, Gauteng, South Africa. The participant teachers were teaching Grades 4-6. A synopsis of each of the chapters is presented and this presents a window to the research process in a summarised manner.

6.2.1. Chapter 1-Introduction

This chapter presented the main problem of the research. Mathematics teacher PDPs have generally been found to be unable to impact on improving teacher practice and therefore the learners' outcomes. Exploring the teacher perception of the effectiveness of PDPs is crucial because if the teachers do not perceive the PDP as effective it is unlikely to bring any transformation in teacher practice and by extension, the learner outcomes (Guskey, 2000). The setting of the intervention, namely Ivory Park, is described, followed by a brief explanation of the intervention, the MTPDP and its components. Thereafter, the problem of underperformance in mathematics in schools, and teacher quality as a crucial factor impacting on learner performance in low-quintile schools was highlighted. The need to improve teacher quality is crucial in the context of low-quintile schools in South Africa as teachers are the main source of support for learners in these schools owing to the poor socio-economic backgrounds these learners come from. Therefore, provision of PDPs for teachers belonging to these schools is necessary to improve teacher quality and thereby teacher effectiveness in these schools. However, the PDPs are criticised for being detached from the needs of the teachers and hence ineffective in impacting on teacher quality and therefore the learner outcomes. This demands

that PDPs are evaluated for its effectiveness on impacting on teacher knowledge and teacher practice to positively impact on learner outcomes so as to inform the design of effective PDPs. As teachers will not change their practice if they do not perceive the PDP as effective (Guskey, 2000), teachers' perceptions' of the effectiveness of the MTPDP was explored using a conceptual framework based on Desimone's theoretical framework for analysing the effectiveness of the MTPDP intervention and the relevant research questions that the research intended to answer, were arrived at.

6.2.2. Chapter 2-Literature review and conceptual framework

The literature review and conceptual framework chapter dissected the problem of mathematics learning, mathematics teachers and teaching in the context of low-quintile schools in South Africa. Evaluation frameworks with theoretical underpinnings that could be used to explore the teachers' perceptions of the effectiveness of teacher PDPs were identified. The critical issue of underperformance of learners in mathematics in South Africa was dissected leading to identification of teacher quality and thereby teacher effectiveness as an important factor affecting learner performance in South Africa. Literature on teacher PD models prevalent in South Africa were analysed. The evaluation frameworks for studying the effectiveness of teacher PDPs were explored and these frameworks were analysed for their applicability to this study. The literature highlighted the various issues with teacher PD, various frameworks proposed for evaluating teacher PD that linked teacher PD to learner outcomes. A research gap was identified with regards to perception studies that used the established theoretical framework of Desimone (2009), which presented a TOC model in depicting a continuum of change in impacting on learner outcomes, for evaluating teacher PD in the context of low-quintile schools in South Africa. A conceptual framework based on Desimone's (2009) theoretical framework was arrived at for exploring the teachers' perceptions of the effectiveness of the MTPDP along the continuum of change with the design features of the MTPDP, enabling acquisition of knowledge in terms of content and pedagogy, thereby leading to change in teachers' classroom practice.

6.2.3. Chapter 3- Research methodology

Qualitative research methodology was resorted to as the study dealt with exploring teacher perceptions of effectiveness of the MTPDP. The research design was a qualitative interpretive

case study. Eight participants who fulfilled the criteria of 80% attendance and who consented to participate in the study were interviewed using semi-structured interviews. An interview guide was used to conduct face-to-face interviews and were transcribed. The conceptual framework formed the basis for delineating data into three broad components and then open coding was applied. The coding process was detailed. The codes identified were then collapsed into themes with purpose of answering the research questions.

6.2.4. Chapter 4-Presentation of findings

Participant profiles were presented which included details of teacher experience, qualifications, grades taught, and attendance in the MTPDP intervention. The coding process was detailed and codes, categories, sub-themes and themes were arrived at and analysed for perception of effectiveness as strong, moderate and least. Each of the codes and themes were explored vis-à-vis the literature reviewed and agreements and dissonance with the findings were noted. The transcribed interviews served as evidence for the same. Major themes identified included 'teacher as a learner' including the subthemes 'enabling teacher learning' and 'enhancing teacher knowledge'; 'teacher self-efficacy'; and 'transformation'. The codes arrived at under the theme 'enabling teacher learning' were derived from the teachers' perceptions of experiences of participation in MTPDP vis-à-vis the salient features of the design of the MTPDP and therefore the categories under which each of these codes were identified under the theme 'teacher as a learner' encompassed the component features of the MTPDP, namely 'content-based workshops' representing 'Category 1', 'facilitator' representing 'Category 2', 'pre-tests and post-tests' representing 'Category 3', and 'classroom-based support' representing 'Category 4'. The individual codes identified under 'content-based workshops' (Category 1) included 'coherence', 'content coverage', 'active learning', 'sharing ideas and teacher collaboration' which were the design features of the MTPDP perceived as effective by the teachers. Content-based workshops thus emerged as the feature that resonated strongly with all the teachers. The codes 'safe learning environment' and 'modelling classroom lesson delivery and monitoring classroom implementation' emerged as strong features of 'classroom-based support' (Category 4). The categories 2 and 3, 'facilitator' and 'pre-tests and post-tests', respectively, though were perceived as strong in effectiveness, the perception was not unanimous. Though facilitator's support was seen as enabling in creating a safe and non-intimidating environment for teachers to learn, the need for facilitator to be equally competent in all content strands intended to be delivered was put forward. Also the pre-tests and post-tests

as a test of knowledge gain did not garner initial support eventually when teachers learnt that they were not full able to answer the tests set at grade level they found the tests as important but expressed feeling insecure about being tested.

The codes 'knowledge of introducing the subject matter', 'knowledge of multiple strategies', 'knowledge of content strands previously skipped', and 'making sense/unpacking of mathematical concepts' emerged under the subtheme 'enhancing teacher knowledge'. However only the codes 'knowledge of introducing the subject matter', 'knowledge of multiple strategies' found strong resonance among the teachers. The theme 'teacher self-efficacy' presented a strong sense of self-efficacy, probably emerging as the mediating theme resulting from 'enabling teacher learning' and 'enhancing teacher knowledge' resulting in the theme 'transformation' informed by the codes 'traditional pedagogic practice to learner-centred pedagogic practice', 'from compliance to autonomous', 'lesson preparation and planning', and 'classroom management practices'.

Thus, the subthemes 'enabling teacher learning' and 'enhancing teacher knowledge' captured the teachers' perceptions of effectiveness of the design features of the MTPDP and the teachers' perceptions of the effectiveness of the MTPDP in knowledge acquisition, respectively, thereby answering SRQ1 and SRQ2. The theme 'transformation' captured the teachers' perceptions of effectiveness of the MTPDP in changing classroom practice, thereby answering SRQ3.

6.2.5. Chapter 5-Interpretation of the findings in regard to the conceptual framework

This chapter analysed the themes individually and as a collective in the conclusion section. The themes were looked at in relation to the conceptual framework. The 'teacher as a learner' theme portrays teacher in this MTPDP intervention as an adult learner and the strong positive perceptions of teachers of the effectiveness of the MTPDP in enabling learning and enhancing knowledge acquisition, despite variations in age, teaching experience and qualifications, emanates from adult learning experiences guiding the MTPDP intervention. Considering that teacher collaboration garnered the maximum buy-in and it emerged organically from among the teachers speaks to the adult learning theories guiding this intervention. The design features of the MTPDP guided by adult learning theories that valued teacher experiences thus enabled knowledge acquisition of pedagogical strategies and the knowledge of introducing the subject matter. Thus, the first component of the conceptual framework, namely design features of the MTPDP led to the acquisition of the new knowledge of pedagogy, which formed the second

component of the conceptual framework, namely acquisition of knowledge of pedagogy. The knowledge of introducing the subject matter and knowledge of multiple pedagogical strategies enabled learner engagement in classrooms and teacher ability to respond to the learning needs of learners of all abilities, thus enabling responsiveness to the context of Quintile 2 schools in which the learners face severe learning deficits. The new knowledge acquired was perceived as effective by teachers in impacting positively on teacher self-efficacy. Teachers perceived self-efficacy must have provided enough confidence in contributing to bringing about a transformation in classroom practice. The transformation in classroom practice, the next component of the conceptual framework, was manifested as perceived by teachers in effecting change from a teacher-centred practice to a learner-centred practice, and from overtly compliant attitude to curriculum delivery to an autonomous attitude to curriculum delivery.

The perception of effectiveness of the MTPDP in enabling learning, enhancing knowledge, impact on self-efficacy, and in transformation to learner-centred practices was perceived as strong. However, it may be recalled that these teachers have been using teacher-centred practices for long, and that learner-centred practices need time to develop and that the role of CK in developing it is crucial. Therefore, it may be concluded that though the MTPDP was perceived as effective by teachers, the low CK may limit the gain perceived to be at the superficial level. Low PCK points to the PCK as likely to not impacted upon as a strong CK is fundamental to PCK development. Concretising learner-centred practices may need consistent efforts, through reflection and collaboration, to narrow the gap between beliefs and practice, thereby impacting positively on learners' learning.

6.3. Final conclusion

The study explored the teachers' perceptions of effectiveness of participating in a mathematics teacher PDP, the MTPDP. The teachers' perceptions of effectiveness were explored on the design features of the MTPDP that enabled teacher learning and the acquiring of new knowledge by participating in the MTPDP, and the change in classroom practice. All this was informed by the conceptual framework of the intervention based on Desimone's (2009) theoretical framework for evaluating the effectiveness of teacher PDPs. The teachers generally perceived the MTPDP as effective.

The design features of coherence and the use of active learning strategies resulted in organic emergence of teacher collaboration; this coupled with content coverage aligned with the ATPs

enabled teacher learning. The active learning strategies provided to teachers implied valuing the experiences they bring to the PD. The organic emergence of collaboration rather than being teacher- or intervention-directed implied that the teachers valued the collaboration. This could probably be explained by similar challenges they faced and therefore valued the knowledge shared by other teachers, especially in the form of multiple strategies, to tackle learner issues in mathematics. The coherent design of the MTPDP aligned with the ATPs ensured that the teachers were prepared well before presenting the content to learners. The strong resonance among teachers on effectiveness of the design features of the MTPDP in enabling learning can be probably best explained by the principles of adult learning theory as guiding the intervention, in which collaboration and reflection is an integral part. Thus, the content-based workshops were perceived to be most effective. The safe learning environments provided by the facilitator was also perceived by teachers as enabling learning to happen.

The teachers perceived the knowledge of introducing the subject matter, by using resources or manipulatives and relating mathematics to everyday life, as enabling learner engagement in classrooms. As the teachers now had something concrete to work on, engaging weak learners became easier, as engaging them was a challenge earlier. The knowledge of multiple strategies for delivering content and knowledge of multiple strategies for doing mathematical operations ensured that teachers could accommodate learners of all abilities by addressing their learning needs better. The teacher buy-in for the knowledge of multiple strategies was so much that teachers unanimously accepted it as the sustainable aspect of the MTPDP. The repertoire of pedagogical strategies amassed from the MTPDP thus found favour, as it enabled to accommodate the learners of all abilities, and especially the weak learners. However, there was no evidence of use of resources as leading to abstract learning and therefore this should be interpreted as deriving from being seen as just first encounters with the use of resources. The knowledge of pedagogy gained precedence over knowledge of content. However, as nearly half of the participant teachers admitted to being unable to complete pre-tests set at the learner level, exhibits low CK possessed by the teachers. Therefore, in the context of low CK exhibited by teachers, it may easily be inferred that there would not have been any development of PCK. The development of PCK demands as much knowledge of content as of pedagogy, PCK being an amalgam of both. However, the transition from knowledge of just one way of doing things to multiple strategies was indeed an immense leap of knowledge in terms of content-specific pedagogy. This probably garnered strong teacher buy-in because the teachers initially possessed a low knowledge base on pedagogical strategies.

The teachers unanimously perceive gaining confidence in delivering lessons and transformation in classroom practice, from a predominantly teacher-centred to a learner-centred pedagogic practice, as manifested in involving learners in their learning as against 'teacher talk' that was the prevalent pedagogic practice. The teacher attitude of compliance to ATPs to teachers exercising autonomy in planning and preparing lessons, with learner as the focus, is indicative of the teacher prioritisation for learners' learning than teacher compliance. The teachers perceive the knowledge gained as instrumental to enabling them to incline towards learner-centred practices.

Teacher knowledge manifests in classroom practice in the use of multiple representations, learner interaction, and therefore is a specialised knowledge, the PCK. The participant teachers in the study do perceive self-efficacy as influencing their beliefs and classroom practice. However, the low levels of CK may not aid a practice that conforms to their beliefs. Therefore, it may be safely concluded that though MTPDP has been perceived as effective by teachers in impacting on their beliefs, the low CK of teachers may act as an impediment to putting it in practice. Thus, the perceived effectiveness of the MTPDP would have been superficial. The teacher perception of the MTPDP intervention as effective, therefore, should be emanating from a first experience or encounter with this kind of PDP intervention. Thus, this MTPDP intervention should be setting the stage for further improving knowledge of content and pedagogy alike, so that the teacher beliefs can be transformed more concretely into teacher practice.

6.4. Recommendations

This research is significant in the context of teacher PD as it relates to mathematics teachers in the context of low-quintile schools in South Africa. It informs the design features, knowledge acquisition and classroom practices that teachers perceived as effective in implementation of a mathematics teacher PDP, the MTPDP. Small sample size makes it difficult to generalize the findings. However, as the low-quintile schools in South Africa share common contexts, this research has implications for designing teacher PDPs in the context of low-quintile schools. The following recommendations are made to improve the intervention to improve teacher learning and therefore learners' outcomes.

[1] Use of active learning strategies that value teacher experience should be advocated because if teachers are exposed to active learning strategies the learners too are likely to be given the

opportunity to learn through active learning strategies. The active learning strategies must include activities that relate directly to learners' outcomes, namely analysing learner books, analysing learner assessments, analysing teachers' classroom discourse, and should be pursued as they show if teacher actions are turning to learner outcomes.

[2] Knowledge imparted in mathematics professional development programmes should deal with both procedural and conceptual knowledge in an in-depth way rather than in a superficial manner.

[3] Use of resources or manipulatives should be encouraged not only as first encounters but that lead to mathematical sense-making leading to abstract learning. This is recommended because learner engagement in classrooms improved for weak learners when concrete resources or manipulatives were used.

[4] Collaborative learning communities need to be encouraged as life-long learning in local contexts and as much as possible should be encouraged to develop organically.

[5] University-school partnerships may be considered for sustained guidance from subject experts.

[6] Evaluation should be inbuilt into the intervention and theories of change need to be defined to delineate the process through which learner outcomes are achieved in the context of low-quintile schools to design more effective PDPs for the context.

6.5. Recommendations for future research

This study was informed by Desimone's conceptual framework. However, more clarity on how each of the components of the framework interact to impact positively on learner outcomes is inadequate. Research on what theories of change are impactful in the context of low-quintile schools, based on rigorous methodologies, that positively impact on learner outcomes, should be carried out to inform mathematics teacher PD to improve quality of the PDP and therefore the teacher quality. Rigorous comparative studies on classroom instruction of relatively well-performing low-quintile schools versus low-performing low-quintile schools in mathematics should inform what type of instruction is effective in improving learner outcomes in the context of low-quintile schools.

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Appendix A: Teacher profile

(Please tick the appropriate boxes where boxes are provided

1. Name of the teacher (Pseudoname)_____

2. Male ☐ Female ☐

3. Age group 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐

4. Years of experience teaching mathematics

Year (e.g. 2014. 2015)		Foundation phase			Intermediate phase		
From	To	Grade1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6

5. Year in which you attended ORT content workshops

Year	Grade you taught	No of ORT content workshops attended	No. of ORT classroom-based support availed
2014			
2015			
2016			

6. Details of other professional development trainings you received for Mathematics other than ORT

S.No.	Name of the training	Name of the Organiser	Content covered	Number of days/hours

7. Highest educational qualification attained by the teacher_____

Appendix B: Overarching Research Questions

Overarching Research Questions

What are the teachers' perceptions of the impact of MTPDP?

RQ1	RQ2	RQ3
What are the teachers' perceptions of the experiences of participation in the MTPDP vis-à-vis the effectiveness of the design attributes of the MTPDP?	What are the teacher perceptions of the effectiveness of the PD in acquiring new knowledge?	What are the teacher perceptions of the effectiveness of the MTPDP in changing classroom practice?

Semi-structured Interview questions (probing questions not included)					
What component of the MTPDP have you found to be most effective?	McGee et al. (2013); Smith (2015)	What new knowledge have you acquired by participation in MTPDP?	McGee et al. (2013); Warnasuriya (2014); Rimbey (2013)	How has your classroom practice changed?	Ross et al. (2011); McGee et al. (2013); Rimbey (2013); Warnasuriya (2014); Smith (2015)
What component of the MTPDP have you found to be least effective?	McGee et al. (2013); Smith (2015)	How do you think the knowledge has enhanced your teaching?	McGee et al. (2013); Warnasuriya (2014); Rimbey (2013); Smith (2015)	How has the knowledge contributed to changing the classroom practice?	Ross et al. (2011); McGee et al. (2013); Rimbey ; Warnasuriya (2014); Smith (2015)

What would you suggest to improve the MTPDP?	McGee et al. (2013); Smith (2015)	How has your view of mathematics changed?
Would you attend the MTPDP if it is offered again?	Ross et al. (2011); Smith (2015)	
What features of the MTPDP you think should be continued		
What features of the MTPDP you think should be done away with?		
What have been your experiences as an adult learner?	Ross et al. (2011); Smith (2015)	

Appendix C: Interview with the facilitator

IQ1: Did the teachers perceive the MTPDP as useful? Why and Why not?

IQ 2: In your view, what components of the MTPDP the teachers found beneficial?

IQ3: In your view, what components of the MTPDP the teachers found non-beneficial?

IQ4: In your view, what new knowledge the teachers have acquired?

IQ5: In your view, how has it changed their classroom practice?