PROFESSIONAL DEVELOPMENT: MATHEMATICS TEACHERS' IMPLEMENTATION OF FORMATIVE ASSESSMENT STRATEGIES

By

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DECLARATION

I declare that “Professional development: mathematics teachers’ implementation of formative assessment strategies” is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I have not previously submitted this work, or part of it, for examination at UP for another qualification or at any other higher education institution.

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Adri van der Nest

24 April 2018

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DEDICATION

I dedicate this research

to

My husband, D.P. van der Nest
who has supported me on all the paths I have set out to take.

and

my son, Bernhard and daughter, Carla
who inspired and encouraged me throughout my studies.

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ABSTRACT

Although buoyed by the induction of a democratic government, and the high ideals of our constitution, the South African education system has in many ways not met the expectations of its people, in this case, the mathematics education community. With the birth of an expansive intended curriculum came the monitoring of the outcomes through systemic type testing, the so-called attained curriculum. In time, it became clear that the inevitable ‘teaching to the test’ would constitute a narrowing of the implemented curriculum. Too much emphasis on systemic test results also resulted in summative assessment (assessment of learning) dominating instructional practices, neglecting other important curricular goals and content, and reliance on only one source of external monitoring to determine learner success in mathematics.

Literature on formative assessment (assessment for learning) reveals great potential for significant improvements in student achievement. However, little is known about mathematics teachers understanding and experiences of formative assessment strategies as an approach to teacher professional development. To counteract these, a project titled Assessment Enhanced Teaching and Learning (AETL) has been initiated to provide Grade 9 mathematics teachers and learners with curriculum aligned formative assessment tasks at strategic points throughout the year.

Against the background of the poor mathematics performance levels in South Africa, interventions for effective teacher development programmes to support practising mathematics teachers are much needed in the country. The review of literature, however, revealed a need for a deepening of understanding regarding the learning processes involved in implementing effective Professional Development (PD) programmes. The literature on Formative Assessment (FA) reveals great potential for significant improvements in student achievement. However, little is known about mathematics teachers’ understanding and experiences of formative assessment strategies as an approach to teacher professional development. To counteract these, a project titled Assessment Enhanced Teaching and Learning (AETL) has been initiated to provide Grade 9 mathematics teachers and learners with curriculum-aligned formative assessment tasks at strategic points throughout the year.

In this study, I explored the understanding and experiences of professional growth of nine Grade 9 mathematics teachers from five different schools in the Pretoria (Tshwane) region as they participated in the AETL project. Through a qualitative case study design I was able to explore, analyse and describe the teachers' understanding and implementation of formative assessment strategies and their perceptions regarding its influence on their professional growth.

The findings indicate a strong sense of motivation to participate in professional development interventions through the need to excel in systemic type testing. The overall results suggest that systemic testing, in particular the ANAs (Annual National Assessments), seems to be the most influential factor on the teachers' instructional and assessment practices. However, in the course of gathering the data, other issues emerged, for example, that teachers' conceptualisation of formative assessment is often misunderstood and not optimally utilised in the learning process. The most challenging factor experienced by the participants seems to be a lack of time and/or skills to accommodate the wide range of learner abilities in one class. It is therefore recommended that further research, beyond the scope of this study, be carried out to investigate these issues.

It was further revealed that the teachers experienced professional growth as a direct result of their involvement in the refinement and implementation of formative assessment strategies.

Keywords: Formative Assessment; Assessment for learning; Mathematics teachers; Professional Development; teacher learning

EDITING CERTIFICATE

Exclamation Translations

To whom it may concern

The thesis entitled, "Professional development: mathematics teachers' implementation of formative assessment strategies" has been edited and proofread as of 30 August 2018.

As a language practitioner, I have a Basic degree in Languages, an Honours degree in French and a Master's degree in Assessment and Quality Assurance. I have been translating, editing, proofreading and technically formatting documents for the past seven years. Furthermore, I am a member of the South African Translators' Institute (SATI) and the Professional Editors' Guild (PEG).

Please take note that Exclamation Translations takes no responsibility for any content changes made to the document after the issuing of this certificate. Furthermore, Exclamation Translations takes no responsibility for the reversal or rejection of the changes made to this document.

Kind regards

Melissa Labuschagne

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LIST OF ABBREVIATIONS

ANA	Annual National Assessment
CAPS	Curriculum Assessment Policy Statements
CPDT	Continuous Professional Development of Teachers
DBE	Department of Basic Education
DoE	Department of Education
FA	Formative Assessment
GDE	Gauteng Department of Education
GET	General Education and Training
HSRC	Human Sciences Research Council
NAPTOSA	National Professional Teachers’ Organisation of South Africa
NCS	National Curriculum Statements
PD	Professional Development
PCK	Pedagogical Content Knowledge

CHAPTER 1 GENERAL ORIENTATION

1.1 INTRODUCTION

Education, the most humanitarian of all professions, falls short in developing its own human capital – its most valuable asset in addressing student achievement: Teachers

(Rotherham, 2008).

This study investigated the learning experiences and professional development of Grade 9 mathematics teachers who participated in the refinement and implementation of structured, curriculum-aligned formative assessment strategies. Teachers from different schools actively engaged in dialogue and collaboration with professional specialists, as well as their colleagues in refining and implementing structured formative assessment practices in mathematics.

Central to this study is how nine Grade 9 mathematics teachers understand and experience formative assessment and how the implementation of structured, curriculum aligned assessment strategies has influenced their professional growth.

1.2 BACKGROUND AND RATIONALE

From my own experience as a secondary school mathematics teacher and educator at tertiary level, I was prompted to undertake this study for the reasons outlined in the following sections.

1.2.1 Poor learner performance and quality in South Africa's mathematics education system

Concerns about the quality of South Africa's education system, and in particular the levels of learners' performance in mathematics, are frequently raised. This is especially the case when external comparative assessments, which focus on outcomes and assessment-based criteria, are conducted in schools.

An example of these concerns is the World Economic Forum's (WEF) "Global Information Technology Report 2014" (Bilbao-Osorio, Dutta & Lanvin, 2014). The forum based its research on interviews held with business leaders to establish their views on the quality of education in their respective countries. This report discloses that the quality of South Africa's mathematics and science education was ranked last out of 148 countries. The report also ranked South Africa's general education quality at 146 out of 148 countries (Bilbao-Osorio et al., 2014, p. 287). Unfortunately, the report, although based only on perception, sparked media headlines such as *"SA has worst maths, science education in world"* (News24.com, 2 June 2014).

Recent media reporting on the Trends in International Maths and Science Study (TIMSS) also reflects the concerns regarding the quality of SA's education system. Phakati reports (2017):

> The TIMSS study is conducted every four years and the 2015 results were released late in 2016, which included 59 countries. The results placed South African grade 5 and Grade 9 pupils second-last in maths. Grade 9s were at the bottom of the class in science, trailing other African countries such as Botswana and Morocco. Grade 5s did not participate in the science tests. The tests cover grade 4 and grade 8 pupils in most countries, but in SA they are done by pupils in grades 9 and 5 instead.
>
> Grade 9 science pupils scored 358, compared to 332 in 2011, while maths pupils scored 372 compared to 352 in 2011.
>
> These scores were below the TIMSS "low" benchmark score of 400, raising questions about pupils' grasp of basic concepts such as graphs and whole numbers" (Phakati, 2017, p.1)

Reflections in the media and similar reports regarding the quality of the South African educational system, and in particular mathematics education and the implementation of the curriculum by teachers, remains a cause for concern.

1.2.2 The use of standardised assessments (systemic testing) to evaluate the quality of mathematics education

Several standardised assessment studies, both international and national, also report the low performance of South Africa's public schools in mathematics and science in particular. For the purpose of this study, I also refer to standardised assessments as systemic testing or high-stakes testing. International assessments such as the Trends in International Mathematics and Science Study (TIMSS), and local standardised assessments such as the Annual National Assessments (ANAs) provide us with information that suggests that there is a lack of learner proficiency in numeracy and literacy, despite Government's effort to improve the quality of education in South Africa. The increasing use of external standardised assessments to assess the quality of education systems is a key feature of recent global developments in education. Standards-based assessment was introduced in the United States in the late 1980s to monitor and improve the quality of education. The Department of Basic Education (DBE) introduced similar systemic and standardised assessments in South Africa in 2012. The Annual National Assessments (ANAs) aimed to provide system-wide information on learner performance and the quality of education in general (DBE, 2011a). Public school learners across Grades 1-8 have been writing the ANAs for both summative and formative assessment purposes since 2012; the ANAs have thus been extended to Grade 9 since 2013. The intention of these large-scale assessments was to improve teaching and learning in our schools, the reality, however, is that there has been little substantial improvement in the areas of greatest need (Long, Dunne & Mokoena, 2014). During the implementation of the ANAs in 2015, teacher unions threatened to discard the writing of these tests. According to the Department of Basic Education (DBE, 2016, p.7) the teacher unions raised the following concerns:

> (a) The tests are administered on an annual basis and hence the system is not given adequate time to remediate.
> (b) There is a need for a more intensive programme of teacher development to address the shortcomings identified through ANA.
> (c) ANA can only be written after it is remodelled.

In an attempt to resolve the disparity between the DBE and the unions, a Task Team was established to re-design the ANAs and an Inter-Ministerial Committee (IMC) to attend to the broader issues raised by the unions. At the time of this study the DBE was in the process of developing and piloting exemplar diagnostic and summative tests to replace the ANAs (DBE, 2016, p.24)

Although these studies provide us with important comparative data, deeper questions emerge concerning whether a high score in international assessments such as TIMSS, PIRLS (Progress in International Reading Literacy Study), PISA (Programme for International Student Assessment) or the local ANAs does indeed indicate quality education and quality student learning. What do we expect from the data obtained? How do we interpret the obtained data from these assessments? There is thus a need to investigate the link between what we as educators regard as effective teaching and learning or ‘good education’, and how we make judgements on the outcomes of external standardised assessments. How do these external assessments influence teachers’ view of the critical role and purpose of assessment to support student learning in their daily practices? In answering these questions, the broader foci of education and the value of measurement need to be considered in all assessment practices and not only in terms of ‘high-stakes’ assessment outcomes. We need to ask ourselves whether high stakes assessments create a situation in which we are valuing only what is or can be measured (Biesta, 2009). Do teachers use assessment only to increase externally assessed test scores, and in the process narrowing the curriculum? Are they only ‘teaching to the test’ and as a result neglecting the learning process? (Popham, 2001; Dreyer,2014; Van der Nest, Long & Engelbrecht, 2018).

Popham (2001) expresses his concern relating to teachers narrowing the intended curriculum through the practice of ‘teaching to the test’,

> American teachers are feeling enormous pressure these days to raise their students′ scores on high-stakes tests. As a consequence, some teachers are providing classroom instruction that incorporates, as practice activities, the actual items on the high-stakes tests. Other teachers are giving practice exercises featuring ′clone items′ – items so similar to the test′s actual items that it′s tough to tell which is which. In either case, these teachers are teaching to the test (Popham, 2001, p. 16).

Assessment is much more than just measuring the learning outcomes of learners; it is an integral part of teaching and learning, and plays an important role in change of, and progress in classroom practices (Black & Wiliam, 1998b; Shepard, 2000). Silver’s words that “standards do not teach; teachers teach" (Silver, 2015, p.1) emphasise the important role of teachers in assessment. Moreover, we need to ascertain how teachers interpret and act on strategies to inform their skills in order to assess for the purpose of *learning.* An important focus of this study was to consider and explore the views held by mathematics teachers on assessment, and in what way it influences their classroom practice.

1.2.3 The need for a deeper understanding of Professional Development

The Human Science Research Council (HSRC) released a report in 2006 that attributed “learners’ poor results to, among other reasons, poor preparation on the part of teachers” (2006, p. 118). The HSRC (2006) report further indicated that, although South African teachers have various opportunities for professional development, learners’ poor performance shows that these opportunities have had a limited impact on teacher development.

Of course, the Department of Basic Education (DBE) realises that our education system needs improvement. Mathematics has always been regarded as a difficult subject and attempts to provide more people with access to its power and usefulness is a primary goal of the government in their effort to improve the quality of our educational system and the professional development of mathematics teachers (DoE, 2006; DoE, 2007). The National Policy Framework for Teacher Education and Development is one such attempt by the government to address the professional development of teachers (DoE, 2007). This policy intends to “develop teachers’ professional knowledge and skills, enabling them to develop continually, by improving their professional self-efficacy, subject knowledge and skills and classroom management” (DoE, 2007, p.3).

Despite these efforts, the ineffectiveness of many of the South African teacher professional development programmes still raises concern. Many local studies support the key role of the teacher in improving student performance. Valuable contributions have been made to address teacher professional development (Adler, 2000, 2009; Bantwini, 2012; Steyn, 2009, 2013). The majority of studies, for example, point out that some of these initiatives do not consider the needs of teachers, or the difference in school contexts (Bansilal & Rosenberg, 2016; Mashile & Vakalisa, 1999), or the lack of leadership support during attendance and after implementation (Steyn, 2011). However, research on professional development is very much focused on specific interventions and activities addressing *what* teachers are supposed to do, but very few studies explain the complexity of teacher professional learning in terms of the various roles that teachers play, i.e. *why* teachers are willing to change and improve the quality of their teaching. It is therefore essential to gain a deeper understanding of how teachers experience professional development interventions in support of their teaching and learning (Guskey, 2002, p.381, Mizell & Learning, 2010; Opfer & Pedder, 2011). If we are to facilitate the continuous professional development of teachers (CPDT), we must understand the process through which teachers grow as professionals, and the conditions needed to support this growth.

1.2.4 Curriculum reform and the impact thereof on teachers' practices

Education is usually at the centre of any government's reform plans, and change in curriculum, quality, and standards is inevitable. Unfortunately, schools and teachers are expected to reflect these intended changes. Such reform cannot be accomplished effectively by simply introducing a new curriculum, as has been so often anticipated in South Africa over the past two decades. Frequent changes in curriculum consequently necessitate a change in the role of the teacher. Not only do teachers have to deal with changing content knowledge, but also a change in instructional and assessment practices, which results in numerous challenges concerning the effective implementation of a new curriculum.

Several changes in curriculum have been introduced in South African schools over the past two decades. Curriculum 2005 (C2005) was the first post-Apartheid curriculum after 1994 and was developed to implement change to redress the inequalities of the past.C2005 was based on the Outcomes-Based Education (OBE) approach in which outcomes statements and associated assessment criteria were to be achieved. Assessment guidelines were, however, not clear and precise enough and as a result, OBE needed to be revised. In 2002, a new curriculum was introduced, the Revised National Curriculum Statement (RNCS) for General Education and Training (Grades R–9) and the National Curriculum Statement (NCS) for Grades 10-12. Assessment standards were described in more detail and consisted of formative and summative assessment guidelines.

Most recently, in January 2012, the Curriculum and Assessment Policy Statement (CAPS)[1] was implemented (DBE, 2011). CAPS encourages teachers to apply a range of assessment strategies to promote student thinking and learning. The CAPS document provides teachers with meticulous descriptions of the different types of assessments to be used in South African schools and broadly describes the assessment process as:

> A continuous planned process of identifying, gathering, and interpreting information regarding the performance of learners, using various forms of assessment. It involves four steps: generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand and thereby assist the learner's development in order to improve the process of learning and teaching (DBE, 2011, p.154).

The significant shift from a teacher-centred approach to a learner-centred approach since OBE, and in the current CAPS curriculum, inevitably implies reform in the teacher's approach to teaching, learning and assessment. The current system requires teachers to familiarise themselves with an interactive goal-orientated method of teaching and a continuous reflective assessment process.

Teachers need time and support to develop skills to improve their assessment practices and ensure effective learning. Important questions also emerge about whether South African mathematics teachers are optimally using assessment opportunities to improve their classroom practices and student learning. How do teachers interpret reformed assessment policies and to what extent do they implement assessment to support student learning?

The important role fulfilled by teachers in curriculum reform in schools is critical to its success. However, very few studies have addressed the aspect of teachers' assessment knowledge and how they implement assessment strategies to support

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[1] CAPS is a comprehensive and concise policy document that replaced the Subject and Learning Area Statements, Learning Program Guidelines, and Subject Assessment Guidelines for all the subjects listed in the National Curriculum Statement (NCS) (Grades R – 12) in 2012.

learning. Dreyer (2014, p.24) draws our attention to an important aspect of educational reform:

> Changing assessment forms and formats without changing the ways in which assessments are used will not change the end result of education. In order for assessment to support student learning, it must include teachers in all stages of the process and be embedded in curriculum and teaching activities.

Change in an education system can also affect teachers' willingness to change their existing practices as teachers have their own beliefs and established classroom-based assessment practices that interrelate with current thinking about education. (Wiliam, 2007). Van den Akker, De Boer, Folmer, Kuiper, Letchert, Nieveen and Thijs (2009) support the stance that teachers' perceptions and attitudes towards a specific change strongly influence the way in which they implement this change in their classrooms. Teachers' willingness and preparedness for curriculum innovation relates to their views on an essential problem that is addressed by this particular change, for example, if teachers take the problem more seriously and feel that they can contribute to the solution, their willingness to change will increase. The authors emphasise the importance of revising the mathematics curriculum on a regular basis to provide learners with the necessary knowledge and skills to progress into the 21st century. However, the involvement of teachers in revising the curriculum need to be considered as this promotes alignment between curriculum, assessment and instruction (Van den Akker et al., 2009).

To improve the quality of mathematics education in South Africa and to reach the desirable learning outcomes, it is essential to emphasise the importance of teachers' knowledge of the curriculum and their understanding of the value of formative assessment, as well as how they apply it in their daily practices (Graven & Venkat, 2014; Long, Dunne & Mokoena, 2014, Van der Nest, 2012). It is therefore important to explore more innovative professional development strategies and to exploit the current assessment-driven education context.

As part of this study, and in collaboration with my supervisors, Professor Caroline Long and Professor Johann Engelbrecht, I explored the impact of formative assessment activities on the development of teacher agency in Grade 9 mathematics teachers in a published study (Van der Nest, Long & Engelbrecht, 2018). Against the background of the poor performance of South African learners in systemic type testing, two possible constraining influences of the systemic test were identified. These were a narrowing of the curriculum, and reliance on only one source of external monitoring. Successive reviews and revisions of the intended mathematics curriculum since 1998 have been conducted in South Africa to tailor the various curricula to narrow prescriptions of curriculum elements. We contend that a tailored curriculum focuses on addressing teachers' lack of content knowledge, but does not address the concerns of professional teacher development. We initiated the AETL Project (see Section 1.4) to involve teachers in the design and implementation of formative assessment tasks as an approach to professional development and to avert the narrowing of the curriculum and teaching to the test. We report on a case study involving four Grade 9 mathematics teachers in focus group discussions at one school in the Pretoria region. Our findings indicate that the teachers had a strong sense of professional agency motivated by their positive conceptions of mathematics and their beliefs that all children should be able to use mathematics in their lives, but also the need to excel in systemic type testing. The argument is for professional development activities to focus on an elaborated curriculum that not only adheres to the conception of mathematics as "a way of thinking and an approach to life", but also to involve teachers in the design and use of structured formative assessment tasks as an approach to professional development (Van der Nest, Long & Engelbrecht, 2018, p. 2).

This research inevitably leads to the following two questions: 1) Could mathematics teachers' participation in curriculum-aligned formative assessment practices allow them to expand their curriculum and assessment knowledge? 2) Could teachers' implementation of formative assessment strategies also contribute to improved changes in their instructional practices and, as a result, succeed in the attainment of their students' intended learning outcomes?

1.3 Problem statement

This research was based on the need to improve the teaching and learning of mathematics against the current poor performance levels of learners in systemic tests. As previously highlighted, the South African education system has in many ways not met the expectations of its people, in this case, the mathematics education community. Although several professional development initiatives were implemented to improve the standard of mathematics educators, many of these initiatives have not significantly changed teaching and learning when teachers returned to their classrooms. A deeper understanding of the central role of the teacher in terms of individual experiences and effective strategies to support professional learning and development remains under-examined (Desimone, 2009; Evans, 2014; Guskey, 2002; Steyn, 2013).

Several studies report teachers as the major role players in the implementation of the prescribed curriculum, however, their successes (or failures) in their performance are measured by externally created standardised (high–stakes) assessments (Bennett, 2011; Crooks, 2008; Stiggins, 2005).

To date, research, especially in the UK and the US, has shown that teachers are situated in a complex system of accountability in which success is measured by means of externally assessed scores (Jennings & Bearak, 2014; Ruthven, 1994; Shepard, 2008). Stiggins (2005), in particular, warns that high stakes summative assessments are used as a ‘power tool’ within educational communities and, as a result, teachers alter their beliefs regarding the intended purpose of assessment to support learning.

Summative and systemic assessment tests, such as the ANAs, currently seem to be dominating the assessment practices of South African classroom teachers (Graven & Venkat, 2014). These systemic assessments are directed by the Department of Basic Education (DBE) and are set by professional test developers with little input from classroom teachers. As a result, teachers aim their instructional practices towards previously tested skills and thus the test scores gained may not accurately represent gains in student learning. As an experienced educator for almost 20 years, I have noticed that many teachers have difficulties in evaluating data and developing appropriate interventions for improvement. This general lack of guidance in understanding and developing assessment strategies to support mathematics learning needs to be explored. Many teachers view assessments as the final step in the measurement of student learning. This defies its real purpose, which is to identify students’ strengths and weaknesses so as to support and encourage learning (Stiggins, 2005;2008).

Although formative assessment (formative assessment) has been shown to be effective when implemented correctly (Bennett, 2011; Chappuis, 2009; Heritage, 2011), the problem is that the circumstances, instances and strategies used by teachers to implement formative assessment are not well known (Clark, 2011). There is a lack of local research regarding professional development strategies to optimise the use of formative assessment in supporting the teaching and learning practices of mathematics teachers. Teachers need support and training in the effective implementation of quality assessment strategies to meet the current mathematics curriculum goals and accountability requirements.

Teachers in South Africa experience the poor performance of their learners in the ANAs and the related negative publicity as counterproductive to the teaching profession (Graven & Venkat, 2014; Long, Dunne & de Kock; 2014; Long, 2015). The implementation of well-designed assessment resources, with the intention of informing the teaching and learning process, is therefore sought by many. Research indicates that teachers do not make optimum use of Formative Assessment (formative assessment) to help them improve their teaching and learning practices (Heritage, 2007; Leahy & Wiliam, 2012). Assessment strategies, for example, class tests, classwork and homework, are primarily imitations of the external exams. However, these exams do not necessarily provide insight into students' thinking processes (Black & Wiliam, 1998b; Shepard, 2000; Stiggins, 2008). Mathematics teachers need developmental opportunities to reconsider their current classroom practices and to learn more about assessment to optimise student learning. This study addresses the current perceptions held by mathematics teachers regarding formative assessment practices, how much they value learning in their classroom-based assessment as it relates to their students' learning outcomes in mathematics, and how their involvement in formative assessment strategies and experiences influence their professional development.

International research on engaging learners in formative assessment practices, particularly in mathematics education, is extensive. However, the majority of research has not focused on individual teachers' involvement in the design or implementation of formative assessment tests. It was therefore important to explore teachers' perceptions and understanding of assessment; designed not only to serve the purposes of accountability, but also to improve teaching and learning (Bennett;

2011; Jennings & Bearak, 2014). It is essential that teachers reflect on or alter their perceptions of formative assessment to accommodate student learning in their daily practices.

Dunn and Mulvenon (2009) reviewed the literature on formative assessment and found a limited body of empirical evidence that supports positive educational outcomes occurring as a direct result of the use of formative assessment. The authors attribute the lack of studies, amongst others, to variations in the definition of formative assessment. Inconsistencies in conceptualising formative assessment as assessment *for* learning, instead of assessment *of* learning, tend to make teachers reluctant to incorporate new assessment strategies or to modify instructions in their classrooms.

Black, Harrison, Lee, Marshall and Wiliam (2004, p. 10) provide a good description of the relationship between formative assessment and assessment for learning:

> An assessment activity can help learning if it provides information that teachers and their students can use as feedback in assessing themselves and one another and in modifying the teaching and learning activities in which they are engaged. Such assessment becomes 'formative assessment' when the evidence is actually used to adapt the teaching work to meet learning needs (Black et al. 2004, p. 10).

For assessment activities to have an impact on mathematics teachers in such a way that they are willing to change or adapt their instructional practices, an in-depth study on how teachers perceive assessment is necessary. A deeper understanding is required of how teachers make sense of formative assessment, and in particular, how they try to find solutions to overcome obstacles between institutional requirements and effective classroom teaching and learning.

Understanding formative assessment in an era of accountability testing is a process where mathematics teachers may identify the ways in which standardised testing systems constrain the effective use of formative assessment, and in the process, prevent changes in existing practices and obstruct professional development. Despite the on-going extensive research and strategies relating to teacher development, the literature reveals that little research has been undertaken to explore the demands of an intended curriculum, or to gain a firm understanding of the links that teachers make between designing formative assessment tasks and meaningful learning experiences (Loucks-Horsley et al., 2010; Wyatt-Smith & Gunn, 2009).

Changes in society also demand new knowledge and skills to be integrated into a curriculum. As a result, this requires the continuous professional development of all role players involved in the development of an effective education system. For example, current views in mathematics education emphasise inquiry-based approaches to teaching and learning to promote problem-solving skills in order to engage students in mathematical thinking, and to deepen their understanding of mathematical concepts (Suurtamm & Koch, 2014).

Teachers are at the heart of any reform in education for they must execute the demands of these reforms in their classrooms. Many reform initiatives have focused on the key role of the teacher in improving learner performance as, on the one hand, teachers have direct, sustained contact with learners, as well as substantial control over what is taught and, in addition, the climate of learning (Desimone, 2009; Opfer & Pedder, 2011; Steyn, 2009). On the other hand, few studies report how practising mathematics teachers understand and make sense of formative assessment strategies and its effect on their professional development. Teachers need to realise the potential of quality classroom assessment to improve their teaching and learning, however, little attention is given to local professional development programmes addressing this need. There is a need to investigate professional development programmes designed to improve teachers' knowledge and practices regarding formative assessment so as to promote student learning. However, learning to enact quality assessment practices that focus on student learning takes time (Bennett, 2011; Cisterna, 2016; Harlen, 2013). As a result, pre-service and in-service teachers are often not fully equipped to enact quality formative assessment practices (Cisterna, Amelia, Kintz, Lane & Roeber, 2016; Heritage, 2011; Stiggins, 2008). It is therefore critically important to provide in-service teachers with sustained opportunities to develop quality formative assessment practices and skills when involving them in professional development programmes.

The Continuous Professional Development of Teachers (CPDT) can be seen as one of the most powerful strategies to improve teacher effectiveness. Not only is it available to almost every educator, but when properly structured and implemented, teachers, regardless of their qualifications or experience, can acquire the necessary knowledge and skills to meet their learners' needs. Therefore, we require teachers who are willing to participate in life-long learning experiences and to exhibit qualities to improve their existing professional knowledge and competencies.

Teachers need to identify themselves as professionals and make decisions that are in the best interests of the learners for whom they are responsible (Batra, 2009; Biesta, Priestley & Robinson, 2015). For that reason, more questions can be asked as to what motivates teachers to engage in professional development activities, and what processes occur causing teachers to change or adapt their instruction, and in the process develop as professionals (Black & Wiliam, 1998a; Guskey, 1986; Loucks-Horsley, 2010; Thijs & Van den Akker et al., 2009). Considering the importance of teachers' "active contribution to shaping their work and its conditions – for the overall quality of education" (Biesta, Priestley & Robinson, 2015, p.624), the concept of teacher agency as an import important dimension of teachers' professional development needs to be explored.

While there is consensus about the characteristics of effective professional development, there are still many questions to ask. How does a mathematics teacher experience the broader purpose of education within the class, attending to the different needs of learners, the school, the intended curriculum, and his or her own professional learning?

The quality of continuous teacher professional development initiatives therefore relies inevitably on the perspectives and input of the teacher. Teachers, especially in South Africa, should be actively involved in developing assessment instruments rather than only administering externally designed assessments such as the ANAs. The need for a broad-based knowledge system of assessment practices to support the teacher to become a professional agent of change and not merely an implementer of the curriculum is expressed by many local (Long, Dunne & Mokoena, 2014; Vandeyar, 2017) and international researchers (Biesta, Priestley & Robinson, 2015; Earl, 2013; Jennings & Bearak, 2014).

In order to contribute to this pool of knowledge, there is a need to understand the processes of change and willingness when teachers are involved in professional development activities, especially when they are interacting and collaborating with other teachers in a supportive environment that is conducive to learning. It is clear that effective professional development interventions to improve classroom-based assessment practices in mathematics, in particular, need to involve teachers and take into account the existing knowledge, skills, beliefs, and vast experience that they can add to optimising their learners' learning experiences in mathematics.

The input of practising mathematics teachers in assessment practices is important, as they are responsible for directly transmitting knowledge, culture, and skills that are relevant to society and to preparing learners for the 21st century. However, large-scale implementations and brief training sessions with large groups of teachers will not necessarily add to a better understanding of how teachers experience professional development interventions as supporting their teaching and learning. A deeper understanding of the central role of the teacher in terms of individual experiences and effective professional development strategies remains under-examined. There is a general lack of research on secondary school teachers' beliefs regarding mathematics *self-efficacy,* i.e. their beliefs about their capabilities to perform mathematics tasks, and mathematics *teaching efficacy,* i.e. their beliefs on how to effectively teach mathematics (Hart, Oesterle & Swars, 2013). The question is whether teachers feel confident that their knowledge of the curriculum content domain is "adequate or complete when compared with the actualised content and performance standards envisaged by the authorities" when external assessments are conducted (Schafer, 2002, p. 88).

Literature on, and theories about teacher professional development emphasising the importance of focusing on teachers' daily practices are in abundance (Cochran-Smith & Lytle, 2009; Earl, 2013; Turner, Warzon & Christensen, 2011). However, few studies have investigated how formative assessment activities can be integrated to inform change in the instructional practices of teachers and, by inference, their professional development (Bennett, 2011; Koh, Lim & Habib, 2015; Vandeyar & Killen, 2007). The strategies used by teachers, as well as the sources of influence in implementing formative assessment, are not well known (Bonner, 2009; Sach, 2012). There is a lack of guidance provided by programme developers on *how* assessment competencies should be developed through a learning and development process within mathematics classrooms. This study does not provide or offer solutions for mathematics learners to excel in systemic assessment but attempts to provide insight into how teachers navigate classroom assessment to promote student learning in a difficult era of accountability.

In general, classroom-based assessment is not utilised optimally for various reasons, which need to be explored. In this study, the sub-optimal use of formative assessment, and factors inhibiting teachers from effectively implementing formative assessment were explored through engagement with the literature and through empirical research.

As Ernest Boyer (in Sparks, 1992) observes,

> When you talk about school improvement, you are talking about people improvement. That is the only way to improve schools unless you mean painting the buildings and fixing the floors. But that's not the school, that's the shell. The school is people, so when we talk about excellence or improvement or progress, we're really talking about the people who make up the building (Sparks, 1992, p. 9).

It is therefore essential to place the Grade 9 mathematics teacher as the major role player in this study and address his/her assessment practices in order to enhance professional development and, as a result, improve students' learning. As CTPD plays a leading role in adding to teachers' knowledge and understanding, it is therefore imperative to provide opportunities for effective professional learning.

1.4 The Assessment Enhanced Teaching and Learning project (AETL)

Being a concerned mathematics educator myself, I became involved in the AETL project. This project is an extension of an initiative in the Centre for Evaluation and Assessment at the University of Pretoria. One outcome of the three-year project was the development of a model of assessment that provides articulation between three components: systemic assessment (monitoring), formative assessment (classroom-based), and professional development to address current assessment practices and problems experienced by mathematics teachers in South Africa.

Bennett and Gitomer (2009) proposed the ‘Cognitively Based Assessment *of*, *for* and *as* Learning’ (CBAL) model, based on three fundamental principles which 1. Describes what students have achieved (assessment *of* learning), 2. Facilitates instructional planning (assessment *for* learning), and 3. Is considered by students and teachers to be a worthwhile educational experience in and of itself (assessment *as* learning) (Bennett & Gitomer, 2009, p. 47). Bennett (2011) makes an important point that these relevant fundamental principles form a coherent system in which formative assessment is a critical part, but not the only part that impacts learning and effective CPDT. Bennett (2011, p.5) explains that new development in formative assessment should focus on “conceptualising well-specified approaches built around process and methodology rooted within specific content domains” to realise the maximum benefit of formative assessment. He further emphasises the importance of the professional development of teachers and the inclusion of fundamental measurement principles to facilitate learning.

The AETL project broadly addresses the following three critical components: curriculum expectations (monitoring component); teaching and learning (formative assessment component); and a professional development component based on the model of Bennett and Gitomer (2009). Figure 1.1 represents the developmental model of assessment as envisaged by the AETL project.

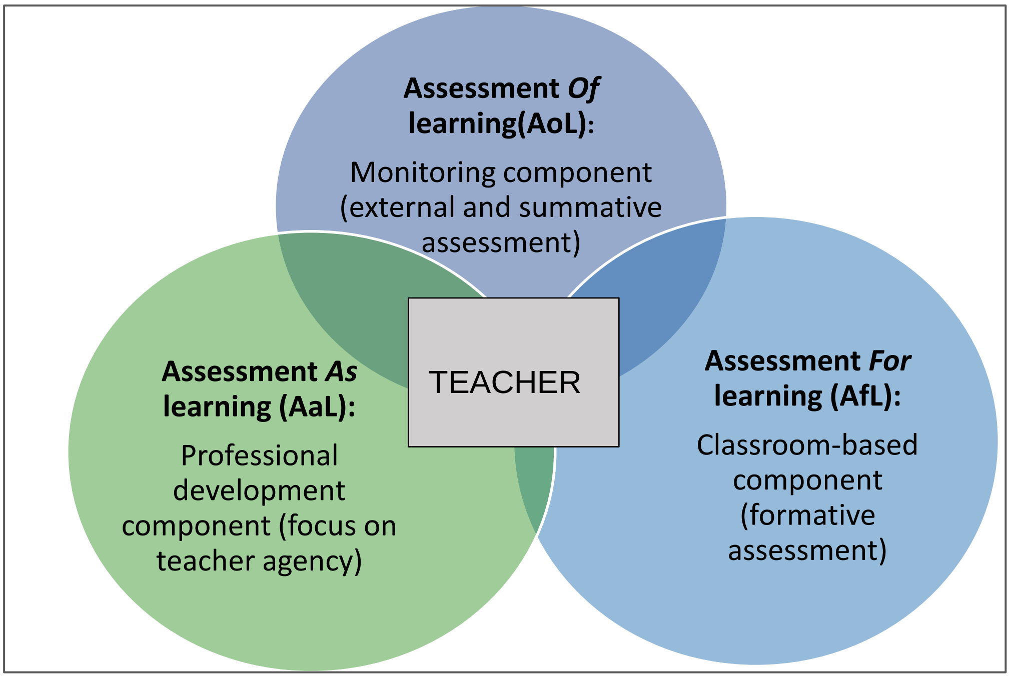

Figure 1.1: A proposed developmental model of assessment *of, for,* and *as* learning (as suggested in the AETL Project). Source: Own compilation

The primary focus of the AETL project is on the formative assessment (assessment for learning) component, where sets of assessment activities are strategically designed to provide intermittent markers in curriculum implementation. These sets of activities are aligned with the Grade 9 mathematics curriculum plan, as set out in the CAPS document (DBE, 2011).

Different sets of activities or tasks, in the form of worksheets, were designed to test the critical aspects of a specific topic area in the Grade 9 mathematics curriculum (see Appendix A). The worksheets comprised tasks that can be used formatively, and for this thesis, were specifically developed to ensure the application and/or promotion of specific "*formative assessment strategies*" as advocated by Wiliam and Thompson (2007) (see Section 2.6.3).Usiskin's (2015) dimensions of understanding that are required to master a mathematical concept also informed the set of worksheets. Usiskin's five dimensions of mathematics understanding refer to the *skills and algorithms* associated with the concept, *use and application*, properties and mathematical justifications (*proofs*), *representations and metaphors,* and the *history of the concept* and its treatment in different cultures (Usiskin, 2015, pp.1-19). In addition to including items that require these dimensions, we also included problem-solving type of questions that can be found in the South African Mathematics Olympiad (Engelbrecht & Mwambakana, 2016; Long, Dunne & De Kock, 2014).

Critical and extensive engagement with the assessment item sets on the part of the teachers forms a critical part of the AETL project. One of the aims of the project is that, through direct engagement with assessment tasks that are designed to highlight critical mathematics concepts, together with reflective implementation of such tasks, teachers may experience formative assessment as productive and informing the quality of their instructional decision-making (Bennett, 2011; Leahy & Wiliam, 2012). Although the formative assessment tasks were structured and standards-based, it provided enough flexibility to the teachers to adapt, implement and refine it to suit their own circumstances. The AETL project offered me the opportunity to obtain valuable data, which addresses the research questions posed in this study.

As a qualified assessor and mathematics educator at both secondary and tertiary levels, my primary interest in the AETL project is to 'hear' the voice of the teacher and to address the need for professional development as expressed by mathematics teachers in an era of accountability and systemic assessment. For the purpose of this study, my focus was only on two components of the broader AETL project. Primarily, this study aimed to explore and make sense of how mathematics teachers experience the implementation of structured formative assessment activities (assessment *for* learning), and to explore to what extent it influenced their professional development (assessment *as* learning).

The engagement and involvement of Grade 9 mathematics teachers is central to the AETL project in strategically designed assessment resources with three aims in mind. These aims firstly comprise the engagement with, and development of quality assessment resources. Secondly, in-depth engagement with the mathematical content, and thirdly, greater insight into assessment principles and processes. The teachers engaged, refined, and implemented the worksheets to improve their understanding of assessment *for* learning with the support of the researcher and the project coordinators. As mentioned earlier in this section, my involvement in the AETL project was primarily to focus on the formative assessment and the professional development components of the AETL project. This project therefore offered me an opportunity to explore teachers' general understanding and experiences of professional development programmes that were offered to add to their formative assessment skills in enhancing mathematics learning for both educators and learners.

1.5 Purpose of the study

Learning is a lifelong process of keeping abreast of change, and the most pressing task is to teach people how to learn — Peter Drucker

Effective professional development should influence change in a teacher's behaviours and beliefs to improve instructional planning and student learning (Desimone, 2009; Evans; 2014; Loucks-Horsley, 2010; Sparks, 1992), and to engage them in processes that are self-perpetuating. The focus of this study was primarily to deepen the understanding of the professional development process of selected Grade 9 mathematics teachers, and how they experienced and understood the use of strategically designed formative assessment activities to inform their instructional practices.

From the assessment developmental model, as suggested in the AETL project (see Figure 1.1), the focus of this study was on the central role of the teacher in assessment *as* learning (professional development), and assessment *for* learning (formative assessment), as described by Bennett and Gitomer (2009).

The intention of this study was not to offer a generalised strategy for the professional development of teachers, but to consider teacher learning as a complex process and to offer an explanation of why and how teachers might or might not adjust their instructional practices. One of the aims of this study was to comprehend how mathematics teachers experienced their involvement in the refinement and implementation of strategically designed formative assessment activities.

Consequently, my focus was on understanding teacher professional learning and growth as teachers engaged with formative assessment strategies based on mathematics learning principles. Another focus was to determine how mathematics teachers position themselves in relation to innovations such as formative assessment strategies and how these can support their professional development.

The perspectives and experiences of nine Grade 9 mathematics teachers from five public schools formed a central part of this study. These participants varied in context and in the ways in which they made sense of their involvement in the implementation of structured assessment tasks. Their experiences were investigated to create a better understanding of the impact of formative assessment strategies on their personal and professional growth. I explored, analysed and explained how and under which conditions the participating teachers integrated newly acquired assessment knowledge into their existing classroom-based practises. The AETL project provided a platform from which teachers could explore their experiences with assessment and engage in dynamic and thought-provoking discussions about mathematics topics that were meaningful to their classroom assessment practices. One of the aims of this study was to support teachers as they engaged in dialogue and inquiry into their practice and the practice of others, and to better understand these mathematics teachers' experiences in implementing new assessment ideas.

Formative assessment is a major area of interest in educational reform as a way to identify the learning needs of students during instruction. However, little is known about teachers' actions and decisions about what they consider as important when they implement it. In general, classroom-based assessment is not utilised optimally for various reasons, which need to be explored. For the purpose of this study, the sub-optimal use of formative assessment, and factors inhibiting teachers from effectively implementing formative assessment were explored through engagement with the literature and through empirical research.

This study therefore aimed to provide a better understanding of the mathematics teachers' experiences of professional growth; and to provide an extensive description from the teachers' point of view of the circumstances, instances and the strategies they use when they implement formative assessment tasks.

Furthermore, an analysis of the literature indicates a need for targeted professional learning initiatives in order to clarify understanding, remove misconceptions, and provide the necessary support to teachers in the effective implementation of formative assessment (Heritage, 2011, Morrissette, 2011; Stiggins, 2008, 2010). This study therefore also promotes the alignment of the curriculum, assessment practices, and the instruction of the participating teachers by providing them with structured and strategically designed activities.

1.5.1 Research objectives

The research objectives were, primarily, to *explore, analyse* and *describe* how Grade 9 mathematics teachers experience and understand the use of strategically designed formative assessment tasks and how this information may influence their professional development.

Other objectives in this study were to *examine*, *describe* and *analyse* the views held and the decisions made by teachers regarding quality teaching and learning in mathematics, as envisaged by the National Policy Framework (DoE, 2007), and in particular, as it links to instructional curricular activities during the formative assessment process. The participating mathematics teachers were provided with resources in the form of worksheets (formative assessment strategies) with explanatory memoranda to help them develop the principles and practices associated with “assessment *for* learning” and “learning how to learn” mathematics. The worksheets incorporated different levels of assessment principles to promote student learning. I will also refer to the worksheets as *formative assessment strategies* in this study.

The research indicates that there is a mismatch between secondary school mathematics teachers’ understanding of the purposes of assessment and the actual types of assessments used in their classrooms (Bell, Leusner & Sondergeld, 2010; Soto & Ambrose, 2016; Stiggins, 2008). This study therefore sought to explore, analyse, and develop teacher assessment knowledge and practices as opportunities for professional development and to support teachers in exploring new ways of enhancing learning experiences in mathematics.

The focus was on the engagement of teachers in formative assessment activities and educational experiences, as framed by the AETL project. Consequently, this study aimed to explore and describe how teachers implemented the formative assessment strategies and report on factors influencing their classroom-based assessment practices.

Furthermore, this study was carried out to provide a better understanding of *how* teachers make sense of their experiences in professional development interventions, such as the implementation of formative assessment strategies, and how this information may influence their professional development.

In light of the above, this study was guided by the following research questions.

1.6 RESEARCH QUESTIONS

The major research question in this study is:

What are the understandings and experiences of Grade 9 mathematics teachers of/with formative assessment as they engage in a professional development *programme with purposefully structured formative assessment strategies and to what extent does this exposure contribute to their professional growth?*

The following critical research questions guided this study:

1. How do these teachers make sense of the use of formative assessment and its relation to mathematics teaching and learning?
2. What are the major influences and constraining factors on the quality of teachers' implementation of formative assessment practices?
3. How does the teachers' involvement in formative assessment strategies influence them in terms of personal and professional development, if at all?

The intention of the study was thus to deepen the understanding of the professional learning process of in-service Grade 9 mathematics teachers as they actively engage in formative assessment tasks in the AETL project. The teachers were given support in the form of training sessions on formative assessment strategies; structured activities in the form of worksheets created by the research team; and collaboration and dialogue opportunities with other teachers from different schools. From the teachers' perspectives, I was able to explore and analyse the aspects of professional development that may influence their realities and decisions regarding their existing formative assessment practices and future practices. It was also important to consider the dilemmas that teachers face when implementing new assessment strategies in the current educational context.

In order to guide the research in the areas of policy and practice, it was also necessary to explore *what* and *how* these teachers learn from professional development experiences and what their perceptions are of the way in which these processes have influenced their professional growth.

1.7 Theoretical foundation

The general aim of this study was to explore and understand teachers' perceptions, beliefs and experiences in a professional development initiative (the AETL project) with a focus on formative assessment strategies. I therefore employed a combination of both social constructivist and developmental theories.

1.7.1 Professional Development Theory

Current perspectives on professional development in mathematics education draw on cognitive, constructivist, and sociocultural views of learning such as Bandura's comprehensive Social Cognitive Theory (1986). This theory provides a theoretical framework for understanding learning based on how the environment, personal cognitions, and behaviour can interact to result in learning. Bandura's social practice approach towards learning (Bandura, 1986), and Clarke and Hollingsworth's (2002) interconnected model of teacher professional growth offers a valuable analytical framework for this research to generate knowledge and understanding of how change in a teacher's classroom-based assessment can impact instructional practices and student learning. Both these frameworks are rooted in Vygotsky's (1978) Social Constructivism theory, which states that social interaction, cultural tools, and activity shape the individual's development and learning.

Bandura's (1986) Social Cognitive Learning Theory, also known as *Triadic Reciprocal Determinism*, explains human learning in terms of continuous reciprocal interaction between cognitive, behavioural, and environmental influences (Bandura, 1986). In the context of this study, the cognitive domain represents the personal development of the teacher in acquiring new assessment skills and knowledge, while the environmental domain represents the formative assessment activities within a professional leaning community. Lastly, the behavioural domain represents the way in which teachers implement the acquired assessment knowledge and skills in their classrooms.

In addition, the Interconnected Model for Teacher Professional Growth of Clarke and Hollingsworth (2002) provides a valuable frame for this study as it offers an interrelated view on professional development, suggesting that teacher change (or growth) occurs through the processes of 'reflection' and 'enactment'. According to Clarke and Hollingsworth, these processes are "mediating processes through which change in one domain is translated into change in another domain" (Clarke & Hollingsworth, 2002, p. 951). Reflection and enactment can therefore be seen as two processes that enable change to occur across domains. Clarke and Hollingsworth employ the term ''reflection'', as ''active, persistent and careful consideration'' (Clarke & Hollingsworth, 2002, p.954).

These processes occur in four distinctive domains that encompass the teacher's professional realm, these are: the personal domain; the domain of practice; the domain of consequence; and the external domain. This model is non-linear in its approach and focuses on interactions concerning effective learning and teacher professional growth. For the purpose of this study, the personal domain is related to the mathematics teachers' knowledge, beliefs, and attitudes. The external domain could refer to sources of new information, e.g. formative assessment resources, in-service support sessions, and conversations with formative assessment specialists. The domain of practice relates to teachers' involvement in refining and implementing formative assessment strategies, and immediate student feedback. Lastly, the domain of consequence could relate to the achievement of student learning outcomes, feedback from the students and adaptation of instruction to accommodate student needs, and motivation for professional learning or growth. Clarke and Hollingsworth's model is therefore compatible with social constructivist theory of learning as it addresses the individual construction of knowledge (personal domain) with a situative perspective on learning (practice domain).

These theoretical frameworks for learning and professional development will be explored extensively in the literature study in Chapter 2 (see Section 2.3).

As an experienced secondary school teacher in mathematics for almost 19 years, and a lecturer at a tertiary level, I also attempted to incorporate new assessment ideas into my professional practice. I can therefore relate to the challenges that experienced teachers face when implementing reformed practices. It is therefore also of personal interest to me to contribute to an effective model that conceptualises the link between the effective professional development and structured formative assessment practices of mathematics teachers in South Africa. This research sought to develop carefully planned opportunities for mathematics teachers in their workplace, and to support them to critically reflect on their existing assessment practices to make learning more meaningful, not only for their learners but also for themselves. However, little empirical research has been done in South Africa to investigate teachers' perceptions, understanding, and implementation of formative assessment and how these may contribute to their professional development.

1.7.2 Formative Assessment Theory

In looking at the conceptualisations of formative assessment by scholars such as Black and Wiliam (1998, 2009), Sadler (1998), and Shepard (2008), the essence of formative assessment can be captured as teachers' collection of information to adjust their teaching to improve learning. Chappuis (2009, p. 5) summarises these scholars' views, although he refers to formative assessment as a *process* rather than an event or activity, "Formal and informal processes teachers and students use to gather evidence for the purpose of improving learning." Formative assessment can therefore be seen as being integrated with instruction, which implies that "the meaning of items or assessment tasks will depend on the environment" (Brookhart, 2008, p.452).

From the above meanings, which describe formative assessment for learning, this study uses Vygotsky's (1978) Social Constructivist Theory and Bandura's Social Cognitive Theory (1986) as foundations to apply to formative assessment (i.e. assessment for learning). This was specifically relevant as the mathematics teacher is actively engaged in developing, implementing and reflecting on formative assessment strategies while being supported by a professional learning community (PLC). The PLC in this study comprised other Grade 9 mathematics teachers from the same or different schools, as well as researchers involved in the AETL Project. Bandura contends that "cognitive responses, behaviour, and environment all work together to create learning" (Bandura, 1986, p.18). It is therefore important to establish an environment that supports assessment as part of the learning process, which includes the recognition of the importance of the relationships between teacher and student, as well as student-to-student in this study (Stiggins, 2005). In this sense, formative assessment practices become an integral part of the teaching and learning process. When implemented correctly and consistently with the Social Development Theory, formative assessment is a strategy that leads to improved student achievement (Black & Wiliam, 1998, 2009; Leahy & Wiliam, 2012; Stiggins & Dufour, 2009).

Torrance and Pryor (1998) elaborate on how formative assessment can be seen as a social construction:

> Classroom assessment is a social construction, accomplished by teachers and pupils through social and pedagogic interaction. Thus, neither its processes nor its outcomes are straightforward or transparent, but neither are they without positive possibilities and consequences. The very complexity and indeterminacy of classroom assessment, as a set of social practices, also renders it a site of immense significance with respect to how teachers interact with pupils and how children learn about themselves and about the processes of schooling (p. 20).

Using a social constructivist and pedagogical knowledge approach, this study could relate to current perspectives on formative assessment as assessment *for* learning. This would be in terms of practicality as the teacher provides immediate feedback to the learners and assessment is therefore integrated into instruction.

This study therefore aims to explore formative assessment as a possible strategy to enhance teacher professional development. This strategy could provide a deeper understanding of the reasons why teachers are reluctant or motivated to develop their teaching and learning skills in mathematics.

1.8 RESEARCH METHOD

1.8.1 Research paradigm

The intention of the study was to gain a deeper understanding of the professional learning process of in-service Grade 9 mathematics teachers as they actively engage in formative assessment tasks. This qualitative research was therefore approached using an interpretivist paradigm as it greatly relied on the "participants' views of the situation being studied" (Creswell, 2013, p. 8).

To achieve the objectives of this research, I needed an in-depth understanding of the teachers' perceptions of formative assessment and what they considered to contribute to their CPDT. I consequently also wanted to know what factors effected the change, if any, in their classroom practice. Qualitative research offers detailed descriptions to show that the researcher's interpretations make sense, "*Understanding* is the primary rationale for a qualitative investigation" (Merriam & Tisdell, 2015, p. 238).

This qualitative research study was exploratory and descriptive in nature. The data were collected over a period of two years by interacting face-to-face with a selected group of practising Grade 9 mathematics teachers. The participants then described and analysed their individual and collective actions, beliefs, thoughts, and perceptions of their experiences (Creswell, 2007; Maree, 2016, p. 55).

1.8.2 Research design

1.8.2.1 Phenomenological case study

Phenomenological research seeks to describe events, activities, and the lived experiences of several individuals who have experienced the same phenomenon (Yin, Olson, Olson, Solvin & Brandon 2014). As this qualitative study aimed to explore and describe the experiences of mathematics teachers in a professional development intervention, I decided to follow a phenomenological case study design as "seen through the eyes of people who have experienced it first-hand" (Leedy & Ormrod, 2005, p. 147). It was therefore appropriate in this research to use an explorative and descriptive case study design as it allowed the participants to share their lived experiences, perceptions, and beliefs related to the implementation of formative assessment strategies and their professional development. Furthermore, the phenomenological approach enabled the researcher to collect rich, thick data and "then depict the essence or basic structure of the experience" (Merriam & Tisdell, 2015, p. 26).

According to Creswell (2007), a *case study* design can be used in research in which a specific situation is studied either to see if it gives rise to any general theories, or to see if existing general theories are borne out by the specific situation. Nieuwenhuis (in Maree, 2016, p. 55) states that case study research offers an opportunity for explorative studies "where a specific case is analysed and studied in great detail to explore and gain a better understanding of a particular phenomenon typical of the case." The author also emphasises that researchers must approach the effective exploration of a given phenomenon with "flexibility in looking for data and open mindedness about where to find data" and set aside their personal bias i.e. "to bracket or suspend personal judgement" (Maree, 2016, p. 55,77). I therefore approached this study with an open mind, working largely on the ideas emerging from the participants' views where I identified key issues and key variables to gain greater understanding of their formative assessment and PD experiences.

1.8.2.2 Sampling

Purposeful sampling methods were followed by selecting a strategic group of Grade 9 mathematics teachers from five participating schools in the Tshwane district. The participation of these teachers was voluntary, and the assigned teachers received the necessary training and support from researchers. In keeping with a social constructivist view of learning, learning communities between teachers and researcher were established within the AETL project (see Section 2.1).

1.8.2.3 Data collection

To add to the depth of the study, I attempted to employ multiple stages in collecting data, i.e. data were collected from the beginning of the AETL intervention during the development and refinement of new assessment strategies, and again after the implementation of the assessment resources. This design allowed an understanding of the changes made in teachers' practice, the cause for and impact of these changes, and a better understanding of the relevant policies and how these were viewed by the teachers and thus impacted their teaching practice (McLeod & Thomson, 2009).

The data collection process in this study consisted of three primary stages of data collection:

- Stage 1: I introduced an *open-ended questionnaire* (see Appendix C), also known as a qualitative survey, to analyse the background information and diversity of member characteristics (Jansen, 2010). The open-ended questionnaire was therefore conducted *before* the teachers engaged in and implemented the Formative Assessment (formative assessment) activities. It also assisted in establishing existing knowledge and understanding related to formative assessment and CPDT.

- Stage 2: Data were collected from three *focus group discussion meetings during* the engagement and implementation of the formative assessment activities.

- Stage 3: In the final stage, I collected data from *semi-structured interviews* (Appendix D) and reflective feedback reports (Appendix B) *after* the teachers had engaged in and implemented the formative assessment strategies to determine if any changes in practice or professional growth occurred.

In addition, I used observational fieldwork and written documents, reflective notes, digital voice recordings, and electronic documents (e.g. e-mails) as research strategies throughout the study to collect empirical data (see a detailed description in Chapter 3).

All interviews were audio recorded and transcribed. The chosen multi-method strategy enhances the trustworthiness of the study by means of triangulation (McMillan & Schumacher, 2006).

1.8.2.4 Data analysis

I tried to establish how the participants made meaning of formative assessment strategies by analysing their perceptions, attitudes, understanding, knowledge, values, feelings, and experiences in an attempt to approximate their construction of the professional development and learning process.

I therefore analysed the data by coding and classifying the collected data into themes and concepts related to the experiences and perceptions of the teachers. The data collection and analyses were interactive, collaborative and occurred in phases, as described by McMillan and Schumacher (2006), and Creswell (2007) (see Chapter 3 for a detailed description).

Based on the teachers' point of view, and their sense of the motivation to change existing practices, I proposed ways to deepen the understanding of the relationship between formative assessment and teacher professional development. I did this using the four domains in Clarke and Hollingsworth's (2002) model of professional development. Applying this model as an analytical framework allowed me to understand teachers' existing practices, provide new strategies to implement, and assist them in the process of feedback and reflection. I thus exploited the use of formative assessment to bolster their professional development.

1.8.2.5 Trustworthiness

I used a combination of possible strategies to enhance design *validity,* such as prolonged fieldwork, multi-method strategies, triangulation, participants' verbatim language, low-inference descriptions, mechanically recorded data, and member checking through participants' reviews (McMillan & Schumacher 2006; Creswell, 2007; Merriam, 1998).

1.8.2.6 Prolonged fieldwork

Contact was carried out by means of e-mails, telephonic conversations, and informal visits to ensure prolonged fieldwork. It continued through communicating with the participants and the research team at the university to provide feedback and follow-up support.

1.8.2.7 Triangulation

I made use of triangulation – comparing multiple data sources in search of common themes – to support the validity of my findings, as described by Leedy and Ormrod (2005). Face-to-face meetings, focus group discussions, telephonic interviews and conversations with all of the role players involved, open-ended questionnaires, and in-depth semi-structured interviews with the participants are all examples of the communication between the researcher and the participants.

1.8.2.8 Internal validity (credibility)

Internal validity in qualitative research deals with the extent to which the researcher's findings match reality (Merriam & Tisdell, 2015, p. 242). It was important to establish a relationship with the teachers built on trust, for example, to learn to understand their culture and the school settings by visiting or phoning them on a regular basis and providing refreshments during all of the meetings. On a more professional level, I respected the fact that these teachers were experienced teachers and not novices in the field of mathematics education. Through experiencing and understanding their reality, it assisted in ensuring that the findings of this study did match these teachers' reality.

1.8.2.9 Reliability (dependability)

According to McMillan and Schumacher (2006), reliability refers to the extent to which the results are similar over different forms of the same instrument or occasions of data collection. I utilised the same data collection instruments of observation, feedback templates, assessment activities, and semi-structured interviews consistently with the different teachers to increase the reliability of the results of this study.

1.8.2.10 Ethical considerations

The study followed the requirements as set out by the Ethics Committee of the University of Pretoria, and the necessary permission was granted to perform the study (see Appendix E). The teachers were informed that participation in the AETL project, the completion of the questionnaire, the implementation of the formative assessment tasks, and the semi-structured interviews were voluntary and that they were under no obligation to participate in the study. All of the relevant information was handled with confidentialitly and no individual will be identified in any publication that may result from this study.

1.9 CLARIFICATION OF TERMS

Several key terms are used throughout this study. These terms are defined below within the context of this research.

1.9.1 Professional Development (PD)

Villegas-Reimers (2003) defines professional development, in a broad sense, as the development of a person in his or her personal role and elaborates it as a "long-term process that includes regular opportunities and experiences planned systematically to promote growth and development in the profession" (Villegas-Reimers, 2003, p. 12).

1.9.2 Continuous Professional Development of Teachers (CPDT)

Fullan (1995, p. 231) describes professional development as "the sum total of formal and informal learning pursued and experienced by the teacher in a compelling learning environment under conditions of complexity and dynamic change." Jojo (2017, p.103) elaborates on mathematics continuous professional development programmes as" systematic efforts to change the practice, attitudes and beliefs of mathematics teachers in the classroom so as to effect the learning outcomes of students and familiarise teachers with the change in curriculum."

1.9.3 Teacher learning

According to Goldsmith, Doerr and Lewis (2014), teacher learning is the sum of their evolving practice. This encompasses gaining new knowledge, adapting and being open to new beliefs, and applying these evolving views in all teaching-related activities.

1.9.4 Teacher professional growth

Teacher professional growth is a term, introduced by Clarke and Peter (1993), to characterise the learning aspects of teacher change as a process (p.167). Teacher professional growth is therefore an inevitable and continuing learning process of a cyclic nature (Clarke & Hollingsworth, 2002, p. 947). The process of teacher professional growth can be seen as "change, occurring through the mediating processes of 'reflection' and 'enactment', in four distinct domains that encompass the teacher's world: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation), the domain of consequence (salient outcomes), and the external domain (sources of information, stimulus or support)" (Clarke & Hollingsworth, 2002, p. 950).

1.9.5 Teacher agency

Agency may be defined as a construct that includes purpose and action, among others. While it is intrinsic to all individuals, it may manifest differently in different environments. Biesta and Tedder (2007) advocate an ecological view of agency, where individuals not only learn new skills and knowledge needed for their work, but also willingly *act* [own emphasis] by prioritising, choosing, and considering what is important in their own lives. In this study, agency can be seen as an important component of teacher professional development as the concept of agency is viewed as not being intrinsic to a person, but rather perceived as occurring interactively with the environment, and that the environment in which individuals find themselves may enable or constrain agentive action. Essentially, agency does not reside entirely in the person, or in this case the teacher, but is a product of the teacher engaging with the environment. It can therefore be seen as a mediating process “in which teachers can make choices and take stances in ways that affect their work and/or their professional identities” (Eteläpelto, Vähäsantanen, Hökkä & Paloniemi, 2013, p.61).

1.9.6 Formative assessment

Formative Assessment (formative assessment) is defined as a process that comprises teachers’ moment-by-moment and day-by-day collections of data regarding their students. Teachers collect this data by listening to students, observing them, and reviewing the various outcomes of their work in a classroom environment (Black, Harrison, Lee, Marshall & Wiliam, 2004). Pedder and James (2012, p. 33) broadly define formative assessment or assessment for learning as “the classroom strategies teachers and students develop and use to support learning.”

1.9.7 Assessment

Assessment is a term used by researchers to describe the process of gathering information about students’ learning. It is very broadly defined because it includes a variety of ways to observe students’ skills, knowledge, and abilities (Woolfolk, 2007). Although this broad definition of assessment is beyond the scope of this research, I need to emphasise the link between classroom-based assessment practices and the learning process in this study.

1.9.8 Formative assessment strategies

For the purpose of this study, formative assessment strategies refer to the strategies used in the purposefully structured, curriculum-aligned worksheets used in the AETL Project.Assessment tasks (worksheets) have been designed to serve a formative assessment purpose. Built into the purposively designed assessment tasks (activities) were dimensions of understanding (Skills-Algorithm, Property-Proof, Use-Application, and Representation-Metaphor) that support the learning of a particular mathematical concept (Usiskin, 2015). The tasks have been strategically designed to address these dimensions but are also aligned to the CAPS curriculum plan. The worksheets also comprised tasks that can be used formatively, and for this thesis, tasks that were specifically developed to ensure the application and/or promotion of specific "*formative assessment strategies*" as advocated by Wiliam and Thompson (2007) (see Section 2.3.6).

1.9.9 Summative assessment

Summative assessments determine the overall achievement and learning success of learners and are given to students at the end of a learning cycle, programme, or phase (Dreyer, 2014).

1.10 EXPECTED OUTCOMES

The quality of professional development intervention programmes for mathematics teachers in South Africa is critical. The teachers' experiences in this study could also contribute to a broader understanding of CPDT as a complex process. It could further address gaps in how and why teachers can be motivated to engage in practices that could help them in their professional growth. As such, this study could contribute to a broader knowledge of how we can improve, not only the professional development of the teacher, but also the performance of learners in external summative assessments such as the ANAs through the scaffolding of formative assessment practices. The findings provide evidence of the critical role of ongoing collaboration and dialogue in supporting teachers' professional development.

A growing body of research has explored teachers' formative assessment practices and effects on student learning (Black & Wiliam, 1998a, Leahy et al., 2005; Stiggins, 2008). However, little research has been done to investigate teachers' perception and understanding of formative assessment. The findings of this study make a contribution to formative assessment literature that concerns how teachers perceive their own practices, influences and constraints that may impact their daily teaching practices.

This could determine how teachers implement and understand formative assessment, it could also inform future researchers and teachers, programme developers, and other educational stakeholders to promote curriculum-embedded, structured ways of implementing formative assessment to improve student learning. By exploring the obstacles that teachers face in the current educational context, specific insights were gained into alternative strategies to improve teaching and learning, particularly in mathematics. Given the current focus on high-stakes testing and summative assessment, teachers need support that will promote their professional development, which will have a positive impact on the implementation of assessment in their practices.

1.11 CHAPTER OVERVIEWS

This research comprises the following five chapters:

Chapter 1: The Introduction

This chapter has set out the background to the research, as well as the problem statement, aims, paradigm perspective and the research design. It also described the definitions that are applicable in this study.

Chapter 2: Literature review

This chapter introduces the results of the literature review on the theory and conceptualisation of professional development and formative assessment. It explores characteristics of effective professional development and formative assessment strategies by placing the teacher centrally in developing an understanding of learning processes. The benefits of formative assessment as a strategy to inform the professional development of mathematics teachers are discussed from different viewpoints on both international and national levels.

Chapter 3: Methodology

In this chapter, the steps in the research method are explained. The overall design and justification for the qualitative approach are discussed. In addition, the researcher describes the methods and instruments used to collect and analyse data from the sample population, as well as the strengths and weaknesses of the research design. This chapter also elaborates on the trustworthiness of findings and presents a discussion on the ethical considerations followed in this study.

Chapter 4: Findings and analysis

In this chapter, an analysis of the empirical and theoretical evidence of mathematics teachers engaging in formative assessment strategies is presented. The results are presented and interpreted and guided by the literature review and theoretical framework as these relate to this study.

Chapter 5: Conclusions, limitations and recommendations

This chapter concludes the study by revisiting the research questions. The challenges, new knowledge, implications for existing theories, recommendations for implementation, as well as a summary of contributions and suggestions for future research are lastly provided.

CHAPTER 2 THE LITERATURE REVIEW

Educators who do not experience effective professional development do not improve their skills, and student learning suffers - Hayes Mizell (2010)

2.1 INTRODUCTION

Mizell's observation cited above regarding teacher professional development is a worldwide phenomenon (cited in Mizell & Learning, 2010, p. 6). The critical role of professional development in mathematics education, as well as the need for effective formative assessment practices lays the foundation for this research. Therefore, this chapter will focus on the literature relevant to important aspects of the two constructs *teacher professional development* and *formative assessment practice*s.

The purpose of this chapter is to clarify the characteristics of both Continuous Professional Development for Teachers (CPDT) and formative assessment by examining scholarship in each of these two fields of knowledge. I have further related the process of formative assessment to professional development.

I begin the review with a discussion on the need for effective professional development strategies, including professional development theory and other applicable theoretical perspectives. After establishing the theoretical lens, a critical analysis of research pertaining to existing professional development models is provided. The relevant empirical studies will be explored by providing a foundational understanding of the nature of teachers' professional development. Quality teacher professional development strategies were analysed to include the range of knowledge and skills needed by mathematics teachers to improve their instructional practices, and in order to support the understanding of the professional development component of mathematics teachers, in particular.

The second part of the review focuses on the theory and conceptualisations of formative assessment and related terms. Relevant studies on components surrounding the effective implementation and the potential benefits of formative assessment are explored. Accordingly, I explored research on the role of formative assessment in teacher professional development and its influence on instructional adaptations to improve student learning. I then conclude with the challenges experienced by mathematics teachers in a variety of contexts when they implement formative assessment strategies.

2.2 THE NEED FOR EFFECTIVE STRATEGIES FOR CONTINUOUS PROFESSIONAL DEVELOPMENT FOR TEACHERS (CPDT)

Villegas-Reimers (2003) defines *professional development*, in a broad sense, as the development of a person in his or her personal role and elaborates on it as a "long-term process that includes regular opportunities and experiences planned systematically to promote growth and development in the profession" (Villegas-Reimers, 2003, p. 12). Guskey (2002) describes professional development as systemic efforts to bring about change in teachers' attitudes and beliefs and in their classroom practices, and as a result, the learning outcomes of their students. In examining the literature on professional development, it became clear that the understanding and conceptualisation of professional development is highly contested in the educational research community. No single clear definition brings justice to the complexity of this phenomenon. However, I agree with Mizell's observation on professional development that "whatever the term, the purpose is the same - to improve learning for educators and students" (cited in Mizell & Learning, 2010, p. 5).

Over the past two decades, the educational research community has made great progress in broadening the knowledge base on the conceptualisation of professional development. Different models of CPDT broaden our knowledge of the conceptualisation of professional development (i.e. *what* it is) and the process(es) of achieving it (i.e. *how* it occurs) (Desimone, 2009; Evans, 2014; Guskey, 2002; Steyn, 2013). However, a deeper understanding of the central role of the teacher in terms of individual experiences and effective strategies to support professional learning and development remains under-examined.

Many local and international researchers identify oversights in previously implemented forms of teacher professional development programmes such as workshops, seminars, and school-based courses, usually provided by school districts. Local studies, for example, point out that some of these initiatives do not consider the needs of teachers, or the difference in school contexts (Bansilal & Rosenberg, 2016; Mashile & Vakalisa, 1999), or the lack of leadership support during attendance and after implementation (Steyn, 2011). Studies also show that programmes that do not consider individual teachers' needs or the contextual factors of the different schools will not change teachers' content knowledge or instructional skills (Ball & Cohen, 1999; Desimone, Porter, Garret, Yoon & Birman, 2002). Van Veen and Sleegers (2006, p. 89) also point out that teachers have very "personal and strong views on how they think they should work." Therefore, programme developers should consider the individual views of teachers if any change in practice is to be expected.

As Guskey (2002, p. 382) suggests, the majority of CPDT programmes fail because they do not take into account two crucial factors:

(1) What *motivates* teachers to engage in professional development; and
(2) The *process* through which change in teachers typically occurs.

Evans (2014) also appeals to educational researchers to be concerned with identifying instances of innovation and quality, and then describing, explaining and theorising these to deepen the understanding of CPDT. Therefore, the challenge for schools, districts and the relevant stakeholders is to design development programmes with a deliberate focus on effective strategies to support the continuous learning and growth of educators. The design should consider the different needs of individual teachers in order to understand how professional development occurs. It is clear that a variety of factors undoubtedly contribute to the ineffectiveness of these professional development programmes. There is a deliberate shift in the research agenda of exploring inefficiencies in PD programmes to a focus on "*what* works, *why*, *how* and under what *conditions*" (Adler et al., 2009, p. 11).

In South Africa, the National Policy Framework for Teacher Education and Development has been an attempt by the government to address the professional development of student teachers, as well as the continuing professional development of practising teachers (DoE, 2007). It acknowledges the "limited conceptual knowledge of many teachers in South Africa", and aims to expect educators to "take charge of their self-development by identifying areas in which they need to grow professionally" (DoE, 2007, p. 3). This policy proposes to develop teachers’ professional knowledge and skills, enabling them to develop continually. Teachers will also be empowered through the improvement of their professional self-efficacy, subject knowledge and skills, and classroom management. This development, in turn, will improve the professional status of teachers, and help them to identify programmes that could assist them in their professional growth (DoE, 2007). It is expected that all teachers registered with the South African Council for Educators (SACE) earn Professional Development (PD) points by attending accredited PD activities that address their professional growth needs (DoE, 2007). Continuing professional development is mandatory for all registered South African teachers and aims to acknowledge and encourage:

- “Individual teachers’ endeavours to improve their own learning and develop themselves professionally;
- Teachers’ participation in collectively developing themselves and improving learning within their schools; and
- Teachers’ participation in professional development programmes offered by employers, unions and others to improve their learning and develop themselves” (DoE, 2008, p. 5).

A study in 2009 by the then Department of Education (DoE) to determine the extent of teachers’ involvement in PD activities indicated that 91% of all teachers are involved in such PD activities (South African Teachers’ Union, News Flash 7, 2009). However, important questions evolved regarding the perceptions of teachers of CPDT activities in order to meet the requirements as specified in the National Policy Framework (DoE, 2007). What kind of professional development would be effective in upgrading the professional competence of mathematics teachers? It is the aim of this literature review to summarise the different professional development approaches and their attempts to gain a deeper understanding of the effect that the PD approach has on the daily practices, and on the change (if any) on the part of the mathematics teacher.

To expand our understanding of effective professional development strategies, we need to consider the complex and multi-dimensional nature of CPDT, and in particular, *how* and *why* teachers change or grow in their profession. Professional development interventions for teachers are not always simple and straightforward -

effective strategies require a better understanding of how teachers develop. Evans (2014, p. 188) states that, “Too often professional development is interpreted narrowly, as relating to what practitioners *do*, in the sense of physical action that is potentially observable … or the impact it has on student learning.” Instead, more research needs to be done on the question, “What occurs inside an individual’s head in order for her/him to experience a professional development ‘episode’?” Clarke and Hollingsworth (2002, p. 947) also point out that, “If we are to facilitate the professional development of teachers, we must understand the process by which teachers grow professionally and the conditions that support and promote that growth.” It is therefore important to direct the attention in professional development research towards a better understanding of the complexity of the process. Despite significant calls for a more complex conceptualisation of teacher professional learning and growth, this analysis of the literature suggests that the majority of research on the topic continues to focus on specific activities, processes, or programmes in isolation from the complex teaching and learning environments in which teachers work (and live).

As a consequence of acknowledging change or growth as a form of learning, I explored components of learning theory and research on teacher professional development. I felt prompted to acquire a deeper understanding of the concepts of mathematics learning and change in teacher professional development and the role that formative assessment tasks might play in their professional growth. Hargreaves (1998) confirms that good teachers are also good learners and the significance of their learning and professional growth cannot be over emphasised. To develop a sensible understanding of continuous professional development, it is important to understand the process of learning and the conditions that support and encourage professional growth (Feiman-Nemser, 2001; Clarke & Hollingsworth, 2002). Hence, some studies have directed their attention towards both the complex link between the design of professional development programmes and teachers’ learning because of their exposure to these programmes, as well as the subsequent changes made in the beliefs and behaviour of teachers (Evans, 2014; Graven, 2004; Guskey, 2002; Penuel et al., 2007). In this study, I aim to build and extend the work of those who advocate a more dynamic understanding of teacher professional learning in an attempt to conceptualise this complex process in ways that provide a foundation for future empirical research.

This study focuses on the process by which mathematics teachers learn and grow professionally, the conditions that support this change, and how this overall professional development experience might influence their learning and growth. By introducing structured formative assessment activities (the AETL project), I focus on mathematics teachers' individual experiences and understanding of how and why this engagement with formative assessment has influenced their instructional practices.

Nations with the best academic achievement scores in external assessments, such as Finland, Korea, and Singapore, recorded a significant improvement in their students' achievements, which they attributed to their investment in teacher professional development programmes (Darling-Hammond, 2010). Indeed, 21st century economies are currently knowledge-based and information-driven and require teachers with expertise and the ability to keep up with the rapid explosion of information. It is essential to establish effective professional development programmes that are geared towards the learning processes of teachers, and programmes that will enable teachers to keep abreast of ever-increasing educational needs, and the challenges associated with the teaching and learning of mathematics.

The next section explores relevant theoretical frameworks and literature that conceptualises PD as a complex process rather than a once-off event.

2.3 PROFESSIONAL DEVELOPMENT: THEORETICAL FOUNDATIONS

This section is organised around the theoretical frameworks that help to understand and conceptualise professional development as a process of teacher learning, change, and growth in this study. The purpose of this thesis is not to provide a comprehensive discussion of the theories of learning, but rather to contextualise teacher professional development as a complex process of learning and change, for the purpose of improving student learning. The intention is not to evaluate the effectiveness of a specific professional development intervention, but rather to explore and describe how teachers experience and make sense of formative assessment and how this can contribute to their professional development.

New expectations for teachers' knowledge and practice have resulted in increased learning demands for teachers, and in keeping with a social constructivist view of learning, this study focuses on teacher learning and continuous professional development. It investigates opportunities, such as structured formative assessment activities, to support mathematics teachers and it focuses on the changes that are deemed necessary for effective professional growth. In examining the dimensions of CPDT, it is important to note the various traditions of learning, and how these may influence change or adaptation in instructional practices.

My examination of teacher learning and development is primarily informed by the theoretical stances regarding the process of human perception and development, including the importance of social learning and professional growth.

In a literature study conducted on models of teacher professional development and change, Evans (2014, p.182) categorises professional development into two groups. Models are either "conceptional" (i.e. what it is) or "processual" (i.e. how it occurs) in focus. Evans describes conceptional models as varying "in specificities and detail, while processual models vary in relation to their location on a hypothetical and theoretical continuum" (Evans, 2014, p.182). In this literature review on professional development, I explore both categories as described by Evans; starting with processual models. This will allow a deeper understanding of CTPD as a process in which growth can occur on different theoretical continuums. A discussion of this category will be followed by the relevant literature on conceptional models to examine specific effective strategies for PD.

2.3.1 Processual models of Professional Development

From the literature, it is clear that no perfect model for professional development exists. As a result, the following theoretical frameworks are used as lenses to frame the study and may provide a better understanding of the complexity of CTPD. These frameworks will also allow us to understand how and why teachers learn when they have opportunities to deepen their own knowledge and skills.

Guskey (1986) proposes a *linear model* of teacher learning and change, suggesting that when teachers try new approaches to teaching and learning, "(s)ignificant change in teachers' beliefs and attitudes is likely to take place only after changes in student learning outcomes are evidenced" (p. 7). Guskey (2002) elaborates on his model of professional learning by recognising the sequence of teacher change as teachers' participation in professional development events. Three major goals in professional development programmes to ensure teacher change are identified as: change in classroom practice; change in student learning outcomes; and change in teachers' beliefs and attitudes. Guskey proposes the following sequence of change:

> Significant change in teachers' attitudes and beliefs occurs primarily after they gain evidence of improvements in student learning. These improvements typically result from changes teachers have made in their classroom practices, a new instructional approach, the use of new materials or curricula, or simply a modification in teaching procedures or classroom format (Guskey, 2002, p. 383).

This linear model is further described in Figure 2.1.

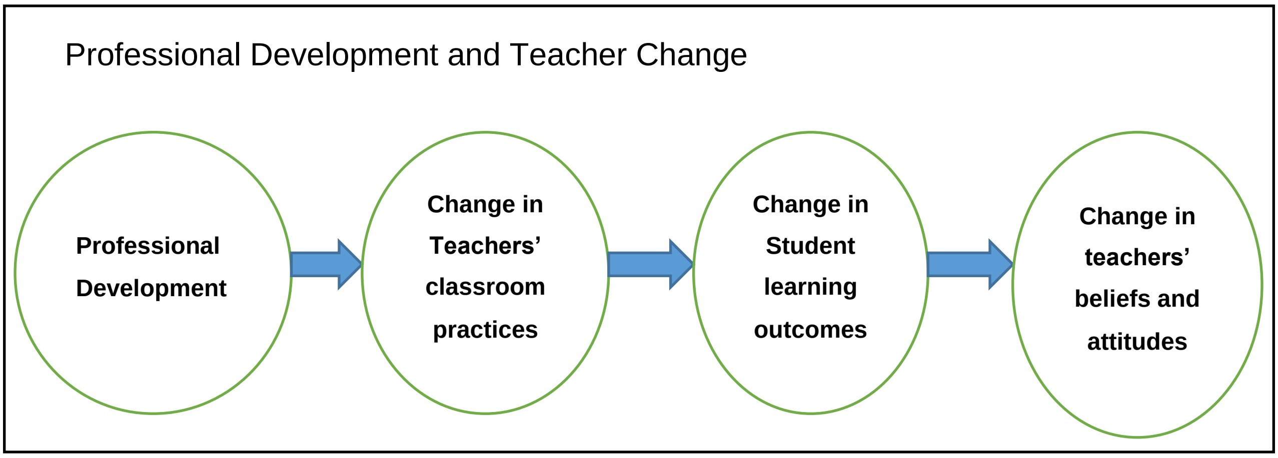

Figure 2.1: A model of teacher change (Guskey, 2002, p.383)

Although Guskey's linear model (2002) identifies the sequence of change in the attitude and behaviours of teachers in this study, it falls short in explaining how and why professional development and learning in individual teachers may occur (Evans, 2014).

Bandura's Social Learning Theory (1986) provides a more cyclical framework for theorising teacher learning based on how the environment, personal cognitions, and behaviour can interact to result in learning. Bandura's theory is rooted in Vygotsky's

(1978) Social Constructivism Theory, which states that social interaction, cultural tools and activity shape the individual's development and learning. Vygotsky's theory (1978) and Bandura's theory (1986) correspondingly emphasise the importance of social learning. Bandura, however, elaborates further and is more concerned with cognitive factors such as beliefs, self-perceptions, and expectations when compared to the Social Learning Theory of Vygotsky. Bandura explains human functioning in terms of a model of triadic reciprocity in which behaviour, cognitive factors, and environmental events all operate as interacting determinants of each other. Environmental events, personal factors, and behaviours are seen as interacting in the process of learning (see Figure 2.2 below).

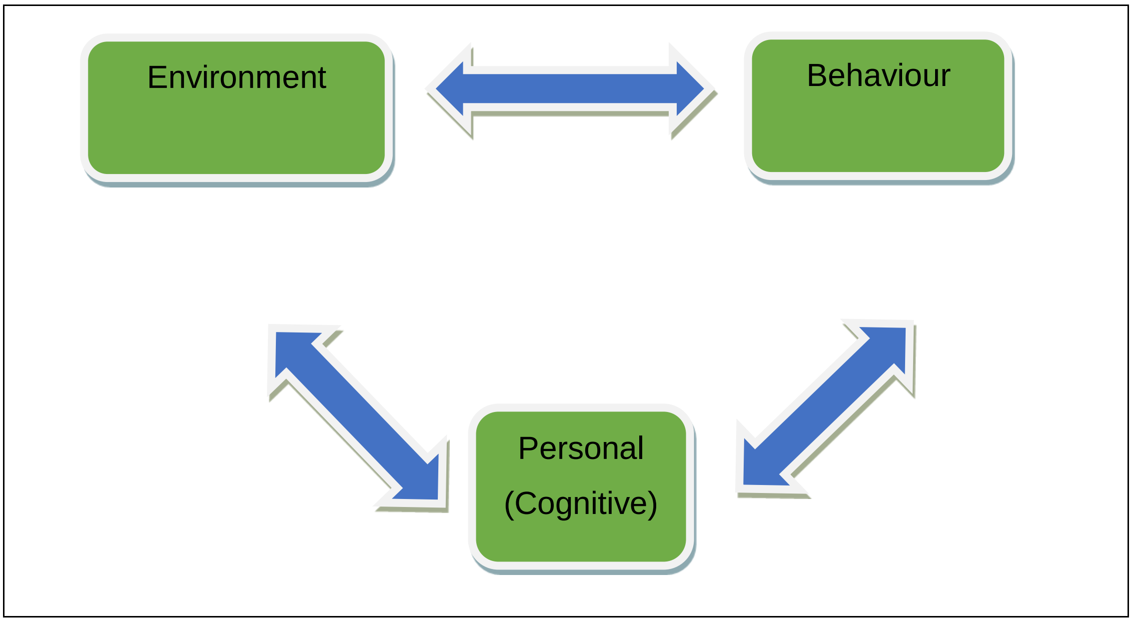

Figure 2.2: Bandura's model of triadic reciprocity in which *learning* is influenced by the interaction of personal, environmental, and behavioural factors (Woolfolk, 2007, p. 330)

By linking Bandura's *Triadic Reciprocity* model of learning, also known as Social Cognitive Theory, to this study, I viewed the learner (mathematics teacher) as thoroughly integrated with the environment within which he or she is learning. The teacher implements and refines structured formative assessment tasks and the teachers' cognitive responses, behaviours, and environments all work together (Bandura, 1986). Indeed, Bandura's model (1986) of bringing more cognitive perspectives of learning together with social perspectives in analysing mathematics teacher professional development created a valuable theoretical frame for this study, but still lacked depth in explaining change or growth in teachers' practices.

More recently, Desimone (2009) has provided a model with a somewhat deeper understanding of the features needed to increase teachers' knowledge and skills, changing their attitudes and beliefs and as a result, leading to changes in how they teach. Desimone (2009, p. 185) refers to this as a 'path model' that incorporates five core features of professional development: content focus; active learning; coherence; duration and collective participation (see Figure 2.3).

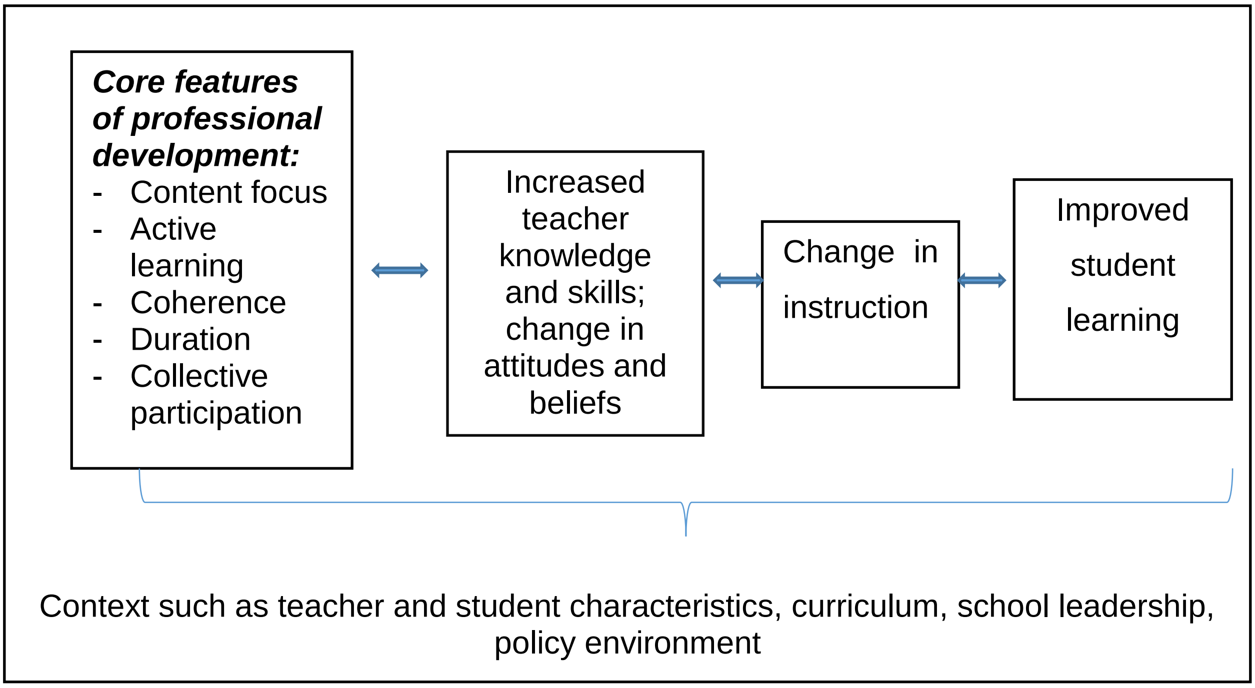

Figure 2.3: Proposed core conceptual framework for studying the effects of professional development on teachers and students (Desimone, 2009, p. 185)

Kuijpers, Houtveen and Wubbels (2010) offer a more practice-focused model to support Clarke and Hollingsworth's (2009) model. Their *'integrated professional development model for effective teaching'* (p. 1687), incorporates the following principles:

- Take the school in question as a starting point (context-specific approach);
- Use a systematic cyclic approach to improvement;
- Focus on internal conditions (teaching and learning processes);
- Focus on school procedures, roles, structures and facilities that support the teaching and learning processes;

- Formulate educational goals at school, teacher and student level;
- Apply a multi-level perspective;
- Adopt integrated implementation strategies;
- Include external support;
- Use integrated information from various research domains (Kuijpers et al., 2010, p. 1687).

Although Desimone's (2009) path-model and Kuijpers et al.'s (2010) integrated model are descriptive and context-specific, these models also offer a limited explication of the process(es) experienced by individual teachers and *how* or *why* they learn and develop professionally. It is clear that many existing models focus on the improved outcomes for students as the ultimate goal of teacher professional development.

Alternative models of professional development, which focus on the mental internalisation process of individual teachers, need to be explored further. Evans (2014), for example, offers a model to which she refers to as 'micro-level professional development' or a cognitive process:

> Professional development– like the professionalism that it is intended to enhance – is multidimensional; it is not simply or narrowly about changing people's behaviour – how they do or go about things, or how much they do or produce, or what generative effect their changed practice has – it is also about changes to their attitudes, intellectual capacity and mind-sets. Yet all too often, it is behavioural change alone that is the focus of professional development efforts and initiatives. (Evans, 2014, p. 188).

In view of all that has been mentioned so far, one may suppose that teacher change cannot be explained or defined as one linear process or event, but needs to be understood as multidimensional (Evans, 2014) with various sub-systems that interact to enhance professional development (Bandura, 1986). In the same vein, Clarke and Hollingsworth (2002) argue that a unidirectional learning model oversimplifies the process of teacher professional growth. They propose a non-linear, dynamic and interactive model to represent the impact of professional learning on teachers' practice.

2.3.2 Clarke and Hollingsworth's Model of Teacher Professional Growth

Clarke and Hollingsworth's (2002) *Interconnected Model of Teacher Professional Growth* offers a valuable framework for deepening the understanding of teacher professional development and change in this study. This model emphasises the recursive nature of teachers' learning and suggests that growth in one aspect of teachers' knowledge and practice may promote subsequent growth in other areas through the processes of reflection and enactment. These processes occur in Clarke and Hollingsworth's (2002, p. 950) model, which "recognises the complexity of professional growth through the identification of multiple pathways between four distinctive domains: the *personal* domain, the domain of *practice*, the domain of *consequence* and the *external* domain" (see Figure 2.4 below).

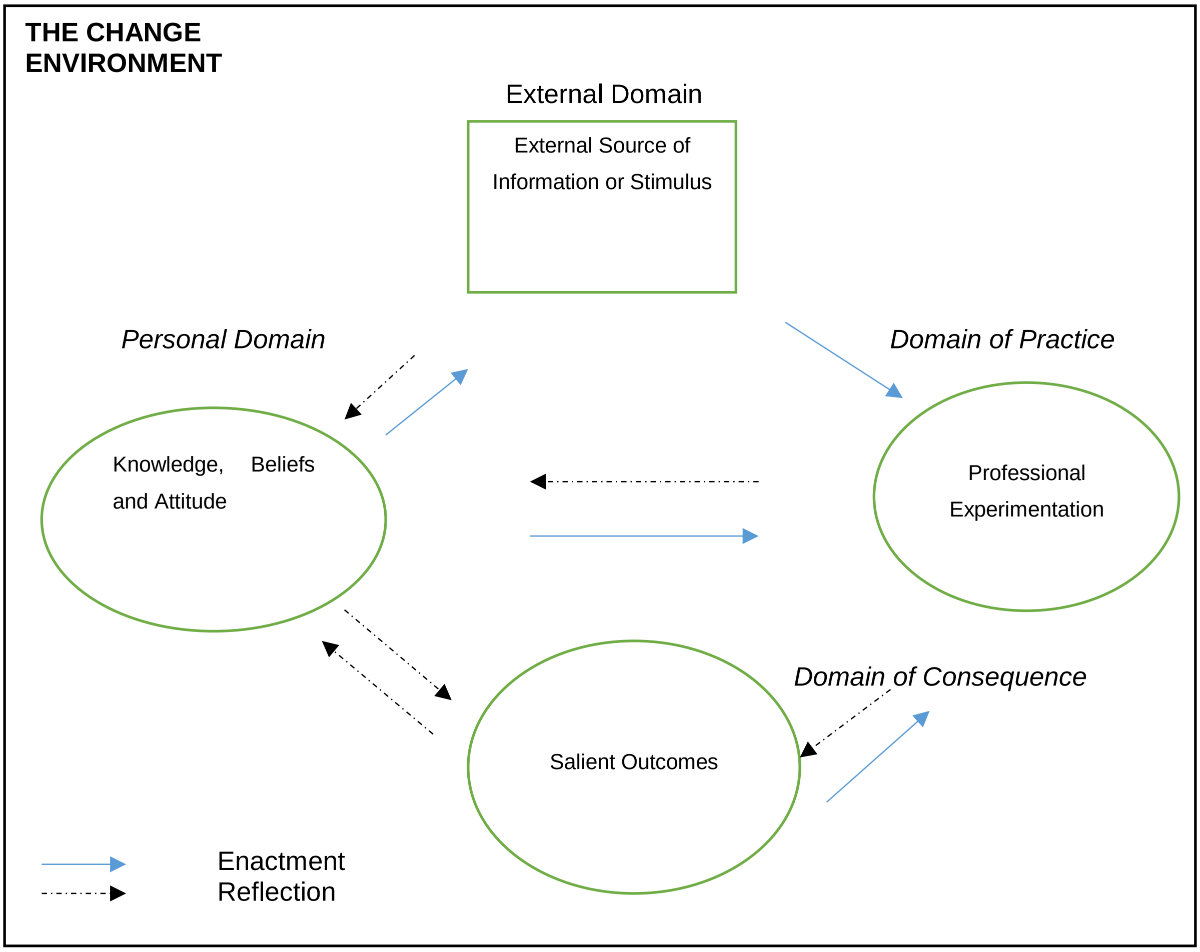

Figure 2.4: The interconnected model of teacher professional growth by Clarke and Hollingsworth (2002, p. 951)

In the interconnected model, teacher professional growth is presented as "an inevitable and continuing process of learning" (Clarke & Hollingsworth, 2002, p.

947). This model emphasises the active participation, special activities, and the consequences if teachers are involved in professional learning programmes.

The four distinct domains that encompass the teacher's world, as suggested by Clarke and Hollingsworth (2002, p. 950), are:

- The *external domain* (e.g. sources of information, stimulus or support, such as in-service training sessions, and conversations with colleagues);
- The *personal domain* (e.g. teacher knowledge, beliefs and attitudes);
- The *domain of practice* (professional experimentation and activities, e.g. the formative assessment tasks in this study); and
- The *domain of consequence* (incidental salient student learning outcomes, teacher control, motivation and student achievement).

The model therefore suggests that the intervening processes of enactment and reflection in one domain may lead to change in another domain. For example, the translation of a belief or a pedagogical model into action is distinguished from 'acting' "on the grounds that acting occurs in the domain of practice" (Clarke & Hollingsworth, 2002, p. 951). In this context, *enactment (*represented as a solid arrow in Figure 2.4) refers to the unseen cognitive processes carried out when translating beliefs into action. Each action represents the enactment of something a teacher knows, believes, or has experienced. In this study, it is particularly relevant as the participating teachers are experienced mathematics teachers and not novices in terms of classroom practice, with ample knowledge, beliefs, and experiences. This model implies that all four of the domains are interconnected and therefore change in one domain may lead to change in the other domains. Thus, just like the personal domain, the domain of consequence also pertains to teachers' individual interpretations (cognitions), while the external domain can be viewed as external stimuli that may influence teachers' understanding. The term *reflection* (represented as a dotted arrow in Figure 2.4) in the context of this study is considered as "active, persistent, and careful consideration" as teachers engage in and implement formative assessment strategies (Clarke & Hollingsworth, 2002, p. 953). Consequently, according to the authors, enactment leads to a change of behaviour, whereas reflection may result in a change of cognition.

The interconnected change model's major value in this study lies in its ability to analyse *teacher change* (or professional growth) within the structure of the AETL project (see Section 1.1). The participants' activities and assessment tasks were structured in such a way that it allowed for enactment and reflection by the participants, and as a result, provided the opportunity to identify change sequences in all four identified domains. The interconnected model additionally provides a framework in which I could assume that when teachers make adjustments to their knowledge, beliefs, and attitudes, their practice will improve, and as a result, student outcomes will improve (Evans, 2014; Guskey, 2002; Zwart et al., 2007). It is important to mention that change in one domain of influence may not necessarily lead to change in another domain. For teacher learning and growth to occur, change must occur in multiple areas or domains of influence (Clarke & Hollingsworth, 2002). This perspective of teacher professional growth fits well with the aim of this study, which is to explore how teachers experience and understand formative assessment strategies to enhance their professional development. Clarke and Hollingsworth's interconnected model is also compatible with social constructivist learning theories in that it recognises the individual construction of knowledge (cognitive perspective) and the development of practice (situative perspective) (Boylan et al., 2018, p.130). Because this perspective fits well within the purpose of the AETL project and teachers' active participation in the process of developing formative assessment knowledge and skills, I decided to use this model as an analytical tool in both the literature review and empirical findings as it relates to this study.

In accordance with the above discussions, I therefore decided to apply the interconnected model of Clarke and Hollingsworth (2002) as the basic framework for structuring and analysing research related to effective professional development in the next section.

2.4 CONCEPTUALISATIONS OF EFFECTIVE PROFESSIONAL DEVELOPMENT COMPONENTS

This section provides a review of the research that is relevant to professional development, focusing on effective components (i.e. what effective PD programmes should look like). It summarises the research findings related to the characteristics of effective professional development for teachers framed within the four interconnected domains of teacher professional growth, according to Clarke and Hollingsworth (2002, p. 951).

Conceptualisations of professional development (i.e. *what* it is), according to Evans (2014), vary in relation to specificity and detail. As a result, it was difficult to find a clear definition that encompassed all effective components. A common list of characteristics for effective teacher professional development was also difficult to find in the literature, however, many studies report on core professional development features. Hence, I adopted Clarke and Hollingsworth's interconnected model (2002) as a fundamental framework to review the literature focusing on different components of professional development practices that are perceived to be effective in their outcomes. I aimed to structure the components in relation to the four domains identified by Clarke and Hollingsworth (2002, p. 950): the external, personal, practice and consequence domains (see Fig.2.4). The interconnected model of Clarke and Hollingsworth (2002) accommodates multiple components of professional growth, as well as the interactions between them. It is important to point out that, according to Clarke and Hollingsworth (2002), the distinct domains that encompass the teacher's world to address PD may not fit perfectly into one of the four domains. These components should therefore not be seen as separate entities, but as components interacting to deepen the understanding and conceptualisation of teacher professional development and how it occurs. Thus, one of the goals in conceptualising professional development in this study was to understand under *what* conditions, *why*, and *how* teachers learn or experience optimal growth.

2.4.1 Professional development and the external domain

Several empirical studies indicate that external sources of information or stimuli provide opportunities for effective teacher professional growth and change in instructional practices. Clarke and Hollingsworth's (2002) interconnected model represents the external domain (depicted by the square in Figure 2.4) as the only domain outside the teachers' personal world (depicted by circles in Figure 2.4) to stimulate and shape teachers' learning. Clarke and Hollingsworth (2002) therefore suggest that opportunities need to be created in the external domain to enhance teacher growth.

2.4.1.1 School Context

It is well established in educational research that the norms of the school, for example, its resources, stakeholder support, and practices can both enable and constrain professional development of teachers (Borko, 2004; Evans, 2014; Feiman-Nemser, 2001; Opfer & Pedder, 2011).

Mewborn and Huberty (2004, p. 2) emphasise the importance of contextual learning in a professional development initiative. They implemented a needs-based model for mathematics teachers on site and their findings revealed three major criteria for CPDT to be effective:

- It should be developed for teachers teaching particular grades;
- It has to be contextualised, sustained, and be appropriate for teachers' classroom practice; and
- Programmes should be "site-based so that the staff developers understand their students, their curriculum, and their school structures" (Mewborn & Huberty 2004, p. 2).

Johnson et al. (2012) studied the influence of the professional environment on teacher growth and report that the professional environment in schools (local circumstances) supports teachers' ability to improve their practice over time. The researchers examined how changes in teachers' productivity over time depended on the professional environments in which they worked. In essence, they drew a comparison between teachers in schools with strong and weak professional environments. From Johnson et al.'s (2012) findings, it can be assumed that the professional environment in schools has the potential to affect teachers' ability to improve their practice and consequently, student achievement. Important elements of the professional environment identified by the researchers are that the strongest predictors of student achievement appear to be effective peer collaboration, access to high-quality professional development opportunities, and administrative support in maintaining order and discipline.

In their view of building teachers' capacity for 21st century teaching and learning, Wiliam and Thompson (2007, p. 45) also argue that teacher professional development is more effective when it is “related to the local circumstances, in which the teachers operate” and by implication in their own classrooms. Effective professional development takes place over a sustained period of time, rather than being in the form of “sporadic one-day workshops, and involves the teachers in active, collective participation” (2008, p. 45).

Opfer and Pedder (2011) adopt a framework of Complexity Theory to review the literature on teacher professional development practices and learning systems. Their conceptualisation of teacher professional learning suggests that a teacher’s individual learning orientation system interacts with the school’s overarching learning orientation system. This enables an understanding and explanation of why and how teachers learn more effectively when learning opportunities are created within their school environment (p. 393). The authors, however, recognise that the specific sets of activities, systems, and supports for learning that are used in one context, with one set of teachers, may be quite different from those that would be necessary to achieve the same result in another context with a different set of teachers (Opfer & Pedder, 2011). It is thus important to understand that there are different ways in which elements from the external domain interact with each other, with contexts, and with the characteristics of individual teachers to ensure effective teacher learning.

It is clear from the professional development literature that research has moved to a focus on job-embedded professional development as a more effective means of changing teachers’ behaviour. However, Carney, Brendefur, Hughes and Sutton (2016) provide contrasting findings which suggest that a one-size-fits-all approach to professional development can also be effective in changing teachers’ behaviour. The researchers are of the opinion that one should consider the significant cost in the ability to up-scale high-quality, job-embedded professional development; as it can seriously limited by resources, such as time, money, and lack of skilled facilitators (p.563). The authors suggest that large-scale professional development initiatives that are structured around a common knowledge base and informed by policy can be effective in changing mathematics teachers’ behaviours. Their study involved 4000 K-12 mathematics teachers and administrators who completed a “Mathematical Thinking for Instruction” course with a particular focus on student thinking, problem-solving, and content knowledge specific to mathematics instruction. Their study reported statistically significant changes in mathematics teachers' knowledge, self-efficacy and beliefs, adding to the usefulness of mandated and large-scale professional development initiatives (Carney et al., 2016).

Although longer and more intensive school-based PD programmes are proposed to be more effective, most of South Africa's PD programmes are done off-site, especially in the case of some rural area schools that are very far apart. In such cases, teachers' travelling expenses for example, must be considered when planning effective PD initiatives (Adler & Reed, 2000; Bansilal & Rosenberg; 2016; Luneta 2011; Van der Nest, 2012).

It is clear that there is no simplistic conceptualisation of PD as much of the research is focused on activities and programmes, which are isolated from the complex teaching and learning environments of teachers. Contextual learning is an essential component of the external domain in CPDT and the conditions that support and promote this learning require further exploration (Borko, 2004; Opfer & Pedder, 2011).

2.4.1.2 Support

Research increasingly emphasises the involvement and support of the relevant stakeholders to promote the quality of teachers and teaching within their school communities. Yendol-Hoppey, Dana, and Hirsh (2010) refer to job-embedded professional development as effective when conditions are created for teachers to learn throughout their professional careers. Teachers tend to embrace professional development as a part of every school day when opportunities for collaboration are created and professional learning tools that are powerful enough to influence student learning are introduced. Feiman-Nemser (2001) also emphasises that learning to teach effectively is a developmental process that unfolds over time when teachers have appropriate support and opportunities to learn. Although she refers to the professional development of beginner teachers, we can relate this to all practising teachers. Involving teachers in professional development activities allows stakeholders to be informed of the teachers' needs, the challenges they experience, the resources needed, and to provide the necessary support for teachers' daily practice. For teachers to be able to implement the strategies and new practices that they learn, the necessary support and reinforcement from their schools and leadership are critical to address their professional development needs.

2.4.1.3 Professional Learning Communities (PLCs)

Research suggests that there is an exceptionally strong relationship between collegiality and professional learning communities and changes in teacher practice. As a result, many university-run and school-based professional development programmes have as a central feature - the opportunity for teachers to participate collaboratively in professional communities.

Collaborative interaction can promote effective teaching practice as it forces teachers to engage in conversation about their practices (Darling-Hammond et al., 2009; Garet et al., 2001; Hord, 2009). “Teachers who work together are more likely to have the opportunity to discuss concepts, skills, and problems that arise during the professional development experiences” (Garet et al., 2001, p. 922). In their study on effective professional development strategies, Darling-Hammond et al. (2009) found that “nations that outperform the United States on international assessments invest heavily in professional learning and build time for on-going, sustained teacher development and collaboration into teachers' work hours” (Darling-Hammond et al., 2009, p. 48).

Other benefits can also be gained from working in positive Professional Learning Communities (PLCs). For instance, Louis and Marks (1998) conducted a longitudinal study amongst schools from a variety of contexts and found that schools with active professional learning communities indicate that their teachers’ content-specific knowledge and skills improved. Their findings not only suggest that PLCs can be a vehicle to establish mutually supportive relationships and developing shared norms and values between schools, but it also indicates that certain schools had lower student absenteeism and dropout rates (Louis & Marks, 1998).

Stoll, Bolam, McMahon, Wallace and Thomas (2006) acknowledge that collaborative PLCs can achieve shared purposes of better teaching practices and feelings of interdependence, but cautions against the existence of micro politics and tension between individuals. According to Stoll et al. (2006, p. 225), the focus is not just on individual teachers’ professional learning, but also on professional learning within a community context – a community of learners, and the notion of collective learning. They elaborate on the five features most commonly identified by contemporary theorists exploring effective PLCs:

- Shared beliefs and understanding;
- Interaction and participation;
- Interdependence;
- Concern for individual and minority views (‘‘members of a community, while sharing interests and a commitment to one another, don’t always agree’’); and
- Meaningful relationships.

Yu et al.’s study (2000) supports this stance but also includes mediating variables, such as school culture and teacher collaboration, to explore the influence of teacher development and commitment on the effectiveness of PD. A collegial culture and supportive collaboration therefore create an ownership of teachers own professional learning and involves teaching that is more effective.

A number of studies have examined the relationship between teachers’ participation in PLCs, how their teaching practices have changed, and how this has improved student achievement (Dunne et al., 2000; Hord, 2009; Louis & Marks, 1998; Stoll et al., 2006). In a study by Dunne, Nave and Lewis (2000), a group of 12 schools established a PLC with specific procedures to guide observations and discussions. The researchers used interview and observation data to compare the practices of non-participants to the practices of teachers who participated in critical friend groups. Researchers found that not only did the PLC teachers change their teaching practice, they also became more student-centred with a focus on student mastery, and as a result, it has been shown to increase student achievement (Dunne et al., 2000). Shirley Hord (2009) supports this stance, and is of the view that professional learning community members operate as constructivist learners. Hord explains that these members are making collegial decisions and planning self-generated learning as they are using data to make decisions about what to learn, how to learn it, how to transfer and apply it to their classrooms, and how to assess its effectiveness (Hord, 2009, p.43). The South African National Policy Framework supports this sociocultural perspective of learning in professional learning communities, “A professionally confident, fully capable, and continually learning community of teachers is the necessary requirement for success” (DoE, 2007, p. 33).

Against the background of the need for establishing effective professional development programmes in South African schools, Steyn (2013, p. 285) proposes a *dynamic* model on how collaboration in PLCs can support and sustain changes in teachers’ practices and enable professional learning. Steyn’s dynamic model for implementing PLCs in schools considers the following critical elements:

- Create a clear understanding of PLCs;
- Identify suitable facilitators for PLCs;
- Create a safe, supportive environment for PLCs;
- Involve principals in PLCs;
- Provide the necessary support and building capacity for PLCs; and
- Network with other schools (Steyn, 2013, p. 285).

For the purpose of this study, Steyn’s model offers a valuable explanatory framework that accommodates external stimuli from a conducive learning environment such as the collaborative support within a PLC, and the influence it has on teachers’ transformed learning and individual orientation towards learning. Steyn’s (2013, p. 285) dynamic model for PLCs to enhance teacher professional development is presented in Figure 2.5 below.

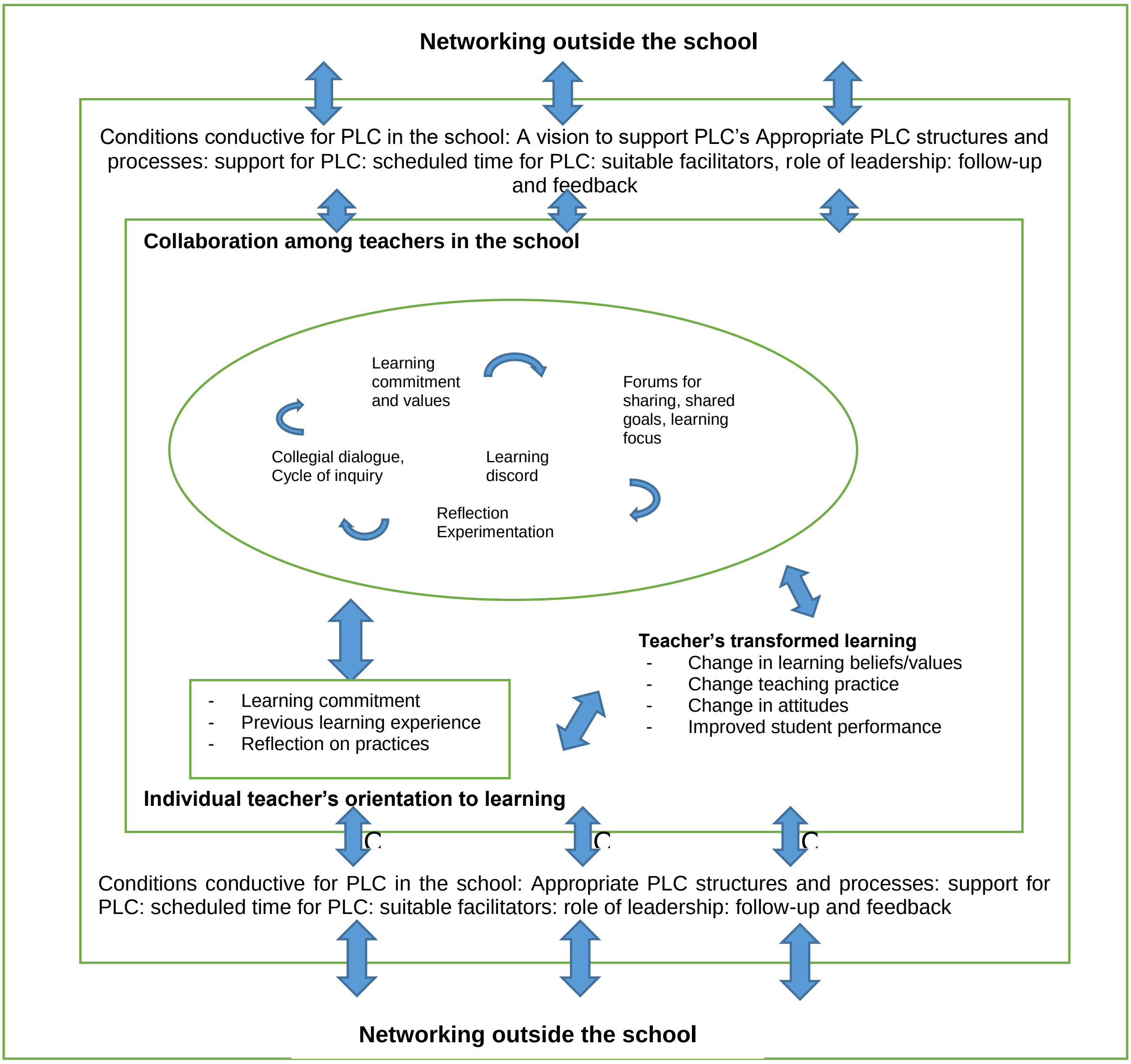

Figure 2.5: A dynamic model of professional learning communities (Steyn, 2013, p.285)

It is evident from the above discussions that there is a strong relationship between the professional environment, and support in schools and teacher professional growth.

2.4.2 Professional development and the cognitive (personal) domain

Clarke and Hollingsworth's (2002) personal domain includes teacher knowledge, beliefs, and attitudes, which form an essential component in the conceptualisation of effective professional development in this study. There is a large volume of published studies describing the role of the knowledge, beliefs and attitudes of teachers and the influence thereof on their teaching practices (Bandura, 1993; Borko,1997, 2004; Clarke & Peter,1993; Ernest, 1989).

2.4.2.1 Knowledge, beliefs and attitude

In 1989, Ernest proposed an analytical model of the different types of knowledge, beliefs, and attitudes of the mathematics teacher, and their relationship with the practice of teaching. He emphasises that “the teacher's thought processes and structures are closely interrelated in practice” (p.15) and describes the general thought processes of a teacher as a cyclic process:

Planning → teaching → reflecting → planning

Ernest (1989) suggests that teachers’ knowledge, beliefs, and attitudes are the “sources of the constructs, relations, procedures, and strategies through which the teacher's thought processes operate” (p.15), indicating that “teacher's procedural knowledge - most notably the pedagogical skills - provide the basis for the teacher's thought processes, before, during and after teaching.” In his cognitive construction of knowledge, Ernest (1989, p. 15) identifies the following essential components of knowledge that affect a teacher’s thought process and practice:

- Practical knowledge of the teaching of mathematics (both pedagogical and curricular knowledge);
- Knowledge of classroom organisation; and
- Knowledge of the school context.

Ernest (1998, p. 30) argues that teachers’ beliefs about “*teaching and learning mathematics”* and their views of the “*nature of mathematics”* have a powerful impact on the selection of content and emphasis on styles of teaching, and on modes of learning. This is supported by Bandura’s (1993) study on perceived self-efficacy.

Bandura (1993, p. 140) discusses empirical evidence that teachers’ sense of personal efficacy (self-efficacy) affects the quality of their instructional practices. He refers to an investigation concerning how teachers’ efficacy beliefs predict students’ level of mathematical and language achievement over the course of an academic year. He further reported the following:

> Teachers who believe strongly in their instructional efficacy support development of student's intrinsic interests and academic self-directedness. Those who have a low sense of personal efficacy favour a custodial orientation that relies heavily on extrinsic inducements and negative sanctions to get students to study (p140).

Recent research conducted by Zee and Koomen (2016) confirms Bandura's view as discussed above regarding teachers' self-efficacy. From the perspective of a consolidated critical review of 40 years' worth of research on teachers' self-efficacy, they demonstrate that teachers' self-efficacy has a direct effect on the quality of their classroom practices, students' ability to understand and learn, and teachers' well-being. The authors further call for "multidimensional measures, research designs that reveal more complex indirect effects and potential feedback loops, and further integration between lines of inquiry" (p. 1011). This correlates directly with my study as I sought to understand the teachers' perception of their own self-efficacy. This allowed me to provide them with strategies, using formative assessment, to improve their knowledge as well as their practice, thus promoting their professional growth and, indirectly, their self-efficacy.

To understand better how knowledge influences teachers' thinking and their actions in the classroom, Borko and Putnam (1995), argue that the "elaboration and expansion of a teacher's knowledge base" should be a central goal in teacher professional development (p. 58):

> Teachers' thinking is directly influenced by their knowledge. Their thinking, in turn, determines their actions in the classroom. Thus, to understand teaching we must study teachers' knowledge systems [...]. Similarly, to help teachers change their practice, we must help them to expand and elaborate their knowledge systems (p. 58).

The continuing professional development of teachers, focusing specifically on the acquisition of content and pedagogy knowledge, has received extensive international attention (Borko & Putnam, 1995; Darling-Hammond et al., 2009; Shulman, 1987).

Shulman (1987) argues that effective professional development programmes need to focus not only on teachers' practices but also on teacher knowledge. He describes how teacher growth becomes a process of the construction of a variety of knowledge types. These knowledge types include the Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) acquired by individual teachers in response to their participation in the professional development programme, and through participation in the classroom. Shulman (1987) therefore identifies the possession of good Subject Content Knowledge (SCK) by teachers as a crucial prerequisite for effective teaching. However, effective teaching goes well beyond just a good knowledge of SCK, it also requires Pedagogical Content Knowledge (PCK).

Based on the work of Shulman (1987), Borko and Putnam (1995) proposed a model of the knowledge base of teaching around three domains of knowledge that they argued were relevant to teachers' instructional practices:

- General pedagogic knowledge;
- Subject-matter knowledge; and
- Pedagogical content knowledge.

Table 2.1 outlines the three knowledge domains and their components as proposed by Borko and Putnam (1995).

Table 2.1: Domains and components of the knowledge base of teaching (Borko & Putnam, 1995)

Domain	Components
General Pedagogical Knowledge	Learning environments and instructional changes. Classroom management. Knowledge of learners and learning.
Subject Matter Knowledge	Knowledge of content and substantive structures. Syntactic structures.
Pedagogical Content Knowledge	Overarching concept of teaching a subject. Knowledge of instructional strategies and representations. Knowledge of students' understandings and potential misunderstandings. Knowledge of the curriculum and curricular materials.

It is evident from the literature that CPDT programmes should focus on ensuring that teachers' subject content knowledge is strongly grounded. Attention should also be given to development in terms of teachers' practices, and when and how to support learners.

More recent and local research conducted by Kanyongo and Brown (2013, p. 107) supports this stance and emphasises why teachers' subject knowledge is so important in supporting their students' learning:

- It influences how teachers engage students with regard to subject matter;
- It affects how teachers evaluate and use instructional materials; and
- It is related to what students learn in the classroom (Kanyongo & Brown, 2013, p. 108).

However, the legacy of Apartheid has left South Africa with a dire need for better-qualified teachers and professional development programmes that need to consider sustained support in improving subject content knowledge and pedagogical knowledge (Centre for Development and Enterprise, 2017, p. 26). The President's Education Initiative research project (1998) states that the "most critical challenge for teacher education in South Africa was the limited conceptual knowledge of many teachers" (DoE, 2007, p. 4). In altering the South African education system, it is important that teachers be suitably equipped to address the needs and challenges to improve their practice. The Department of Education clearly states that teacher PD programmes in South Africa should revolve around the acquisition of content knowledge, pedagogic content knowledge, and conceptual and procedural knowledge to enhance professional growth (DoE, 2006).

Teachers therefore need to be given the opportunity to acquire and use knowledge and skills to make important decisions about classroom practices; how to sequence them so as to enhance the development of concepts, classroom resources; and when and how to intervene when learners struggle or when to support learning by reducing the complexity of tasks (Anthony & Walshaw, 2009, p. 950).

It is important to emphasise that change in one domain, for example, the personal (cognitive domain) may lead to change in another domain (e.g. the domain of practice). This is relevant to teacher professional development and consistent with Clarke and Hollingsworth's (2002) model for professional growth. The mediating processes of reflection and enactment are described by Clarke and Hollingsworth (2002, p. 950) as the mechanisms by which change in one domain leads to change in another. Clarke and Hollingsworth employ the term ''reflection'', as ''active, persistent and careful consideration'' (Clarke & Hollingsworth, 2002, p. 954).

According to Nsibande and Garraway (2011), teachers bring experience and knowledge to their classrooms, but they need to reflect on their attitudes and beliefs to ensure professional learning. The authors regard reflection to be a major tool to broaden the knowledge base of teachers, and propose that experience alone is not enough for professional growth. They propose that for "experience to become learning and knowledge, it needs to be stopped in time, described, analysed, and considered at some length "(Nsibande & Garraway, 2011, p. 2). The authors, however, strongly suggest that enabling purposeful reflection on the notion of context should also be considered, that is "(w)here the identity of the practitioner is strongly developed then they are more likely, given that other enabling conditions prevail, to conduct meaningful reflection and implement change" (p. 9).

Huillet, Adler and Berger (2011) also support teachers' reflection and researching aspects of their own classroom practices and propose that it has the potential to expand teachers' own content knowledge and their knowledge about student learning and reasoning. In this study, mathematics teachers were engaged in research and reflection on their individual assessment practices with the intention of improving their own teacher learning, while also providing data about their teacher learning experiences. Adler (2000, p. 37) adds that the process of reflection is essential to broaden the knowledge base in teacher learning:

> Reflection in teacher learning is understood as a process of increasing participation in the practice of teaching and through this participation, a process of becoming knowledgeable in and about teaching.

Teachers' professional development and curricular reform are interrelated as these cannot be successful when isolated from educational reform (Heritage et al., 2009). In addition, Darling-Hammond et al. (2009) suggest that professional development programmes have a tendency to be more effective when teachers are not isolated from the activities that they are required to do according to local curriculum guidelines.

Curriculum knowledge and implementation

Effective professional development programmes must provide teachers with a way to apply what they learn, directly to their teaching. Holland (2005) argues that professional development leads to better instruction and improved student learning when it connects to the curriculum materials that teachers use, the district and state academic standards that guide their work, and the assessment and accountability measures that evaluate their success. The researchers describe a comparative study where opportunities were provided for mathematics teachers to examine new curriculum materials, and to solve mathematics problems that they would teach to their students. They indicated that these teachers' students performed better in conceptual understanding (Holland, 2005).

Van den Akker et al. (2009) support this stance concerning teacher learning and curriculum change. According to the authors, any curriculum innovation implies changes in the actions, thinking and learning process of teachers. Van den Akker et al. (2009) elaborate on the three dimensions of Fullan (2007) in which change is essential for teacher learning. Fullan (2007) describes the first dimension as the use of other teaching resources (materials); the second dimension of teacher learning emphasises changes in pedagogical, didactical and organisational behaviour in a sense that existing role and routines must change; and the third dimension concerns the change in views and attitudes towards the profession, the pupil's role, and the teacher's own role. Van den Akker et al. add to these dimensions by suggesting that the keys to successful curriculum implementation are the teacher's reorientation and reinforcement of pedagogical content knowledge (Van den Akker et al., 2009). It is therefore essential for teachers, as well as programme developers, to understand the process of learning and to engage in effective instructional practices to meet teachers' needs and to connect their students' learning and needs to the goals of the intended curriculum. The formative assessment tasks in this study are curriculum-aligned and aim to improve teachers' reorientation in the curriculum and as an outcome, deepen their knowledge.

2.4.3 Professional development and the domain of practice

Knowing is not enough; we must apply. Willing is not enough; we must do

- Von Goethe (n.d.)

The domain of practice in the context of this study refers to professional experimentation and activities in which teachers are engaged, for example, the refinement and implementation of formative assessment tasks.

2.4.3.1 Professional experimentation and well-developed activities

A growing amount of research central to professional development emphasises the importance of active engagement and well-developed activities.

Darling-Hammond, Wei, Andree, Richardson and Orphanos (2009) regard effective professional development as focused on concrete teaching tasks and activities, quality assessment, observation, and reflection. They suggest that professional development interventions should create active learning opportunities that allow teachers to change their teaching strategies and not “simply layer new strategies on top of the old” (p. 7). For teacher professional learning to be effective, educators should “learn by engaging in continuous dialogue and examination of their practice and student performance and to develop and implement more effective instructional practices” (Darling-Hammond et al., 2009, p. 49).

Empirical studies done by Desimone et al. (2002, p. 923) suggest that well-developed activities and practices for the effective professional development of teachers should value:

- Subject matter and teaching methods (to improve teachers’ content knowledge and PCK of the subject);
- Changes in teaching practice (activities are designed to help teachers to use particular curriculum materials);
- Goals for student learning (activities are designed to help teachers to improve student performance in the basic skills); and

- The ways in which students learn particular subject matter (activities are designed to help teachers to improve their understanding of mathematics learning principles).

It is evident from numerous studies that PD is most effective when it is approached as a continuous process that involves appropriately planned development in terms of time and follow-up support through feedback. A randomised experiment on activities for teacher professional development by Carpenter, Fennema, Peterson, Chiang and Loef (1989) found that teachers who participated in an extensive 80-hour programme of cognitively guided instruction had students who outperformed the students of teachers who had participated in a brief four-hour professional development programme. Holland (2005, p. 4) agrees that adequate time for professional development is essential. However, the author cautions that more time does not guarantee success or change in practice; the essence thereof lies in how the activities are directly linked to the subject they are teaching and the standards and assessments that they use.

Structured activities in professional development programmes also seem to assist teachers in narrowing the achievement gap in standardised assessments, according to Rieckhoff and Larsen (2012). Professional development partnerships with a focus on structured and research-based practices provide teachers with learning opportunities and support them in transferring new learning into practice.

2.4.4 Professional development and the domain of consequence

The domain of consequence that encompasses the teacher's world includes incidental salient student learning outcomes, teacher control, student motivation, and student achievement, according to Clarke and Hollingsworth (2002). The interconnectedness between the cognitive domain and the domain of consequence, according to Clarke and Hollingsworth's (2002) model, became evident in reviewing the literature on professional growth (Desimone, 2009; Evans, 2014; Suurtamm & Koch, 2014).

Building from Bandura's Self-Efficacy Theory (Bandura,1993), several studies were conducted on teacher efficacy and how it affects student achievement, for example, Holzberger, Philipp and Kunter (2013) have reported that teachers with higher self-efficacy beliefs were able to present a higher degree of cognitive challenge to students during instruction. They also demonstrated effective classroom management and were able to provide more support to individual learners. The judgement of teachers over their own work, their willingness to change and to act upon it, together with the effect it has on student outcomes. The fact that Clarke and Hollingsworth (2002) consider student outcomes as part of the consequence domain has lead me to explore the concept of teacher agency as an important component of effective professional development.

2.4.4.1 Teacher Agency

An increasing amount of research on the concept of teacher agency has also emerged from studies addressing continuous professional development and learning. Central to the professional development component in the AETL study is the supporting and enabling of teachers to act independently, and to make choices as to how they engage in and implement new assessment strategies. Biesta, Priestley and Robinson (2015) acknowledge the importance of teachers' active "contribution to shaping their work and its conditions for the overall quality of education" (p. 624), and describe the opportunities for teachers to exert judgement and control over their *own* work as teacher agency.

In agreement with Biesta et al. (2015), this study regards teacher agency as an important dimension of teachers' professionalism in order to advance toward their goals. Biesta and Tedder (2007) provide an ecological perspective of the concept of agency in that agency is not intrinsic to a person, but rather perceived as occurring interactively with the environment, and that the environment in which individuals find themselves may enable or constrain agentive action. Essentially, agency does not reside entirely in the person, or in this case the teacher, but is a product of the teacher engaging with the environment. This view of teacher agency strongly coheres with Bandura's social cognitive theory (1986), where environmental events, personal factors, and behaviours are seen as interacting in the process of learning (Bandura, 1986). A further point is that teacher agency has historical features in that the teacher may draw on previous experience, a future in that action may be taken towards a future goal, and the present where the teacher has to negotiate the educational and social milieu (Priestley, Edwards, Priestley & Miller, 2012).

For the purpose of this study, I viewed teacher agency from an ecological perspective as suggested by Biesta and Tedder (2007), but also as a *salient outcome* in the consequence domain of the professional development and change process as described by Clarke and Hollingsworth (2002). Although teacher agency is regarded as an important component of professional development, it seems noteworthy to mention that an explicit discussion of agency and its relation to professional learning is not included in Clarke and Hollingsworth's model. As a result, I view teachers' judgement of their own work to *act* as a willingness to change in the 'consequence' domain, but also as a mediating process (as enactment) as suggested by Clarke and Hollingsworth's (2002) interconnected model (see Fig 2.5). Within the limits of this study, a full discussion of teacher agency and its relation to professional learning is not possible.

It is evident that research has provided us with compelling evidence on the critical components of effective professional development. Despite the broad knowledge base on effective strategies and dimensions, as discussed above for teacher professional development, a deeper knowledge of *how* and *why* mathematics teachers learn and grow as professionals is essential. Further exploration of how mathematics teachers perceive the teaching and learning of mathematics is needed to determine which PD activities are effective in meeting their students' needs. The question remains, however, how do practising mathematics teachers continue to develop the knowledge and habits of mind that enable them to teach effectively and to improve their teaching over time?

Many professional development initiatives to improve the quality of mathematics education have been employed in several countries but the core matters of teaching and learning in the classroom seem to be neglected. There is a need to create opportunities for mathematics teachers to become actively involved in assessment activities with the aim of supporting mathematics learning. Professional development programmes need to address classroom practices where a lack of understanding learning processes is involved.

2.5 PROFESSIONAL DEVELOPMENT AND MATHEMATICS TEACHING AND LEARNING

As previously mentioned in Section 2.3.2, it is important to recognise teachers' knowledge, skills, and the commitment that they bring to their teaching when opportunities for CPDT are created.

Feiman-Nemser (2001) emphasises the importance of recognising the interconnectedness of student learning and teacher learning when she writes,

> After decades of school reform, a consensus is building that the quality of our nation's schools depends on the quality of our nation's teachers. Policy makers and educators are coming to see that what students learn is directly related to what and how teachers teach; and what and how teachers teach depends on the knowledge, skills and commitments they bring to their teaching and the opportunities they have to continue learning in and from their practice (p. 1013).

James and McCormick (2009) support this view in their research on teachers' professional learning and their capacity to promote learning autonomy in their pupils. The authors emphasise the importance of creating opportunities for teachers to "learn how to learn" before they can promote learning autonomy in their students. The following quote illuminates this point:

> Teachers need to learn new knowledge (about learning), develop new skills, and reassess their roles. Teachers need to learn, as well as their pupils, and schools need to support them in this…learning how to learn (LHTL) is necessary for both pupils and teachers (James & McCormick, 2009, p. 973).

Opportunities should therefore be created for teachers to reflect on the principles of learning. Teachers' values, beliefs and practices are interrelated and need to be developed together (James & McCormick, 2009).

In mathematics education, a considerable amount of research (Bandura, 1993; Ernest, 1989; Loucks-Horsley, 2010; Shulman, 1987; Thompson, 1992; Wilkins, 2008) underpins the importance of teachers' knowledge, beliefs and attitudes towards teaching and learning in their effectiveness and their choice of instructional practices, and as a consequence, their disposition towards the implementation of innovation.

In addition to knowledge, as discussed above, it is also necessary to consider the beliefs and attitudes of mathematics teachers to account for the differences in their classroom practices. Ernest (1998, p. 30) considers the knowledge components - subject knowledge and pedagogical knowledge - as “cognitive outcomes”, and beliefs and attitudes as “affective outcomes” in achieving educational goals. He particularly refers to mathematics and emphasises that teachers’ beliefs about “teaching and learning mathematics” and their views of the “nature of mathematics” have a powerful impact on the selection of content and emphasis on styles of teaching, and on modes of learning. Ernest (1989, p. 25) suggests that attitudes to mathematics and its teaching are important contributors to a “teacher's make-up and approach, because of the effect they can have on a child's attitudes to mathematics and its learning.” Ernest’s (1989) proposed model for mathematics teaching and learning, is relevant to this study as it provided an analytical frame to explore the knowledge, attitudes and beliefs of mathematics teachers and their acquisition of knowledge and experiences in implementing formative assessment strategies to enhance their professional development. Ernest’s (1989) proposed model for mathematics teaching and learning, is relevant to this study as it provided an analytical frame to explore the knowledge, attitudes and beliefs of mathematics teachers and their acquisition of knowledge and experiences in implementing formative assessment strategies to enhance their professional development.

Goldsmith et al. (2014) reviewed 106 articles written between 1985 and 2008 related to the professional development of practising teachers of mathematics internationally. A key finding is that existing research tends to focus more on programme effectiveness rather than on teachers’ learning. According to the authors, teachers’ learning can generally be described as changes in knowledge, beliefs, and practice (including both practices within and outside of the classroom). A wide range of studies related to the beliefs about mathematics and its teaching showed how teachers have altered their learning beliefs regarding mathematics after they participated in professional learning activities. Their research categorises a number of aspects related to the understanding of in-service mathematics teachers’ professional development and growth. Teachers’ identity, beliefs, and dispositions, their mathematical content knowledge, instructional practices, collaboration, attention to student thinking, curriculum knowledge, and student outcomes are critical aspects to consider in terms of effective professional growth in mathematics instruction.

A study conducted by Tsanwani, Harding, Engelbrecht and Maree (2014) in historically disadvantaged schools in the Limpopo Province explored Grade 12 teachers and learners' perceptions about factors that facilitate learners' performance in mathematics. The participating teachers and learners from high performance and low performance schools indicated that commitment, motivation, attitudes, and the self-concept of mathematics teachers influence learners' performance. The study indicated that learners and teachers from ten different high performing schools shared common characteristics such as being positive about themselves and their ability to do mathematics. Although the authors did not generalise, they emphasised the importance of positive perceptions of mathematics, and sound teaching and learning principles and the effect thereof on the motivation of learners to reach their full potential despite difficult circumstantial factors. This (what?) is of particular relevance in a South African context because "changing school climate and improving the learning strategies in mathematics are much easier to achieve than changing background factors affecting learners' performance" (Tsanwani et al., 2014, p. 50).

In the United States of America (USA), the National Council of Teachers of Mathematics (NCTM, 2014) promoted a vision of mathematics teaching and learning that supports the interconnectedness of student and teacher learning to which Feiman–Nemser (2001) refers. The NCTM developed eight "*Principles to Actions: Ensuring Mathematical Success for All"* in 2014, which are built on constructivist approaches to promote high quality mathematics learning opportunities for all children in the mathematics classroom. Silver (2015) agrees that these principles provide opportunities for high quality education and that the new standards provide guidance and direction. However, he adds that "…they do not tell teachers what to do in the classroom to realize these ambitious goals […] moreover, they neither describe nor prescribe the conditions required to ensure mathematical success for all students" (Silver, 2015, p. 32). Silver (2015) elaborates on the eight teaching practices that offer insight into effective mathematic teaching principles, as related to this study, on how teachers can make changes to their thinking and implement instructional strategies that they are unfamiliar with and draw on mathematics knowledge that they may not yet have.

Table 2.2 highlights how Silver (2015, p. 33) elaborates on the eight teaching practices that are claimed to be essential features of effective mathematics teaching, as proposed by the NCTM (2014). Silver's (2015) explanations of these principles provided a base for discussions and reflections on mathematics teaching and learning in the AETL project (see Section 3.4.3).

Table 2.2: Teaching practices claimed to be essential features of effective mathematics teaching (Silver, 2015, p.33).

Teaching practice	Explanation
Establish mathematics goals to focus learning	The effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals to guide instructional decisions.
Implement tasks that promote reasoning and problem solving	The effective teaching of mathematics engages students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.
Use and connect mathematical representations	Effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem solving.
Facilitate meaningful mathematical discourse	The effective teaching of mathematics facilitates discourse among students to build shared understanding of mathematical ideas by analysing and comparing student approaches and arguments.
Pose purposeful questions	The effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense-making about important mathematical ideas and relationships.
Build procedural fluency from conceptual understanding	The effective teaching of mathematics builds fluency with procedures on a foundation of conceptual understanding so that students, over time, become skilful in using procedures flexibly as they solve contextual and mathematical problems.

Teaching practice	Explanation
Support productive struggles in learning mathematics	The effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and support to engage in productive struggle as they grapple with mathematical ideas and relationships.
Elicit and use evidence of student thinking	The effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

Despite the on-going extensive research relating to the continuous professional development of mathematics teachers, many of them still question their ability to be successful in delivering mathematical instruction. Silver's elaboration on the eight mathematics teaching principles provided an analytical framework for this study through which I could explore teachers' knowledge and practice in terms of mathematics teaching and learning.

Studies on how mathematic teachers learn are important to re-evaluate how much pedagogical content knowledge influences change in their classroom practices. Borko et al. (2000) reported a study where teachers who participated in professional development on alternative assessments altered their beliefs about the nature of mathematical problem solving, and where they lessened the cognitive demand during mathematical problem-solving tasks.

Professional learning activities can shape a wide range of teachers' beliefs about learning and the value of student interaction in their classes (Clarke & Hollingsworth, 2002). Feiman-Nemser's (2001) emphasis on the importance of the interconnectedness of student and teacher learning in improving the quality of education is supported by Usiskin's (2015, p. 19) interrelated "realms of understanding of mathematics." He proposes a multi-dimensional framework for understanding mathematical concepts and problems from both the viewpoints of the student, as well as the teacher, which is relevant to this study. According to Usiskin, there are at least five dimensions to mathematical understanding from the perspective of the student (learner):

- Skill-algorithm dimension;
- The property-proof dimension;
- The use-application (modelling) dimension;
- The representation-metaphor dimension; and
- The history-culture dimension (Usiskin, 2015, p. 1).

Usiskin (2015, p. 19) additionally describes four interrelated realms of understanding of mathematics from the teacher's perspective, in which he emphasises that "the understandings that a teacher needs involve more than the understandings the student needs." According to Usiskin (2015, p. 19), a teacher needs to pay attention to the following four realms of understanding to be able to address and assist students with a mathematical understanding of dimensions:

- The first realm concerns *Pedagogical Content Knowledge* (PCK): designing and preparing for a lesson analysing student errors, explaining and representing ideas new to students, responding to questions that learners have about what they are learning.
- The second realm deals with applying the understanding of mathematical concepts. *Concept analysis*: engaging students in proof, proving choosing, and comparing different representations for a specific mathematical procedure or concept choosing and using mathematical definitions that explain why these concepts arose and how they have changed over time dealing with the wide range of applications of the mathematical ideas being taught.
- The third realm deals with the understanding of problems and problem solving. *Problem analysis*: examining different student solution methods, engaging students in problem-solving that discusses alternate ways of approaching problems with and without calculators and computer technology, offering extensions and generalisations of problems.
- The fourth realm integrates the other three. *Connections and generalisations to other mathematics:* comparing different textbook treatments of a mathematical procedure or topic, extending and generalising properties and

mathematical arguments, explaining how ideas studied in school relate to ideas students may encounter or have encountered in other mathematics studies, realising the implications for student learning in spending too little or too much time on a given topic.

Usiskin's (2015) four realms of what a teacher needs to address in understanding mathematics, primarily informed the formative assessment tasks (worksheets) in the AETL project. Minimal research has been undertaken on the value of formative assessment (classroom-based assessment) in supporting mathematics teachers' professional development in South Africa. It is therefore important to explore ways of breaking these barriers to get a better understanding of current assessment practices and the challenges that these teachers face in their pursuit to improve the quality of the teaching they provide to the learners.

The next part of this chapter conceptualises formative assessment as a strategic approach to deepen the understanding of CPDT and teacher learning.

2.6 FORMATIVE ASSESSMENT

The results of our assessment influence our students for the rest of their lives and careers – fine if we get it right, but unthinkable if we get it wrong.' - Race (cited in Race, Brown & Smith, 2005).

The literature on formative assessment practice establishes a strong rationale for its use as a teacher professional development initiative. I have chosen to concentrate on key aspects such as the conceptualisation and theorising of formative assessment; the benefits of formative assessment; some critical aspects related to effective formative assessment practices; the challenges experienced by teachers in implementing formative assessment, and formative assessment as a strategy for instructional adjustments and professional growth.

2.6.1 Conceptualising formative assessment

Assessment, in general, is a term that is difficult to define as it may mean various things to different people. The concept of assessment is derived from the Latin word "assidere", meaning to "sit beside or with" (Wiggins, 1993).

The general purpose of educational assessment was for the teacher to assist the learner in his or her learning process. Today, however, in 21st century mathematics education worldwide, the emphasis on assessment where the teacher sits beside the learner has shifted towards the assessment of the product of learning, also known as summative assessment (Black & Wiliam, 1998a; Stiggins, 2008; Shepard, 2000).

When using the two distinctive types of assessment in their classrooms, teachers experience some confusion as to how and when to implement formative assessment or summative assessment in the learning process (Black & Wiliam, 1998a; Harlen & James, 1997).

A clear distinction between formative and summative assessment is generally accepted to have arisen from the work of Scriven (1967). Scriven describes formative methods for evaluation as replacing those used formerly,

> In place of the older criteria and the dependent procedures, we need new concepts of educational readiness, strengths on which to build, deficiencies to be addressed, and the like. These new concepts must be based on the assumption of dynamic potential in all or almost all human beings. The evaluation task is to describe or measure phases of this potential and difficulties to be surmounted that can help the individual and the educational institution in improving student learning (Scriven, 1967, p. 16).

Bennett (2011) however, points out that Scriven (1967) used summative evaluations to assess the overall curriculum, and thus his focus was not on student learning. Formative evaluations, as described by Scriven (1967), were used to facilitate change and the overall improvement of a curriculum.

In 1974, Bloom developed the concept of 'mastery learning' through applying assessment strategies by focusing on student learning (Bloom, 1974). Bloom suggests that an overarching learning target breaks up into smaller sequential levels in which students need to master one level before they can progress to the next level. Bloom (1974) highlights the importance of feedback and adjustments to instructions that are consistent with formative assessment practices.

Drawing from the early works of Scriven (1967) and Bloom (1974) in the context of student assessment there exists a clear distinction between formative and summative evaluation. This distinction is particularly between "assessment *for* learning" (formative), where the explicit purpose is to use assessment as part of teaching to promote learning, and "assessment *of* learning" (summative), which is for grading and reporting purposes (James, Black, McCormick, Pedder & Wiliam, 2006, p.109).

Harlen (2012, p. 87) argues that it is not "useful to think in terms of a sharp distinction between formative and summative, since the same assessment results can be used in different ways and there are different ways of serving and reporting learning." He points out that "assessment of any kind should ultimately improve learning", however, it is necessary to distinguish between the purposes and uses of evidence provided by assessment. Harlen describes assessment carried out in various ways and used primarily to help students' learning as 'formative', and assessment carried out in various ways to provide information primarily for reporting on students' achievement as 'summative' (Harlen, 2012, p. 88). He emphasises, however, that that there are different ways of practising and using formative and summative assessment using the same evidence for both purposes. The distinction between the two types of assessment should be made by knowing for what purpose the evidence was gathered and for what purpose it is used.

In the early 1990s, Torrance (1993) expressed the need to broaden and review the conceptualisation of formative assessment by suggesting that a much wider tradition of classroom interaction studies could provide a much firmer basis of evidence about the relationship of assessment to learning,

> Research on assessment is in need of fundamental review. I am suggesting that one aspect of such a review should focus on formative assessment, that it should draw on a much wider tradition of classroom interaction studies than has hitherto been acknowledged as relevant, and that it should attempt to provide a much firmer basis of evidence about the relationship of assessment to learning which can inform policy and practice over the long term (Torrance, 1993 p. 341).

This need to broaden classroom-based assessment knowledge has gained renewed support from several educational researchers worldwide (Black & Wiliam, 1998; Broadfoot et al., 1999; Stiggins, 1990). In the last two decades, there has been a growth of interest in formative assessment, also referred to as 'assessment for learning'. Black and Wiliams' (1998a) study on classroom-based assessment activities, and their impact on improving the quality of education, has resulted in a proliferation of studies addressing the relationship of assessment to learning. Black and Wiliam (1998a, p. 140) conceptualise formative assessment based on a proposition that teaching and learning are interactive,

> We use the general term *assessment* to refer to all those activities undertaken by teachers - and by their students in assessing themselves -that provide information to be used as feedback to modify teaching and learning activities. Such assessment becomes *formative assessment* when the evidence is actually used to adapt the teaching to meet student needs (Black & Wiliam, 1998a, p. 140).

Black and Williams'' (1998a) conceptualisation of formative assessment is essentially rooted in pedagogical knowledge. The need to to locate formative interactions within more comprehensive theories of pedagogy (Black & Wiliam, 2009; Bennett, 2011; James, 2007; Wiliam & Thompson; 2007), and to provide a unifying basis for the diverse practices that are said to be formative, subsequently led the authors (Black & Wiliam, 2009, p. 9) to broaden their definition of formative assessment to:

> Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited.

Black and Wiliam suggest that one consequence of their definition is that formative assessment is concerned with "the creation of, and capitalisation upon, 'moments of contingency' in instruction for the purpose of the regulation of learning processes" (2009, p. 6). It seems clear, therefore, that there has been an increasing acceptance of the fact that formative assessment needs to be understood as a process that facilitates learning and has to involve the consideration of the respective roles of teachers and learners (Black & Wiliam, 2009).

Chappuis (2009) agrees with their definition, but emphasises that it is not the instrument or activity that is formative, but rather the *use of the information* gathered *to adjust teaching and learning*. He describes formative assessment as “formal and informal processes that teachers and students use to gather evidence for the purpose of improving learning” (Chappuis, 2009, p. 5).

As discussed above, a variety of definitions for formative assessment in recent literature exist, specifically addressing different aspects of teaching and learning to broaden the knowledge base of classroom-based assessment (Black et al., 2006; Popham, 2009; Stiggins**,** 2008, Broadfoot & Black 2010). General practices associated with formative assessment can facilitate learning, but it is difficult to generalise and define formative assessment as implementations should be expected to vary widely from one implementation and student population to the next (Bennett, 2011; Leahy & Wiliam, 2012).

Perie, Marion and Gong (2009), who argue for a more comprehensive assessment system, have challenged the debate about many assessment systems that are labelled as formative. The authors contend that the definition and purpose of assessment needs to be considered before categorising it as formative. They distinguish between formative, interim and summative assessment and maintain that interim assessments differ from formative assessment in the sense that it can “be instructional (i.e. to inform curriculum and instruction), evaluative (i.e. to provide evaluative information about the curriculum or instruction), or predictive (i.e. to determine the likelihood of students meeting end-of-the-year criteria)” (Perie et al., 2009, p.5).

Many researchers argue that assessment literacy is an essential component of any teachers’ professional competency (Popham, 2009, Stiggins, 1991, 2014). The term ‘assessment literacy’ has been introduced by Stiggins (1991, p.535), who argues for educators and decision makers to become sufficiently literate in the basics of assessment to know whether their achievement data are sound or unsound. According to Stiggins (2014), if we are to develop truly effective schools, educators must understand how to gather dependable evidence on student achievement and use the assessment process and its results to support student achievement depending on the context. Popham (2009) supports the argument for teachers to become assessment literate:

> Assessment-literate teachers will typically make better decisions…their classroom assessments will be better because those teachers will know not only what it is that constitutes a defensible versus an indefensible assessment and what represents an accurate versus an inaccurate interpretation of assessment-elicited data (p. 6-7).

Heritage (2007) uses the term ‘assessment knowledge’ to emphasise that teachers should know about the range of formative assessment strategies to maximise opportunities to gather evidence (Heritage, 2007, p. 143). The need for teachers to be trained and monitored in the appropriate use of assessment in various contexts to improve learning is expressed by several researchers (Harlen, 2012; Popham, 2009; Stiggins, 2014).

A major focus of CAPS is to provide guidance to South African teachers on how to use the different types of assessment, this is detailed in the following quote from the CAPS (DBE, 2012, p. 154) document:

- “**Baseline assessment:** […] to establish whether their learners meet the basic skills and knowledge levels required to learn a specific Mathematics topic.
- **Diagnostic assessment:** […] to inform the teacher about the learner’s Mathematics problem areas that have the potential to hinder performance.
- **Formative assessment:** […] to aid the teaching and learning processes, hence assessment ***for*** [own emphasis] learning. It is the most commonly used type of assessment because it can be used in different forms at any time during a Mathematics lesson, e.g. short class works during or at the end of each lesson, verbal questioning during the lesson. It is mainly informal and should not be used for promotion purposes. The fundamental distinguishing characteristic of formative assessment is constant feedback to learners, particularly with regard to learners’ learning processes. The information provided by formative assessment can also be used by teachers to inform their methods of teaching.
- **Summative assessment:** Contrary to the character of formative assessment, summative assessment is carried out after the completion of a Mathematics topic or a cluster of related topics. It is therefore referred to as assessment ***of*** [own emphasis] learning since it is mainly focusing on the product of learning. The results of summative assessment are recorded and used for promotion purposes.”

2.6.2 Theoretical foundation for formative assessment

Social constructivism and cognitive theories of learning and teaching underpin the conceptualisation of formative assessment in this study (Black & Wiliam, 1998a, 2009; Chappuis, 2009, Shepard, 2005). According to social constructivist learning theories, learning is constructive as learners construct and build new conceptualisations, and understanding by using what they already know in an environment where learning is shared (McLaughlin, 1997).

Vygotsky's (1978) Social Constructivist Theory, which states that social interaction, cultural tools, and activity shape an individual's development and learning, served as a foundation for connecting assessment and learning in this study. This is also in line with Bandura's Social Cognitive Theory (1986), and how it applies to assessment *for* learning in this study, specifically to the mathematics teacher who is viewed as thoroughly integrated into the environment within which he or she is learning. Bandura contends that "cognitive responses, behaviour, and environment all work together to create learning" (Bandura, 1986, p. 18).

Despite the informative research and new developments in learning theory and assessment practices, Shepard (2000) appeals for models of cognition to be used to guide instruction and, in particular, formative assessment. Shepard (2000) proposes that formative assessment practices must reflect cognitive, constructivist, and sociocultural theories in order to enhance learning and not only be used for measuring purposes. Shepard (2005) explains both socio-cultural learning theories and Vygotsky's (1978) zone of proximal development and how it links to formative assessment and scaffolding as follows:

> Take formative assessment and instructional scaffolding, for example. When you consider the terms in light of sociocultural learning theory and Vygotsky's (1978) zone of proximal development, they're essentially the same thing. Occurring in the midst of instruction, formative assessment is a dynamic process in which supportive adults or classmates help learners move from what they already know to what they are able to do next, using their zone of proximal development (Shepard, 2005, p. 66).

It is therefore important to establish an environment that supports assessment as an integral part of the learning process, which includes the recognition of the importance of the relationships between teacher and student, as well as student-to-student (Stiggins, 2005).

Bennett and Gitomer (2009) support the stance that formative assessment is consistent with the constructivist and socio-cultural views of assessment for the improvement of learning, but caution that the current widely used summative assessment for accountability purposes is not consistent with these views (Bennett & Gitomer, 2009). Researchers agree that standardised summative tests are usually designed to be as objective as possible and that they contain relatively short and superficial test items and exclude many worthwhile learning outcomes such as problem-solving and critical thinking (Bennett & Gitomer, 2009; Harlen, 2005; Shepard, 2000).

Another question remains as to whether teachers actually know how to implement and use formative assessment optimally to enhance learning. Research on elements related to effective formative assessment practises are explored in the next section.

2.6.3 The elements of effective formative assessment practices

Although formative assessment is not consistently defined within the research literature, there seems to be a consensus that when implemented correctly, it has a major impact on student achievement. As Reeves argues: “Assessment is most productive when its purpose is for learning” (2007, p. 2).

2.6.3.1 Correct implementation of formative assessment

Several studies thus far have linked the correct implementation of formative assessment practices to improved student learning. The Assessment Reform Group from the United Kingdom acknowledges the influence that assessment has on learning and proposes the following characteristics of effective assessment. Broadfoot, Daugherty, Gardner, Gipps, Harlen, James and Stobart (1999, p. 7) elaborate further that effective assessment:

- Is embedded in a view of teaching and learning of which it is an essential part;
- Involves sharing learning goals with pupils;

- Aims to help pupils to know and to recognise the standards they are aiming for;
- Involves pupils in self-assessment;
- Provides feedback which leads to pupils recognising their next steps and how to take them;
- Is underpinned by confidence that every student can improve; and
- Involves both teacher and pupils reviewing and reflecting on assessment data.

The importance of the alignment of assessment and curriculum with state standards is emphasised in Stiggins' (2008) research. Stiggins (2008) conceptualises effective elements of formative assessment as a set of carefully designed questions to address student misconceptions and as a tool to address learning gaps. Stiggins refers to the term *learning targets* to describe what is expected from students. Learning targets are aligned with state standards, classroom instruction, and assessment derived directly from these learning targets. Stiggins (2008) primarily provides a framework to ensure that classroom activities are aligned with the set standards and enables teachers to identify and rectify the misconceptions held by students.

A large and growing body of research suggests that student achievement is amplified when teachers employ specific formative assessment practices in classroom instruction (Black & Wiliam, 1998a, 2009; Shepard, 2000; Wiliam, 2014).

In order to provide a better theoretical grounding for formative assessment, Leahy, Lyon, Thompson and Wiliam (2005) provided a framework in which they conceptualise effective formative assessment as comprising five 'key strategies'. These strategies are resulting from crossing three processes (where the learner is going, where the learner is right now, and how to get there) with three kinds of agents in the classroom (teacher, peer, learner), as shown in Table 2.3. Leahy et al. (2005) and Wiliam and Thompson (2007) conceptualise effective formative assessment as consisting of five key strategies:

1) Clarifying and sharing learning intentions and criteria for success;

2) Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding;

3) Providing feedback that moves learners forward;

4) Activating students as instructional resources for one another; and

5) Activating students as the owners of their own learning.

Table 2.3: Aspects of formative assessment (Leahy et al., 2005, p. 19; Wiliam & Thompson, 2007)

	Where the learner is going	Where the learner is now	How to get there
Teacher	**1.** Clarifying learning intentions and criteria for success.	**2.** Engineering effective discussions, tasks and activities that elicit evidence of learning.	**3.** Providing feedback that moves learning forward.
Peer	Understanding and sharing learning intentions and criteria for success.	**4.** Activating students as learning resources for one another.	
Learner	Understanding learning intentions and criteria for success.	**5.** Activating students as owners of their own learning.	

In addition, Black and Wiliam (2009, p. 5) offer a rationale within the framework as presented in Table 2.3. This can also unify the diverse set of practices that have been described as formative. In developing their Theory of Formative Assessment, they relate formative assessment to other pedagogic initiatives, notably cognitive acceleration and dynamic assessment. They also relate it to some of the existing literature on models of self-regulated learning and on classroom discourse to help teachers implement formative practices more effectively. In their study, Black and Wiliam (2009) emphasise that there are three agents of assessment involved: teachers, learners and peers. This implies that teachers should interpret data, provide feedback and learners should use the feedback they receive from their teachers and peers, and through self–regulated actions optimise their learning experiences. Teachers not only need to provide feedback to move their students forward, but they also need to make decisions about subsequent instruction and modify it to make formative assessment more effective. According to Wiliam (2014, p. 8), this framework, as suggested by Black and Wiliam (2009), provides a reasonable conceptual basis for formative assessment. However, this is provided that the two strategies that involve learners and peers (activating students as learning resources for one another and activating students as owners of their own learning) are interpreted as “specifically focusing on moments of contingency in the regulation of learning processes” (Wiliam, 2014, p. 8). This means that formative assessment, when implemented correctly and based on a specific learning goal, is a focused strategy for teachers to gather information from students to move them forward in their learning. According to Black and Wiliam (2009), feedback is a critical piece of the learning cycle with regard to formative assessment. Without feedback, collecting the data is almost meaningless.

Gathered from the literature, it becomes clear that feedback is a crucial component of formative assessment. Hattie and Timperley define feedback as “information provided by a teacher, a peer, or self, regarding aspects of one’s performance or understanding” (Hattie & Timperley, 2007, p.81). The main purpose of feedback is to fill the gap between what is understood by the learner and what is aimed to be understood. As Hattie and Timperley (2007) put it, “To reduce the gap between current understanding or performance and the desired goal” (p. 86).

A general belief is that teachers can help guide students to successful choices (Marzano, 2009; Wiliam, 2014), but teachers must be provided with the necessary knowledge and skills to ensure the effectiveness of formative assessment (Heritage, 2007). Feedback can be in a variety of forms, written, oral, questions or statements but it should be immediate, frequent and descriptive to maximize the positive effects of feedback on learning (Hattie & Timperley, 2007).

Brown, Harris and Harnett (2012) support the stance that teacher and student feedback within an assessment for learning environment is an important component for improved student learning. However, their study on teachers’ beliefs about feedback in 518 primary and secondary schools in New Zealand found that the teachers had a stronger focus on improving learning than on enhancing student well-being (Brown et al., 2012, p. 968). It is proposed that more studies need to be conducted on teachers' beliefs about the purpose of student feedback.

2.6.3.2 Formative assessment and collaboration in PLCs

Teachers have a tendency to work in isolation as they create and administer assessments. Students' test and examination results are recorded and usually submitted at the end of the grading period. Fortunately, however, in recent years, the education community has recognised the value of teachers collaborating with colleagues as they gain new knowledge from assessment data to inform their pedagogy. Research indicates that Professional Learning Communities (PLCs) have several characteristics that are appropriate for supporting teachers in implementing effective formative assessment strategies (Shepard, 2000; Stiggins, 1999). Black and Wiliam (2009) emphasise the importance of collegial conversations and reflective learning experiences where teachers regularly diagnose and assess student learning for mastery within the classroom. According to the authors, PLCs provide opportunities for teachers to collaborate with one another and share common practices and new understanding (Black & Wiliam, 2009).

Stiggins and DuFour (2008) highlight the formative purposes of common assessments in PLCs when collaborative teams of teachers or experts work together:

- First, team-developed common assessments help identify curricular areas that need attention because many students are struggling.
- Second, they help each team member clarify strengths and weaknesses in his or her teaching and create a forum for teachers to learn from one another.
- Third, interim common assessments identify students who are not mastering the intended standards and need timely and systematic interventions.

In the AETL project, we added to the above by positioning the teachers as both experts in their classrooms, and as learners with significant possibilities for learning about engaging with learner errors to improve student learning. We chose a focus -

an engagement with learner errors - that we thought teachers had engaged with differently in the past, and we found ways to position teachers as both knowing and not knowing about learner errors. Teachers clearly know a lot about learner errors, they are faced with them every day and have practised and routine ways of dealing with them.

2.6.4 The benefits of formative assessment on student achievement

The potential of formative assessment to improve learning is reviewed and summarised by Black and Wiliam (1998a, p.82). Their literature review provides a basis for researchers to develop theoretical models for formative assessment and benefits for student learning,

> We checked many books and nine years' worth of more than 160 journals, and earlier reviews of research. This process yielded 580 articles or chapters to study. We prepared a review using material from 250 of these sources. All… studies show that… strengthening the frequent feedback that students receive about their learning during formative assessment produces significant, and often substantial, learning gains. These studies range over ages, across several school subjects, and over several countries (Black & Wiliam, 1998a, p. 82).

Black and Wiliam (1998a) particularly emphasise the importance of providing immediate feedback on a regular basis to ensure that learners are informed about their performance and specific problems that they might experience. Studies on poorly achieving and learning-disabled learners have shown that frequent and immediate feedback improved their learning. The formative approach of immediate feedback with specific recommendations from the teacher benefit these learners as their needs were immediately addressed (Black & Wiliam, 1998a).

Several other studies support the crucial role of descriptive and meaningful feedback during the formative assessment process. Bonner (2009) conducted a quasi-experimental study in which students were given pre- and post-tests to determine the outcomes of formative assessment practice tests on student learning. The study shows that when teachers implement formative assessment strategies, e.g. short quizzes, up to twice a week as part of the classroom routine, student learning increased (Bonner, 2009). Bonner (2009) ascribes this increased learning to the teachers giving specific feedback timeously and making the necessary adjustments in their instruction based on the data collected.

Another benefit of formative assessment, as opposed to summative assessment, is increased student motivation. The research indicates that students become more motivated in doing their work and get more involved in their learning progress with a formative approach rather than being graded in a summative manner (Sadler, 1989; Stiggins, 2008). Stiggins explains, “If we assess to motivate students to try, assessment *for* learning enables students by helping them watch themselves grow - by causing them to believe that success is within reach if they keep trying” (Stiggins, 2008, p. 9).

Clark (2011) attributes this motivation of learners during the formative assessment practices to the social relationships between students and between teachers and students. According to Clark (2011), teachers and students interact more through feedback and discussions when they follow formative assessment practices and, as a result, students take a larger stake in their learning. This practice was also in accordance with the social constructivist view of learning according to Vygotsky (1978) and Bandura (1986) as the students made the necessary adjustments according to the feedback that they received from the teacher, and as a result, they constructed new knowledge.

A study by Johnson (2003) additionally supports the stance of Black and Wiliam (1998a) that formative assessment strategies allow the teacher to adjust the assessment to the needs of the students and improves learning across several contexts. Students in a poor urban area were given an assessment that allowed them to use modes of expressions in which they were fluent or comfortable with, such as arts, oral or verbal modes. This adjustment in assessment to address the multimodal needs of the learners has resulted in improved student achievement in this case.

Leahy and Wiliam (2012) support the view that the use of formative assessment across a range of different school subjects, in different countries, and for learners of different ages can be associated with considerable improvements in the rate of learning. Acknowledging the fact that it is difficult to measure the gains across a variety of contexts, they concluded that the “use of formative assessment can increase the rate of student learning by somewhere between 50% and 100%” (2012, p. 52). However, Wiliam (2009) cautions that outcome measures, which differ in their sensitivity to instruction, cannot be ignored when estimating gains in student learning.

Wiliam and Thompson (2007) suggest that formative assessment, as a lever for school improvement, is likely to be one of the most cost effective and sustainable support for increasing student achievement. They further estimate that it would be 20 times more cost-effective than typical class-size reduction programmes. Leahy and Wiliam (2012) support the cost effectiveness of formative assessment programmes in providing evidence about student achievement and find that these could be used by teachers to make better decisions about instruction. The authors refer to a number of test publishers in their literature review who have produced formative assessment systems to provide for the assessment of student progress at regular intervals, as well as reports that identify students or particular aspects of the curriculum that require special attention (Leahy & Wiliam, 2012, p.52).

The literature reviewed on the benefits of formative assessment supports my argument that practising teachers' perspectives on their experiences with formative assessment strategies can help to develop the teacher professional development experience. University-based programmes and school districts that work together to design and implement an assessment model as part of the teachers’ professional development programme can establish a strong, practice focused environment for in-service teachers.

2.6.5 The case for developing formative assessment as a tool for instructional adjustment and professional growth

Although much has been written about formative assessment as a solution for tracking student progress and ensuring high-stakes test preparedness, the need remains to address the role it plays in the process of changing instructional practice. Teachers’ ability to know what to teach next and how to adapt instruction in light of evidence is critical to effective formative assessment (Black & Wiliam, 1998a, 2004; Heritage, Kim, Vendlinski & Herman, 2009; Stiggins, 2014).

In recent years, there has been an increasing amount of literature on developing ways to support teachers' classroom practice through a focus on formative assessment. Parr and Timperley (2008) conducted a study in which they addressed the relationship between the level of teachers' Pedagogical Content Knowledge and their ability to relate student assessment data to instructional practices. A part of their study included professional development and the use of formative assessments. Prior to the professional development, only one third of the teachers were able to interpret the student data and make instructional adjustments. After the professional development, two thirds of the teachers were able to interpret and apply student achievement data.

Heritage, Kim and Vedlinski (2009) address an important issue regarding teachers' ability to decide what to teach next in response to assessment information. Their study emphasises that teachers' knowledge of how mathematics learning develops is critical to formative assessment. One hundred and eighteen sixth grade mathematics teachers were required to use their mathematical content knowledge and pedagogical content knowledge in ways that reflect their classroom practice. The findings indicated that the majority of the teachers could draw inferences from what their students could or could not do, however, they were uncertain about their next instructional steps. Teachers have different areas of expertise or different exposures to teaching with regard to key principles, for example, some are better at planning the next instructional steps. The authors suggest that assessment feedback provided to the students should help them improve; therefore, teachers should have better conceptions and a deeper knowledge of how learning manifests. Teachers' ability to use formative evidence effectively is critical in knowing what to do with the evidence and what to teach next, as this knowledge has a powerful impact on student learning.

Holly and Walley (1989) also contribute to the importance of deepening knowledge of mathematics learning and its integration into formative assessment to inform instructional practices. Holly and Walley (1989, p. 293) share their interpretation of formative assessment and its relation to teacher professional development,

> An ongoing process that informs practice and contributes to the 'quality of provision' from multiple perspectives. Defining appropriate provisions, methods and

> scheduling for formative and summative assessments, where there are opportunities to integrate and discuss self-evaluations and the evaluation of others, is the scaffolding for professional, staff and curriculum development (p. 293)

Schneider and Randel (2010) reviewed several professional development programmes that foster formative classroom-based assessments and identified several characteristics of effective formative assessment professional development programmes worth mentioning:

- The teachers need "support from the school and district administrators" (p. 262).
- The learning goals for teachers participating in the professional development are not prescribed for all of the participating teachers. This is so that individual teachers can pursue their own inquiries during their participation in the programme (p. 263).
- A successful professional development program focuses on "increasing teachers' knowledge of how to teach a specific content and how students learn the subject matter (i.e. pedagogical content knowledge), rather than merely increasing teachers' knowledge of the subject matter (i.e. subject-matter knowledge)" (p. 263). These include "strategies and methods for designing sound assessments, collecting information of student learning, and communicating the learning expectation to the students" (p. 263).
- Teachers need sufficient time to "acquire knowledge of the principles of formative assessment" and to "integrate newly acquired strategies by practicing them in their daily instruction" (p. 264).
- Collaboration within professional learning communities should be developed to "share ideas, observe one another's classrooms, and incorporate reflections to improve their own practices" (p.265).
- The ideas touted in professional development programmes must be "in alignment with what already exists in the schools, such as their previous professional development programs, teachers' expertise, curricula, and state standards" (p. 265).

- Teachers need “hands-on experience of formative assessment practice rather than mere increased knowledge of principles” (p. 266).

Du Four, Du Four, Eaker and Many (2005) proposed a model of formative assessment systems that may provide evidence about student achievement on a regular base. This could be used by teachers to make better decisions about instruction. Du Four et al. (2005) argue for formal assessment systems of testing students on a regular basis to monitor student progress with the focus on the input of the teacher. They refer to these assessments as ‘common formative assessments’ or ‘interim assessments,’ and have conceptualised it as: “An assessment typically created collaboratively by a team of teachers responsible for the same grade level or course.” Common formative assessments are frequently administered throughout the year to identify:

> (1) Individual students who need additional time and support for learning;
>
> (2) The teaching strategies most effective in helping students acquire the intended knowledge and skills;
>
> (3) Programme concerns –areas in which students generally are having difficulty achieving the intended standard; and
>
> (4) Improvement goals for individual teachers and the team (2005, p. 214).

In the same vein, Bennett and Gitomer (2009) support regular assessment systems, but also address the issues of fundamental inequity in access to quality education and the increased use of assessment as a tool for educational accountability in the USA. They propose a large-scale assessment model that provides articulation between three components: systemic assessments (monitoring), formative assessment (classroom-based) and professional development. Bennett and Gitomers’ (2009) model to improve current practices suggests that assessment designs for external *monitoring* purposes should be aligned with cognitive-scientific principles. These principles should inform teaching and learning practices in the classroom on a continuous base (*formative*) to support instruction. However, most importantly, teachers and administrators should be provided with *professional support* and training to help them understand how to use the accountability and formative systems effectively (Bennett & Gitomer, 2009, p. 55).

Long, Dunne and Mokoena (2014) address similar issues regarding when standardised assessments were introduced in South Africa with the intention of improving the quality of education and addressing equity across the country. The authors propose a standardised assessment design that supports instruction, similar to that of Bennett and Gitomer (2009). This includes a monitoring component, a formative component, and a professional development component. The focus of their research is therefore to design an assessment instrument that integrates external monitoring into classroom-based practice by recognising the central role of the teacher in the assessment process. They contribute the lack of substantive progress to the fact that the assessment instrument does not address socio-economic disadvantage, or the opportunity to learn. Mathematics teachers, additionally, seem reluctant to commit to classroom assessment that is conducive to learning as systemic assessments have little relation to their instructional practices. Long et al. (2014) therefore envisage a nationwide assessment programme that involves "all the important role players, particularly teachers in the design of a continuous range of mathematics tests covering Grades R through to 12, accessible for regular use by teachers in their own classrooms" (Long et al., 2014, p. 174). The emphasis here is on the fact that mathematics teachers should be supplied with common, standardised formative assessments tasks and all teachers should receive the necessary training and support on how to use formative assessment effectively in their own classrooms for optimal learning experiences.

Although long term, common and regularly monitored formative assessments have a valuable role to play in aligning instruction to standards, adding to professional dialogue and for monitoring purposes, evidence on the impact thereof on student achievement is weak (Leahy & Wiliam, 2012; Jacob, Hill & Corey; 2017). However, studies on 'short cycle' formative assessments (Wiliam & Thompson, 2007) seem to have a profound impact on student achievement. Wiliam et al. (2004) describe how a group of 24 mathematics and science teachers were supported in developing their use of 'in-the-moment' formative assessment strategies. Through externally set and standardised assessments, it was found that gains in student achievement were substantial, equivalent to an increase in the rate of student learning of around 70% (Wiliam, Lee, Harrison & Black, 2004, p. 54).

Overall, these studies highlight the need for teachers to view formative assessment as a worthwhile process that yields valuable information about their students' learning. It is agreed upon that teachers require skills and knowledge for formative assessment to ultimately improve learning. Moreover, opportunities should be created for them to view formative assessment as an integral part of their profession (Heritage, 2007).

2.6.6 Challenges in implementing formative assessment

The literature that I have reviewed, and experiences working as a teacher in various contexts suggest that as teachers incorporate new assessment practices and approaches to mathematics teaching and learning, they are likely to face multiple and varied challenges (Adler 1998; Heritage, 2011; Suurtamm & Koch, 2014; Windschitl, 2002).

Windschitl (2002) argues that by exploring the dilemmas influencing classroom-based practice, this enables one to value the complexity of educational change, to better the understanding of the change process, and to suggest ways in which teachers can be supported as they further develop their practice. He categorised the assessment dilemmas into four main groups when teachers implement new ideas: 1) Conceptual; 2) Pedagogical; 3) Cultural; and 4) Political dilemmas (Windschitl, 2002).

In a recent large-scale study, Suurtamm and Koch (2014) adapted and elaborated on Windschitl's (2002) framework to analyse the existing assessment practices of mathematics teachers. They also aimed to address the dilemmas that teachers from different districts in Ontario, Canada face when implementing new assessment ideas. Several challenges were experienced by the mathematics teachers as they participated in an assessment reform initiative. The findings highlight the need for coherence in assessment messages communicated to the teachers and the important role of ongoing collaboration, dialogue and support in Communities of Practice (CoP). From their research, the authors categorise the emerging assessment dilemmas experienced by mathematics teachers as presented in Table 2.2 below.

Table 2.2: Definitions and examples of assessment dilemmas (Suurtamm & Koch, 2014, p. 267)

	Definition	Example
Conceptual dilemmas	Grappling with current thinking in assessment and mathematics teaching and learning; considering the 'why' of assessment.	Understanding the different purposes of assessment. Questioning why a test alone will not suffice in the assessment of mathematics.
Pedagogical dilemmas	Finding efficient ways to record observations. Grappling with the creation of assessment tasks, strategies, and tools; dealing with the 'how to' of assessment	Designing a meaningful rubric. Finding ways to increase students' involvement in the assessment process.
Cultural dilemmas	Focus on changes in classroom and school culture with regard to assessment practice. These often arise when new assessment practices threaten existing cultural practices.	Dealing with student expectations with respect to marks; Being influenced by colleagues' concerns about new approaches to assessment; Addressing parents' or administrators' concerns
Political dilemmas	Dealing with school, district, or provincial policies on classroom and large-scale assessment that may or may not align with teachers' assessment thinking and practices.	Being restricted to pre-made report card comments that do not align with teacher thinking; Aligning assessment levels used on rubrics with required report card percentage grades; Reconciling current thinking in classroom assessment with the requirements of test-based accountability assessments.

Suurtamm and Koch's (2014) framework also provided insights in this study into teachers' thinking and their actions as they experience barriers in implementing new ideas in classroom-based assessment.

According to Suurtamm and Koch (2014, p. 269), conceptual dilemmas in assessment arise as teachers attempt to understand the different purposes of assessment, its value in aligning instruction and assessment and what it means to understand mathematics. A number of studies have identified the lack of agreement on what constitutes formative assessment (Heritage, 2011). Although Popham (2013) argues that the formative assessment process is not particularly complicated, Heritage (2011) explains that teachers often misunderstand the formative assessment process as a test or assignment to be given frequently.

Moss and Brookhart (2009, p.13-15) support this argument in their study on teachers' misunderstanding of assessment for learning. Their findings indicate that most teachers misunderstand formative assessment as:

> A series of tests administer to audit students' learning; a program or method that they must adopt and add to what they already do; and a way of improving a program rather than a way to improve their day-to-day instructions.

Misconceptions can therefore constrain the effectiveness of formative assessment in improving students' learning. For example, Stobart (2008, p.144) explains that conceptual misunderstanding leads teachers into dilemmas in assessment for learning practices, and as a result, it becomes challenging to develop self-regulated learners.

Suurtamm and Koch's (2014, p.268) view that pedagogical dilemmas arise as teachers create and enact new assessment opportunities is supported by Parr and Timperley (2008). Their study involved 117 teachers and included the use of formative assessments in a professional development programme. Their findings indicated how teachers' pedagogical content knowledge impacted their ability to interpret and apply student assessment data to inform their instructional practices. Only one third of the teachers were able to interpret and apply the data they had collected from their students prior to their professional development. After their professional development, two thirds of the teachers were able to interpret and apply the data to change their instructional practices. However, they also found that 40% of the teachers were still unsure of how to create meaningful assessment tasks. Parr and Timperley's (2008) study also revealed that the level of pedagogical content knowledge of the teachers impacted their students' progress. The pre- and post-test data of the students indicated that the teachers' skills and ability to interpret and apply assessment data seemed to be consistent with changes in student gains.

Several studies report on the dilemmas that teachers face within the environment and culture of the school when they implement new assessment strategies. For example, Dorn (2010) suggests that a supportive and collaborative culture amongst teachers from the same school contributes to the effective use of formative assessment strategies. Dorn's findings indicate that teachers who work in isolation without the support of their fellow teachers or school administration experience difficulties in implementing effective formative assessment and a change in their instructional practices.

A study by Duncan and Noonan (2007) indicates that mathematics teachers' decision making in assessment is influenced by external factors such as large-scale assessments, classroom realities and internal policies. Their study involved 513 teachers in 66 high schools in a Western Canadian province participating in provincial large-scale assessments. The researchers created a profile of assessment strategies and grading practices in these schools and found that mathematics teachers demonstrated lower use in classroom assessment practices such as "observations, essay type-questions, projects, and student representations" (pp.11,14), using more traditional assessment forms such as "quizzes, multiple choice/ objective tests, and major exams" (pp. 12,14). Their findings suggested that factors such as the influence of subject, the limitation of class size and school size are affecting mathematics teachers' grading and classroom assessment practices. Duncan and Noonan (2007) suggest that more studies need to examine why teachers use specific classroom assessment techniques. In agreement with this, this study aims to go beyond the influence of external factors on the "nature of teacher decision making in assessment to an investigation of the constraints teachers are under (i.e. realities of classroom management), their internal beliefs and values, and their decision-making rationale for using assessment practices" (Duncan & Noonan, 2007, p. 17).

Individualised students' learning is compromised through summative and systemic tests as immediate feedback is not provided (Black & Wiliam, 2009; Shepard, 2005). However, for assessment to be integrated into instructional practices, teachers need to realise the importance of quality assessment and how to use the obtained information to guide instruction and remediate students' misconceptions. Moreover, individualised students' learning is compromised through summative and systemic tests as immediate feedback is not provided (Black & Wiliam, 2009; Shepard, 2005).

In addition, Crooks (1988) elaborates on the consequences to student learning if too much emphasis is placed on the grading function of evaluation:

> The undesirable effects include reduction of intrinsic motivation, debilitating evaluation anxiety, ability attributions for success and failure that undermine student effort, lowered self-efficacy for learning in the weaker students, reduced use and effectiveness of feedback to improve learning, and poorer social relationships among the students. (Crooks, 1988, p. 468)

For assessment to be integrated into instructional practices, teachers need to realise the importance of quality assessment and how to use the obtained information to guide instruction and remediate student misconceptions.

2.7 SUMMARY

In this chapter, a review was done of the literature on professional development and all related theories and models, as well as formative assessment and all related theories and models. Furthermore, through the literature discussed, the vital link between formative assessment and professional development was shown and strengthened.

The following chapter will focus on all aspects of the methodology employed, as well as the ethical considerations followed in this study.

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

This chapter describes and justifies the research methodology chosen to answer the following main research question:

What are the understandings and experiences of Grade 9 mathematics teachers of/with formative assessment as they engage in a professional development programme with purposefully structured formative assessment strategies and to what extent does this exposure contribute to their professional growth?

The following critical research questions also guided this study:

1. How do these teachers make sense of the use of formative assessment and its relation to mathematics teaching and learning?
2. What are the major influences and constraining factors on the quality of teachers' implementation of formative assessment practices?
3. How does the teachers' involvement in formative assessment strategies influence them in terms of personal and professional development, if at all?

The aim was to explore and develop an understanding of the participating teachers' perspectives on formative assessment practices; how these perspectives relate to mathematical learning; and how the teachers experienced professional development (CPD) and growth, if at all. I had to choose a suitable research approach that would provide answers to these questions and that would lead to the realisation of the aims and objectives of this study. I was specifically interested in how these teachers made sense of the activities and experiences in this formative assessment developmental programme (AETL project), and how their understanding of assessment *for* learning influenced their classroom practices.

Accordingly, in this chapter I first discuss the research approach used in this study, after which I elaborate on the research design and the nature of the phenomenological case study design, as well as the motivation for employing this particular methodology. In addition, I discuss the research instruments, data collection strategies, and analysis procedures. Issues such as validity and reliability, as well as the ethical considerations are also explained.

3.2 RESEARCH APPROACH

My examination of continuous professional development was informed by an *interpretivist* perspective (Angen, 2000; Cohen & Crabtree, 2006). This perspective acts as a lens to understand how teachers view professional development and how engaging in structured learning activities shapes their personal and professional growth. In general, researchers with an interpretivist perspective share the following beliefs about the nature of knowing and reality. The interpretivist framework according to Cohen and Crabtree (2006, p. 413) assumes that,

> Reality, as we know it, is constructed intersubjectively through the meanings and understandings developed socially and experientially. We cannot separate ourselves from what we know. The investigator and the object of investigation are linked in such a way that who we are and how we understand the world is a central part of how we understand ourselves, others and the world.

The interpretive perspective assumes that people interpret and seek to understand their experience of the world in which they live and work. Researchers often use the term *constructivism* interchangeably with the interpretivist paradigm. Creswell (2013) explains the following about constructivism,

> People develop subjective meanings of their experiences […] These meanings are varied and multiple leading the researcher to look for the complexity in views…Often these subjective meanings are negotiated socially and historically. In other words, they are not simply imprinted on individuals but are formed through interaction with others (hence social constructivism) and through historical and cultural norms that operate in individuals' lives (Creswell, 2013, pp. 24, 25).

In the context of this study, Creswell's perspective (2013) sheds light on the interaction between various individuals' developmental capacity, their engagement in professional learning communities, and the activities in which they engage.

Denzin and Lincoln (2007) describe qualitative research as a situated activity where researchers study 'things' in their natural settings, attempting to make sense of, or interpret, a phenomenon in terms of the meaning that people bring to it. Merriam

(2009, p. 6) explains that qualitative research primarily focuses on the meaning that people attribute to their experiences, suggesting the existence of “multiple realities in a given context.” The author emphasises that qualitative research produces a result that is an “interpretation by the researcher of others’ views filtered through his or own view” (Merriam, 2009, p. 6). This suggests that the researcher simultaneously engages in the situation and makes sense of these multiple interpretations through his/her own interpretation. In this study, the focus was on the participating teachers’ multiple perceptions, experiences and meanings related to formative assessment activities, how the researcher interprets these meanings and how these perceptions, experiences and meanings contributed to their professional development and possible changes in their assessment strategies. Accordingly, the qualitative research approach in this study was centred on an “insider perspective” while remaining sensitive to the context and frame of reference of the participants in this study (Mc Millan & Schumacher, 2010, p.16).

Several researchers contend that qualitative research yields the best data when studying human *learning* (Denzin & Lincoln, 2007; Merriam, 2009). This study particularly focused on interpreting and understanding the *learning* experiences of mathematics teachers when they are exposed to structured formative assessment practices. As a result, an interpretive philosophical stance for the research design was adopted.

3.3 RESEARCH DESIGN

The following section provides the background to and reasons for the selection of a phenomenological case study research design through qualitative methods.

Creswell (2007) explains that a phenomenological case study describes several individuals’ meaning of their lived experiences in terms of a concept or a phenomenon in a bounded system over a period of time. Consistent with this explanation, I explored the experiences of nine Grade 9 mathematics teachers with a specific set of CAPS-aligned formative assessment tasks (one bounded system), over a period of time (two years). Detailed, in-depth data involving multiple sources of information, such as meetings with the district officials, programme implementers (AETL Project), mathematics assessment specialists and teachers, enabled me to understand and describe the mathematics teachers' professional development (phenomenon) as they engaged in formative assessment tasks (Creswell, 2007; Merriam, 1998).

For this study, I was particularly interested in understanding the professional development phenomenon and experiences of mathematics teachers when they are involved in refining and implementing formative assessment strategies in a Professional Learning Community (PLC).

A case study design can also be used in research when a specific situation is studied either to see if it gives rise to a general theory or to see if an existing general theory develops out of the specific situation (Goddard & Melville, 2007). It was therefore appropriate in this research to use a case study design to explore and understand professional development in the context of mathematics teaching and learning. I designed and planned this study in order for it to lead to further possible inquiries. It was aimed to provide some detailed descriptions, which in general may contribute to knowledge regarding formative assessment programmes as a professional development tool.

I began this case study with an extensive literature review and document analysis on professional development and formative assessment, focusing on mathematics teachers' professional development. This was done to support and provide an overview of various thoughts and strategies to improve the continuous professional development of teachers. I also reviewed the literature on effective formative assessment strategies employed to improve classroom-based mathematics teaching and learning.

The development of the formative assessment activities and the input given by the teachers enabled me to conduct an exploratory and descriptive case study, built on the experiences with and perceptions of mathematics teachers in terms of formative assessment practices. According to Merriam and Tisdell (2015), qualitative research is primarily an inductive process; the researcher collects data to build concepts, hypotheses, or theories rather than deductively testing a hypothesis. The researcher inductively builds towards themes, concepts, or theory from the observations and understandings gathered from being in the field.

Figure 3.1 provides a schematic representation of the framework for the research design adopted. It also highlights the inductive process followed in this qualitative study.

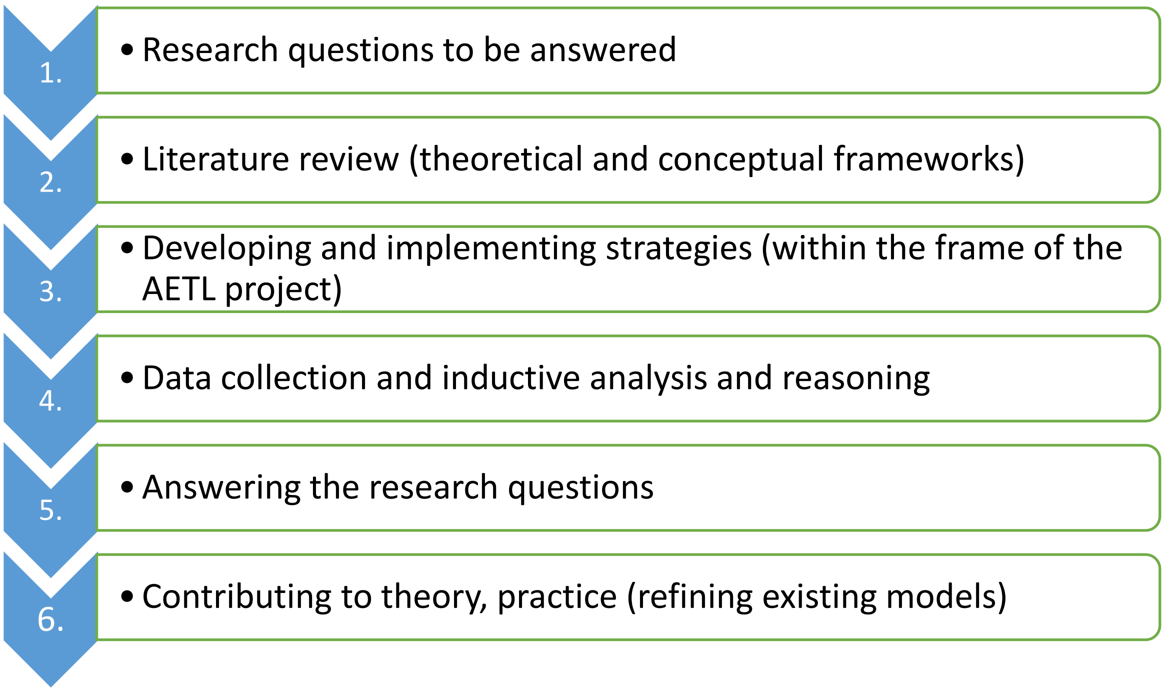

Figure 3.1: An overview of the research design of the study

3.4 DATA COLLECTION

The research questions and the case study design guided the choice of data collection procedures in this qualitative study. The essential processes in this study included an investigation and documentation by the researcher as the primary instrument of collecting and analysing the unique experiences and perspectives of the participant teachers, who worked in a variety of contexts. Merriam and Tisdell (2015, p. 2) add in this regard that,

> Qualitative inquiry, which focuses on the meaning in context, requires a data collection instrument that is sensitive to underlying meaning when gathering and interpreting data. Humans are best suited for this task, especially because interviewing, observing, and analysing are activities central to qualitative research.

The combination of data collection methods, such as archives (documents), interviews, and observations, is typical of a case study design (Yin, 2003). I therefore chose a combination of observations during focus group meetings, semi-structured interviews, and document analysis, with the main emphasis on individual interviews with the selected participant teachers. This methodology gives the teachers a voice and a vehicle for shaping their own professional learning experiences to improve their understanding of formative assessment practices and to implement them with greater consistency in their classrooms (Sadler, 1989; Wiliam, 2014).

In order to identify the participants for the observations during meetings and interviews, I first needed to explore different sampling procedures (Merriam & Tisdell (2015).

3.4.1 Sampling procedures

I chose *purposeful sampling* to intentionally identify a range of teachers and to obtain an in-depth understanding and detailed knowledge of their experiences with the phenomena of professional development and formative assessment. Creswell (2007) defines purposeful sampling as a method of intentionally selecting participants based on their experience with the topic under study. The "inquirer selects individuals and sites for study because they can purposefully inform an understanding of the research problem and central phenomenon in the study" (Creswell, 2007, p.125). Purposeful sampling is based on the assumption that the researcher wants to obtain an in-depth understanding by investigating "information-rich cases" from which one can learn a lot about central issues concerning the purpose of the inquiry (Patton, 2015, p. 53).

3.4.1.1 Selecting the participating schools

The selection of the participating schools was guided by the purpose of the AETL project. As noted earlier (see Section 1.4), my main objective in the project was to use the focus on assessment to include the multiple dimensions required to understand concepts in mathematics and in this way, contribute to the professional development of teachers.

The AETL project was launched in November 2014 in the Tshwane South District in Pretoria. The project involved a two-year involvement in developing assessment enhanced teaching and learning skills for mathematics teachers from at least ten selected public secondary schools from the same district. The number of schools was based on the considerations of time and feasibility. Researchers, mathematics specialists, and evaluation programme developers from the University of Pretoria were responsible for establishing the criteria for school selection. The initial site selection in this study was therefore pre-determined by the location of the project within a distance of 20km from the University of Pretoria.

Although the selected schools were in the same district, they varied in socio-economical, historical and cultural contexts and thus provided this qualitative study with multiple and shared understandings of experiences with professional development programmes. Patton (2015) emphasises the value in this variation in qualitative research by stating,

> Any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central shared dimensions of a setting or phenomenon (Patton, 2015, p. 283).

It is also important to mention that the South African educational system differentiates between schools that are not equally resourced because of financial implications. Through the National Norms and Standards for School Funding policy (NNSS), as stipulated in the South African Schools Act, 84 (DoE, 1996), schools are divided into different quintiles according to the socio-economic status of the school. Quintile 1, 2 and 3 schools, for example, are defined as no fees schools, and quintile 4-5 schools are defined as fee-paying schools (DoE, 1998). I purposefully selected different quintile schools with varied socio-economic, historical and cultural contexts to provide this qualitative study with multiple and shared understandings of experiences related to professional development programmes and assessment strategies (see Table 3.1).

3.4.1.2 Selecting the participating teachers

Using purposeful sampling, I selected participants to represent schools from different socio-economic contexts. The main criteria for the participants in this study were that they had to be Grade 9 in-service mathematics teachers in the Tshwane (Pretoria) district. The additional criteria were based on time, availability and access, and therefore also fitting in the category of convenience sampling (Merriam & Tisdell, 2015).

District officials of Tshwane South and mathematics subject specialists were invited to attend the first training session, together with teachers from the ten selected schools in the area. The AETL project was introduced and existing knowledge, practises, beliefs and attitudes regarding assessment and the learning objectives of mathematics in a local context were discussed during the first session. During the second meeting, detailed discussions were held on formative assessment strategies and how these link to Mathematical Learning Theory. The curriculum ([2]CAPS) aligned formative assessment tasks were then introduced to the participants. Worksheets 1 and 2 (see Table 3.3) were given to the teachers and general assessment principles were discussed.

A *cluster approach* in which small groups of teachers worked together collaboratively was then adopted for the development and refinement of the formative assessment tasks during the second session. The cluster approach provided a professional learning community, which enabled the participating teachers to establish an environment conducive to their learning experiences.

Both the project coordinators of the AETL project and the assessment specialists acted as key informants in providing me with information for the selection of participants. Based on the observations during the information sessions and recommendations of the project coordinators, I identified ten mathematics teachers as likely to be “knowledgeable and informative” about professional development and formative assessment experiences (McMillan & Schumacher, 2006, p. 319).

With the participants’ consent, I arranged meetings with their respective principals and Heads of Department responsible for mathematics development programmes. During the sampling of a specific group of teachers, I also had to consider issues of access to the school sites and participating teachers. I first had to obtain written permission from the Gauteng Department of Education and the respective principals to conduct the research (see Appendices E and G).

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[2] The South African Curriculum Assessment Policy Statement (CAPS).

McMillan and Schumacher (2006) additionally describe *network sampling* as a type of purposeful sampling strategy. Network sampling is “a strategy in which each successive participant or group is named by a preceding group or individual” (2006, p. 321). I also employed network sampling as a strategy in selecting some of the participating teachers, for example, the Heads of Department of Mathematics in two of the schools identified some of the teachers in this study. These teachers, in turn, informed some of their colleagues about the AETL project, i.e. they became participants in the programme by word of mouth.

The selected teachers were informed about the aim of the study, as well as the protocols and procedures, which included informed consent, confidentiality, and data collection procedures. Arrangements with the teachers were made to refine and implement the set of worksheets over a period of ten months. Focus group discussions, informal meetings, and interviews were scheduled; keeping time and cost limitations in mind. If, at times, it proved logistically impossible to interview the participants, I overcame this impediment by utilising voice recordings, telephonic interviews, and e-mail correspondence.

I made use of a template (Table 3.1) to obtain important background information on the participants. This was done to assist them to understand the context of the study, and to determine how well it aligned with their own contexts.

Table 3.1: Template used for the participating Grade 9 mathematics teachers

School	Community & * Quintile (Q) & Language of Instruction	Name of Teacher	Sex	Subjects & Grade(s) Taught	Post Level (PL)	Teaching experience (years)
A	Township Q4 English	*Mr L*	M	Mathematics (9,12)	2	10
		Mr M	M	Mathematics (9)	4	34
		Mr N	M	Mathematics (9;10)	1	6
		Mr O	M	Mathematics (8; 9)	1	2

School	Community & * Quintile (Q) & Language of Instruction	Name of Teacher	Sex	Subjects & Grade(s) Taught	Post Level (PL)	Teaching experience (years)
B	Central city Q5 English	*Mrs B*	F	Mathematics (9) Mathematics Literacy (9)	1	7
C	Suburb *Q3 English	*Mr C*	M	Mathematics (8-12) Economics (8-12)	1	16
D	Suburb *Q5 Afrikaans	*Mrs D*	F	Mathematics (8,9)	1	4
		Mrs F	F	Mathematics (9-12)	1	28
E	Township *Q2 English	*Mr E*	M	Mathematics (9-12)	1	10

***** Quintile (Q) refers to the division of schools according to the National Norms and Standards for School Funding policy (NNSS) as described in Section 3.4.1.

3.4.2 The role of the researcher

Although qualitative studies accept researcher subjectivity as something that cannot be eliminated, it is important for researchers to acknowledge their own influences. In qualitative research, the role of the researcher as the 'primary research instrument' is critical in the data gathering process (Maree, et al. 2010; Leedy & Ormrod, 2005; Merriam & Tisdell, 2015). In this study, the researcher served as the primary instrument for data collection and analysis since the responses of the participants were analysed and interpreted by the researcher herself. Merriam and Tisdell (2015) emphasise that since *understanding* is the focus of a qualitative study, the researcher as the primary instrument of data collection and analysis is able to be immediately responsive and adaptive. Other advantages include that the researcher can:

- Expand his or her understanding through non-verbal as well as verbal communication,
- Process information (data) immediately,
- Clarify and summarise material,
- Check with respondents for accuracy of interpretation and
- Explore unusual or unanticipated responses (Merriam & Tisdell, 2015, p. 16).

In order to prevent subjectivity and bias, and to establish research credibility as the primary instrument of research, I chose to use the strategy of *reflexivity*. McMillan and Schumacher (2006) describe reflexivity as the process of examining one's personal and theoretical commitments in the light of how they allow the one to relate to participants. These should also be examined for the ability to suggest personal self-awareness, or "let the participants speak for themselves" (p. 327) and be accurate in seeking the truth. My purpose was to gather the best accounts of their personal experiences, stories, narratives, and occurrences to provide the most complete description possible of the phenomenon of professional development and formative assessment practices.

3.4.3 Data collection instruments/strategies

Based on the role of the researcher as the primary instrument in collecting data, I employed a combination of particular data collection strategies in this study. Qualitative researchers, such as Creswell (2007), Yin (2011, 2016) and Merriam (2015) recommend multiple data collection strategies because it enhances the trustworthiness of the study through the process of triangulation. For the purpose of this study, I chose an open-ended questionnaire, focus group discussions, and semi-structured interviews to gather data. In addition, I used observational fieldwork and written documents, reflective notes, digital voice recordings, and electronic documents (e.g. e-mails) as research strategies throughout the study to collect empirical data.

The data collection process in this study consisted of three primary stages of data collection. During Stage 1, I collected data using an open-ended questionnaire, also known as a qualitative survey (Jansen, 2010). During Stage 2, data were collected from three focus group discussions and in Stage 3, I conducted semi-structured interviews.

3.4.3.1 Stage 1: Open-ended questionnaire

Subsequent to the purposeful sampling of the participants, and the two initial meetings, all nine participants in the study were asked to complete a set of open-ended questions to establish a variety of meanings. Jansen (2010, p. 1) supports the qualitative type of survey and explains,

> The qualitative survey does not aim at establishing frequencies, means or other parameters but at determining the *diversity* of some topic of interest within a given population. This type of survey does not count the number of people with the same characteristic (value of variable) but it establishes the meaningful variation (relevant dimensions and values) within that population (Jansen, 2010, p. 1).

The open-ended questionnaire was used as a data collection instrument to define, in a pre-structured way, some of the main topics, dimensions and categories beforehand. The questionnaire also guided the semi-structured protocol for questioning or observation and allowed me to see which of the predefined characteristics existed empirically in the population under study (Jansen, 2010, p. 9). I used this data collection tool to collect the diversity of teachers' initial responses related to their prior experiences of professional development and their current formative assessment practices before they were interviewed. It must be noted that this survey was not used to determine any quantitative measures, but rather to add value to the diversity of the teachers' understanding and experiences of professional development and formative assessment. Using open-ended questions gave the respondents an opportunity to provide their thoughts using their own words. It should also be noted that the teachers completed this questionnaire in their own time and individually without being interviewed by the researcher.

Table 3.2 gives a summary of the questions presented in the survey. The questions were divided into five major categories to support the research questions and objectives of this study:

- The background of the teachers;

- Teaching and learning mathematics;
- Assessment, student achievement, progress, and reporting;
- Curriculum implementation and manageability; and
- Professional development.

Table 3.2: A Summary of the qualitative set of questions as a data collection instrument

CATEGORY	OPEN-ENDED QUESTIONS
Background	1. How many years have you been teaching? (Include both part-time and full-time). 2. How many years have you been teaching mathematics? 3. What is your position (designation) in your school? 4. Are you teaching other subjects? (Please specify).
Teaching and Learning	1. Please indicate your degree of confidence in teaching mathematics. High, medium, low, other. 2. If you feel confident, which of the following have contributed to your confidence in using the mathematics achievement objectives (please tick the appropriate boxes), e.g. my knowledge of mathematics, teaching experience, professional development in mathematics, my school has translated the achievement objectives into specific learning outcomes, Other (please state) 3. Please tick which of the essential skills you emphasise in your teaching of mathematics. Put two ticks beside those which you emphasise the most. 4. How do you assess student learning in mathematics? E.g. Assessment Resource Banks, Previous question papers - e.g. ANAs, Investigations, Observation, Peer assessment Practical tasks; Pre-tests/post-tests; Projects Self-assessment. You can choose from this list or other (please specify):
Assessment, Student achievement, Progress, and Reporting	1. What has influenced your formative assessment practices in the last few years? 2. How much has your teaching from the curriculum statements resulted in improved achievement for students? 3. How has each of the following processes influenced decisions about what and how you teach? School/self-review, external reviews/evaluations (from outside the school, e.g. ANAs). Please explain how school/self-review and/or external evaluation have had an impact on your teaching or assessment practices.
Curriculum implementation and manageability	1. How easy has it been for you to use the curriculum (CAPS) that you teach from? 2. To what extent is the curriculum flexible enough to allow you to plan for and meet individual students' needs and interests? 3. From your experience in implementing the curriculum, how long does it take you to feel comfortable with the planning, teaching, and assessing aspects of a new national curriculum statement? 4. How do you rate your own content knowledge for the mathematics curriculum statements that you teach from?

CATEGORY	OPEN-ENDED QUESTIONS
	5. Teachers have reported that new curriculum requirements (such as in the National Education Guidelines) have had varying impacts on their work. Please explain its impact on the following: a) Administration (keeping records): b) External review (e.g. IQMS): c) Assessment/reporting: d) Written planning: e) Other
Professional Development	1. In what ways have professional development activities helped/not helped you in your teaching of mathematics? 2. What sources of professional development have been very useful in your teaching of mathematics? 3. In what aspects of mathematics would you most like to receive professional development to support your teaching of mathematics? 4. What are the three major challenges you have faced in implementing the mathematics curriculum? (Please give some examples, including ways these have been addressed). 5. What teaching approaches/practices would you say have been very effective in improving your students' learning in mathematics? 6. What teaching approaches/ practices would you say have been obstacles in your students' learning of mathematics?

The data gathered from this open-ended survey allowed me to gain multiple perspectives of the context, challenges and previous experiences and understandings of the teachers related to their professional development and formative assessment strategies. The information gathered was also used to ensure that the interview questions were appropriate and applicable to the research (Creswell, 2007).

3.4.3.2 Stage 2: Focus group discussions

It is generally agreed that a focus group discussion is a data collection strategy that is focused on a particular topic. The discussions between the participants create group dynamics that can allow a wide range of responses to generate data (Maree et al., 2016).

O’Reilly and Parker (2012, p. 3) comment that focus group discussions provide “breadth” in qualitative data, whereas the interviews provide “depth”. The following additional reasons for using focus group discussions in this study are:

- The topic is focused due to the previously shared experiences related to formative assessment and professional development by the participants (Yin, 2016, p. 148).
- The focus is on formative assessment strategies. The need for interactive discussions on this particular issue was encouraged (Creswell, 2007).
- The participants were selected based on particular characteristics that they had in common (Yin, 2016). In this group, the teachers were from the same school and taught Grade 9 mathematics.
- The discussions provided a “shared understanding” from several individuals (Creswell, 2012, p. 218).
- The participants were able to build on each other’s ideas and comments to provide this study with an in-depth view of the group dynamics of this particular PLC (Maree et al., 2016, p. 96).

There are, however, certain limitations with the use of focus groups, such as the samples being too small to be representative; and information that may “be biased by more outspoken individuals, who may dominate discussions, and in the process make it difficult to assess individual thinking” (Maree et al., 2016, p. 96). The researcher and AETL project coordinator accordingly addressed these issues by encouraging all the participants to express their feelings honestly and fully, while maintaining focus.

Focus group participants

Through purposeful and convenience sampling, the AETL project coordinator and the researcher selected one school (School A), representative of the total sample population in this study, to conduct four focus group discussion meetings. As mentioned earlier, our main objective in the Assessment Enhanced Teaching and Learning Project (AETL) was to use the focus on assessment to include the multiple dimensions required to understand concepts in mathematics and in this way, contribute to the professional development of teachers. The selected focus group with four participating teachers in the same school additionally offered me an opportunity to explore the group dynamics in a PLC where two of the participants were in leadership positions.

School A is a township school on the outskirts of Pretoria. It is a secondary school with approximately 1 400 learners from Grades 8 to 12 at the time of this study. The Grade 9 teachers who participated in this study were the principal, Mr M, who taught one Grade 9 class; the Head of Department (HOD) for mathematics, Mr L; and two post-level 1 teachers, Mr N, and Mr O. It is not usual in such a large school for the principal to teach, however, Mr M insisted that he should take a Grade 9 class because of the stresses around the ANAs at Grade 9 level. Mr L, the HOD, additionally taught Grade 12 classes to prepare those learners for the final exit examination, the national senior certificate. He performed the function of coordinator for the AETL project at the school. Outside of his school responsibilities, Mr L was the chairperson of a regional branch of the Association for Mathematics Education of South Africa (AMESA) and was in the process of furthering his studies. He was also a teacher moderator for district cluster meetings. Mr N had taught Grade 9 and 10 Mathematics for six years at School A. At the time of this study, he was registered for a Master’s degree at a nearby university. Mr O, the youngest participant, was new to the staff and was responsible for teaching Grade 8 and 9 mathematics for his second year.

Table 3.3 gives an overview of the four teachers from School A, who participated in the focus group meetings. It additionally presents some characteristics and the instruments used to collect the data.

Table 3.3: Summary of the *focus group* teachers from School A (Stage 2)

Name of Teacher	Sex	Subjects & Grade(s) Taught	Teaching experience (Years)	Post level	**Data collection codes** * FG * QS * SI
Mr L	M	Mathematics (**9**,12)	10	2	FG,Qs
Mr M	M	Mathematics (**9**)	34	4	FG, Qs, SI
Mr N	M	Mathematics (**9**;10)	6	1	FG,Qs, SI
Mr O	M	Mathematics (8; **9**)	2	1	FG,Qs

*FG = Focus group discussions; Qs = Qualitative open-ended questions;
*SI = Semi-structured interviews

The focus group discussions were guided by reflective activities and aimed to support teachers in developing an understanding of mathematics teaching and learning from a socio-constructivist and learner-centred perspective.

The purpose of the first meeting was to understand the supporting or constraining factors as experienced by the teachers, and to understand how the various role players, principal, HOD and teachers experienced the pressures, challenges and joys of mathematics teaching. An expectation was that the teachers would have engaged, to some extent, with the formative assessment worksheets. These worksheets were given to the teachers prior to the focus group meetings.

The second meeting comprised a reflection on the implementation of the third term formative assessment worksheets (Appendix A), and a discussion of the NTCM's

“*Principles to Action*”, as described in Silver (2015), which addresses the concerns voiced by teachers in the first meeting. The *“Principles to Actions”* require teachers to:

- Establish mathematics goals to focus learning;
- Implement tasks that promote reasoning and problem solving;
- Use and connect mathematical representations;
- Facilitate meaningful mathematical discourse;
- Pose purposeful questions;
- Build procedural fluency from conceptual understanding;
- Support productive struggle in learning mathematics; and
- Elicit and use evidence of student thinking (Silver, 2015, p. 33).

The third focus group meeting comprised reflection on the previous meeting, confirmation on the part of the researcher of findings, and a discussion of the article “Principles to Action” for effective classroom teaching (Silver 2015, p. 33). The AETL project coordinator, the researcher, and the teachers then had a general discussion on the big ideas of mathematics, and the perceptions held by teachers of the teaching and learning of mathematics.

I scheduled an additional meeting to reflect on the implementation of the formative assessment worksheets. The discussion was structured around the five dimensions of understanding mathematics from a teacher’s perspective according to Usiskin (2015, p. 2),

- The skill algorithm dimension;
- The property-proof dimension;
- The use-application (modelling) dimension;
- The representation-metaphor dimension; and
- The history-culture dimension.

Teachers were asked to reflect on their own understanding and experiences when engaged in formative assessment strategies and mathematics learning principles.

All of the focus group meetings were digitally recorded, transcribed, and revised by the researcher and the AETL project coordinator. The revised materials were stored on a secured computer and back-ups were made. From the data collected in the focus groups I identified certain categories and sub-categories as generated by the participants. These categories were then analysed, refined and coded to guide the questions in the semi-structured interviews.

Subsequent to the focus group discussions, I refined the guiding questions for the interviews to optimise the teachers' conceptual understanding and experiences of the phenomena relevant to this study.

3.4.3.3 Stage 3: Semi-structured interviews

The primary source of in-depth data in this study came from the responses of seven mathematics teachers. This was gathered in face-to-face semi-structured interviews that were designed to elicit their lived experiences. I chose individual interviews as a method of data gathering since it yielded a great deal of useful information related to people's beliefs about and perspectives of the professional development process, their feelings, present and past behaviours, and conscious reasons for their actions or feelings towards the development and implementation of formative assessment strategies.

Before I could begin with these interviews, I tried to build a relationship of trust between the interviewees and myself by establishing a procedure of explaining the key features of the research project and outlining the broad issues that I intended to address in the interview, as well as the amount of time needed to complete the interview. The interviewees were also asked to sign a *consent form* to participate in the study before I started the interview process (see Appendix H). Ethical considerations are discussed further in detail in Section 3.6.

The interviews were designed around a list of *open-ended* questions, the interview protocol (see Appendix D) that explored different components of the professional development experience, such as background information, beliefs concerning teaching and learning mathematics, and how the teachers made sense of formative assessment activities to inform their classroom practice. The open-ended nature of the semi-structured interviews acknowledged that each individual defines his or her experience in a unique way, which allowed the interviewees to answer from their own frame of reference and describe things in their own words (Merriam, 1998). Semi-structured interviews have the characteristics of both structured and unstructured interviews, i.e. the use of both closed and open-ended questions. In order to be consistent, the interviewer had a set of pre-planned core questions, which were the same for each of the participants (structured). As the interview progressed, the respondents were given the opportunity to provide additional information, i.e. unstructured interview questions (Yin, 2016). In other words, I asked certain open questions, followed by further probing and clarification. I was also attentive to the responses of the participants so as to identify emerging data directly related to the research, as proposed by Maree et al. (2016).

In line with the explorative and interpretive nature of the study, the goal of the interviews was to see the research topics, namely professional development and formative assessment, from the perspective of the interviewees, and to understand why and how they had come to have this particular perspective. Yin (2016) confirms that the purpose of qualitative interviews is to allow the researcher to engage the other person's perspective. To meet this goal, I redesigned some of the questions during the research process to reflect and establish a better understanding of the experiences of the individual participants. For this reason, I selected semi-structured interviews that followed a *conversational mode,* meaning that the interviews led to a "social relationship of sorts, with the quality of the relationship individualised by every participant" (Yin, 2016, p. 142).

According to Yin (2016), qualitative interviewing requires intense listening, "A systematic effort to really hear and understand what people tell you. The listening is to hear the meaning of what is being said" (Yin, 2016, p. 142). The interviews with the teachers were therefore all voice recorded, and I could concentrate fully on asking questions and following up on how the interviewees responded during the interviews to interpret what was being said. An individual who was completely independent of the study transcribed the interviews and I analysed these shortly after the interviews were conducted.

3.4.3.4 Observational fieldwork

According to McMillan and Schumacher (2006, p. 207), the *observational method* relies on a researcher "seeing and hearing" things and recording these observations rather than relying on subjects' self-reported responses to questions or statements. Observational fieldwork can be regarded as a major strategy in collecting data in qualitative research as it offers a first-hand account of the situation or phenomenon under study, especially when behaviour is observed and interpreted (Merriam & Tisdell, 2015). I used the focus group discussions and reflection meetings with the participants and based these observations on predetermined categories of behaviour that I would like to observe (structured observation). The theoretical framework and research aims and objectives adopted in this study informed certain predetermined categories. I particularly focused on what the participants' perceptions were, how they negotiated their needs, how they defined instructional improvement in mathematics, as well as on how they reached their educational objectives. I also focused on the extent to which they managed to balance their teaching and learning needs, challenges they experienced, and their instructional goals. I recorded these observations as accurately as possible by making use of field notes and digital voice recordings to ensure that both verbal and non-verbal behaviour could be recorded and studied immediately after the discussions were held (McMillan & Schumacher, 2006). It is important to mention that I did not observe any lessons in this study. The essence of the study and of my analysis was not to evaluate teachers' assessment practices, but rather to gain an understanding of their experience of a particular professional development intervention and of the challenges that they experienced in their assessment practice. I also decided not to do classroom observations, considering the 'Hawthorne effect' where respondents change their behaviour because they are being studied (McMillan & Schumacher, 2006).

I also compiled *field notes* by observing the teachers' behaviour through informal interviews and focus group conversations as we reflected on the formative assessment tasks. The field notes that I made were short descriptions of basic actions observed, objective with no self-reflective notes (anecdotal records), and more detailed, continuous accounts of what was observed in context (running records) in accordance with the suggestions of Nieuwenhuis (in Maree et al., 2010).

These field notes were analysed immediately after the observations had been made during the empirical study to prevent forgetting important details. In addition to taking field notes during observations, I audiotaped informal discussions during meetings.

It was important to experiment with various data recording strategies (field notes, audiotapes, and reflective journals) before the final interviews could commence. Therefore, I decided to use a small digital voice recorder, which enabled me to capture verbal data during the reflection meetings and interviews. The field notes and voice recorder allowed me to limit the shortcomings in observations, which include the researcher unconsciously influencing what people say and do within their presence (Maree et al., 2010).

As a non-participating observer during some stages in the focus group meetings where the teachers and the project coordinator discussed the refinement of the formative assessment tasks and their perspectives on mathematics teaching and learning, I could focus more on the participants' perspectives and interactions without getting involved in the discussions. Yin (2003), McMillan and Schumacher (2006), and Creswell (2007) emphasise the importance of maintaining one's distance in direct observations, as it is the least obstructive form of observation. Although I needed to become part of the situation, as an observer, I maintained my distance during activities to enable me to focus on patterns of behaviour to understand the assumptions, values, and beliefs of the participants, and to make sense of the social dynamics of the professional development component of the AETL project.

Another advantage of using observation as a data collecting method in this qualitative study was its flexibility, "The researcher can take advantage of unforeseen data sources as they surface" (Leedy & Ormrod, 2005, p. 145). At this point, it is important to mention that these observations were not the primary data collection strategy in the study. However, the unanticipated data that I collected during the observational fieldwork, for example, the variances in teacher beliefs and attitudes about the teaching and learning of mathematics, added to a better understanding of the experiences of the teachers while conceptualising formative assessment and professional development.

Used in conjunction with focus group discussions, semi-structured interviews and document analysis, these observations offered me an opportunity to triangulate the data to better understand a variety of perspectives presented during the interviews, and to gain a "holistic interpretation of the phenomenon being investigated" (Merriam, 1998, p. 11). It also provided me with an opportunity to enhance the validity of this study. Appropriate sensitivity towards the participants was enacted in making observational field notes and voice recordings to the extent that the teachers felt comfortable with the process.

3.4.3.5 Documents

Merriam (2002, p. 13) advocates that the strength of documents as a data source lies within the fact that "they already exist in the situation", as they do not intrude upon or alter the setting in ways that the presence of the investigator might. I chose to collect and analyse the following documents prior to the documents obtained from the interviews and field notes from the observations:

- Formative assessment activities (see Table 3.3) compiled by researchers and mathematicians involved in the AETL project (Appendix A). I analysed the adapted worksheets of the teachers.
- Public documents, e.g. newspapers, relevant articles in the media.
- Official government documents, e.g. policies, curriculum documents, (CAPS).
- Documents retrieved from an online environment relevant to the research study (Merriam & Tisdell, 2015), e.g. journal articles, books, conference proceedings, among others.

The choice of documents was primarily guided by the Assessment Enhanced Teaching and Learning (AETL) project and the research questions of this study. As previously discussed (see Chapter 1, Section 1.4), the AETL project is informed by the "Cognitively Based Assessment *of*, *for* and *as* Learning" (CBAL) model of Bennett and Gitomer (2009). The focus in this study was on the formative assessment component (assessment *for* learning) and professional development (assessment *as* learning) where sets of assessment activities for Grade 9 learners were designed to provide teachers with intermittent markers at strategic points in curriculum implementation.

These sets of formative assessment strategies (structured assessment tasks) were aligned with the Grade 9 mathematics curriculum plan, as set out in the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2012, p. 9), and based on the principles underlying the understanding of mathematics (Usiskin, 2015). Mathematics in the senior phase (Grades 7-9), as described in the CAPS document (DBE, 2012, p. 9), covers five main '*Content Areas*':

- Numbers, Operations and Relationships;
- Patterns, Functions and Algebra;
- Space and Shape (Geometry);
- Measurement; and
- Data Handling.

Table 3.4 gives a summary of the worksheets (formative assessment strategies) and memoranda that the teachers received. The worksheets are aligned according to the curriculum plan as set out in CAPS (DBE, 2012, p. 9), but teachers were encouraged to refine and implement it at their own pace and as they saw fit.

Table 3.4 Summary of the formative assessment worksheets (strategies) of the AETL project according to the curriculum plan.

TERM 1	TERM 2	TERM 3
Curriculum Topic: Patterns, Functions and Algebra	**Curriculum Topic: Space and Shape Geometry**	**Curriculum: Patterns, Functions and Algebra**
Worksheet 1: Numeric and Geometric Patterns. Memo: Worksheet 1 **Worksheet 2:** Functions and relationships Memo: Worksheet 2 **Worksheet 3:** Algebraic Expressions Memo: Worksheet 3	**Worksheet 4:** Geometry of straight lines Memo: Worksheet 4 **Worksheet 5:** Theorem of Pythagoras Memo: Worksheet 5	**Worksheet 6:** Algebraic equations Memo: Worksheet 6 **Worksheet 7:** Functions Memo: Worksheet 7

The assessment tasks were designed to test the critical aspects of a topic area, e.g. *Functions* (see Appendix A), drawing on what Usiskin (2015) describes as the dimensions of understanding that are required to master any particular mathematics topic. These dimensions of understanding mathematics include:

- Skills - algorithm;
- Property - proof;
- Use - application; and
- The representation - metaphor dimensions.

In addition to including items that require these dimensions, we also included problem-solving questions of the type that can be found in the South African Mathematics Olympiad (Engelbrecht & Mwambakana, 2016). The worksheets (tasks) were discussed per topic and the teachers were given detailed explanations of how it linked to assessment *for* learning (Bennett, 2011) and understanding mathematics (Usiskin, 2015; Long, Dunne & De Kock, 2014). Detailed memoranda were provided, and the teachers were asked to refine and engage in the activities during these meetings. The worksheets were also used as a reflective activity in which the participants could reflect upon their own assessment knowledge and skills. Each worksheet, based on a specific topic in the curriculum, was accompanied with feedback templates for the teachers to reflect on their assessment strategies (see Appendix B).

The teachers had to reflect on the following questions based on a particular topic, for example, *algebraic equations*:

- What do you think are the key concepts (principles) that each question addresses?
- From the students' responses, what do you think they understand about Algebraic expressions? What do they not understand?
- What feedback would you give to the student/s?
- Based on your responses to Questions 2 and 3, how would you adapt or change your instruction of this topic?
- In which way can this specific worksheet support you in addressing individual learner's needs? I.e. what actions did you take to address these needs?

All of the data that I collected were stored manually in separate files, as well as electronically on multiple hard drives. The focus group discussions and interview transcriptions were individually labelled with assigned codes and field notes, and other documents collected were grouped and filed.

3.5 DATA ANALYSIS

McMillan and Schumacher, (2006, p. 326) describe qualitative data analysis as primarily an inductive process of organising data into *categories* and identifying *patterns* (i.e., relationships) among the categories, seeking plausible explanations.

By analysing the data obtained inductively, I was able to compare, contrast and also identify similarities between the responses of the teachers. I therefore examined the qualitative data by working inductively from particulars (raw data) to more general perspectives, which are called themes or categories (Creswell, 2007).

I also employed *interim analysis* – a process that occurs during data collection to keep track of changes in data collection strategies and evolving ideas. This is done by writing observational field notes and comments on the interview guides to reflect on and write descriptive summaries of the interviews directly after the field visits (McMillan & Schumacher, 2006). Merriam and Tisdell (2015) refer to this strategy as *simultaneous data collection and analysis* as it occurs both in and out of field. In other words, I was analysing data while I was in the process of collecting data, as well as between data collection activities (Merriam & Tisdell, 2015).

The analysis of qualitative data in this study is based on an interpretive philosophy that is aimed at examining meaningful and symbolic content of the acquired data. For this study, I tried to establish how the participants made meaning of an assessment enriched programme by analysing their perceptions, attitudes, understanding, knowledge, values, feelings and experiences in an attempt to approximate their construction of the professional development phenomenon (MacMillan & Schumacher, 2006; Denzin & Lincoln, 1994).

I obtained multiple analysed sources of information such as:

- *Field notes,* which were kept of every observation and all the information collected during the study, the participants' comments during and after the interviews, activities, interactions, conversations, and personal preliminary interpretations (*interim analysis).*
- I listened to the *recordings* of the informal and formal meetings, made notes and transcribed each interview verbatim into a typed text. Documents of

relevance to this study were also analysed throughout the empirical investigation (see Section 3.4).

- *Reflexive* feedback templates (Appendix B), which enabled me to collect individual interpretations, perceptions and behaviour changes that could not be communicated through interviews.
- Completed formative assessment tasks by the Grade 9 students, which were implemented and marked by the teachers to inform their assessment practices.
- An open-ended questionnaire, which were given to the participants prior to the formal interviews to establish existing beliefs, experiences and practices of PD and formative assessment (see Appendix C).
- Semi-structured interviews, which were voice recorded and transcribed (see Appendix D).

3.5.1.1 Data analysis and interpretation

The process of qualitative data analysis and interpretation, according to Creswell (2014, pp. 196-200) involves six steps:

- *Organise and prepare the data for analysis*: the researcher transcribes the interviews, sorts and arranges the different sources of information.
- *Read through all the data:* the researcher gets a general sense of the information and possibly its overall meaning. Researchers write down general ideas about the data.
- *Coding of the data:* the researcher organises the data into chunks of information and writes a word that represents a category in the margin.
- *Description of the setting or people and categories or themes for analysis:* the researcher gives detailed descriptions of the setting or the people involved, as well as descriptions of the categories or themes for analysis.
- *Present the results:* the researcher presents and conveys the findings, often in a narrative passage. It may also include a chronology of events, a detailed discussion of several themes or interconnecting themes.

- *Interpretation of the results of the analysis:* the final phase in which the aim is to answer the following question: 'What were the lessons learned?'

According to the aforementioned structure, I began to *organise and arrange* the multiple sources of data such as observational field notes, transcribed formal and informal meetings, reflexive feedback templates, open-ended questionnaires and the transcribed semi-structured interviews. A person who was independent of the study transcribed the audio files verbatim. The transcripts were then returned to the interviewees to check for accuracy.

For the purposes of this study, manual file folders and computer files were used to organise the data collected in three stages:

- Stage 1: Open-ended questionnaire;
- Stage 2: Focus group discussions; and
- Stage 3: Semi-structured interviews.

I began the in-depth analysis by organising the collected data from each stage separately into categories. Creswell (2007) and Stake (1995) provide valuable guidelines for organising and analysing collected data. I used *categorical aggregation* in which issues relevant to the research questions emerged. I also used *direct interpretation* where I looked at single instances from which to draw meaning and established *patterns* between categories (Creswell, 2007; Stake, 1995). This inductive process of organising the data into initial categories is also known as "open coding" (Creswell, 2007, p. 160).

In identifying categories that might be meaningful, I also employed the criteria as explained by Lincoln and Guba (1985). According to Lincoln and Guba (1985, p. 345), a category (unit) should meet the following criteria:

- "First, it should be heuristic – that is, the unit should reveal information relevant to the study and stimulate the reader to think beyond the particular bit of information.
- Second, the unit should be the smallest piece of information about something that can stand by itself - that is it must be interpretable in the absence of any

> additional information other than a broad understanding of the context in which the inquiry is carried out."

I therefore concentrated on the whole dataset first, then attempted to take it apart and re-construct it again more meaningfully. I first scanned and read the field notes, interview transcriptions and audio tapes to identify and manage key categories by reflecting on the major research question and theoretical framework of the study (heuristic). The key categories were descriptive in order to "see" and "hear" what the participants said within the interpretive context of this study (Creswell, 2013, p. 184).

3.5.1.2 Coding

I made descriptive notes in the margins of all the data documents that I thought to be relevant and important to this study, a process known as open coding (Creswell, 2007; Merriam & Tisdell, 2015). This form of categorisation helped me to make comparisons and contrasts between certain patterns, and to deeply reflect on other patterns and make sense of them.

I then grouped the descriptive text (open codes) into smaller categories of information by focusing on patterns and insights related to the purpose of this study by assigning code labels to emerging themes. For instance, I developed a list of significant statements made by the interviewees about how they experienced professional development and assessment, and then worked towards developing a list of non-repetitive statements to identify themes (also called categories). The code labels in this study were therefore descriptive to develop categories and sub-categories and provide this study with "information that the researcher expected to find before the study, surprising information that the researcher did not expect to find; and information that is conceptually interesting" (Creswell, 2013, p. 186). Throughout the study, each teacher's data were marked with a distinct identification code.

From the analysis and coding, new themes or categories emerged as I refined and revisited the data again through multiple levels of coding. These emerging categories (themes) are broad units of information used to form a common idea to make sense of the data (see Section 4.2). Creswell (2007, p. 161) describes the reviewing of the data to make sense and to identify specific "coding categories" as "axial coding."

In the final interpretive phase of this study, I gave an account of the meaning of the professional development formative assessment-based themes, which surfaced from the participants' experiences and views in this study (see Chapter 4).

Finally, I represent the essential meaning for the participants of their experiences of professional development in the form of a research report, supported by discussions informed by literature and narrative descriptions gathered from the participants (Chapter 4, Section 4.4).

Additionally, I include a refined and proposed framework of how formative assessment strategies can inform effective professional development where conclusions were drawn that may have implications for studies beyond this specific case (see Chapter 5).

Figure 3.2 gives an overview of the stages involved in the process of data analysis and interpretation as described in this study.

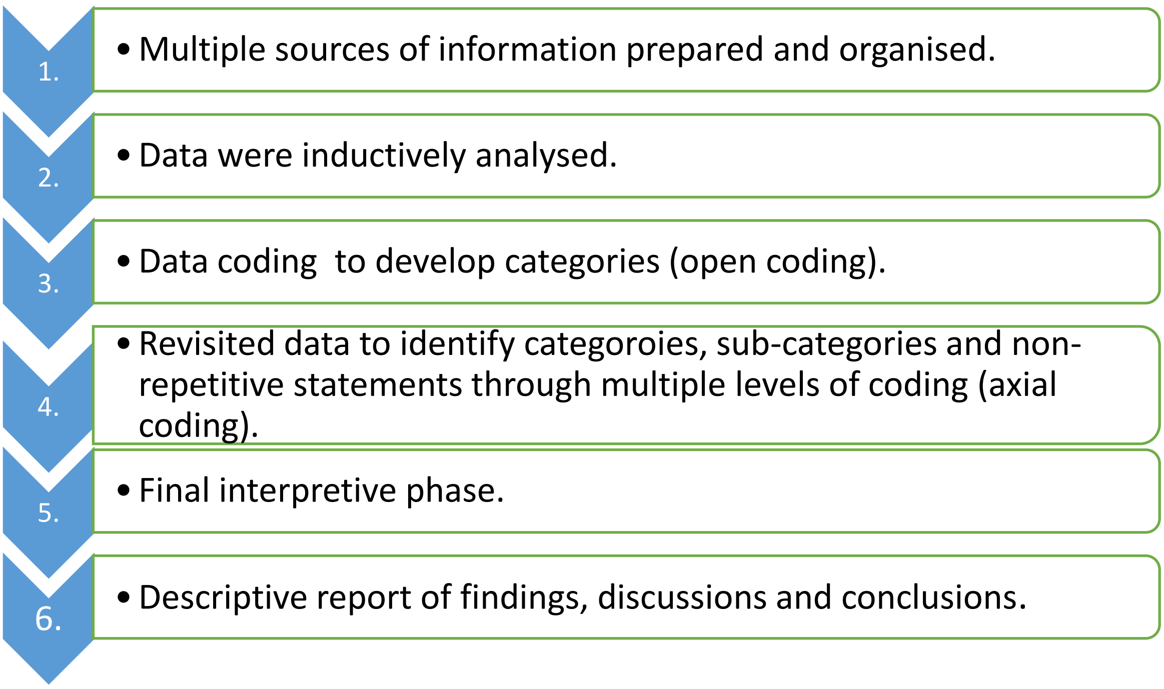


Figure 3.2: An overview of the data analysis process

In the following sections, I focus on the strategies that I applied to ensure that this study is trustworthy.

3.6 MEASURES TO ENSURE TRUSTWORTHINESS

According to Lincoln and Guba (1985), trustworthiness in qualitative studies refers to the truth-value of a study's findings in terms of how the researcher interprets the participants' experiences. They argue that qualitative studies are based on different assumptions about reality and worldviews and "should consider validity and reliability from a perspective congruent with philosophical assumptions underlying the perspective" (Merriam & Tisdell, 2015, p. 238). This is in contrast with quantitative studies, which portray very few descriptive details of individuals, as the qualitative study "describes people acting in events" (Merriam & Tisdell, 2015, p. 238). Lincoln and Guba (1985) emphasise that qualitative research, which is an approach that acknowledges the researcher's subjectivity, requires that the "biases, motivations, interests, or perspectives of the inquirer" need to be identified and made explicit throughout the study (p. 290). Questions have been raised about the criteria for validity and reliability in qualitative studies. This resulted in studies rethinking and reconceptualising the criteria for qualitative studies, as opposed to quantitative studies (Merriam & Tisdell, 2015). Many qualitative researchers prefer to use the term *trustworthiness* to describe the truth-value and methodological rigor instead of "validity and reliability". Lincoln and Guba (1985), for example, use unique terms such as *credibility*, *transferability*, *dependability,* and *confirmability* as substitutes for *internal validity*, *external validity*, *reliability,* and *objectivity* (Merriam & Tisdell, 2015, p. 239).

Although many qualitative studies have different strategies and approaches to enhance validity and reliability, I agree with Creswell (2013, p. 250) that "validation in essence, is an attempt to assess the accuracy of the findings, as best described by the researcher and the participants." Creswell (2013) further recommends that researchers should use multiple "validation strategies" regardless of the type of qualitative approach and employ accepted and well-developed strategies to document the "accuracy" of their studies (p. 250). I therefore applied a combination of accepted validation strategies such as extended fieldwork, multi-method strategies, triangulation, participants' verbatim language, low-inference descriptions, mechanically recorded data, and member checking to establish the trustworthiness of this study (Creswell, 2013, Johnson & Christensen, 2008; McMillan & Schumacher, 2006). I discuss the validity and reliability (trustworthiness) therefore from an interpretivist and constructivist perspective in qualitative research, which suggests that reality is relative to the meaning that people construct within social contexts (Creswell, 2007; Merriam & Tisdell, 2015).

3.6.1.1 Internal validity (credibility)

Internal validity in qualitative research deals with the extent to which the researcher's findings match reality. One of the assumptions underlying qualitative research is that reality is not a single, fixed objective, waiting to be discovered, but it is "holistic, multidimensional, and ever changing" (Merriam & Tisdell, 2015, p. 242). Reality needs to be understood from the perspectives of those involved in the phenomenon of interest. The complexity of human behaviour needs to be uncovered in a contextual framework and interpreted and presented in a holistic manner to ensure that the findings cohere with reality (Merriam & Tisdell, 2015). They explain that human beings are the primary instrument of data collection and analysis and therefore interpretations of reality are directly assessed through their observations, and interviews. Thus, putting us (humans) "closer" to reality than any other instrument (Merriam & Tisdell, 2015, p. 244).

To ensure credibility in this study, I employed *triangulation* – comparing multiple data sources in search of common themes – to support the validity of my findings, as described by Leedy and Ormrod (2005) and Merriam and Tisdell (2015). Multiple data collection methods included face-to-face, formal and informal meetings, telephonic interviews and conversations with all of the participants, in-depth semi-structured interviews (which were digitally recorded and noted), observations during the meetings and focus group discussions that were noted and several documents concerning the AETL project, as well as minutes of previous meetings. These multiple sources of data made it possible for me to compare and validate the data, which I collected in search of commonalities. In accordance with Creswell (2013), this process of triangulation involved corroborating evidence from different sources to shed light on a theme or perspective, of which the focus in this study was the multiple perspectives and realities of the teachers.

I also made use of *member checking* and *respondent validation* to verify my understanding of how the teachers ‘truly’ experienced formative assessment activities to contribute to their professional development. The teachers received an overview of what I had observed during the discussion and reflective meetings and interviews to evaluate if they agreed with my conclusions. I also employed *negative-case sampling* as I had searched through the data to see if any of my expected expectations or generalisations were contradicted in the interviews; I then attempted to find an explanation (Johnson & Christensen, 2012).

McMillan and Schumacher (2006) define *low-inference descriptors* as concrete, precise descriptions from field notes and interview elaborations and regard it as the principal method for identifying patterns in the data. I recorded the exact words of the participants rather than reconstructing the meaning from their own perspectives. The use of a digital voice recorder during the interviews supported the low-inference strategy to enhance the validity of this study.

Participant verbatim language is another strategy to ensure validity (McMillan & Schumacher, 2006). Unfortunately, only one of the interviews I conducted was in the participant’s mother tongue. The other interviews were conducted in their language of instruction, which was English. In presenting quality results in this case study, I had to digitally record and transcribe the semi-structured interviews in the participants’ own words. The interviews were phrased on the level of the informant’s language and not in abstract social science terms. The use of direct quotations from the data illustrated the participants’ meanings and thus ensured validity.

In this study, I allowed interim data analysis and justification to ensure a match between my findings and the participants’ reality by communicating on a regular base with the participants and coordinators of the AETL project. *Prolonged fieldwork* as a validity strategy was carried out by means of e-mails, telephonic conversations and informal visits. I additionally introduced the formative assessment tasks according to the timetable of CAPS, giving the participants at least two years to implement and adapt the tasks to suit their individual programmes. The prolonged engagement and persistent observations included in this study ensured building trust with the participants (Creswell, 2013). The prolonged engagement additionally provided opportunities for continual data analysis and comparison to ensure a "match between researcher categories and participant realities" (Merriam & Tisdell, 2015, p. 244).

3.6.1.2 External validity (transferability)

External validity refers to the extent to which the findings of one study can be applied to other situations, i.e. the generalisability and applicability of a research study (Lincoln & Guba, 1985; Merriam & Tisdell, 2015).

I described the background information, contexts, settings and the assumptions underlying the study of the participating teachers in sufficiently *rich "thick" detail* that allows readers to draw their own conclusions from the data presented. These detailed descriptions serve to understand the extent to which the findings may be generalised to coincide with their own setting based on the similarities between the settings (Merriam, 1998). Another strategy for enhancing the external validity of this study was to give careful attention to selecting the sample to allow for *maximum variation* (Merriam & Tisdell, 2015; Patton, 2015). The selected sites, for example, varied in contexts and settings such as an Afrikaans school, and English schools ranging from the inner-city area suburbs and townships to allow for a greater range of application by readers of the study.

3.6.1.1 Stage 2: Data collected from the focus group discussions

As explained in Section 3.4.3, purposeful and convenience sampling strategies were used to identify four teachers from one school, School A, to participate in four focus group discussions. The focus group discussions were initiated by the AETL project coordinator, and I took the opportunity to attend and participate in all of the meetings. I did this for the purpose of enriching and increasing not only the quality of the collected data, but also to explore the group dynamics of a Professional Learning Community (PLC). The focus group meetings were held on School A's premises during school time and as a result, all four participating teachers attended all of the meetings. Further details of the focus group discussions are provided in Section 3.4.3.2.

Interim data analysis (Creswell, 2007) was conducted as the participants actively engaged in the discussions facilitated by the AETL project coordinator and myself as the primary researcher in this study (see Section 3.4.3.1).

The transcribed recordings of the four focus group discussions and observational field notes were analysed. I made descriptive notes in the margins of all the documents that I thought to be relevant and important to this study, a process known as open coding (Creswell, 2007; Merriam & Tisdell, 2015). Emerging themes or sub-themes were then identified and labelled with distinctive codes.

Themes and sub-themes from the raw data collected during the four focus group meetings were identified, analysed, refined and coded. I then revisited and reviewed the data from the questionnaire and the focus group meetings "to make sense and to identify specific coding categories through the process of axial coding," as described by Creswell (2007, p. 161) (not triangulation).

Table 3.5 provides the names of the participants from School A, and a summary of the preliminary themes and sub-themes identified from the data collected in the focus group meetings.

Table 3.5 Preliminary themes and sub-themes from the *focus group* discussions

Participants from School A	**Themes**	**Sub-themes**	**Codes ascribed to the different meetings**
Mr L **Mr M** **Mr N** **Mr O**	**Knowledge, Beliefs, Attitudes**	*Values, mathematics teaching and learning, Assessment knowledge, PD needs.*	**FG1:** K/I/C/P/m/st/sc/a/t **FG2:** K/I/C/P/m/st/sc/a/t **FG3:** K/I/C/P/m/st/sc/a/t **FG4:** K/I/C/P/m/st/sc/a/t
	Supporting and constraining factors	*Systemic testing (ANAs), school context, collaboration, networking, policy, learner attitudes, large classes, diversity.*	
	Reflection on the worksheets	*Principles of mathematics teaching and learning.*	

	Practical implementation of worksheets	*Time, reflection, feedback.*

At the end of Stage 2, I worked through all the data sources (qualitative survey, observational field notes, reflective feedback notes and focus group transcripts) and analysed, coded and refined these to inform the subsequent interview protocol for the semi-structured interviews. Unexpected data were also analysed and coded.

3.6.1.3 Reliability (dependability)

Traditionally, reliability refers to the consistency of measurement – the extent to which research findings can be replicated with similar subjects in a similar context (Merriam, 1998). However, the replication of a qualitative study will not necessarily yield the same results because there can be numerous interpretations of the same data. Merriam and Tisdell (2015, p. 250) explain that qualitative research is not conducted to isolate the laws of human behaviour, but “to describe and explain the world as those in the world experience it, with many interpretations of what is happening.” In other words, reliability in qualitative research is not concerned with whether the findings of a study will be found again, but whether the results of the study are *dependable* and *consistent* with the data collected (Lincoln & Guba, 1985; Merriam & Tisdell, 2015).

To ensure dependability, I have consistently utilised the same data collecting instruments of observation, feedback-templates, assessment activities, and semi-structured interviews for all of the participants in this study. All of the participants were Grade 9 teachers from public schools, following the same curriculum. I accounted for variables in the changing contexts and experiences of the teachers by providing rich descriptions of the research results as the study emerged (Merriam, 1998). I also monitored the quality of the recordings and transcriptions of the interviews consistently to ensure dependability. The “audit trail” (Merriam, 1998, p. 205) of how the data were collected, analysed, how categories were derived, and how decisions were made throughout the study have already been described in detail in this methodology chapter (see Sections 3.4 and 3.5).

3.6.1.4 Objectivity (confirmability)

To ensure objectivity, I have clarified the approaches and decisions taken in this study in systematic detail. Merriam (1998) and Creswell (2013) emphasise the importance of *clarifying researcher bias* so that the reader can understand the researcher's position and any assumptions that influence the inquiry. As discussed earlier, I engaged in focus group discussions together with the project coordinator from the AETL project. My supervisor assisted me to ensure that biases did not influence either the collection or analysis of data. The fact that my co-supervisor was not involved in the focus group discussions additionally helped to question my objectivity at various times throughout the process.

3.7 ETHICAL CONSIDERATIONS

Considering this study to be qualitative, I had to interact with the participants on a very personal level to collect data and interpret the data from their perspectives. Creswell (2013) emphasises the importance of being sensitive to ethical considerations throughout all phases of the research process. Several ethical issues arose during planning, conducting, and analysing the research, which needed attention and adaptation as the study progressed. Creswell (2013) provides guidelines to address the issues and suggests possible solutions as ethical issues occur prior to conducting the study, at the beginning of the study, during data collection and analysis, in reporting the data, and in publishing the study. I will therefore address the ethical issues as they occurred throughout the phases of this empirical study.

3.7.1.1 Prior to conducting the study

The research team first had to get the permission of the Regional Director of the Tshwane South district prior to entering the research field (see Appendix E). We also had to apply for approval from the ethics committee of the University of Pretoria to conduct the research (see Appendix F).

As the primary investigator in the field, I also had to request permission from the school principals involved, explaining the aim and purpose of the research, taking into consideration that the school's programme would not be interrupted (see

Appendix G). I also familiarised myself with the ethics policy of the relevant schools that I visited.

3.7.1.1 Beginning to conduct the study

I informed the teachers of my role during the research process, which was primarily to monitor their engagement in the AETL project and to interview them after their engagement in the activities. All aspects, e.g. the specific dates for my visits were discussed and confirmed, and the reason for my research was discussed in broad terms with all the participants. For the purpose of this study, it was not necessary to withhold information as full disclosure would not seriously have affected the validity of the results.

During the information sessions, I obtained voluntary participation and informed consent from all of the participants before the commencement of the study. This informed consent assured the participants that they were free to withdraw at any stage during the study without the fear of negative consequences. Procedures, risks, and benefits were explained to all of the participants before any data was collected. I also assured the participants of the protection of their privacy and confidentiality (see Appendix H). I also informed the participants of how long the data will be stored, where the data will be stored, and how it will be destroyed after the appropriate amount of time.

3.7.1.3 Collecting data

The open–ended questionnaire was also answered anonymously to enhance the credibility and trustworthiness of the participants' responses. Well-planned interviews and visits were organised in order to protect the participants from unnecessary stress, embarrassment, or loss of self–esteem. I also respected the site and the participants to minimise disruptions and visits. As a result, the interviews were scheduled outside school hours. The purpose of the study and how the data would be used were discussed in detail with the participants.

I also made the participants aware that the interviews and meetings would be voice recorded. During the interviews, I avoided leading questions, and withheld personal impressions so as not to influence their responses.

3.7.1.4 Analysing data

To avoid disclosing only positive results, I reported multiple perspectives and contrary findings. Respect for the privacy of the participants was addressed by assigning fictitious names.

3.7.1.5 Reporting data

To avoid falsifying any evidence, I reported the findings of this study honestly and did not plagiarise any of the results. I also avoided the disclosure of any information that would harm the participants, and ensured their anonymity. I also kept in mind that too many identifying demographic variables could hinder the anonymity of the participants when I reported on the data.

In addition, I reported my research findings to my professional colleagues in a complete and honest fashion to add to the ethics protocol, as directed by Creswell (2013).

3.7.1.6 Publishing data

I shared the data and findings with others by providing copies of the report to the participants and stakeholders involved in the AETL Project.

3.8 SUMMARY

This chapter provided information regarding the research design and methods utilised in this empirical research. It also addressed issues about the sample, strategies for data collection, and the analysis procedures. An account of the strategies taken to ensure trustworthiness and measures taken to address ethical issues were discussed. In Chapter 4, the findings of the research and an analysis of these findings will be reported.

CHAPTER 4 ANALYSIS OF RESULTS

4.1 INTRODUCTION

The previous chapter explained and justified the research design and methods applied to achieve the research aims and objectives of this study. In this chapter, the findings of this study are presented and discussed.

The intention in this study was to gain a deeper understanding of the professional development process of in-service Grade 9 mathematics teachers when they were actively involved in the refinement and implementation of structured formative assessment strategies. Accordingly, this study addresses the perceptions held by mathematics teachers regarding formative assessment, how much they value learning as part of their classroom-based assessment, and how their use of externally designed formative assessment strategies influences their overall professional development experience.

This study therefore aims to provide an extensive description, drawing from both the mathematics teachers' point of view and their sense of motivation to change existing assessment and instructional practices. The aim was also to provide a better understanding of the crucial role that formative assessment practices can play in the continuous professional development of mathematics teachers. Additionally, the aim in this study is to promote the alignment of the curriculum, assessment practices, and instruction of the participating teachers by providing them with structured and strategically designed activities.

One of the objectives in this study is to *explore* the views held by mathematics teachers on formative assessment, and to determine how much they valued its links to quality teaching and learning in mathematics. As a result, this study reports on how the process of refining and implementing curriculum-aligned formative assessment strategies informs the decisions made by teachers regarding instructional curricular activities during the CPDT process. Therefore, the focus was not only to determine what teachers do to asses *for* learning, but also to explore the process, conditions and overall professional development experience. Furthermore, an analysis of the literature indicates a need for targeted professional learning initiatives in order to clarify understanding, remove misconceptions, and provide the necessary support to teachers in the effective implementation of formative assessment (Heritage, 2011, Morrissette, 2011; Stiggins, 2008, 2010).

I employed a phenomenological research design to explore, understand, and describe the "core meaning or essence of a lived experience that individuals give to a phenomenon" as advocated by Creswell (1998, p. 37). The focus was thus on the experiences and engagement of teachers in formative assessment activities to support their professional development experiences within the AETL project. There was also a focus on how the teachers made sense of their experiences and how it influenced their professional judgement to enable adaptation of their formative assessment practices.

The research findings in this Chapter are presented in four sections. Section 4.1 revisits the purpose of the study, followed by a description of the profiles of the participants (Section 4.2). In Section 4.3, a detailed description of the data analysis procedures is presented. Preliminary themes and subthemes from the different stages in the analysis process are also presented. In Section 4.4, I present and discuss the data according to categories and subcategories, as compared with the existing literature related to the purpose of this study. The presentation of the findings is also enhanced by the verbatim nature of transcriptions, which is true to the nature of qualitative research in which participants' own words are used to "adequately and convincingly support the findings of the study" (Merriam 2002, p. 21).

4.2 PROFILE OF THE PARTICIPANTS

In order to realise the research aim and objectives of the study, the participants were expected to implement formative assessment worksheets (strategies) that were aligned with curriculum assessment standards (CAPS). Two information and training sessions on formative assessment strategies were arranged with teachers and other stakeholders from a range of school contexts in Pretoria, Gauteng. The University of Pretoria arranged these meetings to introduce the AETL project and the researcher used this opportunity for sampling purposes. Purposeful sampling strategies were then used to select the schools and individual teachers (see Section 3.4.1).

Twenty-two Grade 9 mathematics educators from ten different schools and two representatives of the Gauteng Education Department in the Tshwane district attended the first meeting. Twenty of these attendees initially volunteered to participate, but due to time constraints and other responsibilities, only ten of these educators committed and participated in the study. Unfortunately, one of the committed participating teachers passed away before I could commence with data collection.

The nine participating teachers in this study were from five different secondary schools from the same district. The study was conducted over a period of two years to give the participating teachers enough time to engage with and implement the worksheets. It was also important that these teachers should be practising Grade 9 teachers as Grade 9 learners participate in the Annual National Assessments (ANAs) or other systemic assessments such as TIMSS (see Section 3.4.1 for detailed sampling procedures). The data were collected through an open-ended questionnaire, four focus group discussions (School A), observational field notes and individual interviews.

Although biographical data such as gender, post level and teaching experience were not considered during the sampling procedures, this background information assisted me in creating a better understanding of each participant's unique contribution during the analysis of the data.

Table 4.1 provides an overview of the biographical profiles of the nine participating teachers. It also provides a summary of the data collection strategies employed in this study.

Table 4.1 Participant teachers in the AETL Project and a summary of the data collection instruments

School	Community & Quintile (Q) & Language of Instruction	Name of Teacher	Sex	Subjects & Grade(s) Taught	Post Level (PL)	Teaching experience (years)	Data collection codes * FG * QS * SI
A	Township Q4 English	*Mr L*	M	Mathematics (9,12)	2	10	FG,QS
		Mr M	M	Mathematics (9)	4	34	FG, QS, SI
		Mr N	M	Mathematics (9;10)	1	6	FG,QS, SI
		Mr O	M	Mathematics (8; 9)	1	2	FG,QS
B	Central city Q5 English	*Mrs B*	F	Mathematics (9) Mathematics Literacy (9)	1	7	QS, SI
C	Suburb Q3 English	*Mr C*	M	Mathematics (8-12) Economics (8-12)	1	16	QS,SI
D	Suburb Q5 Afrikaans	*Mrs D*	F	Mathematics (8,9)	1	4	Qs, SI
		Mrs F	F	Mathematics (9-12)	1	28	Qs, SI
E	Township Q2 English	*Mr E*	M	Mathematics (9-12)	1	10	Qs, SI

* FG = Focus group discussions

* Qs = Qualitative open-ended questions

* SI = Semi - structured interviews

The sampled teachers' experience indicates that most of the teachers were experienced educators ranging from having two years to 34 years' teaching experience. The experience in teaching is important in that this may influence the perceptions of the participants regarding their pedagogical and subject content knowledge and the way in which they were willing to implement change in their formative assessment and classroom practice (Borko et al., 2000).

It was also interesting to see that two of the participating teachers were in managerial positions, such as post level 2, also described as Head of Department (HOD). One of the educators was on post level 4, which designated him as the principal of the school. Post level 1 teachers can either be junior or senior teachers who have not applied for, or been promoted to, post level 2.

The context of three of the participating teachers in two of the quintile 5 (Q5) suburb schools, and one teacher from the quintile 4 (Q4) school, was a little different in that their learners were perceived to be more privileged than the learners in the Quintile 2 and 3 schools (see Section 3.1). Q4 and Q5 schools are perceived to have better resources and a better infrastructure at their disposal. However, they share the common challenge teaching mathematics in a recently reformed curriculum (CAPS) and their learners' achievements in mathematics are equally evaluated through systemic standardised assessments such as the ANAs (see Section 1.1.3). It is also important to note that this study does not primarily aim to explore diversity, but rather to conceptualise the common essence of the learning experiences of the participants.

4.3 Data analysis

In recognising the "multifaceted world of qualitative research" and the methodological variation, as suggested by Yin (2011, p. 11), I began to organise and arrange the multiple sources of data, which comprised observational field notes, open-ended questionnaires, transcribed focus group discussions, reflexive feedback templates, and the transcribed semi-structured interviews. I arranged and analysed the complete dataset as a three-way process, as illustrated in Figure 4.1.

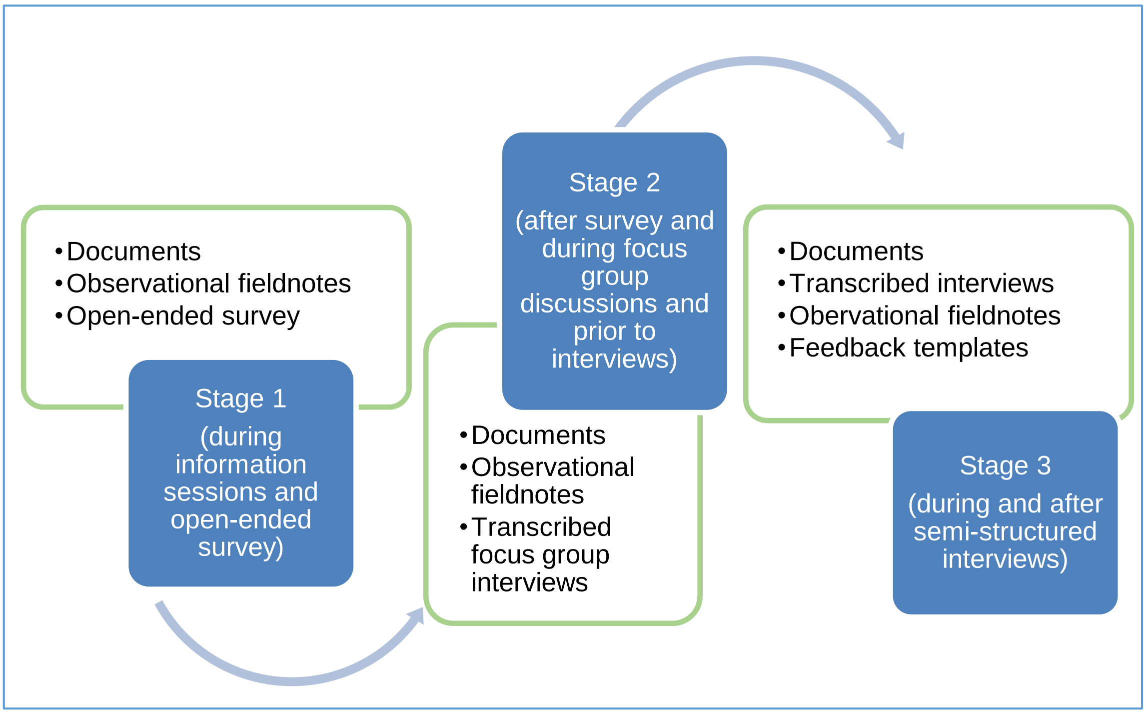


Figure 4.1: An overview of the data analysis process followed in this study

The data collected from each stage were separately analysed and coded to identify preliminary themes and sub-themes relevant to the research questions, as suggested by Creswell (2007) and Stake (1995) (see Section 3.5.1.1).

4.3.1.1 Stage 1: Data collected from the information sessions and open-ended questionnaire

At the beginning of the study, all nine participating teachers (see Table 4.1) completed an open-ended questionnaire (Appendix C) in their own time before the focus group discussions and individual interviews were conducted.

The data from the open-ended questionnaire and field notes were analysed comparatively and in line with the iterative process of qualitative analysis. As described by Yin (2011, p. 198), I combined, refined and re-analysed the subsequent focus group discussions and the final semi-structured interviews (see Section 3.5.1). I also assigned unique codes to each participant's name to distinguish which participant had said what. This subsequently assisted me to select relevant excerpts from the data, which included the views of all of the participants and allowed individual voices to be heard.

Preliminary themes and sub-themes were identified and coded during Stage 1 of the analysis process and are summarised in Table 4.2

Table 4.2 Preliminary themes and sub-themes from data collected during Stage 1 of the data analysis process

THEME	SUBTHEMES	Codes
Formative Assessment knowledge	*Resources, classroom practice.*	QR: K/B/P
Teaching and Learning Beliefs	*Self-efficacy, school context.*	QR:K/B/Se/Te/Sc
Curriculum implementation and manageability	*ANAs, Policies, Time.*	QR: Cu/I/P
Professional Development	*SCK, PCK, External resources.*	QR:PD/K/Res
Challenges	*Student abilities, Time.*	QR: C/St/t

4.3.1.2 Stage 3: Data collected from the semi-structured interviews

Since four of the nine participants were from School A, I decided to interview only two of the four due to time constraints and other responsibilities mentioned by the participants, which brings the interviews to seven in total. I furthermore created sufficient opportunities during the focus group meetings for all four of the participants from School A to express their views.

Purposeful sampling was used to identify and collect data from seven participating teachers from five different schools by means of individual semi-structured interviews (see Section 3.4.3). I only interviewed Mr M and Mr N, and not all four teachers from School A due to time constraints and other responsibilities mentioned by the participants (see Table 4.1).

The seven selected participants for the interviews were, however, representative of the total group. Expected, 'typical' perceptions and perspectives emerged from the interviews that were important to the purpose of this study (Leedy & Ormrod, 2005, p. 147).

The face-to-face semi-structured interviews (Appendix D) lasted between 45 minutes to an hour per individual. These were conducted on the school premises after school hours being the least disruptive of the school programme and better in terms of the availability of the participants. The researcher informed and explained the purpose of the study and informed the interviewees that the data collected was non-evaluative. They were further encouraged to provide their own views and lived experiences regarding the implementation of formative assessment strategies.

In line with the qualitative approach, I employed an in-depth analysis of the multiple data sources; reflected on the experiences of the participants; and identified and coded recurring and relevant themes (refer to Section 3.5.1) to enhance the validity of the study (Maree et al., p. 376).

At the end of the three-stage analysis process as described above, I identified the final categories and sub-categories from the literature and the data collected in this study (Table 4.4). I also made use of triangulation, which entailed the use of multiple data sources in search of common themes. This was done to support the validity of my findings, as described by Leedy and Ormrod (2005).

4.4 RESULTS AND DISCUSSIONS

In this section, I will discuss each major category and its sub-categories in the order in which they appear in Table 4.4. The presentation of the results will not follow the chronological sequence of the three-stage process I described in Section 4.3. Instead, I present the refined and final categories and sub-categories from the collective dataset, in a composite form, to address the key concepts of the research questions and purpose of this study. The findings are presented in a qualitative narrative, as “seen through the eyes of people who have experienced it first-hand”, which is in line with the phenomenological approach as described by Leedy and Ormrod (2005, p. 147). This implies that my discussions will be presented in the form of an overall description of the findings of this study, including a comparison with information from the literature, as well as relevant theories (Creswell, 2009, p.189).

Table 4.3 presents an overview of the major categories and sub-categories related to the experiences of the mathematics teachers as they participated in the AETL Project.

Table 4.3 Summary of the main categories, sub-categories, and codes related to the research questions

Categories	Sub categories	Codes
Teachers' knowledge, attitudes and beliefs	*Mathematics self-efficacy;* *Teaching and learning mathematics;* *Assessment Knowledge.*	*KAB/MSe* *KAB/Tl* *KAB/Ak* *KAB/Afl*
Existing Formative assessment practices	*Marking of homework;* *Oral and written answers;* *Class tests;* *Peer assessment;* *Practical tasks.*	*EP/Pmh* *EP/Wa* *EP/Ct* *EP/Pa* *EP/Pt*
Influences on formative assessment practices	*Influence of systemic testing;* *Educational policies: PD and curriculum;* *School context.*	*IP/St* *IP/Ep/PD* *IP/Ep/Cur* *IP/Sc*
Constraining factors in formative assessment practices	*Learners' socio-economic backgrounds;* *Large classes;* *Lack of parental support;* *Learner attitudes;* *Diversity in learners' abilities;* *Language issues;* *Anxiety related to assessment;* *Communication between schools and the DoE;* *Lack of assessment resources;* *Curriculum Implementation; and Manageability (time).*	*CF/Seb* *CF/Lc* *CF/PS* *CF/LA* *CF/Lab* *CF/Lang* *CF/Anx* *CF/ DoE* *CF/Res* *CF/Curr/Time*
Teachers' engagement in formative assessment strategies	*Initial engagement in the AETL project;* *Practical implementation of worksheets;* *Refinement of the worksheets.*	*Act/Begin* *RQ3/Impl* *RQ3/Refl*
Teachers, Professional growth experiences	*Knowledge and skills development: formative*	*PD/KB*

	assessment, curriculum knowledge *Change in instructional practice* *Collaboration;* *Leadership & Support;* *Student outcomes (Feedback)*	*PD/Cip* *PD/Collab* *PD/LS* *PD/SO/fb*

In the discussion of each category, I used applicable quotes from the various focus group discussions and semi–structured interviews to substantiate the discussion, as well as to compare it with the relevant literature on professional development and formative assessment experiences. I also linked the theoretical models, as described in Chapter 2, *inter alia*, the interconnected model of professional development (Clarke & Hollingsworth, 2002), effective formative assessment strategies (Black & Wiliam, 1998, 2009; Stiggins, 2008), and dilemmas related to assessment practises (Suurtamm & Koch, 2014). I used these as analytical tools to support the findings of this phenomenological study. As this study contains information about the experiences and understanding of participants in a professional development programme, I include narrative information, descriptive reports, and quotes from the individual interviews to report on their perceptions, beliefs, and behaviours to validate the findings of this qualitative study.

The major findings and discussions are presented in a descriptive report and quotes from the participants to substantiate the findings. Note that the quotes are written verbatim, without corrections. Afrikaans quotes were translated into English and confirmed by the participants for accuracy.

At this point, I would like to reiterate that the essence of the study and of my analysis was not to rate the effectiveness of teachers' assessment practices. Rather, in accordance with the phenomenological approach, I sought to gain a better understanding of mathematics teachers' lived experiences with formative assessment and strategies to support their professional growth.

In order to explain how the teachers made sense of their experiences within the AETL Project, and how it influenced their professional learning in this study, I additionally considered the "local knowledge, problems, routines, and aspirations shaped by individual practices and beliefs" as suggested by Opfer and Pedder (2010, p. 379).

To present the findings, I first provide the supporting evidence collected as it relates to the teachers' knowledge, attitudes, and beliefs during the AETL Project. This is followed by an exploration of their existing classroom-based assessment practices. I then present the factors that the teachers regarded as influential in their assessment practices, followed by the challenges experienced by the teachers as they incorporated new assessment ideas into their practice.

I then present a description of how the teachers engaged in activities and implemented the formative assessment strategies during the AETL project.

Finally, I present a summary of the participants' experiences to illustrate the interconnections and relations within, and the influence of the AETL project on the professional development of the participating teachers.

4.4.1 Teachers' knowledge, attitudes and beliefs

One of the aims of this study was to provide descriptions from the mathematics teachers' point of view about mathematics teaching and learning, as well as their experiences of formative assessment. I also sought to gain a sense of their motivation to re-adjust existing instructional and assessment approaches. As mentioned in the literature review, a considerable amount of research (Bandura, 1993; Loucks-Horsley, 2010; Shulman, 1987; Wilkins, 2008) underpins the importance of teachers' knowledge, beliefs and attitudes in teaching and learning. This specifically relates to their effectiveness and their choice of instructional practices, and as a consequence, their disposition towards the implementation of newly acquired skills (see Section 2.4.2).

4.4.1.1 Mathematics self-efficacy and teaching-efficacy beliefs

I specifically looked at Bandura's (1993) study on perceived self-efficacy and its influence on the quality of teachers' instructional practices. Using these principles/identified qualities/beliefs, I explored and reported on the teachers' beliefs about their capabilities in performing mathematical tasks (mathematics self-efficacy) and their beliefs about effective mathematics teaching (mathematics teaching-efficacy) (Bandura, 1993, p. 140).

During Stage 1 of the data analysis process (see Figure 4.1), I asked the participants in an open–ended questionnaire to indicate their degree of confidence in teaching mathematics. They were provided with the following four options: high, medium, low, other. The overall responses from the participants revealed a high level of mathematics teaching efficacy. Of the nine participants who responded to this question, eight indicated that they had a high degree of confidence in teaching mathematics. Only one participant responded with a 'medium' degree of confidence and attributed his lower degree of confidence to "a knowledge gap in geometry" **(QR5:1)**.

Most of the survey participants (seven out of nine) ascribed their high confidence in teaching mathematics to their firm subject knowledge base (mathematics self-efficacy). In addition, two participants attributed their high level of mathematics teaching-efficacy to their years of teaching experience **(QR4,5)**.

The teachers expressed similar views on mathematics teaching- and self-efficacy during the focus group discussions and individual interviews.

A high degree of mathematics self-efficacy was expressed in the interview with Mr M. It is worth mentioning that he ascribed his subject content knowledge to 34 years of teaching experience in a variety of subjects:

> I am almost 100% confident in teaching technical subjects and mathematics as I have majored in math, physics and chemistry … because I have been doing them for the past 34 years, even subjects like mathematical literacy, accounting and economics **(MI:2)**.

Mr M also mentioned that he received training in advanced technical subjects at a university in Tokyo and ascribed his mathematics self-efficacy beliefs to the quality of the training he received. In a similar vein, Mrs F mentioned that "good training at a good institution and 26 years of teaching experience" **(FI:1)** contributed to her high level of mathematics self-efficacy.

Only one of the interviewees admitted to a lower level of mathematics self-efficacy during his individual interview. Mr N explained how his lack of geometry knowledge influenced his mathematics teaching-efficacy:

> But then the lack of confident there … even if when I have to teach geometry there are some chapters … you do preparations but not that far up because …the knowledge, the understanding, but then geometry. When I teach geometry it needs preparation from my side. Hence, I am saying to me … it's quite challenging compared to other content areas **(NI: 3)**.

It is worth mentioning that Mr N did not express his lack of confidence in teaching geometry during any of the focus group meetings. I observed that he was not very talkative in a group situation, but during his semi-structured interview. I obtained a deeper understanding of his sense of mathematics self-efficacy. This observation strengthens the choice of semi-structured interviews as a valuable source of information in this study. It also aligns with Nieuwenhuis's view (cited in Maree, 2016, p. 93) regarding the importance of the correct use of qualitative interviews, "If the persons you are interviewing think the topic is important and they trust you, they will give you information that you will not be able to collect in any other way" (Maree, 2016, p. 93).

The evidence presented thus far supports the idea that the teachers in this study had a high level of mathematics self-efficacy and teaching-efficacy. However, when the participants were asked to indicate in what aspects of mathematics they would like to receive professional development, they indicated that they required further development in a variety of areas. Across the dataset, only two participants mentioned further development in Subject Content Knowledge (SCK), particularly in the area of geometry. These findings do not support previous studies reporting on South African mathematics teachers' lack in SCK (Bansilal, Brijlall & Mkhwanazi, 2014). However, the findings do coincide with those of Tsanwani, Harding, Engelbrecht and Maree's (2014) study on the importance of teachers' perceptions of their ability to teach mathematics on the motivation of their learners.

Another three mentioned the need to enhance their instructional practices (PCK), for example, Mr C explained that he wanted further development in teaching algebra, especially in collaboration with other colleagues:

> So there's need for staff development to continuously develop the teacher. How to teach algebra on Grade 9 level, or grade 8. People comes in and bring their own new ways on how to teach a concept. You know the way you teach a concept maybe different from mine. Now if three or four people comes together and show their ways, one can say ah but I like that one. At least the one which I knew and the new one which someone have taught me, so I am equipped **(CI:30)**.

Only one participant indicated in the open-ended questionnaire that she required technology training to enhance her mathematics classroom practices, and another required PD in how to motivate learners to excel in maths **(QRS:1)**. One interviewee also expressed the need for professional development in "ways to incorporate information technology in the teaching of mathematics" **(EI:7)**.

All nine participants across the dataset expressed their need for professional development opportunities to enhance their assessment knowledge. Some of the comments made were: "We need resources and training to assist us with formative and summative assessments" **(MI:4)** and "I need development in assessment and resources" **(EQ:3)**, as well as "we need more time to discuss assessment strategies with other teachers" **(BI:8)**.

Based on the abovementioned needs expressed by the participants, it seems that the teachers' self-efficacy beliefs did not match their initial confidence in their own abilities and existing knowledge. These results may be linked to Desimone's (2006) study, which revealed that teachers with more confidence in subject knowledge (high mathematics self-efficacy) seem to be more motivated to further develop their knowledge and skills than teachers with less content knowledge (Desimone, 2006, p. 205).

4.4.1.2 Teaching and learning mathematics

The following results report on the link between what the teachers regarded as effective teaching and learning of mathematics, and how it supported student learning in their daily practices.

In the focus group discussions and during the interviews, I asked the participants the following question: *"What is your understanding of a good mathematics teacher?"* The teachers generally had strong beliefs regarding the features of good mathematics teaching. The data from the focus group discussions and interviews revealed that some of the participants responded with affective beliefs, and others based their beliefs on instructional knowledge and skills, while some experienced a mixture of instructional and affective beliefs.

On the one hand, Mr M, the principal of School A, and the most experienced participant in terms of years in teaching mathematics, expressed strong beliefs regarding good mathematics teaching during his interview:

> A good mathematics teacher will inspire learners. That is the most important thing. Help them, inspire them in thinking, and have good practice – or good practices of mathematics. Be patient **(MI: 5)**.

Mr M also expressed his positive attitude toward mathematics teaching and learning and its influence on his students: “I think if learners are allowed to express themselves in classes that are less rigid, they will enjoy mathematics even better” **(MI:6)**.

Mrs F, somewhat differently, described strong instructional practices as good mathematics teaching, and she emphasised the importance of the effective use of a variety of instructional methods:

> A good teacher uses a variety of instructional methods to explain to the learners so that all can understand **(FI: 1)**.

From Mrs F ‘s response, it is clear that instructional knowledge was important to her, but she also seemed to be aware of the diversity in the abilities of her learners (affective). She additionally shared her views on her confidence in PCK and the importance of the quality of training that a teacher receives at tertiary level:

> The quality of training a teacher received at College or University level is usually an indication of the knowledge base in subject content and instructional knowledge of a good mathematics teacher **(FI:1)**.

Some of the other participants’ views were more affectively focused, such as Mr N, who displayed a sensitivity to the needs of his learners during his interview:

> Know your learners … like, we have learners with different levels, levels of understanding, there are different learners, so that is why I am saying, you need to

> know your learners. You must know that okay in this class, in this specific class I have learners who are struggling in mathematics, I have learners who are little bit brighter, and I have confident learners in mathematics. That is what you must know is a good teacher in mathematics **(NI: 1)**.

A mixture of affective and instructional beliefs influenced Mrs B's perception of a good mathematics teacher. During her interview, she displayed strong mathematics self-efficacy beliefs and placed a high value on instructional competencies. The following excerpt clearly illustrates Mrs B's strong instructional beliefs:

> A good maths teacher … obviously someone who has got a great subject knowledge. You have to be able to do all the questions yourself and obviously, every question you give to the learners you should be able to do it yourself, so I think that is the important thing is the subject knowledge (**BI: 11)**.

At the same time, she also displayed strong affective beliefs regarding accommodating the different needs of her learners:

> I think accommodating all types of learners, learners from different backgrounds, learners who are failing, learners who are getting 80% you want them to do better so you have to be able to do that. Accommodate all the learners, be able to teach in different ways, be patient; you've got to have lots of patience **(BI: 12).**

Mr C strongly believed that a good mathematics teacher needs to motivate students by setting high goals for them and preparing them to be good citizens (affective focus). Mr C further explained why a good mathematics teacher should motivate his or her learners in some way to achieve their learning outcomes:

> What I do normally, even with my learners. What I did with them, I had to set my pass mark to 60. We agreed with the class that my pass mark will be 60%. And as a result, everyone passed at the end of the year. Out of 24 learners, all of them passed. Because they knew that for me to pass, I must get 60… because we are not supposed to just teach a child for the exam. We are supposed to teach a child knowing that that child is the future citizen of this world. So the only way for you to pass is to make your aim high to achieve more **(CI: I6)**.

Mr C's response is also an indication of his knowledge about the curriculum and its overall goals. This finding confirms that this teacher was motivating his students to *"learn across and beyond school",* which is a critical component for professional development when assessment *for* learning (AFL) is used, as according to James et al. (2006, p.3).

In response to the question: *“What are the reasons we teach mathematics?”* during the second meeting of the focus group discussions, the participants provided me with a range of beliefs regarding the value of mathematics teaching.

For Mr O, the value of mathematics teaching and learning was in the acquired knowledge that his learners could apply in real life situations. He emphasised the value of mathematics in solving contextual problems:

> We are not teaching for exams. We are teaching mathematics for knowledge. Because this knowledge is what we are applying in our daily lives **(FG2:3)**.

Mr M added that mathematics promotes “reasoning and problem-solving skills”, which corroborates one of the eight principles that are essential for effective teaching, as described by Silver (2015, p.33).

> For teaching mathematics … is problem solving. Another one is stimulating our minds. Most of the time you become inquisitive … you want to learn more. Anything that is in the form of a number. We want to know what is really happening. But at the same time, we must give them chance to express themselves. Because if you don’t give them chance to express themselves, they will know these mathematics X^2 multiplied by X^2 is X by the power of 4, but they will never be able to say if something comes out in life like that, how are they going to solve it. You will find that they know mathematics but outside they cannot be able solve **(MI: 5)**.

Mr M furthermore elaborated on the importance of mathematics and explained how he attempted to make mathematics a meaningful learning experience for his students. He avidly illustrated how passionate he was about mathematics:

> Why is mathematics important? You can’t do anything without mathematics. Mathematics every day you come across anything. Even if you are not knowing that I am doing mathematics, go send a child to the shop. Go and buy maybe airtime. Give that child R10. I want R5 airtime. That child must know that the R5, it’s R10 – 5. So they must give me R5. That’s mathematics. In everything. Even when they are cooking, they do mathematics. They take 5 ml of something, that’s mathematics **(FG 2:2)**.

It is interesting to note that Mr M was the only participant who mentioned that he was not rigid in his class and wanted to move away from the perception that "mathematics cannot be fun":

> We have a lot of rules for these kids, sometimes learners need to express themselves, math is like music ... they need to show what they know and discover what they don't know. Do not spoon-feed them, no, they must grow on their own, to be able to solve their own problems **(MI: 5)**.

All seven of the participants in the interviews mentioned the relevance and application of mathematics in everyday life experiences. For example, Mrs B emphasised the importance of mathematics in career prospects and expressed her beliefs as follows:

> I think it is just a good stimulation for the brain. Gets them to work hard, have a mental workout each day, there are certain sections that we do that are so relevant like the financial maths and the statistics that no matter what career path they choose, they'd use that, especially the financial maths, they learning a lot from that now. But it also just for the learners it keeps their options open in terms of what they want to study in the future, and think it is a good subject **(BI:2)**.

It is encouraging to find that the overall beliefs and attitudes of the participants in terms of the value of mathematics correspond with Hom's (2013) description of the extent of mathematics in the world around us (as cited in Van der Nest et al., 2018, p. 2):

> Mathematics is the science that deals with the logic of shape, quantity and arrangement. Math is all around us, in everything we do. It is the building block for everything in our daily lives, including mobile devices, architecture (ancient and modern), art, money, engineering, and even sports.

Despite the participants' positive beliefs and attitudes in terms of mathematics, and their intended aims and objectives, the question arises as to how much these values are in line with how these teachers perceived their own practices. Future studies on this value-practice gap are therefore recommended. From the open–ended questionnaires, interviews, observational field notes and reflective sheets, I could establish that the majority of the participating teachers seemed to have high expectations for their students, despite several challenges, which will be further discussed in Section 4.4.

The above results also confirmed how the teachers' beliefs regarding the "teaching and learning mathematics" and their views of the "nature of mathematics" impacted the selection of content and emphasis on styles of teaching, and on the modes of learning as suggested by Ernest (1998, p. 30) (see Section 2.4.3).

4.4.1.3 Assessment Knowledge

A major focus of CAPS is to provide guidance to South African teachers on how to use the different types of assessment. Formative assessment and its purposes are clearly outlined in the CAPS document. According to CAPS, the main purpose of formative assessment is:

> To aid the teaching and learning processes, hence assessment ***for*** learning. It is the most commonly used type of assessment because it can be used in different forms at any time during a Mathematics lesson, e.g. short class works during or at the end of each lesson, verbal questioning during the lesson. It is mainly informal and should not be used for promotion purposes. The fundamental distinguishing characteristic of formative assessment is constant feedback to learners, particularly with regard to learners' learning processes (DBE, 2012, p. 154).

For the AETL project to impact teachers in such a way that they would be willing to implement assessment for learning (AFL) activities and adapt their instructional practices, I first had to explore the teachers' understanding and perceptions of formative assessment.

The most striking observation to emerge from the data was the general lack in the teachers' conceptualisation of the different types of assessment despite the prescribed guidelines by the CAPS document (DBE, 2012) (see Section 2.6.1).

During the two information sessions at the beginning of the AETL project, all nine participants were engaged in discussions regarding the purposes of formative assessment in general and how they relate to mathematics learning. All of the participants received a set of curriculum-aligned worksheets together with memorandums and explanatory notes related to mathematics learning (see Appendix A).

Despite the participants' engagement with formative assessment strategies during the initial two workshops at the beginning of the AETL Project and the implementation of the worksheets, they defined formative assessment in a variety of ways.

I explored the teachers' understanding of the formative assessment process considering Wiliam's (2007, p. 191) broad definition of formative assessment: "Students and teachers using evidence of learning to adapt teaching and learning to meet immediate learning needs minute-to-minute and day-by-day."

When I asked the participants to define formative assessment during the initial stages of the study, most of the participants (six of the nine) in the open-ended questionnaire confused formative assessment with summative assessment and three of the six defined it as "formal evaluation" **(QRS:1).**

As the study progressed, I repeated the question in the individual interviews, and again it seemed as if a deeper conceptualisation of formative assessment still eluded the participants. Four of them confirmed their confusion between formative and summative assessment. Mr N's conceptualisation during his interview reflected a general misconception:

> My understanding of formative assessment is like … it is a formal assessment. Formative assessment is the assessment that contributes to the promotional mark of a learner in a grade. That is my understanding of formative assessment. You know, summative assessment in my understanding like a … is the daily assessment that … we are doing in a class. You go to a class after what you taught. Then you do the summative assessment **(NI: 3)**.

Only three of the interviewees defined formative assessment at the classroom level as consolidating with learners during the learning process. The following definitions by the participants illustrated an evolved understanding of formative assessment as the study progressed.

> They [referring to formative assessment] are formal and then you need … mmm … they are structural**.** Structured. In a way…. I think they are more important than maybe assignments because there you want to get whether… **you want to get the knowledge of the learner (MI4)** (emphasis added).

Mrs F clearly illustrated that she understood formative assessment to be informal, as shown in her instructional practices:

> Formative assessment is **informal assessment by means of worksheets** and summative assessment is based on formal class tests, term tests, and examinations **(FI: 1)** (emphasis added).

Mrs B revealed her uncertainty in conceptualising formative assessment:

> The summative would be at the end, at the end of the section we try and test at the end of every chapter in order to see how much the learners have grasped or where they are in terms of that section and then the formative … **I am not sure?** We … because what we do mainly summative and then **we do the diagnostics** which I guess is the baseline? **(BI: 5)** (emphasis added).

These results seem to be consistent with other studies that have found a strong disconnect in mathematics teachers' understanding of the different types and purposes of assessment used in their classrooms (Bell, Leusner & Sondergeld, 2010; Soto & Ambrose, 2016; Stiggins, 2008) (see Section 1.5.1).

4.4.2 Existing formative assessment practices

In this section, I elaborate on the teachers' understanding of formative assessment by exploring their day-to-day practices. An analysis of the participating teachers' existing formative assessment practices suggests that they were using a variety of assessment strategies to identify their learners' current status in the learning process.

I analysed the teachers' formative assessment practices by referring to Black and Wiliam's (2009, p. 9) definition of formative assessment as a process occurring in three stages:

1) Evidence elicitation of student learning,

2) Teacher interpretation of the evidence elicited, and

3) Using the evidence and interpretation for subsequent instruction.

In the open-ended questionnaire, I asked the participants how they assessed their students' learning in mathematics, and their responses showed that most of them used assessment resource banks such as previous question papers. Seven of the nine teachers responded that they mostly used previous question papers as pre- or post-tests to 'grade' their learners' knowledge during instructional practices. This is an indication that they mostly applied summative assessment strategies (assessment of learning) to elicit evidence of student thinking in class. Only two teachers in the survey indicated that they mostly used practical tasks and observations to assess student learning in class.

In the focus group discussions and individual interviews, however, the teachers reported that they used a variety of assessment strategies to determine the level of understanding of their learners on a daily basis. The results of these interviews and the group discussion formed part of Stages 2 and 3 of the data analysis process. As such, I worked on the assumption that some of the participants, as denoted below by reference, had previously engaged with the strategies during the AETL project on some level and in some form.

In relation to the assessment strategies discussed in these interviews and the focus group discussions, the teachers mentioned the different levels of formative assessment practices that they used to elicit evidence, interpretation of the evidence and subsequent instructional practices, as described by Black and Wiliam (2009). For example, marking of homework, oral and written answers, class tests, peer assessment and practical tasks seemed to be the most popular formative assessment practices employed by the teachers on a daily basis.

4.4.2.1 Marking of homework

It emerged that marking homework was the most common assessment practice to elicit evidence of student learning. Mrs B's description in the interview is representative of what the majority of the teachers (eight out of nine) in this study viewed as practising formative assessment on a daily basis:

> Well, you give them homework and then you mark their homework the next day. And then obviously, you will ask them question, and when they say: we didn't understand this one and that one, then you do it with them. But that's how every lesson goes, you always start each lesson with marking their homework and then from their thoughts on the homework or their feedback, then you are able to tell whether you can move on or must we spend more time **(BI: 4)**.

Mrs B's description of this classroom routine encompasses all three components of effective formative assessment as described by Black and Wiliam (2009, p. 9). Her response indicates that she first elicited evidence of student learning by marking the homework and by asking questions. Secondly, she then interpreted the evidence and responded by giving immediate feedback, and thirdly, she made adjustments to her subsequent instruction by spending more time on a topic if her learners indicated that they did not understand.

In contrast with the majority of the teachers, one participant indicated that "he realised that homework is not the best way to assess learning" **(NI:5)** and that he preferred that his learners finish the work in class. He explained why it was important for him to monitor his learners' homework:

> Then they will just copy from one learner's book. The whole class has copied one sum from one learner … I came to a point where I no longer give them more homework. I can just give them one sum as a homework. Then … I come to a class then they sit and write … I intended to give them as homework but then they write that as part of a classwork, which I monitor **(NI:5)**.

4.4.2.2 Oral and written answers

Another strategy most commonly used by the participants to elicit and use evidence of student thinking was oral and written answers. Five of the seven interviewees elucidated how they normally demonstrated how to solve example problems on the board. They would then walk around the class while the learners solved similar problems in their workbooks. Two teachers explained that they analysed learners' written work and observed oral presentations of their problem-solving skills. For instance, Mr M from School A encouraged his students to explain their written answers on the blackboard in a way that could be understood by their classmates. Mrs B also supported the involvement of all her learners in identifying weaknesses from the learners' written or oral responses. She illustrated how she used the evidence and interpretation for subsequent instruction:

> And then you have to like really look at what you did and then try and teach it in a different way. If you can't then you ask like another learner who understands, can you explain it to … maybe they will understand from their peers **(BI: 8)**.

Posing purposeful questions seemed to be a useful assessment strategy for diagnostic purposes. It was also used as evidence and interpretation for subsequent instruction by most of the teachers in this study as eight of the teachers mentioned that they continuously asked questions while teaching. For example, in the third focus group meeting, Mr N emphasised that he asks a lot of questions while he walks around the class to assess learners' sense-making and understanding of mathematics. After prompting Mr N to elaborate, he explained why it was important to pose purposeful questions when orally assessing learners' level of knowledge:

> Because normally, we question them to get their understanding. Sometimes you might find that one learner might understand things differently from that learner. In their understanding sometimes it can be faulty or wrong. Learners' understanding of a particular concept is wrong, though the learner understood it in the way he or she has interpreted it, is different. We ask questions for the purpose of finding out does he understand the concept correctly? **(NF3:6)**.

At the time of the interview, it seems as if Mr N may have engaged with Silver's (2015) article, which was given to the participants during the first focus group meeting. Silver (2015, p. 33) proposes that purposeful questions can be effective "to assess and advance students' reasoning and sense-making about important mathematical ideas and relationships."

Overall, most of the teachers indicated that they walk around in class, asking questions to make a quick analysis of where the learners are in the learning process. This informal way of assessment not only provided learners with immediate feedback:" I don't have to wait for tomorrow to help them" **(EI:3)**, but is also helpful in supporting adaptive instruction and social construction (Torrance & Pryor, 1998)

4.4.2.3 Class tests

Another common strategy for eliciting evidence of student learning was the use of class tests. The majority of the teachers mentioned that they assessed their learners' knowledge of a certain topic by writing small class tests to monitor their progress.

During the second focus group meeting, Mr O described how he used a variety of different text books to set class tests as a formative assessment strategy:

> Like I use different text books … And that is like we normally do, teachers set questions based on every single chapter. We see how the textbook asks the questions and then we pick some questions from the textbooks **(OFG2:2)**.

Mrs F and Mrs D, teachers from the same school, used standardised (the same test for all the Grade 9s in the school) class tests on a weekly basis to monitor the progress of all the Grade 9 learners. These tests were usually set by one teacher and all of the Grade 9 teachers would take turns to set the test. According to these teachers, the evidence elicited from the class tests assisted them in making adjustments in their instruction and it broadened their assessment knowledge.

Although most of the teachers in this study regarded class tests as an effective method of formative assessment, five of them indicated that they did not use class tests as frequently as they should due to a lack of time (time constraints are addressed in Section 4.4.3). Mrs B voiced this common frustration:

> We don't test as often as we'd like, like whatever type of test it is, because of the time limit we have in our teaching. So as teachers, we always want to check whether learners are up to date and how much they know … it is like to spend 10 minutes of a lesson on that, is a lot for us, and so we don't do it, I don't know if it is a weakness but we don't do it as often as we should **(BI:5)**.

Another important finding across the dataset was that all the teachers indicated that they made use of previously set class tests or questions from the prescribed textbook as a formative assessment strategy due to time constraints.

I also observed that class tests were often marked by the learners themselves or their classmates. Two of the teachers provided me with evidence of written class tests marked by their classmates. Mr E, for example, explained that he frequently applied peer assessment in an effort to "save time" **(EI: 4)**.

Mrs F explained that she asked her learners to mark each other's class tests to "involve the learners in the lesson" **(FI: 5)**. Mrs F's explanation may suggest that she frequently involved her learners in assessment activities to review and reflect on the learners' level of understanding, as proposed by Broadfoot et al. (1999).

4.4.2.4 Peer assessment

Mr M was one of only three teachers who mentioned the importance of collective learning between teachers, learners and peers during the formative assessment process, as described by Black and Wiliam (2009. P. 5) (see Section 2.6.3.1). He explained in his interview how he created opportunities for students to engage in peer- and self-assessment practices to promote learning:

> I like using something like co-operative learning. I like learners teaching themselves. Eh … because I like learners play whilst you teach. I like learners doing … sort of setting their own miniature questions to each other **(MI: 6)**.

Mr M was also the only participant who claimed that he regularly involved his learners in self-assessment practices by allowing them to set question papers for each other. The learners were divided into groups, provided with textbooks and previous question papers to create structured questions in their own words. He explained his reasons as follows:

> You develop and teach them to how to develop questions, this exposes the learners to different ways of questioning and answering so to stretch their minds and thinking **(MI: 8)**.

This finding is supported by Broadfoot et al.'s (2007, p. 7) research, which shows that self-assessment practices can be seen as an effective strategy to inform the learning process as it helps learners to know and to recognise the standards for which they are aiming. Peer-assessment, as implemented by Mr M, can also be seen as a strategy to "activate students as learning resources for one another" (Leahy et al., 2005, p. 19) (see Section 2.6.3). This interaction and new knowledge constructed during peer assessment activities between students and teacher also coincide with social development theories (Vygotsky, 1978).

In contrast to Mr M's remarks and implementation of peer assessment strategies, Mr N expressed that he strongly believed in collecting individual evidence of student learning. After prompting Mr N during his interview, he explained how and why it enabled him to elicit and use student evidence to inform learning:

> I just give them questions, then I move around to check that every learner is doing his or her own work without being assisted. Because what I am interested in is to

> get the learners' understanding, not generally … the learners' personal understanding **(NI: 5)**.

Mr N's explanation of the collection of individual evidence supports the productive struggle in learning mathematics as advocated by Silver (2015) (see Table 2.2, Section 2.5). The last part of Mr N's observation also confirms the association between "activating students as owners of their own learning" and assessment for learning as described by Black and Wiliam (2009, p. 5) (see Section 2.6.3).

4.4.2.5 Practical tasks

From the open–ended questionnaire, three teachers indicated that they regularly assessed their students' learning by means of practical tasks. In addition, four of the interviewees described how they employed practical tasks to assess their learners in class and how they engaged their students in "making connections between mathematical representations to deepen their understanding of mathematics concepts and procedures" as suggested by Silver (2015, p.32).

Mr C and two other interviewees gave similar examples of how they approached financial mathematics with the use of practical tasks to gather evidence of student learning:

> Go and check the prices of these things. List the items there in Shoprite, there are prices. Ask even if you come across the manager. What was the price last year if they can remember? Then calculate on your own the percentage increase. Or even use your mother in fact. Ask them, last year how much was a loaf of bread. Or two years later how much was a loaf of bread. Calculate the percentage of increase. That's mathematics. You must … when you go to other subject there is economics like inflation. That's how you teach them to go and do inflation. Go to the shop practically, see today. Some parents can have old newspapers. Old advertisement. Bring that and we check the price. This year it was so much, after two years it's now this. How do you do it? You take now the compound interest from here and show them – here is a compound interest formula **(CI: 8)**.

Only one participant mentioned how she integrated technology to assist her in her classroom assessment:

> There is a programme I have on my laptop. It's called 'ten quick questions pro'. I don't know if you have it. Like that's a nice way of… you choose a topic and you put the timer on. I always use it at the beginning of the year just with straight forward multiplication and I give them five seconds per question so it flashes and you see ten answers and then I take it to four seconds three seconds two, just to get them awake.

The selection of formative assessment practices mentioned by the teachers in the above section support Borko and Putnam's (1995) argument that teachers' thinking and classroom actions are directly influenced by their knowledge systems. The argument is that teacher cognition has a powerful impact on their teaching through processes such as the selection of content and the emphasis on styles of teaching and modes of learning (see Section 2.4.3.1).

4.4.3 Influences on teachers' assessment and classroom practices

One of the objectives of this study was to explore and analyse the aspects that may have influenced the participating teachers' realities and decisions regarding their formative assessment experiences.

Three broad themes emerged from the analysis of the complete dataset as having the most influence on the participants' assessment and instructional practices: 1) The influence of systemic testing; 2) Educational Policies, and 3) School context.

4.4.3.1 Influence of systemic testing

The influence of systemic testing on the participating teachers' assessment and classroom practices was evident throughout this study. It was clear from the focus group discussions and interviews that most of the participating teachers invested a lot of time and energy in teaching towards the ANAs.

Surprisingly, only one participant in the open-ended questionnaire indicated that external evaluation systems (e.g. the ANAs) had largely influenced his/her formative assessment practices in the last few years **(QRC3:2)**. In response to the question: "What teaching approaches/practices would you say have been very effective in improving your students' learning in mathematics?" the same participant responded with: 'teaching to a test or task and group activities' **(QRC3:7)**.

However, in response to how they assessed student learning in mathematics, all of the participants indicated on the same questionnaire that they predominantly used tests from assessment resource banks, such as previous question papers (e.g. the ANAs), for summative assessment purposes. These results clearly contradict the purpose of assessment for learning as described by Wiliam (2007) (see Section 4.4.1.4). A possible explanation for this might be that the open-ended questionnaire was conducted before the teachers were actively engaged in the refinement and implementation of the formative assessment strategies as proposed in the AETL project. This discrepancy may therefore be related to the respondents' general lack of assessment knowledge, as previously discussed in Section 4.4.1.3.

As the AETL study progressed, data from the focus group discussions and interviews also revealed that the primary influence on the teachers' formative assessment classroom practices seemed to be external evaluations such as the ANAs and previously set summative assessment question papers.

In accordance with the social constructivist approach during the focus group meetings, the participants were encouraged to engage in dialogue and reflective discussions as influences and issues related to their formative assessment practices emerged. The results obtained from the focus group discussions indicate that, in general, the participants experienced systemic testing as having a primarily positive influence on their practice. A variety of reasons were given during the focus group meetings in support of systemic testing such as the ANAs.

During the first focus group discussion, one of the participants claimed that systemic testing assisted him to align the curriculum with his instructional planning:

> If it was not for ANAs, most teachers will fail to complete the curriculum. **(OF1: 4)**.

Another participant made an interesting statement that systemic testing, such as the ANAs, contributes to the improvement of mathematical language:

> We don't hate ANA, it keeps us on our toes, and we stay focused. It also brings in the improvement, language improvement, mathematical language improvement, the way you must set questions, that we must teach, as we teach we are focused. That is why whatever we teach we look into ANA questions, the similarities and give the learners the questions **(NF1:4)**.

Mr N's remark about the way in which systemic testing was used to compare the questions with his own assessment were supported and agreed with by all the participants in the meeting. On my observational field notes during this meeting, I wrote that the teachers seemed to "constantly express the need for standardised and quality assessment questions. It appears as if they place a very high value on the systemic questions and it seems as if they have a lot of confidence in the quality and standards set by the ANAs" **(OFN: F1)**.

The influence of systemic assessment on the assessment practices of the teachers emerged again during the third focus group meeting. In discussing assessment resources, such as the availability of TIMSS questions, Mr M, the principal, responded with a sense of urgency in his tone as follows:

> I need to get these questions [referring to TIMSS questions]. Our aim is to make them [referring to the school's forthcoming internal examination] challenging **(MF3:5)**.

Mr M's comment also illustrates the influence of systemic tests on his own summative assessment practices.

Although the focus group participants' views on systemic assessment were mainly positive, the influence of systemic testing on the teachers' sense of accountability and the school's academic programme became evident in the third focus group meeting. Mr M was not only the principal of School A, but also a Grade 9 mathematics teacher. It is not usual in such a large school for the principal to teach, however, Mr M insisted that he should take a Grade 9 class because of the stresses around the ANAs at Grade 9 level: "teachers feel exposed by the ANA since the ANA results reflect on their performance as teachers" **(MF3:10)**. He explained that he held an additional weekly class on Saturday mornings for his Grade 9 class in preparation for the ANAs due to the normal disruptions during the week occasioned by visits from departmental officials or parents.

The influence of systemic testing on School A's academic programme was also evident in the way Mr M involved his Grade 9 staff in preparation for the forthcoming ANAs:

> What can we do? We are writing ANA on the 18th September. We are only left with 30 days if I am not mistaken. Are we on the right track? From here let me tell you what you are going to do. At one point we are going to call **X** [referring to the Head of the Mathematics Department, Mr L]**,** everybody, this one is going to tackle factorisation, this one is going to tackle maybe geometry … maybe triangles … we give each other work like that. (**MF3:10)**.

It is interesting to note that only one participant from the complete dataset questioned the value of national systemic testing in contributing to the acquisition of the necessary mathematical skills and knowledge of learners as they advance from Grade 9 to Grade 12. During the first focus group meeting, Mr O made the following remark: "You may find the learners get good results in ANA in Grade 9 but fail to do well in Grade 12" **(OF1:4).**

Although the comment made by Mr O was not discussed in this focus group meeting, it provided support for further research into the use of the results of large scale assessments by schools and teachers. It can therefore be assumed that Mr C's comment is a call for relevant policy makers to revise the way in which the results of the current systemic tests are reported. A recent study by Kanjee and Moloi (2016) supports this call for further research as they identify key shortcomings in the current reporting framework of the ANAs. Their findings indicate that the current reporting framework of the ANAs "overestimates the percentage of learners classified at the lowest performance levels and underestimates those in the next category" (p. 29). They suggest standard setting procedures to develop meaningful reports to assist schools and teachers by identifying specific learning gaps to improve the results of large-scale assessments (Kanjee & Moloi, 2016).

Another recurrent concern amongst the teachers in the focus group meetings was that the Grade 9 learners did not take systemic assessment seriously. Mr N attributed this concern to the fact that Grade nine learners know that the scores they obtain in the ANAs will not contribute to their promotional marks:

> One thing I hate about ANA; it doesn't add value to our promotional marks. It is an external assessment that is fine. We must have it as in the Grade 12s. But it does not add value in the learners' promotional mark **(NF1:4).**

Similar views on how systemic assessments influence teachers' assessment practices surfaced in the interviews. In response to how the ANAs influenced his instructional and assessment practices, Mr C exemplified the perceptions of most teachers on the influence of systemic assessment on school reviews. He made the following statement: "Schools are so results oriented these days, we need to adapt our practices." **(CI: 14)**. I prompted Mr C to elaborate on how he adapted his instructional practices to integrate systemic assessment to inform student learning. He explained how the ANAs influenced his daily instructional practices and how he aligned the prescribed textbook with previous ANA questions:

> If you go to the first chapter, if I had to take the ANA book and the maths book. We are talking in differences in numbers, you will see there will be number patterns in ANA and in the textbook, right. I teach them with my maths text book, and give them work from my maths textbooks, the homework I will give them is from the ANA. So that maybe it is the same concept but being asked in another way **(CI: 15)**.

Mr C's response also illustrates the relationship between formative and summative assessment in using the same evidence for both purposes to improve learning, as suggested by Harlen (2012) (see Section 2.5.1).

All of the teachers in the interviews perceived systemic assessments to be setting benchmarks against which teachers measure their standards. One participant summarised the general feeling of how the standardisation of the ANAs influenced their teaching and learning experience:

> Whenever you are doing anything, you must be able to gauge yourself. Put yourself on a scale and compare yourself with something. It can be knowledge, it can be the way you do your practical work, you can be able to compare yourself with somebody next door, it can be a school next to you, and it can be international. It can be provincial. You just compare yourself: where am I? How is my knowledge stretched in a particular topic compared with the others? And then once you get … your standard you say, okay, I am at this level, you try to improve on that level, okay you try to go to their level **(MI: 3)**.

However, one participant made a contradictory statement in his interview as he experienced the current systemic testing as not being CAPS-aligned: "I prefer to stick to CAPS … ANA is just an assessment … I give it to the learners after teaching, the manner in which they set the test, it's not … it's not CAPS aligned" **(NI: 10)**.

Another participant explained how he used a variety of previously set summative assessment tasks for formative purposes. He also elaborated on how this influenced the way in which he planned his instructional practices:

> Basically, I have to first of all, I have to see a content which I am going to teach them. Or I get that from the test to say which things I am going to test my learners on. What should they do for them to tackle my questions? What should they know?
>
> **Interviewer**: Now that test, where do you get that test?
>
> Uhm… from a variety of sources. I can get it from the textbook, I can get it from the … those … uhm… revision or past exam papers, I can get them from many. I will go and get the last year final exam. Maybe take the first part of the question and give them. Maybe question 1 and 2 **(CI: 4)**.

Two of the interviewees, Mrs B and Mr C, mentioned that the 2015 ANAs were of a good standard. They also indicated that they felt confident in using it for both summative and formative purposes to enhance their learners' exposure to external assessments. Mrs B, however, complained that policy makers should reconsider when they were supposed to write the ANAs. This timing seemed to be having a negative influence on the school's academic programme. She suggested the following:

> My view, okay … as a department, as a maths teacher, we love the actual ANA question paper. We believe it's of a good standard, it's levelled correctly and we'd love to write it every year, but we just feel that it should be written at the end of the year as the Gr 9 November exam, like the Matrics [Grade 12's] write their final exam, they must write it at the end of the year. So that is a positive … so that all the curriculum has been covered **(BI: 13)**.

The same participant, however, admitted during the second meeting (Stage 1) that she felt guilty that she would often "teach to the test, my teaching skills are in the same format as ANA's" **(S1:2)**. Confirming the dominant influence of systemic testing on her classroom practices, Mrs B also mentioned that her school not only placed emphasis on achievement in the ANAs, but also on the Grade 12 (National Senior

Certificate) examinations. She explained how this systemic type assessment affected the learners:

> Our Matrics [Grade 12 learners] this year I think actually got shocked after their paper 2 exam because it was nothing like it's been previously. And we're all guilty of doing it, it's like past papers, past papers, past papers… obviously because that's the resource that we have for revision, but when they get something now and these questions that they've got in the exam was so different to what's been… like then… they didn't do well, and they were very upset.

Alternatively, two participants in the interviews mentioned how the use of ANA questions assisted them in their questioning techniques. For example, Mr M would give his learners "a particular type of question from ANA, then you work with your learners and you develop and teach them how to develop questions like this format" **(MI:8)**.

Mr C specifically mentioned how he integrated ANA questions into his practices to accustom his learners to the level of the questions and how these are asked in systemic tests:

> Right uhm … what I do is I use these exams for instance I can take these ANAs right, go through them, I see the level of my learners, where is the area of difficulties and to what level are the questions so that I equip my learners with such questioning techniques. If a child can answer the higher order questions more, so yes, I know that uhm… I would produce results at the end of the year **(CI: 15)**.

Another example of the major influence of systemic testing on the teachers' assessment and instructional practices was evident in Mrs F's interview. In response to how she usually assessed her students' learning, she responded that her experience as a marker in the National Senior Certificate (Grade 12) examinations provided her with "valuable guidelines on important content knowledge and how to structure my own assessment and planning" **(FI: 25)**.

Despite the overall positive influence of systemic testing on the professional development and formative assessment practices reported by the teachers, it comes, however, with its own political tensions and unintended consequences. At the time of the study, the largest teachers' union, SADTU (South African Democratic Teachers' Union) refused to administer the ANA tests because the effectiveness of the ANA was in dispute between the five major teacher unions and the Department of Basic Education (Nicholson, 2015). Union members were advised to boycott the ANAs but the Minister of Basic Education, Angie Motshekga, showed a willingness to respond to the union's concerns when she announced that the ANAs would be postponed but that the department was firm that they would continue with the tests. Most of the teachers in this study indicated that they were members of SADTU. However, they all indicated that they wanted to proceed with the ANAs despite the politics involved.

The above findings illustrate that the teachers placed a high value on their students' assessment scores and were reliant on systemic assessment to inform their instructional practices. However, the above responses also support the fact that the teachers in this study seemed to be very much dependant on summative assessment resources such as previous exam papers or systemic assessments such as the ANAs or TIMSS. Teaching to the test, therefore, seems to be very influential in most of the participants' planning of their instructional practices and their formative assessment strategies. This feature of instructional practice supports assumptions by other scholars that 'teaching to the test' could be a major factor causing teachers to narrow down the intended curriculum (Popham, 2001; Van der Nest et al., 2018).

4.4.3.2 Educational Policies

a. Curriculum (CAPS)

A recurrent theme from the dataset was that curriculum reform played a significant role in the participants' instructional and assessment practices. As previously mentioned) (see Section 1.2.4), several changes in the South African curriculum have been made since the fall of apartheid in 1994. Teachers were introduced to Outcomes Based Education (OBE), the Revised National Curriculum Statements (RNCS) and shortly after that a change in the national assessment policy (CAPS).

The influence of the changes in curriculum and assessment policy on the teachers' assessment practices is also evident in this study. The participants reported that the curriculum statements and assessment policy as outlined in CAPS have had varying effect on their work.

Most of the participants across the dataset shared a common view that CAPS provides more guidelines and objectives related to assessment practices than previous curricula. Five of the nine participants in the questionnaire indicated that changes in national assessment policy had positively influenced their formative assessment practices in the last few years. Two of the five respondents indicated that teaching from the curriculum statement resulted in improved achievement for their students, especially for the English second language learners. In response to how this impacted their teaching or assessment practices, they responded with: “it helps improving my knowledge” **(QR2)**, and “I have more time for revision” **(QR5)**.

These findings support Mohlala’s (2011) view in an article in the Mail and Guardian that CAPS lessens the administration burden of teachers by incorporating more time focusing on teaching, learning and assessment. However, Mohlala (2011) cautions teachers to manage their time wisely to address other time-consuming activities such as additional moderation, school-based assessment, recording and reporting of assessment.

Mohlala’s warning was realised in this study as six participants in the questionnaire indicated that the revised curriculum and assessment policy had had a great impact on their administration and record keeping. One participant commented that the “weekly planning according to the curriculum is not flexible enough to allow for planning to meet individual students’ needs and interests” **(QR4)**.

One of the interviewees expressed his positive view towards CAPS and how he positioned himself in terms of the changes in policy. Mr O explained:

> With CAPS yes. That’s what we have been doing for the past two years, so these you know… it’s just only the terminology which was changed. Not a lot of things were changed. It’s only the curriculum, it’s of that’s the one which was changed. But the concepts are the same. It is still mathematics. It is as far as I am seeing it assessment is improving **(OI: 2)**.

Mr O indicated that CAPS provided him more specific guidelines on assessment and as a result, positively influenced the way in which he perceived assessment.

Another participant, Mr C, elaborated on how the CAPS guidelines influenced his planning and assessment practices:

> Uhm. When you are developing an assessment you first off have to know the contents which you are going… the concept which we are going to test, right, then from the concepts you can now maybe see if you have covered the content and maybe plan to cover for that in another way, it also promotes teaching to a test. Where you have first of all to teach the concepts then test it the end of the concept **(CI: 3)**.

It is evident that Mr C experienced the guidelines provided by CAPS with regard to subject content as clear and well-delineated as he described how it informed his knowledge of the content to be covered. However, further analysis of his above-mentioned comment revealed how his interpretation of the curriculum influenced his teaching and assessment practices. The narrowing down of the curriculum can be clearly seen in his remark "… it promotes teaching to the test".

b. Policy on professional development

As mentioned in the literature review, the National Policy Framework for Teacher Education and Development Policy (DoE, 2007) and the South African Council for Educators (SACE) expect that all practising teachers have to earn Professional Development (PD) points by attending accredited PD activities that address their professional growth needs (Section 2.2). The intention of this policy is to particularly focus on the teacher as the key to improving learner performance. Teachers therefore need to be appropriately equipped to meet the challenges and needs in a reformed democratic education system (DoE, 2007, p.4).

It was therefore not surprising that three of the respondents in this study indicated in the questionnaire that this mandate to participate in professional development activities had had a major influence on their professional development and assessment practices.

In order to deepen my understanding of the participants' experiences and perceptions related to effective professional development initiatives, I had to consider the quality of professional development experiences to which they were previously exposed. This also provided the teachers with opportunities to describe themselves as learners and reflect on their motivation to engage in PD programmes.

It was therefore significant to ask the question: ‘In what way has earlier engagement in professional development activities helped/not helped you in teaching mathematics?’ Interestingly, all nine participants in the questionnaire only shared their experiences of PD activities that helped them to meet educational policy requirements, and that assisted them to address their professional growth needs. There was not a single response to the part of the questionnaire where the participants were asked to indicate which PD activities did not help them in contributing to their teaching and/or assessment practices.

The responses from the questionnaire further revealed that the teachers mostly valued PD programmes of a collaborative nature, designed around subject-specific content that is embodied in the curriculum standards. The following two responses from the questionnaire illustrate the high value that the teachers placed on PD programmes that focus on cooperative learning opportunities in which they can share assessment strategies:

> “My colleagues and I appreciate advice from other mathematics teachers and experts” **(QR7)**; and

> “Other teachers who are willing to assist and share knowledge and resources assisted me a lot” **(QR4)**.

Most of the questionnaire participants (five out of nine) also indicated that they valued PD activities that are structured around curriculum goals to deepen their content knowledge and knowledge about how to teach and assess specific content. One respondent indicated:

> “The most inspiring PD activity I attended was when the author of the CAPS based textbook we used, offered a workshop on how to use the textbook” **(QR2)**.

Another participant also emphasised the value of curriculum-guided PD activities and explained how it influenced her instructional and assessment practices:

> “Curriculum-based activities equipped me with new skills to enhance teaching and learning as well as knowledge content” **(QR3)**.

The teachers' explicit views on their professional learning needs suggest that they are willing to engage in PD activities that are more practical in nature and aim to meet their specific needs.

The constraining influence of educational policies is being elaborated upon in Section 4.4.4.

4.4.3.3 School context

One of the essential findings in this study was the role that school context played in determining an understanding of the teachers' professional development experiences, especially when implementing formative assessment practices.

It became evident from the dataset that some of the teachers experienced the context of their schools to be challenging while others experienced their context as supportive when they engaged in professional development and assessment activities.

One teacher confirmed in her interview the positive influence of her school's policy on her assessment practices, as well as her professional development experiences. She explained that she and her colleagues actively participated in conversations about issues regarding students' learning goals, assessment and teaching practices in her school:

> As a maths department of 14 educators, majority of our professional development happens internally and from learning from each other. When it comes to like exam papers and we set an exam paper we always … we spend like two maybe three hours discussing … like the questions how the learners might ask, maybe we come up with a different answer or we'll think about like the wording, but we learn from each other all the time. That is when we learn a lot, is when we discuss exam papers, when we're marking and there might be learners who have done that a different way and come up with the same answer **(BI: 4)**.

Unfortunately, this teacher also indicated that these types of discussions were limited to examination times and that most of the time, their departmental meetings were based on administrative issues. She did not view this as being a major contribution to her professional development and formative assessment experiences.

Teachers D and F were employed at the same school. Both of them indicated that assessment discussions during their subject meetings informed their assessment practices. Mrs D gave an example of how the school's management, based on school reviews, "[had] incorporated more time for revision in the year planning" **(DQR:4).** Even though these two teachers seemed to be very appreciative of the support from their principal and colleagues as they engaged in PD activities, they expressed the need for external support from "knowledgeable subject experts from outside, for guidance in our assessment practices" **(FI: 3)**.

Mr C, alternatively, described his colleagues as less supportive and reluctant to discuss assessment practices during their departmental meetings. He explained that he expected his colleagues to be more involved in discussions when the formative assessment strategies (worksheets) were introduced to them. However, "they were saying it's more work, it's more work, maybe they didn't know exactly how to implement it" **(CI:25)**. According to Mr C, his colleagues did implement the worksheets in their classes or used them for summative purposes such as class tests, but he felt that "they end up saying it's more work, as a result I ended up doing it alone" **(CI:25)**.

From the above results, it can be seen that systemic testing, educational policies and school context influenced these teachers' experiences related to their formative assessment and instructional practices. These results are consistent with those of Duncan and Noonan's (2007) large scale study, which revealed that mathematics teachers' decision making in assessment is primarily influenced by external factors such as large-scale assessments, classroom realities and internal policies (see Section 2.6.6).

The next section will elaborate further on the challenges and constraining factors that the teachers experienced in the current educational context while pursuing quality education for their learners.

4.4.4 Constraining factors in formative assessment practices

Opfer and Pedder (2011) suggest that "a teacher's individual learning orientation system interacts with the school's learning orientation system to understand and explain why and how teachers learn more effectively when learning opportunities are created within their school environment" (p. 393). It is thus important to understand that there are different ways in which elements from the external domain interact with each other, with contexts, and with the characteristics of individual teachers to ensure effective teacher learning.

This study sought to understand the teachers' formative assessment experiences within their classes, attending to the different needs of learners, the school and intended curriculum. This study thus aimed to address and identify the barriers to teachers' implementation of effective formative assessment strategies.

The teachers identified the following constraining factors in their pursuit to optimise teaching and learning experiences in mathematics.

4.4.4.1 Learners' socio-economic backgrounds

Many learners in South African townships and rural areas come from families affected by poverty, hunger and parents with little or no education themselves (Jojo, 2017). It is therefore not surprising that one of the participants in the questionnaire expressed the need for "cost-effective resources which provide opportunities for the deepening of mathematics content knowledge in areas that are weak" **(QRE:4)**.

Two of the teachers from School A mentioned (in a focus group meeting) that most of their learners were from poverty-stricken areas, and that some of the learners travelled great distances to attend this school. According to Mr M, these learners were determined to get out of their current circumstances through the perceived quality of education in mathematics, science, and technology offered by the school:

> I have 80% of my learners come from the informal settlement. If you look at the conditions there, it is very, very poor stricken areas. Very, very poor, but some of them are engineers today **(MF2:2)**.

Despite the difficult socio-economic background of the majority of the learners, as mentioned by the participants from School A, all four of the teachers had high expectations for their learners. A mutual perception expressed by the teachers from School A was that learners believed that the school offered quality education, which inevitably led to an increase in the size of the classes **(FG2)**.

Mr C and Mr E (both from quintile 2 schools) also mentioned that the majority of their learners were from poor socio-economic backgrounds, which made it difficult for them "to incorporate technology in their classrooms" **(EI:4)**. They expressed the need to be supported with resources such as visual aids and "proper training in technology to assist their learners' needs, especially in geometry" **(CI:23)**.

The above results reflect the relevance of addressing the socio-economic backgrounds, and the inequity thereof, of South African learners when professional development interventions are offered to teachers.

4.4.4.2 Large classes

All of the participants from the focus group discussions (School A) shared that they experienced challenges in their day to-day instruction because they were not able to fully meet the needs of all the learners in their classes due to the size of their classes. Mr L voiced his concern regarding the large classes and the influence this had on the effective implementation of formative assessment:

> I have 55 learners in the class, due to this number of learners, you will find that it becomes impossible to go to ... every single learner individually during a period of… because normally we have 35 minutes **(LF2:3)**.

On the one hand, it is interesting to note that School A, although classified as a quintile five (Q5) school (perceived to be more resourced), was struggling with large classes. On the other hand, teachers from the other two Q5 schools (School B and School D) indicated that they only had an average of 25 learners per group. Although Mrs B and Mrs F agreed that their class sizes were manageable, they also mentioned that they found it difficult to attend to the different needs of their learners.

Mr E, from a Q2 school (less resourced) with an average of 28 learners per class, did not indicate that class size affected his ability to implement effective formative assessment practices. However, he found the learners "different backgrounds, coming from different schools and different levels of understanding" **(EI: 7)** to be a major challenge. This was also the case for Mr C, from a Q3 school, with an average class size of 35 learners (see Section 4.4.3.5).

4.4.4.3 Lack of parental support

Four of the teachers were of the opinion that parents need to assist teachers in monitoring their child's performance on a regular basis to optimise learning.

Mr C, for example, explained how the lack of parental support negatively impacted his assessment for the achievement of learning goals:

> Parents do not monitor their children when doing homework. Learners come to the exams unprepared. Their parents at home they don't … help, even if you give them a breakdown to say that we are going to test these concepts – their parents don't even go through the content. Why? Because some of them they don't even have time with their learners, with their children they don't have time. Some they work odd hours, there are so many factors **(CI: 16)**.

In contrast with the above findings, Mr E experienced more support from parents in his township school:

> "In giving a lot of homework – learners are assisted by parents and siblings" **(EQR:7)**.

These findings seem to support the general view of the teacher as the primary educator. Despite the reported lack of parental support, the results suggest that the teacher remains the most important role player in assessing the students' learning progress.

4.4.4.4 Learner attitudes

A common concern amongst the participants was the negative attitude of learners towards assessment activities, especially those that did not contribute to their progress reports. Four of the participants suggested that systemic assessment such as the ANAs must be considered to add to learners' progress reports. According to Mr C, if any form of assessment tasks does not contribute to the learners' year marks or reports, they are not interested in doing it:

> Our learners, they are not even self-motivated. Even if you give them those activities, those tests, they won't do it … because they know that if anything comes and you tell a learner it is not for marks at the end of the year, they lose focus **(CI: 5)**.

Mr C then elaborated on the value that his learners placed on formal examinations:

> Learners of today – one thing which they value most is the examination. So if they know that what I am teaching you who come in the exam they must … and if you tell a child that look, I am teaching you, I am not the one who is going to set the final exam but I know these things which I am teaching you, they may come in the exam, they will make it serious **(CI:6)**.

From Mrs B's interview, the same concern was reflected in her remark:

> Even the ANA. Uhm… I can say partially it is not a true reflection of our learners because they don't even take it seriously themselves. Because they will be saying it is not coming on my school report. You understand. It is not on my assessment; it doesn't count even for my progression to go to the next level. So, they just do it. Just do it for the sake of doing it **(BI:5)**.

This reluctance of learners to participate in systemic assessments because of their expectations with respect to marks is described by Suurtamm and Koch (2014, p. 267) as a cultural dilemma. This dilemma may also be enhanced by the notion that individualised student learning is compromised through summative and systemic tests as immediate feedback is not provided (Black & Wiliam, 2009; Shepard, 2005).

Another constraining factor concerning learners' attitudes was raised in a focus group discussion. Although the teachers from School A recognised that their learners "want to learn maths, science and technology" **(FG2:2)**, they also voiced their concern during the focus group meetings that learners in general had negative attitudes toward the teaching profession and not many learners considered the possibility of becoming mathematics teachers themselves. During the first focus group discussions, two of the teachers raised the concern that the educational profession does not receive the recognition it deserves in South Africa. Mr O, who seemed to be a very passionate mathematics teacher, described his experience with some of his high achieving learners:

> Most of the learners who are achieving high marks, they look for engineering, they look for other courses … They tend to look down on teachers **(OF2:3)**.

According to these teachers, learners' attitudes and perceptions of formative assessment had a negative influence on the level of their achievement. A further observation was made that learners had negative perceptions of the profession of mathematics teaching itself. Although this observation is beyond the scope of this study, I would recommend further research regarding learners' perceptions of mathematics education as a profession.

4.4.4.5 Diversity in learners' abilities

One of the major teaching issues that emerged from the dataset was the wide range of learners' abilities in any one class. All of the participants in this study mentioned this as a major challenge in effectively implementing strategies to support student learning in their daily classroom practices. I noted that the participants referred to this concern 18 times across the dataset.

During the second focus group meeting with the participants from School A, one of the factors identified as further contributing to this problem was that there was little continuity from the feeder primary schools for this secondary school. It was also mentioned by one of the teachers that some of the schools in the same district gave prospective Grade 8 learners a pre-test in mathematics to determine if they should continue with mathematics or take Mathematics Literacy as an alternative in further grades. This was not the case with School A, which was a secondary school. However, the principal, Mr M, encouraged all learners in his school to pursue mathematics. He explained that the school "does not want to discriminate at all" and expressed his belief that "every learner should be able to pursue the career of his or her choice" **(MF2:1)**.

This view of Mr M was confirmed again in the third focus group meeting when two of the other participants mentioned that they experienced the diversity in the learners' ability as a major challenge. This was the case as they mentioned that their learners' abilities ranged from extremely poor to above average across all of their classes **(FG3:4)**.

Mr M responded with how he addressed this issue and offered the following interesting solution:

> I have groups including six learners including higher achievers and lower achievers. They can learn from each other. The leader will give me a report. The final report must be ready in September. If there is no improvement they must tell me what is the problem. Levels 1 and 2 can learn from the others. These learners (Level 3 and

> 4) will be giving me a report on levels 1 and 2. And if there is a problem, they must tell me what the problem is **(MF3:4)**.

Two of the other participants from different schools in different suburbs ascribed the differentiation in levels of understanding to the major influence of the primary schools on learners' background knowledge.

> The background like where are they coming from. Like we have a problem. A child comes to Grade 9 without grasping all the concepts in Grade 8. That child, if you do a diagnostic in Grade 8, they come from primary school without mastering the concepts in Grade 7 **(CI: 5)**.

> You may be surprised that in generally a child can come to Grade 8 without knowing very simple things in mathematics. Simple addition … you see. So all those things, even the knowledge must go down to the primary school teacher **(EI: 2)**.

Mrs B also mentioned that the diversity in the learners' ability in any one class created pedagogical dilemmas for her. She shared her difficulties when "providing engaging activities for those students who are not with [her] while [she] is engaged in small group instruction" **(BI:8)**.

The overall results suggested that the diversity of learners in any one class was one of the most influential constraining factor in terms of school context for the teachers in this study. Considering the demands of the National Curriculum in South Africa, it is not surprising that multi-level abilities are a constraining factor. According to the Department of Basic Education (DBE, 2011b), it is expected of the teacher to provide the necessary time and support to a learner who is not ready to perform at the expected level. The DBE acknowledges that learners learn in different ways and at different levels. In order to address this issue, the DBE proposes that they must be given multiple opportunities to be assessed in different ways (Gouws, 2014, p. 84).

This learner-centred approach to assessment necessitates teachers to consider alternative ways of helping learners to progress to the next level (Gouws, 2014, p. 91; Dreyer, 2014, p. 64).

4.4.4.6 Language issues

The majority of the teachers in the AETL project worked in a variety of multilingual or bilingual contexts. In each of these contexts, English was not the main language of the teachers and learners. This finding is another example of the dilemma that South African mathematics and science teachers face: “the double challenge of teaching their subject in English while learners were still learning this language” (Setati & Adler, 2001, p. 244).

Only one of the schools in this study, School D, offered mathematics to the learners in their mother tongue. The majority of the teachers and learners were fluent in their mother tongue but had to teach in English and to students for whom English was a second, third or even fourth language. The problem of language fluency in the language of mathematics instruction was an inevitable concern raised by the majority of the participants.

In a focus group meeting, Mr L voiced his concern by emphasising that his learners were struggling to read the questions:

> Once they see a quadratic equation, they just solve it, but they do not read (**LF2:3)**.

In addition, Mr M gave a detailed example of his learners’ struggle with mathematics language. He detailed his learners’ struggle with language issues, especially quadratic equations and algebraic expressions. He explained to the other teachers during the meeting how he addressed this issue:

> Each and every time I say that when you say the “difference between two squares” explain to them that “difference” means subtract. The child must say, in other words, I am subtracting two squares. And then I will make use of numbers, maybe 25 minus 16. And then I write it in the form of squares, 5 to the power 2 and then subtract 4 to the power 2. The answer is 9. Write 9 in the form of … exponential form; like 3 to the power of 2 [explaining on a piece of paper]. So the child must say, we are not starting from an empty space. He knows something. I start with simple variables; with a… and then afterwards I will put a number, maybe 9, and then he will be able to give you the answers and then he will be able to give you difficult ones like is equal to He will struggle at first… one over four … So we do this step by step till he understands **(MF2: 3)**.

Considering the diverse language backgrounds of South African learners, the results in this study are therefore not unique. Gouws (2014 p.91) cautions teachers to keep in mind that that many learners have to learn and answer their assessment in a language other than their home language. She also urges teachers to focus more on the relevant skills and to ascertain whether the learner has understood the concepts rather than to focus on a learner's fluency in a specific language.

4.4.4.7 Anxiety related to assessment

Mr M reported another challenging external factor, stating that "there was great anxiety in relation to testing" amongst learners.

> The big difference between what learners wrote in response to a test question and what they answered when engaged after the test could be explained by anxiety in relation to testing **(MI:5)**.

It was clear that Mr M engaged in formative feedback discussions with his learners to fill the gap between "what is understood by the learner and what is aimed to be understood" (Hattie & Timperley, 2007, p. 81). He came to the conclusion that this related to anxiety about summative or formal testing on his own. This not only confirmed his affective beliefs regarding teaching and learning, as previously mentioned in Section 4.4.1, but also the value he placed on engaging his learners in the assessment process.

Other participants also shared stories of learners' anxiety during exam times and systemic testing. During one of the focus group meetings, two participants related this anxiety to the great amount of emphasis placed on "achieving good marks" **(FG4:2)**. This situation reflected a focus on marks and achievement rather than on understanding mathematics, a phenomenon to be expected given the anxiety around systemic assessment results (Van der Nest et al., 2018, p. 6).

This heavy reliance on achieving high scores in summative assessment practices is juxtaposed with formative assessment purposes and can be problematic for teachers and students alike. As Crooks (1988) confirms, "Too much emphasis has been placed on the grading function of evaluation, and too little on its role in assisting students to learn" (p. 468).

4.4.4.8 Communication between schools and the Department of Education

The important role of the various schools' interpersonal relations with the Gauteng Department of Education (GDE) and the effect this has on the implementation of the formative assessment tasks was confirmed in this study.

At the time of the second focus group meeting with School A's participants, a sudden change in the teaching plan had been ordered by the GDE. Instead of starting Term 1 with Algebraic Expressions and Functions, all of the Grade 9 teachers across the province had been told to start the term teaching "Addition and subtraction of algebraic expressions" with very little notice. The last-minute instructions from the GDE and schools resulted in many frustrations experienced by the teachers as it impacted their planning and the implementation of the worksheets. For example, Mr M exclaimed:

> I was almost at this point [pointing to worksheet on Functions]. This was also in that workbook of Inzalo. I gave them a lot of this then I had to stop … Let me start everything again according to the department … the Department came up with something else **(FG2:6)**.

The AETL project coordinator then asked Mr M if the GDE gave any reasons why they changed the teaching plan, Mr M confirmed the poor communication between his school and the GDE in his reply:

> I did not want to ask them. They don't have the facilitator. The lady we were supposed to have was the facilitator before…we are glad we have her, but somehow the politics are difficult **(FG2:7)**.

Mrs B, from another school, also experienced the short notice by the GDE as impacting negatively on the school's timetable. She explained that it affected her planning in terms of the ANAs:

> We have a different work schedule. We don't go according to what they have given us. So that was a challenge. In terms of our planning. You see because we were all working towards this 18th of September and making sure that we have covered everything that they're going to be tested, and now it's time consuming where let's say we're revising the number patterns and they get it wrong, it's the marking that's the time consuming … taking the time to mark and explain whereas that's our time we would have been using for a new topic that we haven't covered yet **(BI:14)**.

Mr N and Mr L mentioned another concern related to poor communication between schools and the Department of Basic Education (DBE) in a focus group meeting. Mr M mentioned that the department had not visited the school for at least one year at the time of this study. Mr N and Mr L then elaborated on the School's "incorrect" quintile status. Mr N suggested that the DBE should reconsider the school's categorisation as a quintile 5 (Q5) school:

> When we look at the location of our school it can just be mistaken by saying the learners from this school has a good background. That is the mistake that this Government of ours make, by just checking out the school, forgetting to go beyond to check where these learners come from in terms of the quintiles, we are quintile 5, only to find the majority of the learners come from poverty-stricken schools **(NF1:2)**.

Interestingly, Mr E was the only participant who mentioned during his interview that the subject advisors had been resourceful and "very useful for the teaching of mathematics" **(EI:4)** when he engaged in a professional development programme arranged by his school.

4.4.4.9 Lack of assessment resources

The need for quality assessment resources to assist teachers in setting examination question papers for summative purposes was also expressed by two other participants during the discussion meetings. Two participants indicated on the questionnaire that the textbooks they used were not sufficient to assist them "to set quality questions" **(QRD: 4)** and the textbook was not in alignment with CAPS.

The teachers from School A seemed to be on the constant lookout for external assessment resources against which to measure their own standards. During the second focus group meeting, two of the participants indicated that they were also constantly on the lookout for resources that would support learners' achievement in the ANAs. For example, Mr M. mentioned how he discovered a stack of revision books in a neighbouring school in the same district and how he persuaded the principal of that school to hand the books over to him for School A's learners.

Mr N, alternatively, incorporated resources such as previous question papers and ANA papers at the end of his lessons to help identify weaknesses in his learners' responses, and to inform his planning for the following lesson. Mr L and Mr O used previous question papers, textbooks and the internet as their main resources for assessment. In my observational field notes, I captured that most of the teachers displayed a lack of confidence in their own ability to set high-quality assessment tasks. Mr L's comment supports this finding:

> Maybe, in addition, I can say this [referring to the worksheets] can be of assistance, because most of the educators, we find it difficult to do our own worksheet, so this it might work as a guideline to us **(LF2:9)**.

Across the dataset it emerged that teachers spent a lot of their time and energy looking for assessment resources such as high-stakes examination papers. This may be contributed to their paucity of assessment knowledge and the pressure to increase externally assessed test scores. This further supports and confirms the urgency to provide teachers and administrators with *professional support* and training to help them understand how to use the accountability and formative systems effectively (Bennett & Gitomer, 2009, p. 55; Stiggins, 2005).

4.4.4.10 Time

This section is a further elaboration on Section 4.4.3, which presented a discussion on the factors that influenced the teachers' assessment practices. Time constraints were found to impact their practice the most in terms of curriculum implementation and manageability.

The teachers reported that the curriculum requirements had varying impacts on their work, but indicated that the strongest impact was on their administration duties, especially concerning reporting on assessment. With the demands placed on teachers to teach the curriculum in a limited period, many feel that they do not have time to analyse the data that they have collected from formative or summative assessments to meet individual students' needs.

The responses from most of the participants indicated that they were still finding it difficult to pace learning for the different levels and learning styles of learners within each class; as required in the national curriculum (see Section 4.4.4.5). In terms of this issue, Mrs F said:

> The difference in learners' abilities in one class … it takes time to create opportunities for the teachers to attend to individual needs **(FI: 2)**.

Although most of the participants (seven of the nine) indicated that the national curriculum statements (NCS and CAPS) were easy to teach from, they also indicated that the flexibility in the prescribed CAPS work plan was a challenge as it does not always allow for planning to optimise Assessment for Learning (AFL) practices. Two of the participants remarked: *“It feels like there is not enough time to cover each topic thoroughly and to practice certain concepts”* **(DI:5)** and, “The syllabi is too long and time is limited such that some topics are not given adequate attention” **(EI:7)**.

For Mr C, the most time-consuming factor in his assessment practices was the mandatory record keeping of his continuous assessment (CASS) practices. CAPS requires teachers to keep comprehensive records of all assessment activities in the form of portfolios as evidence to ensure the quality of any judgements made (DOE, 2011a). Mr N had strong views on why he regarded portfolios as time-consuming and irrelevant:

> Throw it away the portfolio thing, CASS whatever, throw it away. Go to … that’s why you see that our products they can’t match with other countries. Take a child to maybe let me say neighbouring country Zimbabwe. They won’t cope with it. They won’t. Take them to United States they have to go and do some other entrance test for them to be accepted. Why? Because they know the system which we are using. If you go to other countries, they don’t have this portfolio work … no. It’s just these assessments [referring to the assessment tasks and summative tests] which are preparing them for the final exam **(CI: 15)**.

In this section, I have presented the key dilemmas that teachers in this study were confronted with in their effort to implement assessment for learning strategies in their classrooms. The dilemmas voiced by the teachers in this study are in no way limited to the AETL project. They are issues that must be confronted in the design of all professional development projects and I believe that the articulation of these dilemmas provides a useful tool for conscious reflection and working practice in the development of all PD initiatives in general (Adler, 2000; Desimone et al., 2006; Mewborn & Huberty, 2004; Steyn; 2011).

4.4.5 Teachers' engagement with strategically designed assessment sets/ activities during the AETL project

In answering the critical research question: How does the teachers' involvement in purposefully designed formative assessment tasks influence them in terms of personal and professional development, if at all? I had to investigate the activities to which the teachers were exposed and the way in which these activities caused the teachers to reflect upon their existing classroom practices. This question also relates to the quality of the activities' content in the teacher professional development programmes, as addressed in several studies (Darling-Hammond et al., 2009; Desimone et al., 2002; Loucks-Horsley et al., 2010) (see section 2.4.3).

The literature has shown the importance and efficacy of concrete teaching tasks and activities that focus on quality assessment and reflection in professional development programmes. Such PD programmes should create learning opportunities that allow teachers to build on their previous knowledge and make changes in their teaching strategies (Darling-Hammond et al., 2009; Loucks-Horsley, 2010; Rieckhoff & Larsen 2012).

In the AETL project, we added to the above by positioning the teachers as both experts in their classrooms, and as learners with significant possibilities for learning about formative assessment strategies to improve instruction, and ultimately, student learning. In order to understand how the teachers positioned themselves in relation to professional development innovation and, in particular, the AETL project, this study explored and reported on the activities, experiences and understanding of the participants in this intervention. I therefore include the descriptive reports and quotes of individuals to recount their engagement with the formative assessment strategies, and to confirm the findings of this study.
The participants' engagement with the strategically designed formative assessment tasks in this study broadly followed three phases in which active learning opportunities for the teachers were created:

- *Initial engagement (Goals and strategies of the AETL project)* – The sampled teachers attended two workshops during which the specific goals and strategies of the AETL project were discussed (see Section

1.4). They were then provided with a complete set of formative assessment worksheets with accompanying memoranda (Appendix A) to deepen their understanding of formative assessment strategies and its relation to mathematics learning theories. As mentioned earlier, these strategies were designed to embrace the idea that teachers must experience mathematics learning that reflects the national standards. These strategies were also created to provide opportunities for all students to engage in challenging mathematics content through inquiry. The teachers were also given the opportunity to give input regarding the refinement and structuring of the questions during these two sessions

- *Practical implementation of the formative assessment tasks* – The participating teachers implemented the worksheets in their classrooms at their own pace and as experts in their own classrooms.

- *Reflection and refinement* – The sampled teachers then reflected on the activities and implementation of the formative assessment worksheets during focus group meetings and individual interviews. Oral or written feedback on how the activities could be redesigned, improved or informed by their classroom instruction were given by the teachers.

4.4.5.1 Initial engagement in the formative assessment strategies of the AETL Project

The initial stage of the AETL Project provided the participants with two training sessions with a particular focus on 1) assessment literacy, 2) the refinement of structured formative assessment tasks, and 3) strategies based on mathematics learning principles (NCTM, 2014; Silver, 2015) (see Section 2.4).

During these meetings, the teachers received formative assessment strategies in the form of worksheets with accompanying memoranda (see Appendix A). The structured worksheets were set according to Usiskin's "four realms in understanding mathematics from a teacher's perspective" (Usiskin, 2015, p. 19):

a. Pedagogical Content Knowledge (PCK),

b. Concept analysis,

c. Problem analysis, and

d. Connections and generalisations to other mathematics (see Section 2.5).

The teachers also participated in discussions based on Silver's interpretation of "mathematical learning principles and how it relates to FA" (Silver, 2015, p. 33).

From the observational field notes and document analysis during the two training sessions (the first stage of the teachers' engagement with the formative assessment strategies), the following relevant results emerged.

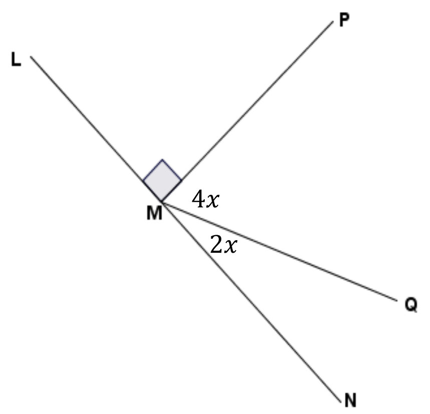
The teachers were very appreciative of the worksheets and seemed interested in engaging with the activities. The attendees actively participated in the discussions and gave valuable input on the worksheets. For example, it was unanimously decided that the mark allocation on all of the worksheets should not be taken away. Some technical issues related to the worksheets were discussed and Mr L offered his support to carry out the technical refinements of the worksheets.

An in-depth engagement with worksheet 4 (see Appendix A) during the second meeting not only offered the opportunity to discuss effective formative assessment strategies and mathematics learning principles, but also to refine the worksheets collaboratively with colleagues from other schools.

For example, Question 2.1 (Worksheet 4: Straight line Geometry) is shown below:

Calculate the value of x in each of the following:

2.1.



One of the participants suggested that we should ask the learners to "provide reasons during each step in solving x" **(NS1:1)**. He explained that he "wants reasons to see where misconceptions are" **(NS1:1)**. A discussion followed, and another participant responded that "from a learners' viewpoint; it would discourage them at this stage" **(SS1:1)**.

Another participant also gave valuable input, which drew our attention to the language issues experienced by the learners, for example:

Question One: Geometry of straight lines

Complete the following table:

Number	Write a verbal description	Draw a sketch	Write down the mathematical expression
1.2	When lines XY and WZ **intersect** at point O, the vertical opposite angles are equal.		

The participant suggested that "the word *intersect* should rather be *cross each other*" **(MS1:1).** He explained that all of his learners were English second additional learners and were thus not familiar with this term.

It appeared that the participants valued the collaboration with colleagues from other schools. Engagement with the formative assessment worksheets and discussions based on formative assessment strategies provided motivation for the teachers to refine and implement the worksheets. Acknowledgement and appreciation were expressed for the "good quality of the worksheets" and several teachers personally thanked us for the "valuable resources to enrich their assessment practices" and the "opportunities created by the University to support them in their professional development" **(MS1)**.

The above results illustrated some of the examples of the teachers' initial engagement in formative assessment strategies as offered by the AETL project. It also provided some evidence of the efficacy of a Professional Learning Community

(PLC) in PD programmes, as suggested by the literature (Darling-Hammond, 2009; Stoll et al., 2006; Steyn, 2013) (see Section 2.4.1).

As previously explained, it was also during these two meetings that the four focus group participants form School A were selected. I also purposefully selected the other participants for the interviews (see Table 4.1, Section 4.2). The selected nine participants revealed a high level of commitment to implementing the strategies, they were also particularly appreciative of the unrushed support offered in the AETL project: “Thank you for not rushing us to implement the worksheets” **(FN: M2:C)**. Another participant commented: “I like that we can implement it according to the curriculum plan” **(FN: M2: B)**.

4.4.5.2 Practical implementation of the formative assessment worksheets

The supporting and enabling of professional agency, in which teachers act independently and make choices in order to advance toward their goals is central to the professional development component in the AETL study (Priestley et al., 2012). In acknowledging Biesta, Priestley, and Robinson’s (2015) view of the importance of teachers’ active “contribution to shaping their work and its conditions for the overall quality of education” as teacher agency (p. 624), we offered the formative assessment tasks (worksheets) to the teachers with the flexibility to implement these in whatever way they preferred. This approach recognised the teacher as being in control, the decision maker, and the one managing his or her own classes.

A variety of implementation strategies were reported by the participants and some evidence of effective mathematics teaching and learning principles were displayed. These are discussed in this section.

As the HOD for mathematics in School A, Mr L mentioned that it was important for him that all of the Grade 9 teachers “use the worksheets as guidelines to set their own worksheets” **(FG2:2)** to deepen their understanding of the formative assessment process. Mr L reported that he had not only implemented all of the worksheets in his Grade 9 class, but also across grades. For example, “I have used the assessment tasks as part of my revision planning for the grade 12 classes” **(FG3:2)**. According to Mr L, he implemented all of the worksheets and he “used some of the worksheets for class tests, and some of it for revision exercises” **(FG3:2)**.

Mr L and Mr M, the principal, both decided that all of the mathematics teachers from School A should discuss the formative assessment worksheets during their subject meetings on a weekly basis. Mr M's reason for involving the whole mathematics department and not only the Grade 9 teachers differed slightly from that of Mr L. Mr M placed a high emphasis on the alignment of the teachers' assessment practices with the intended curriculum. Mr M explained why he believed that all of his teachers could benefit from the worksheets:

> Most of the things that we get, we align with our teachers in class, and we even go beyond. We expand and say okay, in Grade 12, this thing is going to be like this. In Grade 10, this thing is going to be like this. We stretch them a little bit. While you are teaching in Grade 8 and 9 you usually stretch over whatever topics. You say hey. You must know in Grade 12 you are going to get this topic. And this topic is going to be like this **(MI:18)**.

Mr M's strategy to set clear goals and involve teachers and students to know and recognise the standards for which they are aiming is described by Broadfoot et al. (1999, p. 7) as an effective formative assessment strategy. Mr M added that he personally implemented all of the worksheets, either by means of a class test, group activities or self-assessment tasks for his students. He also provided evidence that he adapted some of the worksheets "according to the level of his learners by using only certain sections of a worksheet and the structuring of some questions" **(MI:19).**

According to Mr N, for enrichment purposes, he implemented the worksheets once he had completed a section. He explained: "They should be used for a variety of methods and how the questions should be asked – that is why I am saying for enrichment" **(NI:5)**. He also explained that he implemented the worksheets for both summative and formative reasons:

> I use them both [as formative and summative] during the instructional learning hence like even after the instructional learning. Then eh … that assessment it's like the assessment information looking at what learners' responses are. What learners' work tells you. Then I go back to say, okay, you say that I haven't done enough yet. Before I can move on to the next section" (**NI: 6)**.

It was evident from Mr N's planning documents and his comments that, in his planning, he established clear goals for the mathematics that students were learning, and he used these goals to guide his instructional decisions. He also explained during his interview that he tried to align his formative assessment practices with the curriculum policies and documents (Hattie & Timperley, 2007; Stiggins, 2008). However, as he tried to implement a variety of strategies from different external sources, he found that it caused him to fall behind in terms of his teaching schedule:

> It's like I am always far behind, when I look at the worksheet each time I am far behind. Like for example right now I have … I am two weeks behind**.** You know the reason it's like … then I stick to what the learners struggle with before I can just move on **(NI:6)**.

Mr N confirmed his commitment towards his learners by assisting them with problematic areas before he moved on to the next topic, he also tried to use a variety of strategies in the implementation of the worksheets. However, Mr N's effort to integrate teaching, learning, and assessment to optimise learning resulted in time constraints and frustration due to not achieving the leaning goals. This result may be due to a lack of clarity and confidence regarding the curriculum and assessment policies. Gouws (2014) attributes some of the time constraints experienced by senior phase teachers in South Africa to a lack of clarity in curriculum interpretation - more specifically, the alignment of assessment methods, tools and forms with learning activities and learning outcomes (Gouws, 2014; p.84).

Mr O, also a teacher from School A, explained during a focus group meeting that he would give "a particular worksheet on a Monday and discussed the topic with his learners" **(FG3:1)**. As soon as the learners completed the worksheets, they would mark it themselves. He would then have a memo discussion with the learners. The idea of the AETL project was that the learners should receive the memo to reflect on the possible solutions. Mr O additionally provided evidence on how he refined some of the worksheets to align with his lesson planning. He explained that he did not use a complete worksheet, but only used some of the sections applicable to his lesson: "I am going to use some of the sections out of it (the worksheets), whatever is pertinent. So I won't use them just … straight, I might adapt" **(OF2:2)**.

In contrast with Mr N and Mr O, Mr C (School C) gave the worksheets to his learners before he introduced a new topic. Mr C was of the opinion that this strategy assisted him in determining his learners' prior knowledge:

> Because mostly I was giving those tasks before the lesson, before the concept, right? Before the topic, before I teach algebra I could give them first. So that it gives me a guide on what do they know **(CI: 24)**.

Mr C's description of how he implemented the worksheets revealed that he not only used formative assessment strategies to elicit evidence of his students' learning (Black & Wiliam, 2009), but he also employed the principle of "productive struggle in learning mathematics" as suggested by Silver (2015, p. 33).

Mrs B also implemented the formative assessment worksheets in a variety of ways. She initially used it as homework activities, however it resulted in learners not doing it themselves. She explained:

> Because nowadays like what you find is that so many learners are going for extra tuition, they've got a tutor and so sometimes it's like you can't send things home, like even the homework, it will be in someone else's writing" **(BI:9)**.

As a result, she implemented the worksheets as class tests or group activities during instruction. Interestingly, Mrs B did not believe in group activities during the initial stages of the AETL project. When I asked her why she did not employ group activities initially, she responded: "Why not group activities? … uhm… the biggest thing I think is the time. Time consuming" **(QR B:10)**. However, as the study progressed, she applauded the effectivity of implementing the worksheets as group activities because "learners support each other" (BI:19).

Mrs B and three other participants mentioned that they also used the worksheets for revision. At the time of her interview, she remarked: "It's always nice for revision. Like now this time of the year we're always looking for stuff" **(BI:19)**. Mrs B is one of two other participants who emphasised that they only implemented the worksheets after they had introduced and explained the content on the worksheets to the learners.

Although Mrs D and Mrs F were employed at the same school, they indicated that they never discussed implementation strategies with each other due to a very tight schedule and time constraints. As a result, they implemented the worksheets according their individual schedules. Mrs F used three of the worksheets as class tests and the learners marked it themselves. She provided evidence of the marked tests and presented a summary of the results and remarks written on the worksheets. It needs to be mentioned that, on the one hand, Mrs F only had one Grade 9 class and was regarded as a senior teacher in terms of years of experience and she thus additionally offered Grade 11 and 12 classes. Mrs D, on the other hand, only offered Grade 9 mathematics, and was less experienced in terms of years. As a result, she could implement all the worksheets in a variety of ways, mostly to inform her instruction. She implemented the worksheets mostly during instruction, as group activities, informal class tests or as homework activities. Mr E also indicated that he implemented all the worksheets as class tests or for revision purposes.

Although the teachers differed in the extent to which they implemented the formative assessment worksheets in their classes, the data revealed that most of them used them as class tests. Although most of the participants indicated that they used the class tests as informal tests to support formative practices, three participants indicated that they had used it as formal class tests (for summative purposes). Despite the difference in the use of the worksheets as tests, they all agreed that the tests provided them with evidence of their learners' current knowledge status and supported them in identifying common mistakes made by their learners, i.e. for diagnostic purposes.

An important finding that emerged from the data was that the participants implemented the worksheets in a variety of ways. This revealed components of assessment strategies that are closely aligned with Black and Wiliam's (2009) essential formative assessment principles: "to elicit evidence of student learning, interpret the evidence and use the evidence for subsequent instruction" (p. 9).

The opportunities for teachers to exert judgement and control over their own work in the AETL project also resulted in the abovementioned variety of strategies used by the teachers.

4.4.5.3 Refinement of the worksheets

One of the aims of the AETL Project was to provide teachers with examples of structured, content-based formative assessment materials. Although the activities were standardised and purposefully constructed, we made it clear from the onset of the AETL project, that teachers can adapt and refine the worksheets according to their local contexts. Thompson and Wiliam (2008, p. 35) address the issue of creating balance between activities that are “sufficiently flexible” and activities that are “sufficiently rigid” for professional development interventions to be effective. They developed an adopted framework entitled “tight but loose”:

> The Tight but Loose formulation combines an obsessive adherence to central design principles (the ‘tight’ part) with accommodations to the needs, resources, constraints, and particularities that occur in any school or district (the ‘loose’ part), but only where these do not conflict with the theory of action of the intervention. (Thompson & Wiliam, 2008, p. 35, emphasis in original).

In supporting Thompson and Williams’ (2008) professional development model, teachers in this study were given the flexibility to refine and adapt the worksheets to the local circumstances; however, the activities were sufficiently rigid to address curriculum standards.

In terms of refinement, two participants reflected on the order of complexity of the questions during the interviews. Mr N changed the order from easy to more complex in worksheet 4 **(NI:17)**, and Mrs B also suggested that “the most difficult question should be the last question “**(BI:10)**. Mr M changed the formulation of some of the questions on the worksheets to address the learners’ language issue (see Section 4.4.4). Although he discussed his refinements orally, Mr M did not provide written evidence of how he adapted and refined it.

Mrs D was the only participant who provided me with detailed feedback templates of all the worksheets. It seems as if the participants experienced the feedback templates as too elaborate and time consuming. Most of the feedback and refinement- evidence were written on the worksheets or discussed during the interviews. Mrs D refined some of the worksheets by “shortened some of the activities due to time constraints” **(DI:23)**. This refinement was also mentioned by three other participants. She also expressed the need for “more practical examples on the worksheets” **(DI:23)**.

Mr N and one other participant reflected on worksheet 1 and suggested that he added “more questions on content” before he implemented it, however his” learners liked no.1 “(Patterns) **(NI:22)**. Mr N also showed evidence of how he adapted some of the worksheets by adding some of his own questions to enhance the content of the worksheets. Three other participants also showed me how they had combined some of the worksheets to extend their learners’ connections and generalisations to other mathematics, as suggested by Usiskin (2015, p.19). For example, Mrs D combined some of the questions of worksheet 3 (Algebraic expressions) with worksheet 6 (Algebraic equations) as she identified that the majority of her students “don’t know order of calculation” **(D: FBT:3,6)**.

The participants’ feedback with regard to the AETL project is inherently related to their professional growth experiences in taking part in this project. In the following section, I report on their reflections and experiences of personal and professional growth.

4.4.6 Teachers’ experiences of professional growth: the benefits of formative assessment

In answering the critical research question: How does the teachers’ involvement in purposefully designed formative assessment tasks influence them in terms of personal and professional development, if at all? I had to explore the participants’ reflections on their experiences of growth and the benefits of the AETL project.

Throughout this study, the teachers were given sufficient time (two years) to implement and reflect on the purposefully structured worksheets. Teachers were encouraged to continually reflect on their own changes in classroom assessment practice and to consider best instructional practices during their engagement in the AETL Project. The primary findings regarding the participating teachers’ own experiences of growth are summarised and described with supporting examples and excerpts as these emerged from the dataset.

4.4.6.1 Formative assessment knowledge, attitude and skills development

One of the aims of this study was to expand the understanding of effective PD strategies by considering the complex and multi-dimensional nature of the professional learning process. I therefore explored and analysed the participating teachers' experiences of growth in knowledge, attitudes, and skills development by locating these in the personal domain, as suggested by Clarke and Hollingsworth's (2002) model for professional growth. This approach is also in agreement with Evans' (2014) cognitive model of professional learning, which consists of three components (domains): behavioural, attitudinal and intellectual development. Evans' (2014) model for professional learning is also located at the micro-level of the individual cognitive processes (personal domain) when teachers engage in a single professional development 'episode', such as finding a better way of teaching (see Section 2.2). Evans argues that PD or change occurs when a teacher recognises a 'better way' of doing something (Evans, 2014), she focuses primarily on the influence of cognitive aspects of PD on teacher outcomes (motivational change in instructional practice). The following growth experiences related to knowledge (intellectual) development were reported by the teachers.

a) Formative assessment knowledge (focus group)

I first report on the feedback of the focus group participants' reflections on their cognitive professional growth experiences before I discuss the feedback from the rest of the dataset. The reason for this was that the teachers from the focus group discussions (School A) were given Silver's (2015) article to read during the week in preparation for the discussion the following week (third focus group meeting/ FG3). In so doing, the aim was for them to reflect on the alignment of the ideas expressed in the article with the needs and current assessment practices in their school. Silver (2015) identified two focus points in the research as distinct to ensure mathematical success for all students:

> 1) Cognitively demanding tasks, and
>
> 2) Teachers must apply formative assessment techniques to "elicit, interpret, and use evidence about students' thinking to make instructional decisions" (p. 34).

Variations in the teachers' idea of mathematics assessment principles helped to identify the conceptions that each teacher brought to his or her engagement with the principles described by Silver (2015) during the third focus group (reflection) meeting.

Mr M mentioned a few examples of the importance of "establishing mathematical goals to focus learning" (Silver, 2015, p. 34) when he reflected on his formative assessment practices. He gave one example of a discussion with his learners: "I say look at yourself. Where do you want to be? There can be improvement. I compare the first term and the second term marks" **(FG3:2**). Mr M and the other participants agreed that any task or activity in mathematics should "promote reasoning and problem solving" "…this is my aim. Every time you give them a question you must make them able to think" **(FG3:4)**.

In his reflection on how he implemented the worksheets and had memo discussions afterwards, Mr O emphasised that he used the worksheets as classwork with close monitoring to see how his students were doing: "We have a memo discussion and then I ask them … ok what have you done with this question?" **(FG3:2)**. Mr O thus confirmed how he used this strategy to elicit and use evidence of student thinking.

In contrast with Mr O, two of the other participants disagreed with the learners having memo discussions. Mr N gave the following reasons:

> Now what I think about that. Learners will see the pattern, that they do the work and thereafter you give them the memo, they will relax and then will wait for the memo [Laughs]. Ok I see. Even the classwork sometimes. They do not complete it. They leave empty spaces there. When you are busy doing the corrections, showing them how to work out the problems, they are busy filling the gaps that they left, and after they mark it correct **(FG2:3)**.

Mr L added that he only gave the memos to learners if they provided him with evidence that they had completed the worksheets on their own. He explained that: "If you don't … No, you must go and do that thing. Submit it back to me as your written work, then I will give you the memorandum" **(FG2:3)**. This confirmed that he activated his students as the owners of their own learning (Black & Wiliam, 2009; Leahy et al., 2005; Wiliam &Thompson, 2007).

As the focus group participants reflected on the quality of the questions in the worksheets, they all agreed that there were enough problem-solving skills for the learners to engage in meaningful discussions to promote mathematical reasoning **(FG3)**. This confirmed their willingness to promote their learners' mathematical reasoning and problem-solving skills during classroom discussions (Silver, 2015).

Although the focus group participants' implementation strategies varied, they all agreed that the biggest value of the formative assessment worksheets was its diagnostic ability to identify learners' needs (eliciting and using evidence in student thinking).

It became clear from the reflections and feedback from the focus group discussions that the participants experienced significant growth in their understanding of the formative assessment process. The results also indicated that the teachers became more conscious of the importance of integrating formative assessment into their classrooms to inform their instructional practices.

b) Formative assessment knowledge (complete dataset)

With regard to teachers' experiences of growth from the total dataset (including focus group meetings), the results relating to growth in the cognitive (personal) domain will now be discussed further.

As the participants engaged in the refinement and implementation of strategically designed formative assessment activities, it became evident from their reflections and feedback that they primarily experienced growth in assessment knowledge and skills. At the beginning of the study, the teachers' lack of knowledge regarding formative assessment practises was clear (see Section 4.4.1). For example, Mrs B's initial reaction to the question: "What is assessment?" during our first informal interaction with each other was: "It's a test, written tests" **(OFB: 5).**

However, the definition she provided as the study progressed illustrated the growth in her conceptualisation of formative assessment: "formative assessment we regard as continuous, the process during the classroom assessment" **(BI:5)** (see Section 4.1.1.3).

During his interview, Mr C illustrated how his conceptual understanding of formative assessment had evolved since the beginning of the AETL project. He provided me with evidence of how he analysed worksheets 1 and 2, and his learners' results for diagnostic purposes. The following remark clearly illustrates how his newly acquired formative assessment knowledge assisted him in adapting his instructional practices:

> When you are developing an assessment you first off have to know the contents which you are going … the concept which we are going to test, right, then from the concepts you can now maybe see if you have covered the content and maybe plan to cover for that in another way, it also promotes teaching to a test. Where you have first of all to teach the concepts then test it **(CI:9)**.

Mr C's evolved understanding of the implementation of formative assessment strategies also became evident as he reflected on his experiences with the worksheets during the AETL project:

> One of the things is after I have done the assessment, I could go and do a diagnostic of each and every question. Why? So that I know where the weakest point in the concept is. If I set a question I must know that this question is testing what. And I have to re-teach or revisit that before I move on to the next topic **(CI: 10)**.

Mr C's above remarks show how he positioned himself through the effective use of the evidence of his students' learning to adapt his teaching to meet their immediate learning needs, as suggested by Wiliam (2007, p. 191).

Another participant, Mr N, elaborated on how his engagement with the formative assessment strategies improved his understanding of the effectiveness of immediate feedback in the learning process of his students:

> You know normally, looking at the way the learner has answered the question, I normally look at … maybe this is just a careless mistake, if I can just quickly check with the learner, and then he says, I should have said this and that. I am not worried about that, but then eh, conceptual knowledge, I can also see, in that the learner answered the question **(NI:5)**.

Five of the participants also mentioned how their evolved understanding of assessment for learning (formative assessment) informed their general assessment practices. For example, Mr N explained how it broadened his questioning techniques:

> What I gained from the worksheets here like mmm … the questioning techniques. Like … I … I actually learned like that like some questions like you can put them like – in this you can ask them to the learner in this way then you can structure the question in this way. That's like specifically the technique that I have learned from the worksheets **(NI: 26)**.

Two other participants were appreciative of the challenging questions in the worksheets and indicated that it informed his teaching and provided him the opportunity to promote his learners' reasoning skills: "It broadens our minds in the way we teach ... the questions are challenging" **(FG2:3)**. This remark by Mr M, supports Silvers' (2015) argument that teachers must encourage and not lower cognitively demanding tasks to ensure effective mathematics teaching and learning. The formative assessment worksheets were also designed to help the teachers to use particular curriculum materials and specific mathematical content knowledge in order to make changes and adaptations in their teaching practice. It is therefore somewhat surprising that none of the participants mentioned any development or growth in their Subject Content Knowledge (SCK). Only two participants mentioned how growth in their assessment knowledge, and in particular the worksheets, enhanced their curriculum knowledge. For example, Mrs D explained: "I am now more familiar with CAPS" **(D: FT:3).**

Mr N's comment during a focus group meeting is a good reflection of four other participants who came to the realisation that they were previously very much dependant on textbooks and previous question papers to inform their classroom assessment practices:

> Using this material [referring to the worksheets] … same thing … but then in a different way. I envisage to use them for enrichment. Like I use different text books. And that is like we normally do, teachers set questions based on every single chapter. We see how the textbook asks the questions and then we pick some questions from the textbooks and then we, in my case like for enrichment, for learners to be able to see that ok this is another, it is a worksheet with some questions, now it is not from the teacher it is not from the textbook. Now after the

> learner is able, or is struggling with some things, now after that I want to diagnose that, after I have assisted with these worksheets, how far can they grasp **(NFG: 2)**.

Another theme that emerged from the collected data was that the formative assessment worksheets were used as a resource to address the challenge that the teachers experienced with the wide range of learners' abilities in one class (see Section 4.4.4.5).

Three participants reflected on the quality of the worksheets and attributed their motivation to implement formative assessment in their classrooms due to the "balance in the different levels of understanding on the worksheets" **(BI:10)**. Mrs B referred to worksheet 4 (straight line geometry) and indicated that the worksheets she implemented assisted her to address the diversity in the learning needs of her learners. A similar reflection was expressed by Mr C: "The first two worksheets helped me to determine the different levels of learners and improved my questioning techniques" **(CI:31)**.

In her response to my question: 'What was the single most important skill that you required during the whole formative assessment development process?' Mrs D's reply mirrored two other participants' views (translated from Afrikaans):

> To accommodate all groups in the class. To make sure everybody is up to date with the work! **(CI:5)**.

The above results suggested that the teachers' engagement and implementation of formative assessment strategies and activities primarily resulted in enhancing their formative assessment knowledge. It also illustrates the interrelatedness of the teachers' knowledge, attitudes and beliefs (personal domain), and their motivation to change their instructional practices, as described by Evans (2014) and Clarke and Hollingsworth (2002).

4.4.6.2 Change in instructional practices

The participants provided me with vivid descriptions of how the AETL project and their exposure to formative assessment strategies had influenced their overall assessment practices and the adjustments they made to instruction. From the individual codes I made across the dataset, teachers' experiences with formative assessment strategies and its effect on adjusting instruction occurred 56 times. Mrs F's perceptions in terms of instructional experiences summarised the average experiences of the teachers in this study:

> It developed me as an educator to adjust my lessons in order to pay more attention to poorly answered questions **(FI:3).**

> So, in creating formative assessment tasks, you will be able to see what the problem areas are. In this way, you can also find new ways to explain tasks [to the learners]. You would also have to think how learners understand written instruction **(FI:5).**

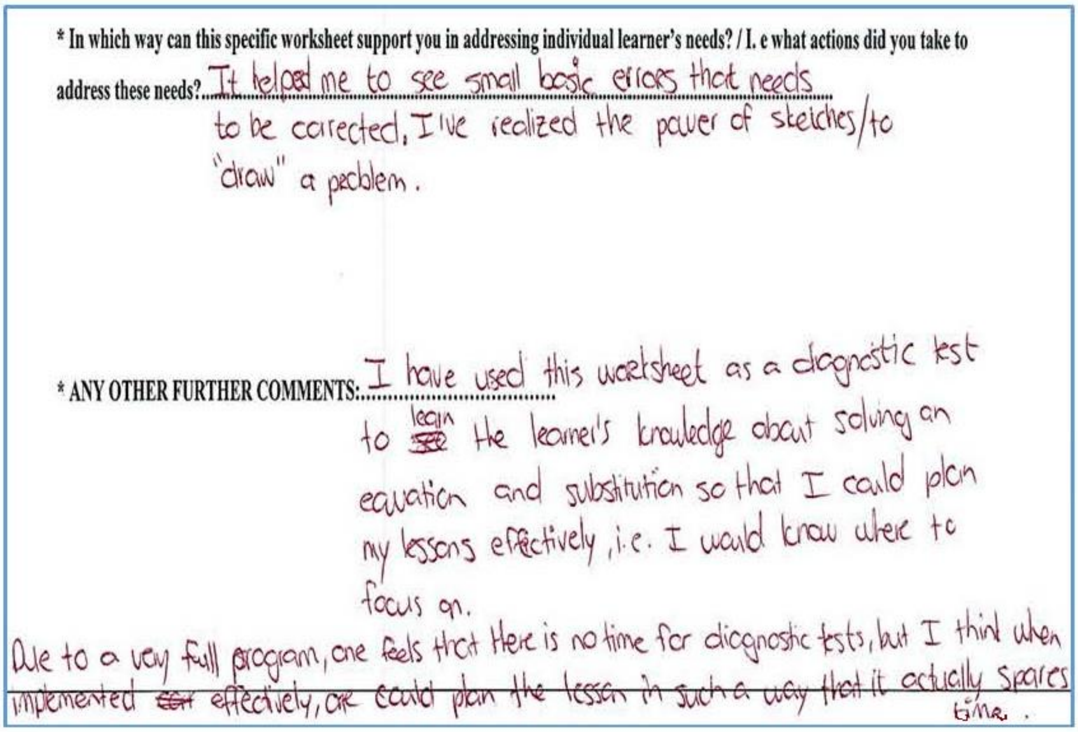
One of the practices used in the formative assessment process is the use of social interactions, peer assessment and group work as part of the lesson, which coincides with the Social Constructivist Theory. Seven of the nine participants mentioned that the worksheets assisted them in creating more opportunities for the students to interact with each other or with the teacher. For example, Mrs B's reflection on peer assessment strategies, as proposed by Silver (2015), led to her use of group work. Her initial concerns regarding group work were as follows: "… uhm… the biggest thing I think is the time. Time consuming" **(QR B:10)**. However, as the study progressed, she appreciated and highly praised the effectivity of implementing the worksheets as group activities as "learners support each other" **(BI:19)** and:

> I did a group work activity with them, that worked so well, so I actually, it made me think you know maybe it's not so bad as everyone thinks it is and I've actually tried it out twice now since **(BI:9)**.

Six participants also mentioned how the formative assessment worksheets influenced their lesson planning. For example, Mr C changed how he planned his lessons, and adapted his instructional practices:

> Right? So, basically, I could know that if I give my learners even those who are not at par they would get something. Right. And it will give me a true reflection of what I am working with. Then from there I know where should I take more time and where should I take less time. So it helped me even in planning (**CI: 19).**

Mrs D also reflected on how worksheet 4 supported her in addressing the individual needs of her students. She further detailed how she addressed their needs by adapting her lesson planning and classroom instruction.



*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs?**....It helped me to see small basic errors that needs to be corrected, I've realized the power of sketches/to "draw" a problem.

*** ANY OTHER FURTHER COMMENTS:**....I have used this worksheet as a diagnostic test to ~~see~~ learn the learner's knowledge about solving an equation and substitution so that I could plan my lessons effectively, i.e. I would know where to focus on.

Due to a very full program, one feels that there is no time for diagnostic tests, but I think when implemented ~~con~~ effectively, one could plan the lesson in such a way that it actually spares time.

Mrs D's final comment: "I think that when implemented effectively, one could plan the lesson in such a way that it actually spares time**" (DRS:4)** implies a significant shift in Mrs D attitude towards formative assessment and the amount of time she believed it would have taken to implement it, as compared to her initial beliefs.

These results have offered insights into how teachers can make changes to their way of thinking and implement instructional and assessment strategies that they are unfamiliar with and draw on pedagogical content knowledge they may not have. These findings on how the teachers changed their instructional practices are also strongly in agreement with Biesta and Tedder's (2007) view on the achievement of agency:

> [T]his concept of agency highlights that actors always *act* by means of their environment rather than simply in their environment [so that] the achievement of agency will always result from the interplay of individual efforts, available resources and contextual and structural factors as they come together in particular and, in a sense, always unique situations (p. 137; emphasis added).

Although not explicitly mentioned by the participants in this study, but by the overall responses, I can make the conclusion that the majority of the teachers had experienced development in their PCK as a direct result of their engagement with the formative assessment strategies (worksheets) in the AETL project.

4.4.6.3 Collaboration

The importance of having supportive colleagues and engaging in collaborative activities in the same school contexts were also evident in this study. In their view of building teachers' capacity for 21st century teaching and learning, Wiliam and Thompson (2008, p. 45) also argue that teachers' professional development is more effective when it is "related to the local circumstances, in which the teachers operate' and by implication in their own classrooms." Moreover, effective professional development takes place over a sustained period of time, rather than being in the form of "sporadic one-day workshops, and involves the teachers in active, collective participation" (2008, p. 45).

The collaborative gains reported in this study were most evident from the teachers who participated in the focus group discussions. The data that I collected and analysed from School A's teachers during the focus group discussions are in agreement with Garet et al.'s argument that "teachers who work together are more likely to have the opportunity to discuss concepts, skills, and problems that arise during the professional development experiences" (Garet et al., 2001, p. 922). The selected teachers from School A's context and their backgrounds offered me an opportunity to examine the extent to which the evidence of teacher agency, the dynamic competency to engage with problems, was influenced by the curriculum and teaching organisation, as well as their conceptions of teaching and learning mathematics.

The focus group participants reflected on more than one occasion on the positive relationships that had emerged from the AETL project. They also highlighted the collaborative support within a PLC as a positive learning experience. For example, in one focus group meeting, Mr L and Mr M shared numerous strategies with their colleagues to ensure that all learners had the best possible chance of doing well in the summative examinations, as well as in the ANAs.

During his interview, Mr C expanded on the benefit of developing a variety of instructional practices (PCK) while collaborating with colleagues and researchers from the University during his participation in the AETL project. He proposed more workshops “like these”:

> Workshops on content. Like these. Tasks on content. We … make a workshop on a similar or something on a general topic. How to teach algebra on Grade 9 level, or grade 8. People comes in and bring their own new ways on how to teach a concept. You know the way you teach a concept maybe different from mine. Now if three or four people comes together and show their ways, one can say ah but I like that one. At least the one, which I knew, and the new one which someone have taught me, so I am equipped **(CI:6)**.

Although Mr C experienced development in PCK knowledge during the AETL project, he expressed the need for further collaboration with colleagues from his own school:

> I adapted to one or two things, right – but, as we go on through the practices, I could see that my colleagues were losing interest because they were saying it’s more work, it’s more work. Maybe they didn’t know exactly how to use that things [referring to the assessment worksheets] …So they … end up saying it’s more work and they’re giving us more work, as a result, I ended up doing it alone. Because we only did in the first together, I think the first weeks **(CI:2).**

All of the teachers mentioned that the worksheets were useful assessment resources, but Mr M elaborated on how collaborative activities, such as the information sessions and focus group discussions, provided him with useful resources to assist his learners with problem-solving skills:

> I am using everything I come across, to improve math. I like what comes from the outside because I can see it challenges our learners **(MFG3:4).**

Mr N further elaborated on how his participation in the AETL project supported not only his own professional development, but also created opportunities to engage the learners through the formative assessment strategies:

> Because like at the moment, for professional development, I … have lack of professional development. We only have a … just the workshops for that specific weekend and thereafter it is class, class, class. Then at least this one has professional development, I think like we were truly engaged like … see, while we

> are like being developed even the learners, like on the other hand they get something, see **(NI:25)**.

These findings are consistent with the Social Constructivist Learning Theory related to this study (Bandura, 1986; Clarke & Hollingsworth, 2002). It also supports the view of Yendol-Hoppey, Dana and Hirsh (2010), who suggest that job-embedded professional development is most effective when conditions are created for teachers to learn throughout their professional careers. The overall reflections of the teachers also revealed that they tended to embrace professional development as a part of every school day when opportunities for collaboration were created, and professional learning tools were introduced that were powerful enough to influence student learning (Steyn, 2011; 2013).

4.4.6.4 Leadership and support

Effective leadership was demonstrated the most in School A in this study. Steyn (2011) identifies a number of aspects that may influence the effective implementation of PD, the first of these being the principal as:" the principal serves as a catalyst for building teacher knowledge" (Steyn, 2011, p. 45).

School A has shown strong evidence of how conditions for an effective PLC were created by the principal to support the teachers' professional growth. It was evident that the principal, Mr M, and the head of the mathematics department, Mr L, place a great deal of emphasis on their staff's professional development. This could be seen as they both supported the teachers to optimise professional development opportunities. Taking it one step further and demonstrating his commitment to being a leader in support of progress, Mr L showed the researchers a quantitative analysis that he had made of all the Grade 9 learners' term marks and how he used it as a diagnostic tool to identify which questions were not answered by the learners.

Mr M's high premium on developing his staff was evident in the explanation given below:

> Because one other thing that we have done that makes us to be one like that, is that we … every Tuesday we have our departmental meetings and we discuss about the progress of our learners and the progress of what we are doing as a department. Also we inspire young teachers. We want them to be at our level or to be even beyond our level. It is up to them. That is why people like Mr L, is our head of

> department, and is now doing a Master's degree at the University of Pretoria and in the field of mathematics. We have Mr N is now doing a Master's degree in mathematics at the University of Johannesburg. Because I want them to be developed. I do not want them to be afraid of mathematics. I want them to stretch. They must stretch themselves (**FG2:11**).

It was clear from the onset of the AETL project that Mr M's leadership style followed a horizontal approach and allowed each teacher to have a voice. Mr M also displayed how much he valued collaborative relationships between management and the rest of his teaching staff:

> I am doing a lot, and I share it with Mr L and my colleagues here. Even if they are young, they give me more information. Mr N there … he is doing a masters' degree – we talk about these things **(FG2:10)**.

The principal also illustrated how he networked with other schools, departmental stakeholders and researchers to invest in the professional development of his teachers:

> This is the approach, and I will also tell her [referring to the Chief Director of the district] about the approach that we use at our school. I have already told the Director. We have a relationship … She was already at our school; with the University of Pretoria … together with Professor X. You know Professor X is the Head of Department, or the Dean of the Department. This is our approach in mathematics. They want the principal alone, because they want to hear from me **(FG2:10).**

The critical role of the principal and school-based leadership support in effective PD, as advocated by many researchers such as Steyn (2011, 2013), Loucks-Horsley, Stiles and Mundry (2010), is evident from the above results. This is especially the case as the principal not only provided the necessary support and building capacity for PLCs in his own school, he also promoted networking and collaboration with other schools and educational stakeholders (Steyn, 2013).

4.4.6.5 Student outcomes/ feedback from students

Reeves (2007) asserts, "Effective feedback not only tells students how they performed, but how to improve the next time they engage the task. Students need for their teachers to change and to meet them where they are" (p. 229).

All of the teachers reported that the worksheets provided them with evaluative feedback from their students. As a result, this enabled them to provide the students with immediate feedback and also to adapt their instruction accordingly.

Mrs B illustrated how she adapted her instruction as a result of the feedback from her students. She gave one of the worksheets as a homework exercise to her learners and elaborated on their feedback:

> I mean, there's days where they're like Mam, we've got everything right, the homework was so good and then you know you can go on. But there will be days that they walk into the class and they'd be like Mam, that homework we've got everything wrong. And then you have to like really look at what you did and then try and teach it in a different way. If you can't then you ask like another learner who understands, can you explain it to maybe, they will understand from their peers **(BI:7)**

Mrs D reflected on the learners' responses (feedback) from a worksheet and acted on their feedback by adapting her instruction. Students were given the following questions from worksheet 6, based on *algebraic equations*:

1) Solve for *x*:

a. $5x-3=x+29$

b. $2x^2=6^2-4$

2) Complete the tables below for *x* and *y* values for:

a. the equation: $y=3x-4$

x	− 4	− 3	− 1	0		5	9	
y					5			41

b. the equation: $y=x^2+3$

x	− 2	− 1	0		6		12	
y				19		103		628

From the learners' outcomes (feedback), she could identify three common mistakes made by the learners when doing algebraic equations. Mrs D, in return, responded by giving the learners immediate feedback on the common mistakes they had made. It is therefore evident that she acted on this reflection and, as a result, modified her instruction of algebraic equations as illustrated by the following excerpt from her feedback template:

WORKSHEET 4 Algebraic equations GR 9 — Content Area: 2.

Topic: 2.4 Algebraic equations

QUESTION	TOPIC	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Numeric and geometric patterns? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1 + 2	2.4 Algebraic equations Equations • Use substitution in equations to generate tables of ordered pairs • Extend solving equations to include: o Using additive and multiplicative inverses	Q2 Learners must know that a negative number to the power of 2, becomes positive. Q1 They must know that a quadratic equation has 2 solutions.	Q1 - Most of them didn't know that a quadratic eq. has 2 solutions. Q2 - They forget to include brackets when raising a negative number to a power. Q2 - They know how to substitute a positive number to get the y-value. Q1 - They don't know order of calculation.	Q1 - They must be more careful when doing easy maths (-3 instead of +3) • $(-1)^2$ i.s.o. -1^2 Q1 - Quadratic eq. has 2 solutions.	For the solving of quadratic eq. I would show the picture of a parabola to show the 2 solutions ex $x^2 = 16$ -4 4 → sketches always made them remember. → also show that $x^3 = 8$, has 3 solutions so that they can make a connection between the power and the # solutions.

Two interviewees also emphasised how their students' feedback on the formative assessment worksheets assisted them to effectively integrate formative assessment into their instructional practices and to use it for summative purposes at a later stage. Both participants admitted that the feedback they used to give to their students was mostly evaluative (summative) and not specific to inform learning (formative). It became clear that Mr C had begun to use formative assessment as a tool to guide instruction and remediate misconceptions. He then used the obtained student feedback from the formative assessment as summative assessment:

> These tasks, the first thing is I used them as a tool to assess my learners, the level of understanding. And also I had to use them … to find out if they have grasped the things which they did. I was even taking some of the things into the summative assessment at the end of the term **(CI:20)**.

Mr M gave similar feedback as he had also begun to use summative assessment as formative assessment, where previously he had also only seen them as separate entities:

> We combined it. Also in the formative, also in the summative. Because we wanted our learners to expand in it, I prepare learners with exam strategies **(MI:16)**.

Mr M and Mr C's descriptions of how they used feedback from their students for both formative and summative purposes support Leahy, Lyon, Thompson and Wiliams' (2005, p.19) view that for formative assessment to be effective "the divide between instruction and assessment blurs". Harlen (2012) also points out that it is not "useful to think in terms of a sharp distinction between formative and summative, however, it is necessary to distinguish between the purposes and uses of evidence provided by assessment" (Harlen, 2012, p. 87). In analysing both teachers' remarks, it became clear that they could not only distinguish between the two types of assessment and its purposes, but they have also revealed a deeper understanding of how to elicit, interpret and use evidence of assessment for the ultimate purpose of learning.

Mr M also provided me with evidence that one of his learner's marks improved by 7% in the exam (summative) after they had engaged in the formative assessment worksheets. In fact, Mr M was the only participant who provided me with detailed accounts of how he considered his learners as part of the learning process. He explained that his learners are also "assessors" **(FG3:1)** and described how he implemented worksheet 3 in his class and afterwards asked them to "write on a piece of paper…What did you think of the lesson today?" **(MI:19).**

Mr M provided me with a good example of how student feedback became a central component of his students' learning process. Mr M's explanation revealed his social constructive approach to mathematics teaching and learning:

> So the child must say, we are not starting from an empty space. He knows something. I start with simple variables; with *a* squared and *b* squared and then afterwards I will put a number maybe *9* and then he will be able to give you the answers and then he will be able to give you difficult ones like 1 over 4 is equal to *a* squared. He will struggle at first... one over four … So, we do this step by step till he understands. **(MF2: 3)**.

The above findings support the ideas of Broadfoot et al. (1999' p.7) and the NCTM (2014) that it is important to involve both teacher and learners in reviewing and reflecting on assessment data to ensure effective mathematics learning. It also supports the argument that if students are seen through a constructivist lens to learning through which they are seen as co-constructors of knowledge, then feedback becomes a central component for students' acquisition of knowledge (Hattie & Timperley, 2007; Sadler, 1989; Tittle, 1994).

To summarise: the evidence collected reveals that the teachers in this study experienced professional growth in a variety of areas. The findings throughout this study also reflected the "recursive nature of teachers' learning" and suggests that growth in one aspect of teachers' knowledge and practice may promote subsequent growth in other areas through the processes of reflection and enactment (Clarke and Hollingsworth's, 2002, p.954).

4.5 SUMMARY

This chapter presented data analysis and representation procedures of the findings of a phenomenological case study. I started with a description of the profile of the participants and the settings in this study – the experiences of Grade 9 mathematics teachers in a district in Tshwane. The chapter then proceeded with the presentation of the qualitative results collected in three stages from an open-ended questionnaire, four focus group meetings, semi-structured interviews, including observational notes and document analysis. Dominant themes emerged from the data analysis process that revealed the experiences of the in-service teachers as they engaged in formative assessment strategies and activities. These findings not only included their knowledge, beliefs and attitudes towards teaching and learning mathematics, but also the extent to which they implement formative assessment strategies in their daily classroom practices.

The findings also revealed the major influences and constraining factors that the participants experienced in dealing with the implementation of new assessment strategies. The findings additionally include the engagement in activities, which the participant teachers were exposed to, how they made sense of these experiences, as well as the way in which the engagement in the AETL project influenced their personal and professional development. The next chapter presents the conclusions, recommendations, and limitations of the study.

CHAPTER 5 CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

5.1 INTRODUCTION

This chapter presents a discussion of the primary findings, conclusions, limitations, and recommendations based on the results of the research. This study reflects on the experiences of nine Grade 9 mathematics teachers in the Tshwane district of Pretoria as they participated in the AETL project. The aim of the study was to deepen the understanding of teachers' professional development experiences, from their point of view, when they are involved in strategically designed formative assessment activities. Accordingly, the objectives of this study were to explore, analyse and describe the circumstances, instances and strategies that these teachers used when they implemented strategically designed formative assessment tasks.

The findings and conclusions presented in this chapter therefore serve to answer the major research question, namely:

What are the understandings and experiences of Grade 9 mathematics teachers of/with formative assessment as they engage in a professional development programme with purposefully structured formative assessment strategies, and to what extent does this exposure contribute to their professional growth?

The major research question was divided into three critical research questions to address the aims and the objectives of this study:

1. How do these teachers make sense of formative assessment and its relation to mathematics teaching and learning?
2. What are the major influences and constraining factors on the quality of teachers' implementation of formative assessment practices?
3. How does the teachers' involvement in purposefully designed formative assessment tasks influence them in terms of personal and professional development, if at all?

Accordingly, this final chapter focuses on the following:

- A discussion of the primary research findings and the conclusions drawn from the findings (as the study aimed to provide answers to the research questions);
- Recommendations (derived from this study and for further research);
- Limitations that reflect the shortcomings of this study; and
- A brief conclusion that summarises the study as a whole.

5.2 RESEARCH FINDINGS

In order to provide a logical sequence to this section, I have aligned the headings with the critical research questions that emerged from the major research question. This approach also provides a framework for the discussion of the conclusions drawn from the findings from both the literature review and the empirical study conducted.

5.2.1 How do teachers make sense of the use of formative assessment and its relation to mathematics teaching and learning?

The first critical research question aimed to explore and describe Grade 9 mathematics teachers' perceptions and understanding of formative assessment. This was done to further gain insight into how their knowledge and beliefs about mathematics teaching and learning support their classroom practices. It also addresses the extent to which teachers believe they understand and practice the phenomenon of formative assessment.

In order to deepen the understanding of the teachers' professional development experiences, this research question also aimed to address the personal domain (knowledge, beliefs and attitudes) prior to the teachers' active engagement with formative assessment strategies, as well as the domain of practice (implementation). This was based on Clarke and Hollingsworth's (2002) Interconnected Model for teacher professional growth (p. 950).

5.2.1.1 Teachers' knowledge, attitudes and beliefs

The literature review has described the important role of teachers' knowledge, attitudes and beliefs regarding the teaching and learning of mathematics in terms of their teaching practices (Bandura,1986, 1993; Borko & Putnam, 1995; Darling-Hammond et al., 2009; Shulman, 1987) (see Section 2.4.4). Borko and Putnam (1995), for example, explore professional development from a cognitive psychological perspective and conclude that teachers' beliefs and knowledge systems directly influence their classroom actions. They argue that for CTPD to be effective and "to help teachers change their practice, we must expand and elaborate upon their knowledge systems" (p. 58) (see Section 2.4.2).

It is evident from the literature that our understanding of formative assessment knowledge has evolved and continues to evolve in education internationally. Formative assessment has become an important component in educational research as it not only addresses teachers PD, evidence of learner benefits is also reported. Several international studies report on strategies to develop mathematics teachers' formative assessment knowledge to provide guidance on how to assess learners for the purpose of learning. However, only a few studies in South Africa report and provide empirical evidence on formative assessment as a strategy to support the CTPD of mathematics teachers.

The relevance of exploring and elaborating on teachers' prior knowledge and belief systems to understand their professional learning (growth) clearly surfaced in the empirical findings of this study.

a) Teachers' perceptions regarding mathematics knowledge

The findings during the initial stages of the study revealed that the teachers had entered the AETL project with high levels of mathematics self-efficacy beliefs in terms of Subject Content Knowledge (SCK). It was clear from the data that most of the participants (8 of 9) ascribed their high confidence in teaching mathematics to their firm subject knowledge base (high mathematics self-efficacy). Only one teacher ascribed his lower degree of confidence in teaching efficacy (PCK) to a lack in "geometry knowledge" (SCK) **(NI:3)** (see Section 4.4.1.1). Within the limits of the purposes of this qualitative study and its interpretivistic approach, I did not evaluate the teachers' actual SCK.

In terms of the teachers' attitudes towards mathematics and their beliefs about what they perceived as being a good mathematics teacher, it occurred throughout the dataset that the participants were motivated and willing to adapt their instructional practices to optimise their students' mathematics learning experiences. One of the primary motivations for the teachers' participation in the AETL project appeared to be their positive attitudes towards the importance and beauty of mathematics. For example: "math is like music ... they [referring to learners] need to show what they know and discover what they don't know" **(MI:5)** and the general belief that their learners must be empowered to use mathematics in their daily lives. However, it also appeared that they were strongly motivated by their need to excel in systemic-type testing (see Section 5.2.2).

Despite the teachers' awareness of the important influence of mathematics on their learners' lives, their positive belief in the learners' abilities and their high mathematics self-efficacy (confidence in their SCK), they also provided me with evidence that they needed further development in the following three major areas:

1) Assessment knowledge;
2) Content-specific practices to assist them in teaching mathematics (PCK); and
3) Collaboration with colleagues and universities to expand the variety of their instructional strategies (PCK).

This information therefore identifies the under-examined need for developing targeted PD interventions. My suggestion therefore, is that these interventions should aim to provide mathematics teachers with an opportunity to not only become assessment literate, but also to develop their instructional practices (PCK) and by implication, improve student learning.

b) Teachers' perceptions regarding formative assessment

The literature has shown that when teachers implement formative assessment effectively in accordance with best practices, this strategy has been shown to support teaching and learning, and as a result, improve student achievement (Black & Wiliam, 1998, 2009; Heritage, 2011; Leahy & Wiliam, 2012; Stiggins & Du Four, 2009). However, the literature also reveals a general lack in teachers' formative assessment knowledge and its relation to effective mathematics teaching and learning (Goldsmith et al., 2014; Heritage et al., 2009; Schneider & Randel, 2010).

This study produced results that corroborate these earlier findings. With regard to teachers' initial understanding of the formative assessment process, the most striking observation to emerge from this study was the lack in the teachers' conceptualisation and purposes of formative assessment. The teachers' initial understanding of formative assessment revealed a considerable lack of knowledge about the formative assessment concepts. A clear lack of understanding at various levels of the process was reported in this study. Most of the participants could not differentiate between summative and formative assessment and they defined formative assessment as "formal" **(NI:3)**, or as a way of grading students: "FA is a test" **(BI:1)**. Although formative assessment is regarded as an on-going process (Black & Wiliam, 2009; Shepard, 2008; Wiliam, 2007), all of the participants referred to it as a product, no one defined it as a process (see Section 4.4.1). However, it should be noted that while I view formative assessment as a process, I did design a product to be used for this purpose. These findings are therefore consistent with Heritage's (2011) findings that teachers often misinterpret the formative assessment process as a "series of tests to audit students' learning, rather than to improve their day–to-day instructions" (p.15).

Although the participants initially reported an inability to conceptualise formative assessment, it does not mean that they were not able to employ some of the essential features of the formative assessment process as suggested by Black and Wiliam (2009) (Section 4.4.2). Teachers reported a variety of strategies in which they were able to collect evidence of student learning, provide feedback or make appropriate adjustments to address the learners' needs. The participants primarily used observational strategies such as marking homework, and oral and written answers as they collected evidence to assess student learning. A common strategy used by all of the participants to elicit evidence and provide feedback to their students was the use of class tests. Some of the participants also reported the use of peer assessment activities and practical tasks, not only to elicit evidence of student leaning, but also to involve their students in the learning process (see Section 4.4.2). The extent to which they described their formative assessment practices, however, revealed a deeper lack of understanding of the formative assessment process as the majority of the responses indicate that the teachers were using it for summative purposes.

As already mentioned, one of the major findings in this study is that all of the participants shared the need for professional development opportunities to enhance their assessment knowledge throughout the study. The participants' responses during the second and third stages of the data analysis process, however, indicate that there were significant shifts in their knowledge and attitudes towards formative assessment as a strategy to support student learning. They entered the study with uncertain views about their understanding of formative assessment as it relates to mathematics learning principles; but as the AETL project progressed, and participants had opportunities to reflect on their involvement in refining and implementing the formative assessment worksheets; there was a significant increase in their confidence related to these understandings (see Section 4.4.6). Furthermore, they shared that they believed and understood the importance of implementing and using purposefully structured formative assessment strategies to enhance the quality of their classroom practices to inform student learning. Despite all the positive attitudes and beliefs about the value of assessment for learning echoed by the teachers, it was not possible to establish if these beliefs had actually been implemented in their classrooms. Classroom observation was not a data collection strategy in this study as the evaluation of teacher effectiveness in implementing the formative assessment tasks was not the major focus of this study. Future studies on this value-practice gap are therefore recommended.

To summarise: the abovementioned findings from the literature and the empirical evidence support the major influence of teachers' cognition (knowledge, beliefs and attitudes related to formative assessment) on the way in which they had organised their classroom and assessment practices. The evidence provided by this study also indicated that teachers in general experienced a lack of explicit guidance in the formative assessment process despite numerous descriptions in the policy documents. This finding has important implications for professional development programme developers and educational stakeholders to create opportunities to address teachers' assessment literacy.

5.2.2 What are the major influences and constraining factors on the quality of teachers' implementation of formative assessment practices?

This research question aimed to explore and describe aspects that may have influenced the participating teachers' classroom-based decisions regarding their formative assessment experiences. It also aimed to explore and identify different barriers keeping them from effectively implementing formative assessment strategies.

5.2.2.1 Influences on formative assessment practices

The literature review provided me with the relevant information to come to an understanding of the way in which certain factors influence the experiences of mathematics teachers as they attempt to implement formative assessment strategies. The results in this study seem to be consistent with Duncan and Noonan's (2007) research, which found that external factors, such as large-scale systemic assessments, educational policy and school context influence teachers' decision making in their assessment practices (see Section 2.5.5).

a) Influence of systemic testing

As mentioned in the literature review, prior studies have noted the major influence of high-stakes and systemic testing on the classroom assessment and instructional practices of teachers (Jennings & Bearak, 2014; Perie et al., 2009; Ruthven, 1994; Shepard, 2008; Stiggins; 2005). A general shared opinion from the literature is that systemic testing (high-stakes testing) and summative assessment are usually designed to be as objective as possible to serve monitoring purposes. However, it usually comprises relatively short and superficial test items, and excludes many worthwhile learning outcomes such as problem solving and critical thinking (Bennett & Gitomer, 2009; Harlen, 2005; Shepard, 2000).

The literature review has also described the importance of a balanced assessment system in which teachers use formative, summative and systemic assessments to monitor and enhance student learning in relation to the curriculum standards and goals for mathematics proficiency (see Section 2.6.5). For example, Bennett and Gitomer's (2009) proposed "Cognitively Based Assessment of, for and as Learning" (CBAL) model, which describes what students have achieved (assessment *of* learning), facilitates instructional planning (assessment *for* learning), and is considered by students and teachers to be a worthwhile educational experience in and of itself (assessment as learning) (Bennett & Gitomer, 2009, p. 47).

The dominating influence of systemic testing, in particular the ANAs, on the participating teachers' assessment and classroom practices was evident throughout this study. Most of the participating teachers invested a lot of time and energy in teaching towards the ANAs (see Section 4.4.3.1). The teachers in this study seemed to be very much dependant on summative assessment resources such as previous exam papers or systemic assessments like the ANAs or TIMSS. Teaching to the test, therefore, seems to be very influential in most of the participants' planning of their instructional practices and their formative and summative assessment strategies. Teacher perceptions of assessment in general, and of large scale assessment such as the ANAs, is not that of student learning but rather an evaluation of teacher effectiveness.

Given the current climate of school accountability and data-driven decision making, teachers are expected to use sound assessment practices as a means for improving student outcomes. I also observed and noted on my observational field notes the following.

> The teachers seemed to constantly express the need for quality assessment resources. It appears that they placed a very high value on the systemic questions used in systemic tests and it seems that they had a lot of confidence in the quality and standards set by the ANAs **(OFN: F1)**.

This observation is an indication that the teachers were very much dependant on only one source of external monitoring. As explained by Mr M, normal teaching was happening in the classroom, for the most part, and all attempts to improve and excel in the ANAs and the matric exams went above and beyond the normal teaching that took place in the classroom **(MFG2:4)**. However, because of the public, and high-stakes nature of the ANAs, it is understandable that for three weeks in the third term prior to the ANAs being written all of the focus is on performing well in the ANAs. An implication of this finding is the possibility that teachers are so motivated to excel in systemic tests that they inevitably focus more on teaching to the test. When they do this, it narrows down the curriculum and neglects important mathematics learning principles.

As mentioned in the literature review, systemic tests in South Africa are set by the Department of Basic Education (DBE). The Annual National Assessments (ANAs) aim to provide system-wide information on learner performance and the quality of education in general (DBE, 2011) (see Section 1.2.2). These tests, however, are assumed to be set by professional assessment developers who use research-based and policy-based criteria to develop and interpret the outcomes of these tests. According to Schneider, Egan and Julian (2013, p. 55), the observed knowledge, skills, and processes measured by teachers' classroom or other assessment practices may differ from these high-stakes tests. It is therefore inevitable that teachers, students, and parents may receive mixed messages from each assessment source regarding what the student is actually able to do. Moreover, "The ability of the teacher to summarize information either to assist student learning or to understand student progress may be hindered… due to substantive differences in how high-stakes assessments are developed as compared to classroom assessments" (Schneider, Egan & Julian (2013, p. 56). The empirical findings of this study support Schneider et al.'s view that these conflicting messages about student achievement may, in part, be due to substantive differences in how high-stakes assessments are developed as compared to teachers' classroom assessments.

Teachers' lack of confidence in their own abilities to set quality assessments was particularly evident in this study. Several accounts by the participants confirmed that they were on a constant lookout for high-stakes assessment resources against which to measure their standards. For example, Mr L's comment: "most of the educators, we find it difficult to do our own worksheet, so this [referring to the formative worksheets] it might work as a guideline to us" **(LF2:9)**. It seems as if the teachers were neither aware nor adequately trained in the construction and implementation of quality assessment tasks to promote student learning.

This finding supports the urgency for professional support to help teachers understand how to use accountability and formative assessment systems effectively

(Bennett & Gitomer, 2009; Stiggins, 2005). To counteract a narrowing down of the curriculum, teachers need training in research-based and policy-based assessment strategies from which they can make more valid inferences about their students' learning. They also need training in strategies to effectively integrate systemic test results that not only allow them to successfully elicit students' understanding of the content but also to help students learn skills that are measured in high-stakes assessments. Although, it is beyond the scope of this study, I also propose further research investigating the interplay between formative assessment and high-stakes testing.

Educational policy

Another recurrent theme from the empirical data revealed the significant influence of educational policies such as curriculum reform, and in particular, the current assessment directed curriculum (CAPS) on teachers' assessment practices in this study. Although the teachers in this study experienced CAPS to be more descriptive in terms of guidelines and objectives related to assessment practices than previous curricula, most of them still experienced difficulties in distinguishing between the different types of assessment as described in CAPS. The comments made by the participants throughout this study all contained elements of vagueness or misinterpretation, which revealed a clear absence of a deeper understanding of the formative assessment process. This may suggest that either the teachers were not familiar with the curriculum documents (CAPS), or the manner in which educational policy documents alluded to the importance of formative assessment in mathematics teaching and learning was not clear.

As mentioned in the literature review, knowledge of the curriculum and educational policies is important for the effective teaching and learning of mathematics (see Section 2.4.1). Being an effective mathematics teacher requires more than subject content (SCK) and pedagogical knowledge (PCK), which most teachers should have. Knowledge of the intended curriculum and educational policies are also required and beneficial to teachers so that they are in a position to support their students' learning.

The teachers' explicit views on their professional learning needs suggest that they were willing to engage in PD activities, supporting the National Policy Framework for Teacher Education and Development Policy (DoE, 2007) and the South African Council for Educators' (SACE) plan to continually develop teachers' professional knowledge and skills. They particularly expressed the need for professional development programmes that are practical in nature and that aim to meet their specific needs, such as collaborative, subject-related professional development experiences to enhance their formative assessment knowledge and skills in the implementation thereof (see Section 4.4.3.2).

b) School context

One of the essential findings of this study was the important role of the contextual environment on the teachers' professional development experiences as they implemented formative assessment strategies. Most of the teachers experienced their school context as supportive when they engaged in PD activities. The responses from the participants support the important role of social conditions, such as support from their colleagues and school leadership, in their perceptions of professional development processes. Only one participant experienced his colleagues as less supportive when he attempted to involve them in discussions on the formative assessment tasks. Two other participants were appreciative of the leadership support from their schools, however, they expressed the need for networking with colleagues from other schools. In both instances, time seemed to be the most influential limiting influence on the experiences reported by the participants.

In short, the findings, as they relate to the abovementioned influential factors on the teachers' experiences of professional development and formative assessment skills, led me to conclude that external factors and the conditions of teachers' work matter a great deal. Collaboration between colleagues and external support from other colleagues or researcher PLCs, leadership support, and encouragement allow teachers to acquire and implement new skills while helping them improve their personal and professional skills. Teachers are constantly making decisions on how to best utilise the limited teaching time available to them, and constantly seek guidance from people who they regard as experts (more knowledgeable), their school settings and curriculum documents about what needs to be prioritised. This is also an important reminder that teacher growth and professional change is a multidimensional process, which is reciprocally influenced by a stimulating and supportive and socially constructed environment (Bandura, 1986; Clarke & Hollingsworth, 2002). The results from this study therefore indicate that the status of formative assessment to improve mathematics teaching and learning can be further promoted through attendance at well-structured and curriculum-aligned PD programmes.

5.2.2.2 Constraining factors on formative assessment practices

In order to understand that there are different ways in which elements from the external domain interact with the teachers' individual learning orientation, this research question aimed to explore and identify different barriers keeping them from effectively implement formative assessment strategies.

The literature suggests that students occupy a central and active role in all feedback processes in assessment systems, especially in the monitoring and regulation of their learning progress. Understanding students and their learning needs is at the heart of professional development design as Corcoran (2007, p. 5) states, "Effective professional development is designed to help teachers meet the specific needs of real students in real classrooms." It was therefore not surprising that this research has found that most of the constraining factors on teachers formative assessment (assessment for learning) practices were experienced on a micro-level (inside the classroom), related to their students' learning experiences and needs (see Section 4.4.4):

- Learners' poor socio-economic backgrounds;
- Large classes;
- Lack of parental support;
- Learner attitudes;
- Diversity in learners' abilities;
- Language issues;
- Anxiety related to assessment;

- Communication between schools and the Department of Education;
- Lack of assessment resources; and
- Time.

All of the abovementioned concerns raised by the participating teachers require further understanding, and additional research would be beneficial to improve the quality of mathematics teaching and learning. However, the overall results in this study suggest that the diversity of learners in any one class was one of the most influential constraining factors in terms of school context for the teachers in this study. Considering the demands of the National Curriculum in South Africa, it is not surprising that multi-level abilities in one class seems to be a major constraining factor (see Section 4.4.4.5).

Across the dataset, it also emerged that teachers spent a lot of their time and energy looking for assessment resources such as high-stakes examination papers. This requirement may be attributed to both their paucity of assessment knowledge and to the pressure to increase externally assessed test scores. This observation further supports and confirms the urgency to provide teachers and administrators with professional support and training to help them understand how to use the accountability and formative systems effectively (Bennett & Gitomer, 2009; Stiggins, 2005).

Reflecting the influence of a society that places a high value on achievement in systemic tests and grading, the teachers in this study experienced their learners' attitudes toward assessments that do not add to their progress marks as negative. Three of the participants mentioned that the majority of their learners were not interested in doing assessments such as the ANAs or the formative assessment worksheets as they not only expected immediate feedback on assessments, but they also wanted to be graded. Lipnevich and Smith (2008), however, conducted a large-scale study involving 464 students and their response to assessment feedback. The authors concluded that overall, detailed feedback was most effective when given alone, unaccompanied by grades or praise. Their findings showed that students who received grades and no comments showed no learning gains, those who received grades and comments also showed no gains, but the students who received comments and no grades showed large gains. Andrade (2013, p. 26) and Lipnevich and Smith's (2008) find that assessment information or feedback from teachers comes in a variety of forms from informal, formative comments to formal, summative grades. In support of this, I suggest that additional research on the relationship between summative grades, achievement, and motivation in secondary mathematics classrooms is needed. As Andrade (2013, p. 26) points out,

> If the results indicate that grades do indeed interfere with learning and achievement, the hard work of figuring out how to minimize or even eliminate that negative effect within the context of our grade-addicted society could begin in earnest (p.26).

To conclude, the overall results suggest that systemic testing, in particular the ANAs, seems to be the most influential factor on the teachers' instructional and assessment practices. The participants' motivation to excel in high-stakes and accountability tests seems to dominate their classroom practices and, in the process, important mathematics learning principles may be neglected. The most challenging factor experienced by the participants seems to be a lack of time and/or skills to accommodate the wide range of learner abilities in one class. As previously mentioned, the dilemmas voiced by the teachers in this study are in no way limited to the AETL project. They are issues that must be confronted in the design of all professional development projects and I believe that the articulation of these dilemmas provides a useful tool for conscious reflection and working practice for future research in mathematics education in general (Adler, 2000; Desimone et al., 2006; Mewborn & Huberty, 2004; Steyn; 2013).

5.2.3 How does the teachers' involvement in purposefully designed formative assessment tasks influence them in terms of personal and professional development, if at all?

This research question aimed to gather evidence on whether or not formative assessment strategies caused the teachers to reflect and act upon their existing classroom assessment activities.

Clarke and Hollingsworth's (2002) interconnected model of teacher change (professional growth), which is grounded in social constructivism, provided a theoretical framework that enabled me to address this research question. In addition, it offered a valuable analytical and explanatory frame to understand the complexity of the teachers' professional learning experiences in this study. The model's ability to accommodate multiple and interactive domains in which change can occur assisted me in analysing the participants' growth experiences in this study.

As mentioned earlier (see Section 1.7.1), two mediating processes are required through which the effects of change (or professional growth) may occur: reflection and enactment (Clarke & Hollingsworth, 2002). The literature on teacher professional development and change theories highlights the importance of reflection in relation to professional growth. According to Schön (1987, p. 114), reflection begins with "reflecting-on-action" and eventually progresses to "reflecting-in-action". In agreement with Schön (1987) and Clarke and Hollingsworth's (2002) views, this study also drew on the reflection of the participating teachers' experiences with formative assessment strategies and activities to analyse their professional development experiences (see Section 4.4.6). In this study it should be noted that all of the significant themes and examples of growth experiences described and discussed in Section 4.4.6 were mediated through reflection. Throughout this study, the teachers were given enough time (two years) to implement and reflect on the purposefully structured activities. The teachers were encouraged to continually reflect on their own changes in classroom assessment practice and to consider best instructional practices during their engagement in the AETL Project.

Enactment, according to Clarke and Hollingsworth (2002) is the process through which the translation of a belief or pedagogical model results in action. Stated differently, enactment may result in a change of behaviour as a consequence of changed beliefs, whereas reflection may result in a change of cognition. The literature reveals the significance of teacher agency as an important component of professional development. However, in exploring theories of learning, an explicit discussion of agency is not included within any of the models that I reviewed (see Section 1.3). Considering the importance of teachers' "active contribution to shaping their work and its conditions – for the overall quality of education" (Biesta, Priestley & Robinson, 2015, p. 624), I could not omit agency as an important process in Professional Learning Theory. However, I found it difficult to decide where to locate its position within Clarke and Hollingsworth's (2002) model. Initially, I had located agency in the domain of consequence (as a motivational reaction to positive outcomes), but eventually realised that each of the examples of the teachers' professional growth that I reported on in Chapter 4 culminated in the teachers as agents who actively contributed to improving their existing practices or beliefs. From a sociocultural perspective, I viewed agency in accordance with Eteläpelto et al.' s (2013) view that agency does not reside entirely in the person, or in this case the teacher, but as a product of the teacher engaging with the environment. In this study, agency can therefore be seen as a mediating process in which teachers can act as a result of altered beliefs or knowledge. When agency is viewed as residing within the person, the assertion can be made that agency can be a salient outcome dependent on teacher beliefs (see Figure 5.1). Within the limits of this study, an elaborated discussion of theories of agency and their relationship to professional learning is not possible. However, I find the concept of teacher agency an important dimension of teachers' professional development which needs to be explored further.

The findings and conclusions in this study are in line with the interrelated four domains of teacher learning and growth (Clarke & Hollingsworth, 2002) (see Section 2.3.2; 4.4.6). A discussion of the major findings of teacher professional growth (change), as it emerged from the study, follows in relation to the interaction between these four domains:

1) The external domain (e.g. sources of information (AETL project), stimulus or support, such as in-service training sessions, and conversations with colleagues);

2) The personal domain (e.g. teacher knowledge, beliefs and attitudes);

3) The domain of practice (professional experimentation and activities, e.g. implementing the formative assessment tasks); and

4) The domain of consequence (incidental salient student learning outcomes, teacher control, motivation and student feedback).

5.2.3.3 External domain

As mentioned in the literature review, effective professional development is rooted in teachers' specific professional contexts and influenced by factors such as characteristics of the school culture and its population, the available time, and local support for professional development (Steyn 2011; 2013; Wiliam & Thompson, 2007) (see Section 2.5.5; 5.2.2.1).

In this study, external factors such as large-scale systemic assessments, educational policy and school context were found to be the most influential in teachers' decision making regarding assessment practices.

The dominating influence of the ANAs (systemic testing) on the teachers revealed a strong motivation to participate in professional development interventions. Participation in the AETL project was a voluntary process, and their commitment towards the programme might indicate that they had experienced the formative assessment process as contributing to their professional development. They also indicated that they had experienced various opportunities of growth as a result of their participation in the AETL project. For example, the teachers experienced the formative assessment tasks as resourceful in contributing to growth in their general assessment knowledge. Several participants also expressed the need for CPD interventions, such as the AETL project, for sustained support in developing their assessment skills and knowledge. This study identified a need for quality and strategically designed assessment resources that are aligned with educational policy and curriculum standards.

Consistent with the social cognitive perspective, this study reveals that the effects of the teachers' school context (e.g. leadership support, supportive colleagues) and the positive relationships that they experienced with teachers from other schools, and the researchers, allowed them to acquire and implement new instructional skills. In the process, this assisted them in improving their personal and professional skills. School A, for example, has shown strong evidence of how conditions for an effective PLC were created by the principal to support the teachers' professional growth.

Furthermore, this study suggests that providing teachers with continuous support using curriculum-aligned, content-rich opportunities to develop formative assessment strategies could bolster teachers' understanding and perceptions of mathematics teaching and learning. The participants also commented that the AETL project differs from one-day workshops in which they had participated in the past, where they learned new content and instructional strategies but did not fully experience long-term changes in their assessment practices. Desimone et al. (2006, p. 205) suggest "scaffolding" PD opportunities by offering programmes targeted for teachers with varying levels of content knowledge and skills. Moreover, teachers prefer programmes that are more practical in nature and aim to meet their specific needs (Loucks–Horsley et al., 2010; Robinson & Carrington, 2002). Desimone et al.'s (2006) study reveals that teachers with more expert content knowledge have more confidence and motivation to further develop their knowledge and skills than teachers with less content knowledge. The overall reflections of the teachers also revealed that they tended to embrace professional development as a part of every school day when opportunities for collaboration were created, and professional learning tools were introduced that were powerful enough to influence student learning (Steyn, 2011; 2013).

This study has shown that growth from a stimulus from the external domain has a direct influence on salient outcomes. Furthermore, it improves the collaborative nature and communication, not only between colleagues, but also between the teacher and his or her learners (Clarke & Hollingsworth, 2002) (see Section 2.3.2). In addition, it has also contributed to the understanding of the major influence of the external domain on teachers' personal domain (change in their formative assessment knowledge, attitudes toward formative assessment) and on the domain of practice (change in instructional and assessment practices).

5.2.3.4 Personal domain (cognitive factors)

In the South African context, there is much literature on what should change in mathematics education, but there is very little on what strategies and programmes can be implemented to affect change in teachers' knowledge, attitudes and beliefs about formative assessment. The educational literature underscores the centrality of the personal domain of the teacher in sustaining educational change.

The findings of this study revealed that the engagement in formative assessment strategies did not change the perceptions of the teachers with respect to teaching and learning, i.e. what they have perceived as ‘being a good teacher’. The data obtained from across the dataset revealed that all of the participating teachers had a strong sense of personal commitment and professional identity. This was the case as they personally constructed an understanding of what it is to be a good mathematics teacher, and how to be reflective in their classroom assessment practices. The participants held varied and fixed knowledge and beliefs on what they perceived as good teaching practices. Some of the teachers expressed their perceptions based on emotional beliefs such as: “a good mathematics teacher will inspire learners” **(MI:5)** and others on instructional beliefs, for example: “a good teacher uses a variety of instructional methods” **(FI:1)**. The extent to which the teachers in this study have changed in terms of beliefs is difficult to describe in terms of Clarke and Hollingsworth’s (2002) model. This could possibly be for the reason that change occurs as an iterative process and often comes later when teachers use a new practice on their own and see the benefits to their students (Ball & Cohen, 1999). In this study, however, I did not focus on learner achievements and as a result, the student benefits were not explicitly explored.

The findings in this study further provide evidence that formative assessment supports the development of, and refocusing on important teacher behaviour such as self-reflection about their professional roles and practices, and social skills development. These findings are also in line with Bandura’s (1997) ‘‘academic self-efficacy” definition, as discussed in Chapter 2 (see Section 2.3.1). In particular, teachers’ self-efficacy beliefs affected their choices of formative assessment activities, their efforts to perform tasks successfully, and their persistence and resilience to overcome obstacles. As one engages in tasks and activities and interprets one’s previous performance, one develops beliefs about the ability to do subsequent tasks and activities (Bandura, 1997).

Consistent with Clarke and Hollingsworth’s (2002) model for teacher change, this study provides information that reveals that the personal domain regarding teachers’ perceptions of teaching (or what they perceived as being a good teacher) has a direct influence on the domain of practice (or the way in which they implement formative assessment strategies in their classrooms). All of the teachers in this study expressed the need to develop effective formative assessment skills as they believed that this would enable them to be successful in the implementation of the lessons that they have planned.

This study therefore illustrates that the teachers' awareness of formative assessment enabled them to be cognisant of the important role it plays in enabling effective mathematics teaching and learning.

5.2.3.5 Domain of practice

The AETL project aimed to provide the teachers with the skills and resources to improve their subject content knowledge, pedagogical knowledge, and assessment knowledge as it aligns with the nature of the subject and curriculum standards (see Section 4.4.1).

The teachers in this study participated in a variety of content-rich, purposefully structured formative assessment activities. These activities included research and policy-based tasks, also referred to as worksheets, not only to improve their formative assessment knowledge as it aligns with the curriculum (see section 1.4), but also to involve them in refining and adapting it to their individual needs. The teachers were very appreciative of the worksheets and seemed interested in engaging with the activities (the initial meetings, focus group discussions, refinements, and implementation of the tasks). The attendees actively participated in the discussions and gave valuable input on the worksheets. The use of collaborative group work, reflective activities and content that are all specifically linked to the curriculum were all forms of professional experimentation for the participating teachers in this study.

The participants also commented that the AETL project differs from the one-day workshops in which they had participated in the past where they learned new content and instructional strategies but did not fully experience long-term changes in their assessment practices. Desimone et al. (2006, p. 205) suggest "scaffolding" PD opportunities by offering programmes targeted for teachers with varying levels of content knowledge and skills. Moreover, teachers prefer programmes that are more practical in nature and aim to meet their specific needs.

All of the teachers in this study expressed the need for assessment resources and activities in which continuous support would enable them to be successful in the implementation of assessment strategies. However, as the AETL project progressed, they seemed to have focused more on other issues, such as a lack of time in addressing the different levels of abilities in one class. This might be an indication that there could have been an adaptation in their instructional strategies due to the support they received from the formative assessment activities.

5.2.3.6 The domain of consequence

The findings in this study support the ideas of Broadfoot et al. (1999) and the NCTM (2014) that it is important to involve both teacher and learners in reviewing and reflecting on assessment data to ensure effective mathematics learning. It also supports the argument that if students are seen through a constructivist lens in terms of learning through which they are seen as co-constructors of knowledge, then feedback becomes a central component for students' acquisition of knowledge (Hattie & Timperley, 2007; Sadler, 1989; Tittle, 1994).

The teachers reported that the worksheets provided them with evaluative feedback from their students, and as a result enabled them to provide the students with immediate feedback. This also enabled them to adapt their instruction accordingly (Section 4.4.6.5). This observation might be an indication that their students' feedback on the worksheets motivated them to adapt their instructional practices.

Gathered from the data and reported examples in Chapter 4, the teachers experienced a renewed interest in formative assessment and several examples of change in instructional practices have been reported in Section 4.4.6.2.

Figure 5.1 describes the findings in this empirical study and the reciprocal nature of the four domains suggested by Clarke and Hollingsworth's (2002) model of teacher professional growth.

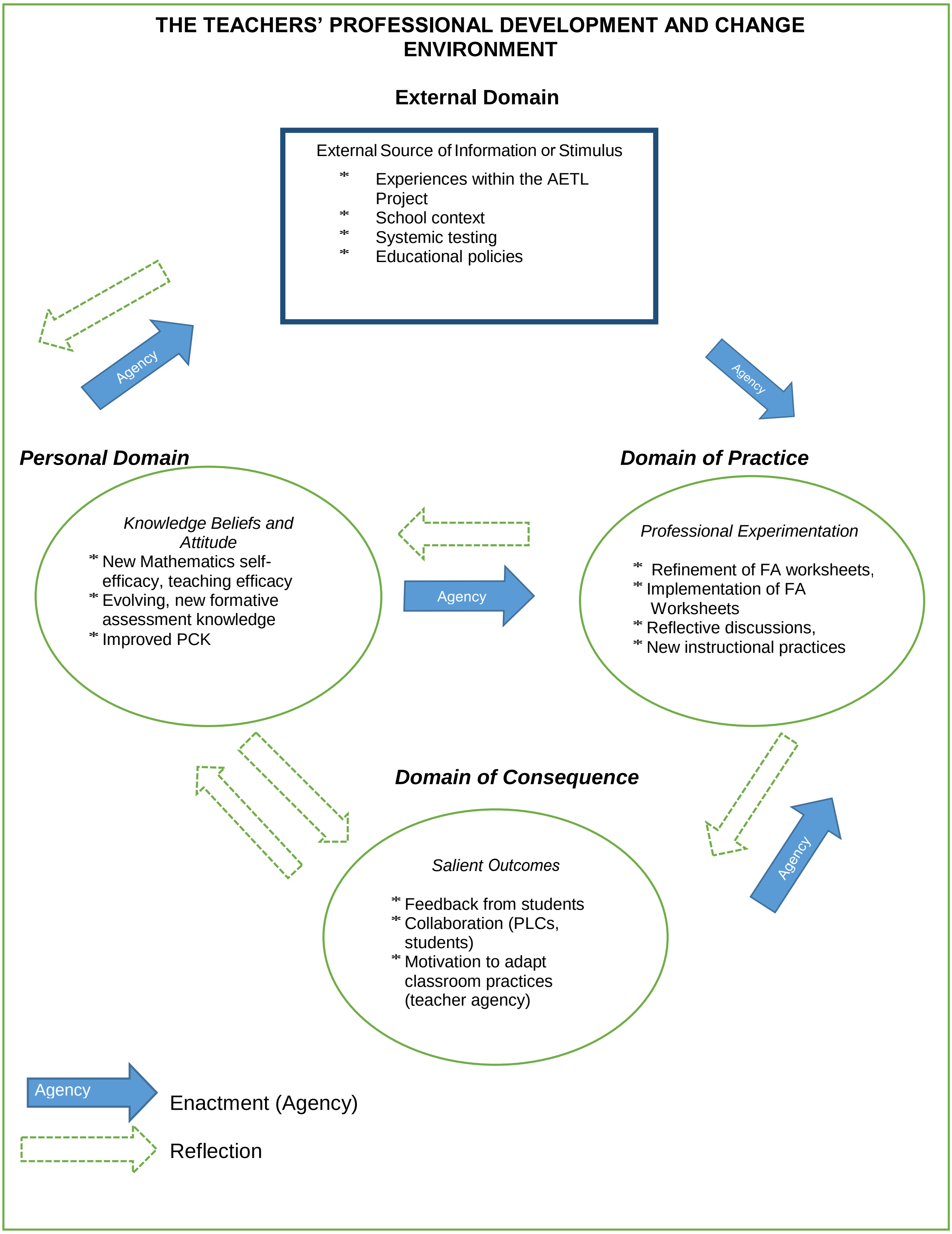


Figure 5.1: Teachers' professional development and change as it relates to the findings of the AETL Project.

Consistent with the social cognitive perspective, this study also reveals that the effects of the external domain environment (for example, a supportive school context, collaboration within a PLC, the AETL project) interacted reciprocally with the cognitive domain (for example, acquired formative assessment knowledge, change in PCK), and the domain of consequence (for example, student outcomes, motivation to change). This in turn reciprocally influenced their domain of practice (for example, change in classroom practises). The results of this study indicate that teachers' engagement and implementation of formative assessment strategies addressed all four domains of learning and teacher professional growth as outlined by Clarke and Hollingsworth's interconnected model (2002).

To summarise the findings of this study as they relate to research question three: I can conclude that the teachers experienced a measure of personal and professional growth due to the interactions identified in all four domains pertaining to learning, as suggested by Clarke and Hollingsworth (2002).

5.3 Recommendations

Based on the results of this study, the suggestions for further research are as follows:

- Despite all of the positive attitudes and beliefs regarding the value of assessment for learning reported by the teachers, it was not possible to establish if these beliefs had been actualised in their classroom practice. Future studies on this value-practice gap are therefore recommended.
- Teaching to the test seems to be very influential in most of the participants' planning of their instructional practices and their formative assessment strategies. Teacher perceptions of assessment in general, and large-scale assessment such as the ANAs, are not that of student learning but an evaluation of teacher effectiveness. Teachers need training in strategies to effectively integrate systemic tests that allow them to effectively elicit student understanding of the content, but also to help students learn skills that are measured in high-stakes assessments. Further research investigating the interplay between formative assessment and high-stakes testing is therefore proposed. I also recommend further studies on the ANA replacement tests as proposed by the Department of Basic Education (DBE, 2016) (see Section 1.2.2).

- Designing and implementing formative assessment is not only a complex process, but one that requires extensive knowledge, including knowledge about student learning, assessment and pedagogy (Chappuis, 2009). It is important that teachers realise how important it is that tests should be set in a way that teaching to them makes sense. More research is needed to determine the efficacy of assessment literacy, and in particular, formative assessment, on the instructional practises of teachers.
- This study strongly suggests that if education in South Africa is to provide quality teaching for all learners, then the schools must become places that support the professional development of teachers by investing in sustained developmental initiatives as illustrated in this study. With this research, I intended to show that providing teachers with development programmes catering to the specific needs of the mathematics teachers can contribute to their personal and professional growth. For example, needs such as the continued support from school leadership, guidance and support in developing quality assessment resources that are content-specific and curriculum-related should be examined.
- This study contributes to the understanding of teacher learning and change, and the commonalities and differences in perceptions of the teaching and learning of mathematics as experienced by in-service teachers. It would be interesting to compare the views held by novice teachers and experienced teachers.
- To improve the relation between research and practice, the research community should also get involved in efforts not only to support teachers in addressing their assessment needs, but also to support professional development more generally. My suggestion is for researchers to motivate teachers to engage in meaningful research themselves. Teachers need to be encouraged to carry out reflective research in their own classrooms in order to improve their practice in the classroom and improve the quality of education for their pupils.

Suggestions for Practice

- The findings of this study indicated that having collaborative interactions with researchers and colleagues from other schools had a positive effect on professional development in this study. Future research could investigate the characteristics of PD interventions that focus on formative assessment activities to provide effective professional learning opportunities on-site.
- The research literature and the empirical study clearly demonstrate that the formative assessment process, as a professional developmental experience, is complex and highly specific to the context, situation, and person. The conclusion can therefore be drawn that CPD goes beyond the acquisition of instructional strategies and content knowledge. It implies that professional development opportunities should be organised in ways that closely align to teachers' professional practice and their school culture, as displayed by this research. Different levels of support might be appropriate based on teachers' professional development needs. It could be of value to establish multiple PLCs within one school to provide the necessary support. It would be interesting to study what level of support is necessary to produce large-effect gains in whole school assessment (evaluation).
- Given the current emphasis on assessment and the teachers' general lack of understanding of the uses of formative assessment, teachers need to be involved in the design of a continuous range of formative assessment strategies to be embedded in every day practice. Based on the findings of this study, it is entirely plausible that a nationwide assessment programme involving not only relevant stakeholders such as policy makers and PD programme developers, but also the teachers be rolled out on a large scale to move towards a comprehensive assessment system.
- This study identifies the under-examined need for developing targeted PD interventions aimed at providing mathematics teachers with an opportunity not only to become assessment literate, but also to develop their instructional practices (PCK) and by implication, improve student learning. Of all the aspects of professional development, sustaining positive change is perhaps the most neglected. "It is clear that, to be successful, professional development must be seen as a process, not an event" (Guskey, 2002, p. 388). The formative assessment process is also time-consuming and can

easily be neglected; it is therefore necessary to invest in teachers' assessment literacy and sustain this professional development initiative for it to be successful.

- With regard to general assessment practices in mathematics education, guidance is needed for teachers to develop more refined methods to improve the quality of educational assessment. Multiple formats for developing a variety of assessment strategies to be implemented in classrooms are needed to optimise mathematics teaching and learning.

5.4 LIMITATIONS

The limitations of the research are discussed with regard to the literature review and the empirical study.

- A limited amount of literature is available on the influence of formative assessment on student achievement in mathematics in a South African context.
- In terms of this empirical study, the sample size of nine participating teachers in one district was not big enough to generalise the results to refer to a larger group of teachers. However, the findings are compelling enough to make a case for a wider study to be conducted.
- Considering that this study's primary aim was not to monitor the effect of the AETL project on student outcomes, I did not contemplate whole-school and student achievement in the actual ANAs. However, further research on student outcomes when integrating a model for external monitoring within classroom-based practice is strongly suggested.
- Important features have been left out, e.g. what teachers actually do in the classroom to assess their students (domain of practice), nevertheless rich data were provided to contribute to knowledge about teacher growth in other domains, as outlined by the selected framework underpinning this study (see Figure 5.1).

5.5 SUMMARY

Even though I cannot make definitive assumptions and conclusions regarding the teachers' professional growth based on this single case study, I can draw several lessons from the teachers' experiences with formative assessment as a strategy to optimise mathematics teaching and learning.

There is a need for a substantial change of approach to formative assessment within the mathematics education community, especially with regard to the teachers. There is ample evidence that a significant proportion of the teacher practices are sub-optimal, and that substantial improvements in student achievement would be possible with changes in teachers' classroom practices.

Teachers also need to develop new forms of delivering assessment. They seem to be constantly on the lookout for a variety of assessment resources. This may be an indication of the fact that there needs to be developed assessment tasks that address a wide range of content and skills, different contexts, and a variety of learner ability levels.

Effective teaching and learning involve continually assessing where the learners are, choosing appropriate learning activities based on the assessment, offering scaffolding to support learning, and assessing again to inform the next instructional decisions (Black, Harrison, Lee, Marshall & Wiliam, 2003). This includes engaging the students in self-assessment and the monitoring of their own learning, as well as using informal assessment to drive instruction (Carlson, Humphrey & Reinhardt, 2003; DiRanna et al., 2008). The evidence collected shows that the teachers in this study believed that formative assessment is an important part of their professional environment, and that its status can be further raised through specified and well-structured in-service professional development programmes.

It is clear that if formative assessment is to be an integral part of the teacher's professional teaching and learning practice, a major investment in teachers needs to be made. Leahy and Wiliam's (2012) viewpoint summarises the approach of the mathematics teachers in this study to the acquisition of formative assessment skills:

> *The problem is not ignorance, nor wilful disobedience. A specified procedure is needed* - Leahy and Wiliam (2012, p. 49).

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APPENDICES

APPENDIX A – FORMATIVE ASSESSMENT TASKS

1. WORKSHEET 1

Name:	

WORKSHEET 1 **GR 9**

Content Area: 2. Patterns, Functions and Algebra

Topic: 2.1 Numeric and Geometric Patterns

1. Below is a pattern describing the relationship between each term and the following term. Write the next three terms in the sequence and describe the pattern in words.

   (a) 5; 8; 11; ………; ………; ………; …

   In words: ____________________________________

   (b) 2; 4; 8; ………; ………; ………; …

   In words: ____________________________________

   (c) 1; 4; 9; ………; ………; ………; …

   In words: ____________________________________

[6]

2.

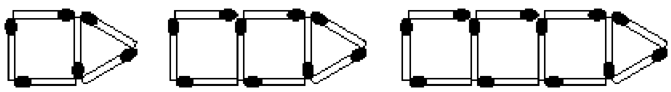


Figure 1 Figure 2 Figure 3

   (a) How many matchsticks are in each figure?

   (b) Determine the rule for the pattern shown by the matchsticks.

   (c) How many matchsticks are needed to construct the 30[th] figure?

   Hint: Use the rule you have determined to describe the pattern.

   Answer by completing the table:

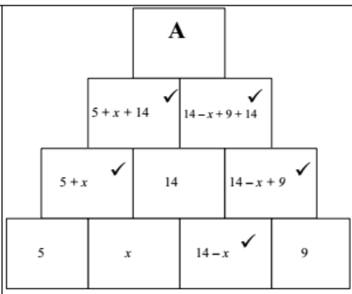
Figure	Figure 1	Figure 2	Figure 3		Figure 30
Rule: __________					

[6]

Item Set: Assessment enhanced teaching and learning UP, April, 2015

WORKSHEET 1 MEMO

MEMO 1 **GR 9** **Content Area:** 2. Patterns, Functions and Algebra
Topic: 2.1 Numeric and geometric patterns

QUESTION	TOPIC	DIFFICULTY	SPUR	ANSWER	EXPLANATION
1	**2.1 Numeric and geometric patterns** **Investigate and extend patterns** • Investigate and extend numeric and geometric patterns looking for relationships between numbers, including patterns: o represented in physical or diagram form o not limited to sequences involving a constant difference or ratio o of learner's own creation o represented in tables o represented algebraically • Describe and justify the general rules for observed relationships between numbers in own words or in algebraic language	E	S	(a) 14; 17; 20 ✓ Add 3 to the previous term to get the next term ✓ OR: Times 3, Add 2 (b) 16; 32; 64 ✓ Multiply the previous term by 2 to get the next term ✓ OR: 2^n (c) 16: 25; 36 ✓ Square each term OR: n^2 ✓	Find and describe the rule Apply rule
2		M	U	Figure: Rule: ✓✓ $y = 3x + 3$ | Fig 1: ✓ 6 | Fig 2: ✓ 9 | Fig 3: ✓ 12 | Fig 30: ✓ 93	Apply rule (formula)
3		E	P	(a) 3; 5; 7 ✓✓✓ (b) 0; 7; 26 ✓✓✓	Determine the rule Use the rule
4		D	Olympiad type Question	 $A = [(5+x)+14]+[((14-x)+9)+14]$ $= 19 + x + 37 - x$ $= 56$ ✓	Many ways of doing this question. Our way: Place x next to 5

WORKSHEET 2

WORKSHEET 2
Grade 9

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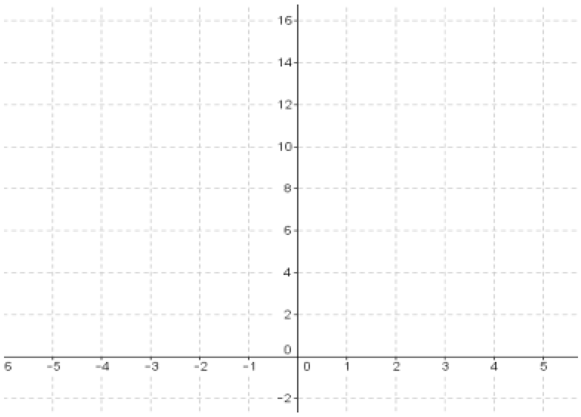
Question One.

1.1. Use the table to generate coordinate pairs for the function $y = 2^x$ where x can be any real number

x	-4	-3	-2	-1					
y					1	2	4	8	16

1.2. Plot the coordinate pairs of the function on the axis system below.



1.2.1. Write down the point where the graph cuts the y axes

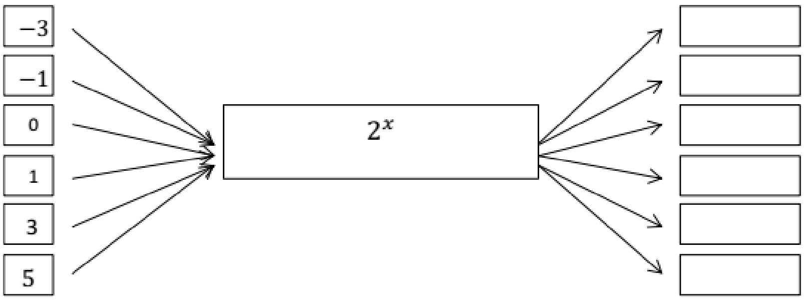
1.2.2. State whether the following statement are **true or false**

i. $y = 2^x$ is a continues function

ii. $y = 2^x$ is a non-linear function

iii. $y = 2^x$ is a decreasing function

1.3. Complete the following flow diagram by filling in the missing output values.



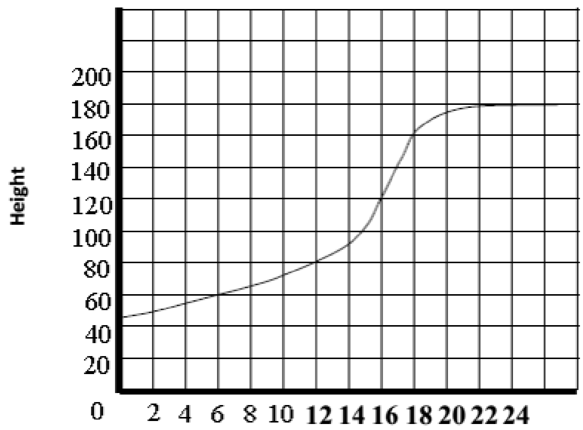
1.3.1.How many different input values can be fed into the flow diagram? The input values can be any real number.

1.3.2. Write the input and out values as coordinate pairs. Plot these points on the same axis system where you drew the graph of the function of $y = 2^x$. What do you notice?

Question Two.

Below is a graph showing Frank's height

Frank's height vs. age



Use the graph to answer the following questions.

2.1. At what age was Frank's height 140 cm?

2.2. By how many centimetres did Frank's height increase from age 16 to age 18?

2.3. During which one of the following periods, was the rate per year at which Frank grew the fastest? How do you know?

A. 0 to 12 years B. 12 to 16 years C. 16 to 18 years D. 18 to 20 years

2.4. What happens to the curve after Frank turned 23? Why?

Question Three.

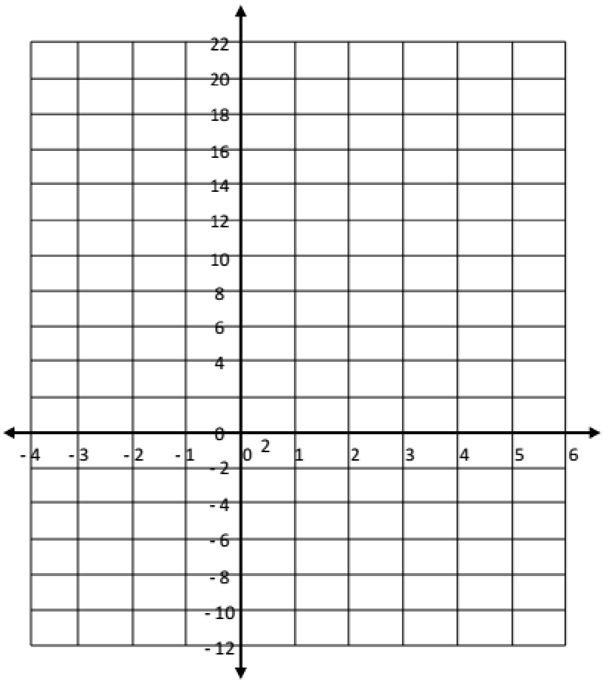
3.1. Represent the function $y = 3x + 2$ where x is any real number.

3.1.1. in a table of values for the set of integers from -4 to 6:

Input number	-4	-3	-2	-1	0	1	2	3	4	5	6
Values of: $3x+2$											

3.1.3.What is the value of $\boldsymbol{x}$ if $\boldsymbol{y} = \mathbf{4, 5}$

3.1.2. Use the following axis system to represent the function $y = 3x + 2$ graphically.



Question 4

The integers greater than 1 are written in a pattern as shown:

Row 1:	1			
Row 2:	2	3		
Row 3:	4	5	6	
Row 4:	7	8	9	10
Etc.				

What is the last number in the 20th row?

WORKSHEET 2 (MEMO)

MEMO
Grade 9 TERM 3

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Task 2 Functions

This assessment task aims to act as an assessment for and as learning. Assessment of learning may happen by default. Learners need to engage with the activities to demonstrate their reasoning and thinking, and not only rely on memory. It will be good if learners view mistakes as opportunities to learn.

Aim of the four questions.

Question 1
Create an awareness of equivalent representations of the same functions

Question 2
Learners will be able to assess their own knowledge about how graphs behave by analysing and interpreting a global graph.

Question 3
Learner need to demonstrate their knowledge and in-depth understanding of the linear function. Learners will be able to assess themselves and learn about their learning.

Question 4
This is an Olympiad type of question to challenge learners' mathematical reasoning and thinking and give them opportunity to experience the interrelatedness of mathematics

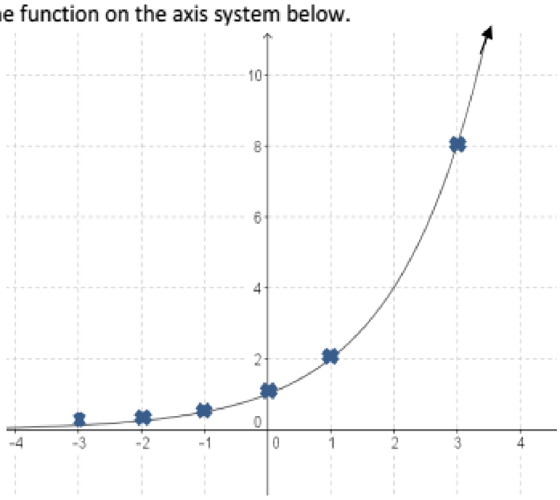
MEMO: Formative assessment activity on functions and relationships in the third term.

Question One.

1.1. Use the table to generate coordinate pairs for the function $y = 2^x$ where x can be any real number

x	-4	-3	-2	-1	**0**	**1**	**2**	**3**	**4**
y	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	8	16

1.2. Plot the coordinate pairs of the function on the axis system below.



1.2.1. Write down the point where the graph cuts the y −axes **(0;1)**

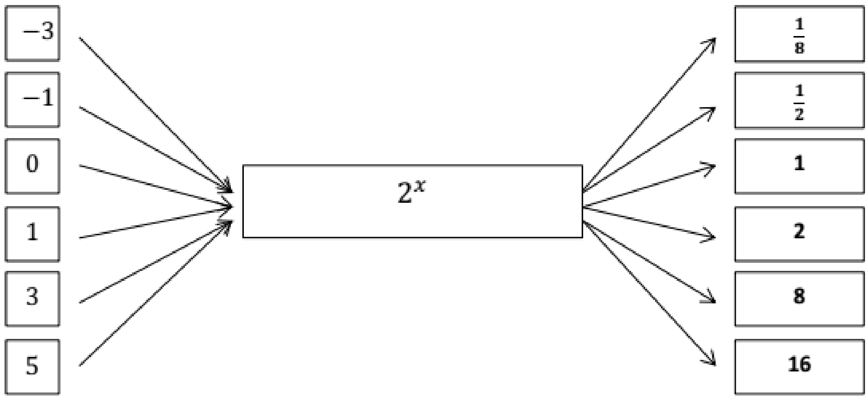
1.2.2. State whether the following statement are **true or false**

i. $y = 2^x$ is a continues function **True**

ii. $y = 2^x$ is a non-linear function **True**

iii. $y = 2^x$ is a decreasing function **False**

1.3. Complete the following flow diagram by filling in the missing output values.



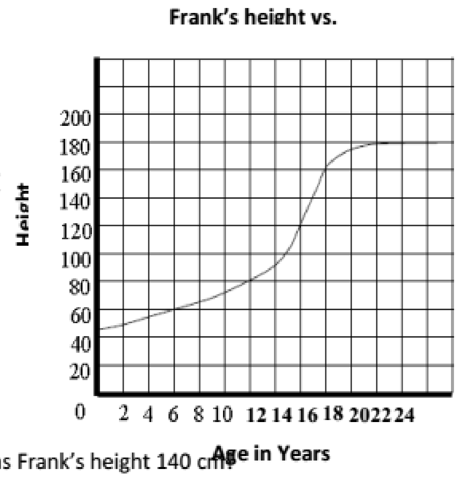
1.3.1. How many different input values can be fed into the flow diagram? The input values can be any real number. **Any real number can be an input number.**

1.3.2. Write the input and out values as coordinate pairs. Plot these points on the same axis system where you drew the graph of the function of $y = 2^x$. What do you notice?

$\left(-3;\frac{1}{16}\right);\left(-1;\frac{1}{2}\right);(0;1);(1;2);(3;8);(5:16)$ **It forms exactly the same curve when we plot these points. We say the all these different presentations of the function $y = 2^x$**

Question 2

Below is a graph showing Frank's height at different age values



Use the graph to answ

2.1. At what age was Frank's height 140 cm?

17 years or almost 17 years

2.2. By how many centimetres did Frank's height increase from age 18 to age 20?
20 cm

2.3. During which of the following periods, was the rate at which Frank grew, the fastest? How do you know?
A. 0 to 12 years   B. 12 to 16 years   C. 16 to 18 years   D. 14 to 18 years   E. 19 to 23 years
C He grew 40cm in two years. That is 20 cm per year or The curve is the steepest during that period

2.4. What happens to the curve after Frank turned 23? Why?
The curve becomes a horizontal line because his height stayed the same even though he grew older.

Question 3

3.1. Represent the function $y = 3x + 2$ where x is any real number.

3.1.1. A table of values for the set of integers from – 4 to 6:

Input number	– 4	– 3	– 2	– 1	0	1	2	3	4	5	6
Values of: $3x+2$	$\mathbf{-10}$	$\mathbf{-7}$	$\mathbf{-4}$	$\mathbf{-1}$	$\mathbf{2}$	$\mathbf{5}$	$\mathbf{8}$	$\mathbf{11}$	$\mathbf{14}$	$\mathbf{17}$	$\mathbf{20}$

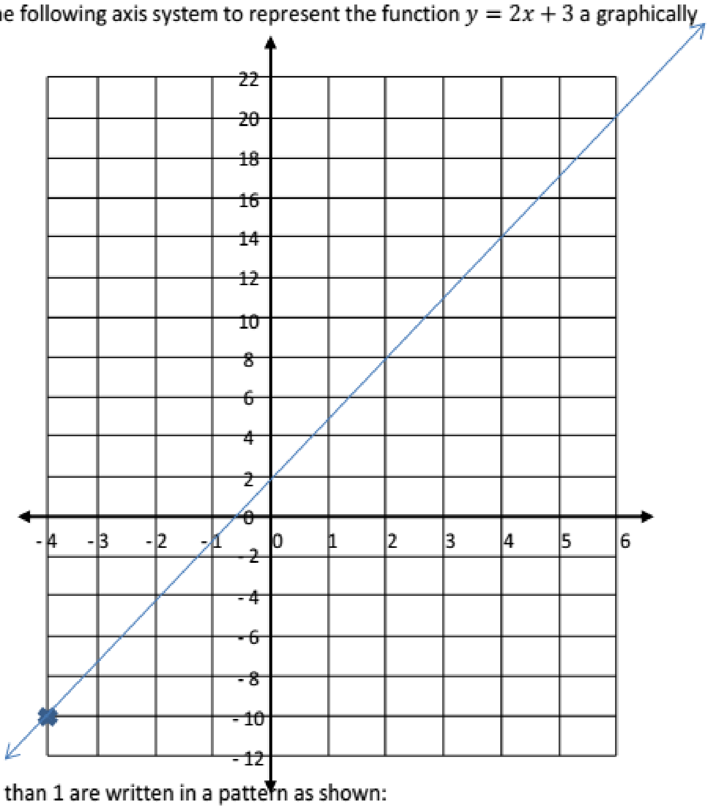
3.1.2. What is the value of x if $y = 4,5$

$$\mathbf{4,5 = 3x + 2}$$

$$\mathbf{3x = 2,5}$$

$$\boldsymbol{x = \frac{2,5}{3}}$$

3.1.3. Use the following axis system to represent the function $y = 2x + 3$ a graphically



Question 4

The integers greater than 1 are written in a pattern as shown:

Row 1: 1

Row 2: 2 3

Row 3: 4 5 6

Row 4: 7 8 9 10

Etc.

What is the last number in the 20th row? There are many ways of finding the it. Here are a few.

Method 1: Complete the pattern up to the 20th row

Method 2:

Note the following: Row 1 has one number; row 2 has two rows etc. row 20 will have twenty numbers.

Ry1	1																				Add 1 to 0 to get the last term in row 1
Ry2	2	3																			Add 2 to 1 to get the last term in row 2
Ry3	4	5	6																		Add 3 to 3 to get the last term in row 3
Ry4	7	8	9	10																	Add 4 to 6 to get last term in row 4
Ry5	11	12	13	14	15																Add 5 to 10 to get the last term in row
Ry6	16	17	18	19	20	21															Add the number of the row to the last number in previous row to to get the last term in row
Ry7	22	23	24	25	26	27	28														
Ry8	29	30	31	32	33	34	35	36													
Ry9	37	38	39	40	41	42	43	44	45												
Ry10	46	47	48	49	50	51	52	53	54	55											
Ry11	56	57	58	59	60	61	62	63	64	65	66										
Ry12												78									
Ry13													91								
Ry14														105							
Ry15															120						
Ry16																136					
Ry17																	153				
Ry18																					
Ry19																					
Ry20																				210	

Method 3

													Number of numbers per row	Numbervalue of last number in row
ROW1	1												1	$1 \times 2 \div 2$
ROW2	2	3											2	$2 \times 3 \div 2$
ROW3	4	5	6										3	$3 \times 4 \div 2$
ROW4	7	8	9	10									4	$4 \times 5 \div 2$
ROW5	11	12	13	14	15								5	
ROW6	16	17	18	19	20	21								
ROW7	22	23	24	25	26	27	28							
ROW 19													190	$19 \times 20 \div 2$
ROW20													210	$20 \times 21 \div 2$

Grade 9 term 3 Learners FRA teaching and learning experiences

Learners learned about *number and geometric patterns* in the *foundation phase* and the skills gained was mainly to extend geometric patterns, which include patterns with shapes, lines and other physical objects; and to extend number patterns by counting on in different intervals.

While they were in the *intermediate phase* learners were given opportunities to learn

- How to complete and extend patterns.
- How to represent patterns in different ways that is equivalent e.g. Verbally, in a table, flow diagrams, and number sentences.
- How to identify and describe patterns.

Other skills and knowledge that intermediate phase learners had the opportunity to develop are:

- Conceptual understanding of the properties of operations on numbers. These are the distributive, commutative, and associative properties of operations. *Addition* is the inverse of *subtraction,* and *multiplication* the inverse of *division*.
- Calculating input and output values and represent relationships with tables, flow diagrams and verbally. This may contributed to their ability to reason and think mathematically about relationships between variables. Other advantages include:
    - Learners develop insight in to the structure of algebra. They may be more comfortable to manipulate/transform algebraic expressions.
- The use of number sentences contributes to the development of number sense. A good number sense prepare learners to conceptualise algebra as an extension of arithmetic.

Operations in mathematics are addition, subtraction, multiplication, and division.

(Intermediate Phase CAPS, 2011).

During grade 7, 8 and the first term in grade 9 learners have been given opportunities to engage in a number of mathematical transformations:

1. Numbers
    - The existence of negative numbers and experienced the operation subtraction is an open operation.
    - The mathematics community established exponential notation for repetitive multiplication. Learners had the opportunity to derive several exponential laws and learned that the properties of operations irrespective of how numbers are expressed. Or represented.
    - Rational and Irrational numbers were defined and learners may have engaged numbers such as $\sqrt{-9}$, $2\sqrt{-3}$ etc that do not exist in the real number system.
    - The properties of operations hold for all the positive and negative rational and irrational numbers.

2. Relationships, functions and algebra.
    - The teaching and learning of patterns, functions, and relationships is more formally and algebra is used to explain the relationship between variables. They make use of symbols to:
        i. represent the variables as a general number
        ii. represent variables
        iii. Solve algebraic equations where the variable acts as an unknown.
        iv. Represent the different dimensions in formulae
        v. Variables are used in formulae.
        vi. Learners learn about the structure of algebra which allows the manipulation of algebraic expressions
        vii. Learners solved equations in a geometry and a measurement context, and as a tool to solve

general problems.

3. Mathematical Reasoning and Thinking
   - The learners need to transform from inductive thinking about geometry to deductive thinking.
   - Learners thinking about mathematics transform from thinking about mathematics as lose standing topics and facts to thinking and reasoning mathematically about the interrelatedness of topics and facts. The interrelatedness of mathematics is within the general content areas and across the general content areas.

The focus of learning about functions in grade 9 term 3 is

1. To make sure that learners are aware of the equivalence of the different representations of relationships; These different representations include a verbal description; a flow diagram; a table; a formulae; an algebraic equation; and a graph.

2. Consolidate learners' conceptualization of input and output values of a function using flow diagrams, tables, formulae and equations.

3. **Global Graphs**
   Consolidated gr 7 and 8 knowledge: Learners need to be able to interpret graphs in terms of the following trends and features:
   - Linear or non- linear graphs.
   - Is the graph behaving as a representation of a constant, or increasing, or decreasing, or increasing and decreasing relationship?
   - Read off maximum and minimum values.
   - Distinguish between continuous and discrete functions.

4. **The linear function**
   i. Point wise understanding.
   ii. Properties of linear functions.
   iii. Experience the linear functions as an object that behaves in certain way for instance:
      - Intercepts on the $x-$ and $y-$ axes.
      - Constant, increasing and decreasing functions
      - How the parameters $m \ and \ c$ of the general function $y = mx + c$ influence the behavior of the function.

WORKSHEET 3

WORKSHEET 3 GRADE 9 TERM 3

Algebraic expressions

Question One

1.1. Find the following products:

1.1.1. 7×5

1.1.2. $abc^2(3a^2 + bc^2)$

1.1.3. $(7 - 3x)(7 + 3x)$

1.1.4. $(7 + 3x)(7 + 3x)$

Question Two

2.1. Factorise $4x^2 - 81$

2.1.1. Determine the value of $(999)^2 - 1$ without using your calculator.

Question Three

3.1. Factorise $5x^2 + 6x + 1$ and hence

3.1.1. Calculate the value of $5 \times 16 + 6 \times 4 + 1$. Do NOT use a calculator.

Question Four

Calculate the value of $\frac{5x^2+x}{5x+1}$ if $x = 1054$ without using your calculator.

Question Five

5.1. How many values of x make the given expressions true?

5.1.1. $2x + 3x = 6x - x$;

5.1.2. $2x + x = 3x^2$;

5.1.3. $x + 30 = x + 50$.

5.2. How many values of x make the given expression true?

5.2.1. $y = 2x - 5$.

Question Six

6.1. If $20x - 15$ is expressed in the form $a(4x + b)$, determine the value of $(a + b)$.

6.2. In a magic square the sum of the numbers in each row, in each diagonal and in each column are equal. Determine the value of x in this magic square.

	6	
	10	x
9	14	

WORKSHEET 3 (MEMO)

WORKSHEET3 MEMO
GRADE 9 TERM 3

Task 1 Algebraic expressions

Question One

1.1. Find the following products

1.1.1. $7 \times 5 = \mathbf{35}$

1.1.2. $abc^2(3a^2 + bc^2) = \mathbf{3a^3bc^2 + ab^2c^4}$

1.1.3. $(7 - 3x)(7 + 3x) = \mathbf{49 - 9x^2}$

1.1.4. $(7 + 3x)(7 + 3x) = \mathbf{49 + 42x + 9x^2}$

Question Two

2.1. Factorise $4x^2 - 81 = \mathbf{(2x - 9)(2x + 9)}$

2.1.1. Determine the value of $(999)^2 - 1$ without using your calculator

$\mathbf{(999)^2 - 1 = (999 - 1)(999 + 1) = 998 \times 1000 = 998\,000}$

Question Three

3.1. Factorise $5x^2 + 6x + 1 = \mathbf{(5x + 1)(x + 1)}$ and hence

3.1.1. Calculate the value of $5 \times 16 + 6 \times 4 + 1$. Do NOT use a calculator

$\mathbf{(5.4 + 1)(4 + 1)}$

$= \mathbf{(21)(5) = 105}$

Question Four

Calculate the value of $\frac{5x^2+x}{5x+1}$ if $x = 1054$ without using your calculator.

Learners may attempt to find the value of the expression by substituting the value $x = 1054$ into the expression. $\frac{5(1054)^2+1054}{5(1054)+1} = \frac{5(1110916)+1054}{5270+1} = \frac{1111970}{5271} = 1054$

The value of $\frac{5x^2+x}{5x+1} = \mathbf{\frac{x(5x+1)}{5x+1} = x = 1054}$ **if** $\mathbf{x = 1054}$

Question Five

5.1. How many values of x make the given expressions true?[1]

5.1.1. $2x + 3x = 6x - x$; **The LHS = RHS for any value of x.**

5.1.2. $2x + x = 3x^{2;}$ **The LHS = RHS only for $x = 1$ *or* $x = 0$.**

5.1.3. $x + 30 = x + 50$; **The LHS $\neq$ RHS for any value of x.**

5.2. How many values of x make the given expressions true?

5.2.1. $y = 2x - 5$; **The LHS = RHS for any value of x. In this expression $y = 2x - 5$, x acts as an independent variable and y as a dependent variable. Thus y varies as x varies.**

Question Six

[1] Please read extra notes at the end of the memo.

6.1. If $20x-15$ is expressed in the form $a(4x+b)$, determine the value of $(a+b)$

$\mathbf{20x - 15 = 5(4x - 3)}$ ***Therefore*** $\boldsymbol{a = 5}$ **and** $\boldsymbol{b = -3}$. **So** $\boldsymbol{a + b = 2}$

6.2. In a magic square the sum of the numbers in each row, in each diagonal and in each column are equal.

Determine the value of *x* in this magic square.

	6	11
	10	x
9	14	7

The sum of the numbers in the middle column is $\mathbf{6 + 10 + 14 = 30}$

The sum of the numbers in the bottom row is $\mathbf{9 + 14 + \cdots = 30}$

The number in the open block is therefore 7

The sum of the numbers in the diagonal from top right to bottom left is:

$\mathbf{9 + 10 + \ldots = 30}$ **The number in the open block is 11.**

$\mathbf{11 + \boldsymbol{x} + 7 = 30}$ **thus** $\boldsymbol{x} \mathbf{= 12}$

APPENDIX: Additional notes about questions

Questions Two, Three and Four

The first aim of these questions is to allow learners the opportunity to demonstrate their skill to factorise.

The second part of each question is to let learners experience that their factorising may support them to do calculations.

Question Five

Equations, expressions, identities (equivalent expressions) and functions.

We tend to refer to the following algebraic expressions as equations because of the "=" sign.

- $2x + 3x = 6x - x$
- $2x + x = 3x^2$
- $x + 30 = x + 50$
- $y = 2x - 5$

Each one of the given expressions has a different meaning. It is more likely that learners may conceptualise Algebra more deeply if they can understand the difference between these expressions. Learners need to engage with the expressions and they have to think about what they are doing, and formulate the differences in their own words.
A possible strategy: Learners can create a table for each expression as follows:

Algebraic Expression	INPUT Value	x	-5	$-2\frac{1}{2}$	$-0{,}25$	0	1	2,5	5	150	Describe what you notice.
$2x + 3x = 6x - x$	LHS	$2x + 3x$									
	RHS	$6x - 1$									
$2x + x = 3x^2$	LHS	$2x + x$									
	RHS	$3x^2$									
$x + 30 = x + 50$	LHS	$x + 30$									
	RHS	$x + 50$									

$y = 2x - 5$	(LHS) INPUT Value	x	-5	$-2\frac{1}{2}$	$-0{,}25$	0	1	2,5	5	150	2 000 000
	(RHS) OUTPUT value (y)	$2x - 5$									

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Questions Two, Three and Four

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- $x + 30 = x + 50$
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A possible strategy: Learners can create a table for each expression as follows:

Algebraic Expression	INPUT Value	x	-5	$-2\frac{1}{2}$	$-0{,}25$	0	1	2,5	5	150	Describe what you notice.
$2x + 3x = 6x - x$	LHS	$2x + 3x$									
	RHS	$6x - 1$									
$2x + x = 3x^2$	LHS	$2x + x$									
	RHS	$3x^2$									
$x + 30 = x + 50$	LHS	$x + 30$									
	RHS	$x + 50$									

$y = 2x - 5$	(LHS) INPUT Value	x	-5	$-2\frac{1}{2}$	$-0{,}25$	0	1	2,5	5	150	2 000 000
	(RHS) OUTPUT value (y)	$2x - 5$									

After they engaged and made sense of the meaning of each one of the expressions, we can consolidate the knowledge gained as follows:

- $2x + 3x = 6x - x$
  The LHS = RHS $for\ any\ value\ of x$. Such an expression is called an *identity* because it is true for any real number. Here the variable acts as a generalized number. "Simplify an expression" actually means to write a different equivalent expression to get an identity.

- $2x + x = 3x^2$
  The LHS = RHS only for $x = 1\ or\ x = 0$. An expression that is only true for a limited number of values is called an *equation*. Here the variable acts as an unknown. At the end of the grade 9 year learners must be able to find the unknown values in linear equations, quadratic equations and exponential equations.

- $x + 30 = x + 50$ This expression will not be true for any value of x and is called an algebraic impossibility.

- $y = 2x - 5$ In this expression x can be any real number. y can also be any number. Note that the y value here depends on value of x. We may say that there is a relationship between the variables. The input value is usually called the independent variable and the output value (y) the dependent variable. Thus the variable x acts as an independent variable and y varies as x varies. The input value with its corresponding output value may be written as ordinate pairs in brackets.

$(-5; -15), (-2{,}5;\ -10), (-0{,}25; -5{,}5), (0;\ -5), (1; -3), (2{,}5; 0), (5; 5), (150; 295), (2\ 000\ 000; 3\ 999\ 995)$

Comments on School Algebra

Learners need to remember that:

- $2a =\ 2 \times a$ and $3a =\ 3 \times a;\ \ 6a =\ 6 \times a;$ and $a = 1 \times a$
  and in the same way $2n = 2 \times n,\ n = n \times 1$ and $3n^2 = 3 \times n \times n, etc.$
  The mathematics community decided that $2 \times a + 3 \times a$ can be written as $2a + 3a$
- symbols, (here we use the symbols $\boldsymbol{a, n, q, y\ and\ x}$) represents a value/number.
- when we choose a value for a symbol it follows that each symbol in the expression is substituted by the same value e.g. When we choose a value for a it follows that each a in the expression is substituted by the same value.
- When there are two or more different symbols in an expression they may have different values, or the two symbols may have the same value.

The mathematics community made these decisions and learners need to be told and accept them and remember them (Hewitt, 2012). Learners cannot discover it, reason it out, or think that it must be so. We can compare this knowledge to social knowledge. This include that a learner needs to be told the "+" sign indicates addition. Teachers can only know the learners names if the learners provide their names. A teacher will not understand what the learners names are, he needs to remember it. We, the teachers and the learners develop mathematical reasoning and thinking skills and can express their reasoning and thinking by using the knowledge was told. Learners who try to memorise everything and do not learn to reason mathematically are very likely to fail.

The meaning of the Equal "=" sign.

Many learners think the "=" sign is an operator. Learners then react on "=" by providing an answer.

The mathematics community however decided to use the equal sign "=" to indicate that the expression on the left hand side (LHS) is exactly the same as the one on the right hand side (RHS), the LHS is equivalent to the RHS for example:

$19 + 5 = 24\ The\ LHS = RHS.$ The equal sign is used correctly
$19 + 5 = 7 + 17\ \ The\ LHS = RHS.$ The equal sign is used correctly
$24 = 19 + 5\ \ The\ LHS = RHS.$ The equal sign is used correctly
$2 \times (4 + 5) = 8 + 10\ \ The\ LHS = RHS.$ The equal sign is used correctly
In the following example, the LHS is not equivalent to the RHS. $2 \times 4 + 8 = 2(4 + 8)$
$The\ LHS\ \neq\ RHS.$ The equal sign must be taken away.
Learners who conceptualised the property of operations and were exposed to different number sentences in the intermediate phase may have a deeper understanding of the meaning of the equal sign. It is very important that learners have the correct understanding of the equal sign.

WOKSHEET 4

GRADE 9 TERM 2

TASK 1 Geometry of straight lines

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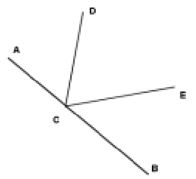
Question One

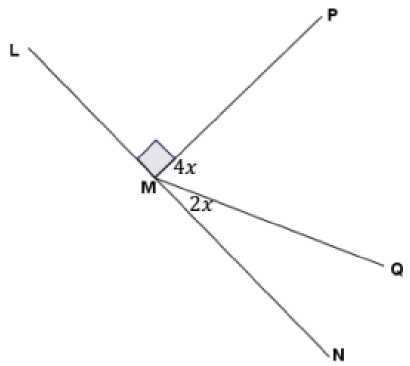
Complete the following table: The 1.1 is completed as an example

Number	Write a verbal description	Draw a sketch	Write down the mathematical expression
1.1 This row is completed as an example is completed	The three acute adjacent angles with the vertex (corner point) C in the drawing adds up to 180^0		$A\hat{C}D + D\hat{C}E + E\hat{C}B = 180^0$
1.2	When lines XY and WZ intersect at point O, the vertical opposite angles are equal.		
1.3			$PQ \perp MN \ at \ O$

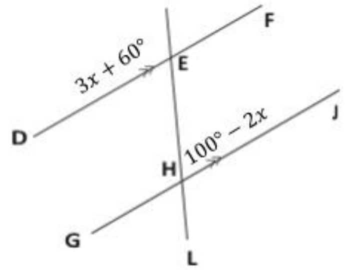
Question 2

Calculate the value of x in each of the following

2.1.



2.2.



Question 3

In the given diagram $PV \parallel WZ$ and $V\hat{Q}Z = Z\hat{Q}N$

Indicate whether the following statements are true or false. Justify your choice.

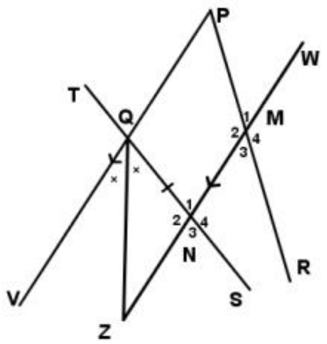
a. $\widehat{N}_1 = \hat{N}_3$

b. $\widehat{N}_1 + \hat{N}_4 = 180^0$

c. $\widehat{M}_3 + \hat{N}_4 = 180^0$

d. $\widehat{M}_3 + \hat{N}_4 < 180^0$

e. $\hat{P} + \widehat{M_2} = 180°$



1.2.2. What type of triangle is ΔQZN

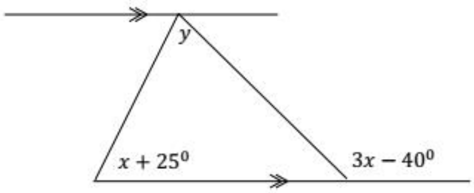
1.2.3. If $V\hat{Q}Z = 43°$ *and* $\hat{P} + \widehat{N}_1 = 180°$,

a. Determine the size of $Z\hat{Q}N$ and $Q\hat{Z}N$

b. What is the size of $\widehat{M}_1$

Question 4

What is the size of the angle that is marked by y? Show your work.



A.	$2x + 65°$	B.	$65°$	C.	$2x - 65°$	D.	$2 \times 65°x$

WORKSHEET 4 MEMO
MEMO
Grade 9 TERM 3
TASK Straight line geometry

The assessment task functions as assessment of, for and as learning. The assessment activities that pupils need to do will give pupils the opportunity to demonstrate whether they gained the geometric knowledge, skills and geometric thought as set out in the grade 9 curriculum for term 2 op to the end of straight line geometry. The focus will be on the "new" knowledge and skills gained in grade 9. Learners who know their work and have developed some procedural fluency may complete question one successfully. In question two and three learners need to be more able to demonstrate conceptual understanding. Question 4 is adapted from an SAMF Olympiad question.

General Comments:

The relationships between angles which are adjacent on a straight line; angles that form when two lines intersect in a point and the angles when a transversal id drawn through two lines provide a mean to determine unknown angles and whether lines are parallel or not. Learners will also be able to use this knowledge to deduce more precise definitions for the different quadrilaterals and the relationships between angles in a triangle.

Aims of the activities

Activity One
Aim: to determine learners' ability to describe a geometric situation of straight lines verbally, represent it as a drawing and/or as a mathematical expression. All the solutions require knowledge about geometry of straight lines.

Activity Two
Aim: to determine if learners can apply their knowledge about geometry of straight lines in simple mathematical contexts.

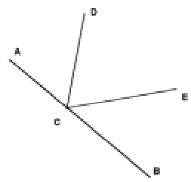
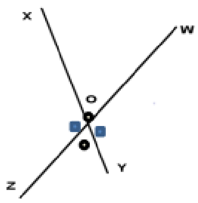
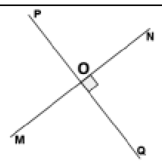
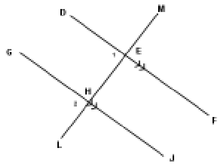
Activity Three
Aim: to determine whether learners can work with all the subtopic under the geometry of straight lines can work in one situation. Learners need to demonstrate that they can work with the subtopics of geometry of straight lines. The diagram has a huge amount of information and learners may need to manage their knowledge to answer the questions.

Activity Four
Aim: To determine learners' ability to synthesize different geometry topics and their ability to reason analytical and evaluative. Are the learners willing to accept answers which include variables.

Memo: Formative Assessment on Straight line geometry.

Question One

Complete the following table: The first row is completed as an example

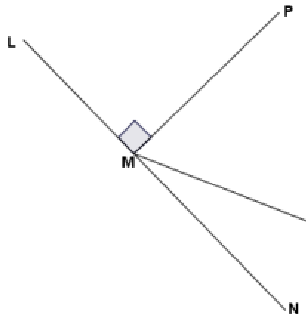
Row	Verbal description	Drawing	Mathematical expression	Comments
1.1 This is an example	The sizes of the three acute adjacent angles with the vertex (corner point) C on the straight line AB add up to 180^0		$A\hat{C}D + D\hat{C}E + E\hat{C}B = 180^0$	**Verbal Description** *Learners may not be able to formulate the verbal descriptions as formally at this stage. If their verbal expression make sense in terms of the their level of thinking allocate full marks.*
2	When lines XY and WZ intersect in O, the vertical opposite angles are equal.	 ✓✓	$X\hat{O}W = Y\hat{O}Z$ *and* ✓ $X\hat{O}Z = Y\hat{O}W$ ✓	**Drawing** If the learner drew the lines and name correct give full marks and acknowledge good work. Point out learner' maturity and describe what more is needed.
3	PQ and MN intersect each other perpendicularly in O. ✓✓	 ✓✓	$PQ \perp MN$ *at* O	**Mathematical expression** The expression needs to be correct. Order may differ.
4	Angle DEH is equal the corresponding angle GHL because the lines are parallel.		$\hat{E}_1 = \hat{H}_1$ *corresponding angles* $DF \parallel GJ$	

(12)

Question 2

Calculate the value of x in each of the following.

2.1.



2.1. Two methods can be used to determine the value of x.

1. $2x + 4x$✓ $= 90°$ ✓ $6x = 90°$✓ $x = 15°$✓

OR

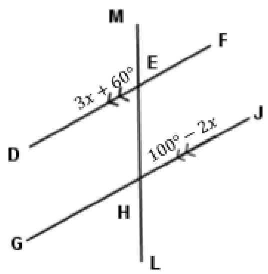
2. $2x + 4x + 90°$✓ $= 180°$✓
$6x = 90°$✓ $x = 15°$✓

OR

3. Learners may just write $x = 15°$ ✓✓✓✓

Reasons for answers or motivating steps were not requested. However learners who are already operating in level 3 may give reasons. Teachers need to acknowledge this work. **(4)**

2.2.



2.2. Various ways but the same method can be used to determine the value of x.

1. $Angle\ MEF = 100 - 2x$✓ or $G\hat{H}E$ = 3x+60° or
$H\hat{E}F = 3x + 60°$
$therefore\ 3x + 60° + 100° - 2x$✓ $= 180°$✓
$x = 20°$✓

OR

2. $G\hat{H}E = 180° - (100° - 2x)$✓ $= 80° + 2x$✓
$80° + 2x = 3x + 60°$ ✓ $x = 20°$✓

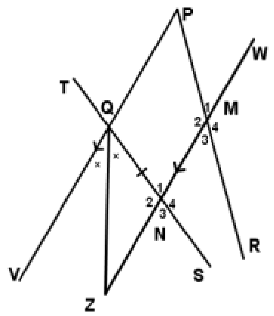
3. Learners may write $x = 20°$ ✓✓✓✓

Reasons for answers or motivating steps were not requested. However learners who are already operating somewhat in level 3 may give reasons. Teachers need to acknowledge this work. **(4)**

Question 3

3. Analyse the given diagram

3.1. Write whether the following statements are true or false. Motivate your choice.



3.1.1. $\widehat{N}_1 = \widehat{N}_3$ **True✓ (vertical opposite angles ✓)**

3.1.2. $\widehat{N}_1 + \widehat{N}_4 = 180^0$ **True✓ (adjacent angles on a straight line)✓**

3.1.3. $\widehat{M}_3 + \widehat{N}_4 = 180^0$ **False ✓** $(\boldsymbol{TS} \nparallel \boldsymbol{PR})$✓

3.1.4. $\widehat{M}_3 + \widehat{N}_4 < 180^0$ **✓True If(TS and PR are extended they will intersect in a point. MN and the extended segments from N and M to point of intersection form a triangle. $\widehat{M}$ and $\widehat{N}$ and the angle at the point of intersection adds up to 180⁰. Therefore $\widehat{M}_3$** $+\widehat{N}_4$ is less than $180°$) ✓

3.1.5. $PV \parallel WZ$ **True✓ The geometric notation for parallel lines is used.** ✓ **(10)**

3.2. What type of triangle is ΔQZN? **An isosceles triangle (geometric notation)** ✓ **(1)**

3.2.1. Determine the size of $Z\hat{Q}N$ and $Q\hat{Z}N$

$\boldsymbol{Z\hat{Q}N = 43°}$✓ Geometric notation shows that $V\hat{Q}Z =$ of $Z\hat{Q}N$ ✓

$\boldsymbol{Q\hat{Z}N}$ = $\boldsymbol{Z\hat{Q}N}$✓ angles opposite equal sides in Isosceles Δ ✓ **(4)**

3.2.2. What is the size of $\widehat{M}_1$

Various methods can be used.

$\hat{P} + \widehat{N}_1 = 180°$✓ $(given)$

$but\ \widehat{N}_1 = \widehat{N}_3$✓ $(vertical\ opposite\ angles)$

$and\ \widehat{N}_3 = 180° - \widehat{N}_2$ ✓ $(Angles\ on\ a\ straight\ line)$ or $\widehat{N}_3 =$ $86°\ exterior\ angle\ of\ a\ triangle$✓

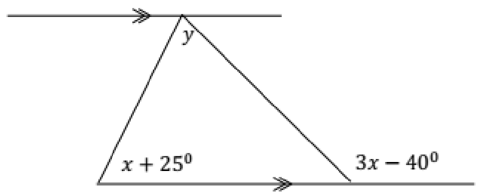
$\widehat{N}_2 = 180° - 86° = 94°\ interior\ angles\ of\ a\ triangle\ and\ \widehat{N}_3 = 86°$

$therefore\ \hat{P} = 94°$ ✓ $and\ \widehat{M}_1 = 94°\ alternate\ angles$✓ **(6)**

Not many learners may succeed to find the size of $\widehat{M}_1$. This activity however gives learners the opportunity to realise that if they are not able to control their knowledge, it is difficult to work logical in various geometry situations. They will also be busy applying their knowledge about geometry of straight lines and the properties of triangles.

Question 4

The angle marked y is equal to? Show how you worked to get the answer.



A. $2x + 65°$ B. $65°$ C. $2x - 65°$ D. $2 \times 65°x$

Various methods:

1. $y = 180° - (x + 25^0) + 180° - (3x - 40°)$✓ *angles on a straight line*✓ *and angles of a traingle*✓
   $y = 2x - 65°$ ✓

2. $y = 3x - 40° - (x + 25°)$✓ *exterior angles of a triangle* ✓✓
   $y = 2x - 65°$ ✓

3. *The angle on the right hand side of* $y = 180° - (3x - 40°)$✓ $= 220° -$
   $3x$ *alternate angles and parallele lines and angles on a straight line*✓
   $x + 25° + y + 220° - 3x = 180°$ *Interior angles ans parallel lines*✓
   $y = 2x - 65°$✓

Note: The value of y is determined by the value of x. *Therefore* $2x - 65^0 < 180°$

(4)

Total (45)

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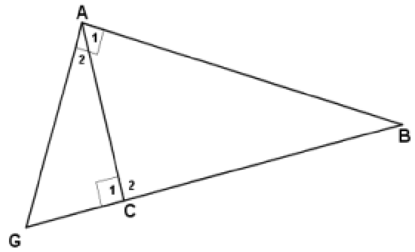
WORKSHEET 5

GRADE 9 TERM 2

Task 1 Theorem of Pythagoras



1.1. How many triangles do you see in the diagram? **(1)**

1.1.1. Give the names of all the right-angled triangles and the names of the hypotenuse of each. **(3)**

1.1.2. Indicate whether the following statements are True or False. Give a reason for your answer.

i) $In\ \Delta\ ABC\ AB^2 = AC^2 + BC^2$

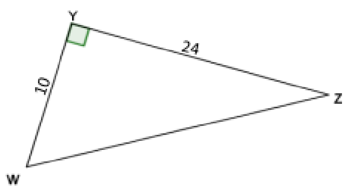
ii) $In\ \Delta ACG\ AC^2 - GC^2 = AG^2$

iii) $In\ \Delta ABG\ BG^2 - AG^2 = AB^2$

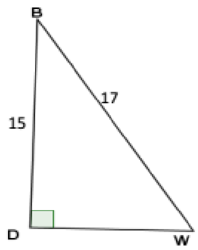
iv) $AB^2 - BC^2 = AG^2 - GC^2$ **(8)**

1.2. Calculate the length of the missing side(s) in each of the following triangles if possible. If necessary leave your answer in surd form.

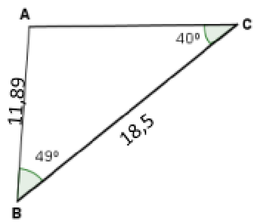
1.2.1



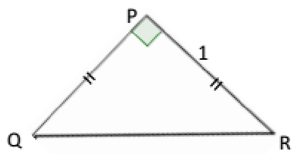
1.2.2



1.2.3



1.2.4



1.3 A triangle has the following side lengths: 30, 19 and 24. Is it a right angled triangle? Show all working necessary to support your answer.

(3)

GRADE 9 TERM 2

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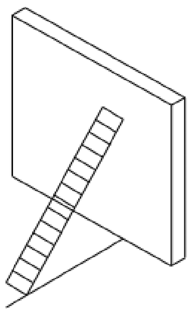
Task 2 Theorem of Pythagoras

Question 1.

A ladder (Steppes) with a length of 5m is placed at an angle against a wall. The bottom of the ladder is 1,5 m away from the wall. How far up the wall will the ladder reach? Round your answer of to two decimal places.

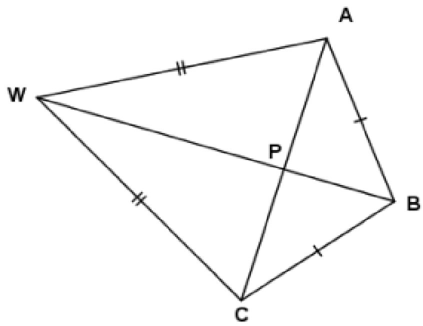
(3)



Question 2

WCBA is a quadrilateral with $WA = WC$ and $AB = BC$. Determine the perimeter of WCBA if $AC = 12\ cm$ and $BP = 6\ cm$ and $BP : PW = 1:2$.

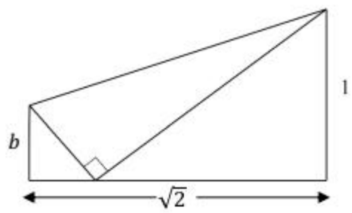
If necessary give your answer correct to one decimal place.



(9)

Question 3

A rectangular sheet of paper with side lengths$\sqrt{2}$, and 1.The left hand corner has been folded as shown so that it meets the opposite long side as shown. The length b is



A. $2\sqrt{2} - 1$ B. $\sqrt{2} + 1$ C. $\sqrt{2} - 1$ D. $\sqrt{5} - 2$ E. $\sqrt{3} - 1$

Show all working necessary to support your answer.

(6)

Total (45)

WORKSHEET 5 MEMO

Theorem of Pythagoras

TERM 2 Grade 9

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This formative assessment activity aims to provide opportunities for teachers and learners to identify what was learned, what is needed for learning and what can be learned about the teaching **and** learning of the Theorem of Pythagoras. Teachers can use the task in different ways. Here are a few suggestions:

- The learners complete the task. The teachers mark the task and provide written feedback to each learner. The teacher may use this opportunity to identify problem areas and misconceptions learners may have. When the learners hand back the test an interactive classroom discussion between teachers and learners are conducted about the solutions.
- The learners complete the activities in groups of two to three and the teacher provide support as necessary.
- Teachers and learners can use the activities with the aim to learn about the learners' conceptual knowledge and/or to reflect about the teaching practices.

This task is structured to function as assessment of, for and as learning

General Comments.

The theorem of Pythagoras states the relationship between the lengths of the sides of a **right angled triangle**. Learners in grade 9 can deduce the theorem and develop conceptual understanding if they had the opportunity to learn about:

- The properties of triangles and different types of triangles
- The properties of quadrilaterals and different types of quadrilaterals
- Constructing a perpendicular lines at any point on a line and from a point to a line.
- The types of angles and the possible sizes for each type of angle.
- The relationship between the angles when lines intersect, the angles that form when a transversal are drawn through parallel lines.
- The possible uses of a variable: the variable as an unknown in an equation, a variable as a general number in an algebraic expression, variables in the context of formulae and about functional relationships between variables.
- Variables in the context of geometry.
- Numbers and the properties of numbers specifically the positive rational and irrational numbers. This includes for example square numbers, surds etc.
- The operations with numbers and the properties of the different operations.

Some learners may not have conceptualised all of the above by the time learners need to learn about **Theorem of Pythagoras.** Learners may then not experience the learning of the new knowledge as meaningful and may learn the procedure on how to use the Theorem of Pythagoras to calculate an unknown side in a right-angled triangle by rote. The content areas *Number, Operations and Relationships; Space and Shape; Patterns, Functions and Algebra are interrelated*. Learners may conceptualise the bulleted knowledge while they are busy working with the theorem of Pythagoras. It is thus necessary to plan teaching and learning activities with the aim to 1) identify possible knowledge gaps and misconceptions and 2) the development to conceptualise knowledge of the topics from the interrelated content areas as mentioned, while learners are learning about the theorem of Pythagoras.

Aims of the assessment activities
Learners have the opportunity to demonstrate their ability to:

Activity One:

- Identify different triangles in one diagram.
- Interpret the Theorem of Pythagoras generally.
- Reason deductively.
- Apply the Theorem of Pythagoras in simple mathematical situations.
- Use rational and irrational numbers in the context of geometry.
- Use the knowledge of the variable as unknown in equations in the context of geometry.

In Activity Two:

- Use inter-related knowledge of quadrilaterals, triangles and mathematics to apply the Theorem of Pythagoras.
- Round off

Aims of Activity Three

- Apply the Theorem of Pythagoras in a real life context.

Aims of Activity Four. SAMF Olympiad question.

- Solve problems in a geometry context.
- Analyse and mathematical interpretation of information in a sketch.
- Inductive and informal deductive thinking.

Please Note: The memorandum demonstrates two methods to solve the problems. Learners can be innovative methods. Learners are encouraged to provide reasons for their statements but when they use a logical process to reach the answer it is very good.

Learners and Problem solving

Many learners in Grade 9 have not yet develop the thought processes to solve problems.
Polya (the father of problem solving) suggests four phases (steps) that learners may use the following steps when they solve problems.

Step 1: *Understand the problem.* Here the learner Identifies what is given, interpret the information to identify implicit given information. May times it may help to draw a sketch or look at a simple situation.
Step 2: *Make a plan.* Here the learner use the information and the knowledge he brings to the situation to make a plan
Step 3: *Carry out the plan.* Learners carry out the plan. Reflect all the time to ensure they are working accurately and logically.
Step 4: *Look back.* The learner assesses him /herself, reflects on the answer to see if it makes sense. S/he tries to determine if there is more questions that can be asked. S/he may think of alternative strategies that can be used or new questions that can be formulated.

This process is demonstrated in the memorandum (Question four)

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MEMO
GRADE 9 TERM 2

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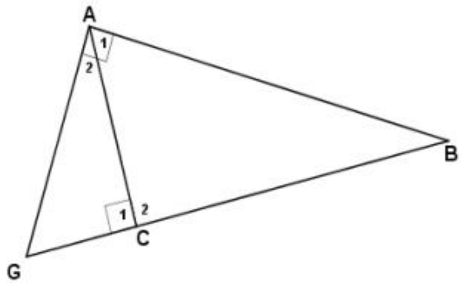
Task 1 Pythagoras



1.1. How many triangles do you see in the diagram? **Three** ✓ **(1)**

1.1.1. Write down the names of all the right-angled triangles and the names of the hypotenuse of each.

ΔAGC ✓ or ΔGAC *or* ΔCAG *Hypotenuse*: AG✓
ΔACB ✓ or ΔABC *or* ΔCAB *Hypotenuse*: AB✓
ΔAGB ✓ or ΔGAB *or* ΔBGA *Hypotenuse*: GB✓

(6)

1.1.2. Write down whether the following statements are True or False. Give a reason for your answer.

i) *In* $\Delta\, ABC\ AB^2 = AC^2 + BC^2$ **True**✓
ΔABC *is a right angled triangle (Theorem of Pythagoras)* ✓

ii) *In* $\Delta ACG\ AC^2 - GC^2 = AG^2$ **False**✓
Even though ΔACG *is right angled triangle and the theorem of Pythagoras is applicable the expression is written incorrectly. It should be* $AC^2 + GC^2 = AG^2$ ✓

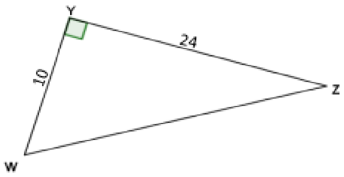
iii) *In* $\Delta ABG\ BG^2 - AG^2 = AB^2$ **True** ✓
ΔABG *is a right angled triangle (Theorem of Pythagoras indicates that* $BG^2 = AG^2 + AB^2$ *and using our knowledge about equations allo us to write* $BG^2 - AG^2 = AB^2$ ✓

iv) $AB^2 - BC^2 = AG^2 - GC^2$ **True** ✓
In ACG $AC^2 = AG^2 - GC^2$ *and in* $\Delta\, ABC\ AC^2 = AB^2 - BC^2$ *(Theorem of Pythagoras)*
therefore $AB^2 - BC^2 = AG^2 - GC^2$ because the LHS and the RHS is equal AC^2 ✓

(8)

1.2. Calculate the missing side(s) length in each of the following triangles. If necessary leave your answer in surd form.

<table>
<tr>
<td>



</td>
<td>

In ΔWYZ $WZ^2 = WY^2 + YZ^2$ ✓

$WZ = \sqrt{10^2 + 24^2}$ ✓ $= 26$ ✓

(3)

</td>
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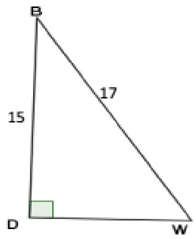
<tr>
<td>

1.22



</td>
<td>

In ΔBDW $DW^2 = BW^2 - DB^2$ ✓*(Theorem of P)*

$DW = \sqrt{17^2 - 15^2}$ ✓ $= \sqrt{(17-15)(17+15)}$

$= \sqrt{2 \times 32} = \sqrt{64} = 8\ units$ ✓

Note: *The learners may prefer to work as follows:*

In ΔBDW $BW^2 = DW^2 + DB^2$ *(Theorem of P)*

Therefore $17^2 = DW^2 + 15^2$

Therefore $DW^2 = 17^2 - 15^2$ ✓

Therefore

$DW = \sqrt{17^2 - 15^2}$ ✓ $= 8\ units$ ✓

(3)

</td>
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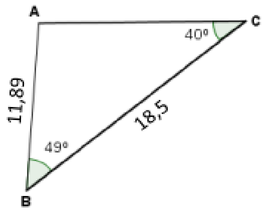
<tr>
<td>

1.2.3



</td>
<td>

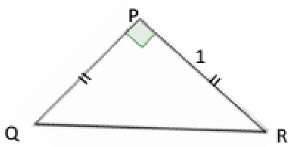
The length of AC cannot be calculated using the Theorem of Pythagoras because the $\hat{A} \neq 90°$

The sum of the angles of a triangle. ✓✓

(2)

</td>
</tr>
<tr>
<td>

1.2.4



</td>
<td>

$PQ = 1\ unit\ \Delta PQR\ is\ an\ Isoceles\ \Delta$ ✓

$QR^2 = PR^2 + PQ^2$ ✓

$QR = \sqrt{1^2 + 1^2} = \sqrt{2}$ ✓ *(Leave the answer in surd form mean do not use your calculators to determine* $\sqrt{2}$ *)*

(3)

</td>
</tr>
</table>

(11)

1.3 A triangle has the following side lengths: 30, 19 and 24. Is it a right angled triangle? Show all working necessary to support your answer.

(The triangle will be a right angled triangle if the square of the longest side is equal to the sum of the squares of the shorter sides or in short, when the Theorem of Pythagoras is applicable).

$30^2 = 900$✓

$19^2 + 24^2 = 361 + 576 = 937$✓

$937 \neq 900$✓

The triangle is not a right angled triangle ✓ **(4)**

WORKSHEET 5 TASK 2 (MEMO)

MEMO
GRADE 9 TERM 2

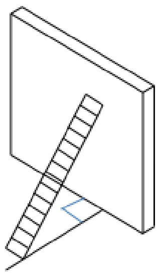
Task 2 Pythagoras

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Queston 3.

A ladder (Steppes) with a length of 5m is placed at an angle against a wall. The bottom of the ladder is 1,5 m away from the wall. How far up the wall will the ladder reach? Round off your answer to two decimal places.



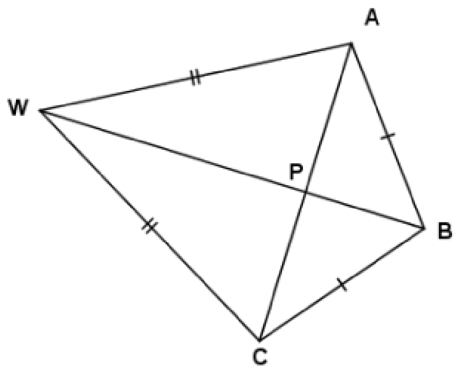
The line from the top of the ladder to the wall is perpendicular on the line drawn at that point to the ladder (see diagram).
The ladder will reach = $\sqrt{5^2 - 1{,}5^2}$✓ = $\sqrt{22{,}75}$✓ = $4{,}77m$ up the wall✓✓. (Theorem of Pythagoras)

(4)

Question 1

WCBA is a quadrilateral with $WA = WC$ and $AB = BC$. Determine the perimeter of WCBA if AC =12 cm and BP is 6cm and BP : PW = 1:2.

If necessary give your answer correct to one decimal place.



Learners need to recognise that WCBA is a kite and be able to use its properties to respond to the

The perimeter is the total distance around the shape—the lengths of the sides of the shape added together.

WCBA is a kite✓ *Pairs of adjacent sides are equal*

$AP = \frac{12}{2} = 6\ cm$ ✓*The longer diagonal bisects the shorter diagonal perpendicularly.*

$PW = 12\ cm$ ✓ $PB\ =\ 6\ cm$ and $PB : PW = 1 : 2$

All the triangles are right angled triangles. (*The diagonals of a kite intersect perpendicularly*)
In $\Delta APB\ AB^2 = AP^2 + PB^2$ *Theorem of Pythagoras*
$AB = \sqrt{6^2 + 6^2} = \sqrt{72}$ ✓✓
In $\Delta APW\ AW^2 = AP^2 + PW^2$ *Theorem of Pythagoras*
$AW = \sqrt{6^2 + 12^2} = \sqrt{180}$ ✓✓
The perimeter of the Kite $WCBA = 2\,(\sqrt{72} + \sqrt{180}) = 43{,}8\ cm$✓✓

(8)

Queston 2.

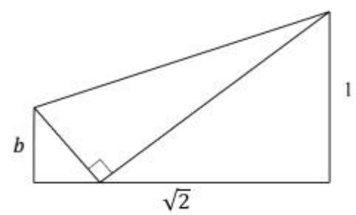
A ladder (Steppes) with a length of 5m is placed at an angle against a wall. The bottom of the ladder is 1,5 m away from the wall. How far up the wall will the ladder reach? Round off your answer to two decimal places.

The line from the top of the ladder to the wall is perpendicular on the line drawn at that point to the ladder (see diagram)
The ladder will reach = $\sqrt{5^2 - 1{,}5^2}$✓ $= \sqrt{22{,}75}$✓ $= 4{,}77m$ up the wall✓✓. (Theorem of Pythagoras)

(4)

Question 3

A rectangular sheet of paper with side lengths$\sqrt{2}$, and 1 is used. The left hand corner has been folded so that it meets the opposite long side as shown. The length b is



A. $2\sqrt{2} - 1$ B. $\sqrt{2}$ +1 C. $\sqrt{2} - 1$ D. $\sqrt{5} - 2$ E. $\sqrt{3} - 1$

Show all working necessary to support your answer.

Polya (1956) suggests the following steps to solve problems:

1. **Understand the problem**
   a) **Rectangular sheet –** The implicit information in this case is that learners need to know the properties of a rectangle. (Knowledge that learners bring to the situation). Investigate if the knowledge can be used to solve the problem.

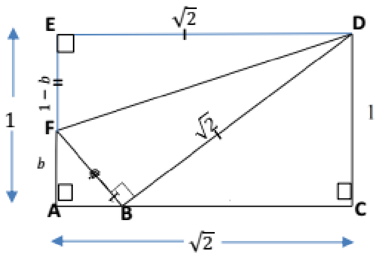
i) Pairs of opposite sides have equal lengths and are parallel. (Can this help? If yes how?) **Yes, Shown in Sketch**

ii) The angles are equal to 90^0 (Can this help? If yes how?) **Yes, Shown in Sketch**

iii) Each diagonal divide the rectangle into two congruent right angled triangles. (Can this help? If yes how?) **Ignore no diagonals drawn**

iv) The diagonals are equal in length and bisect each other. (Can this help? If yes how?) **Ignore no diagonals of rectangle drawn**

Use the knowledge and given information to identify the lengths of the sides where possible. Show on sketch. Name each vertex to be able to communicate/write mathematically.



Note: EABC is the rectangular sheet before the left hand side corner is folded.

FDCA is the diagram where the left hand corner is folded to the opposite side.

2. Make a plan: Method 1, Worked with:

- b is the length of FA which a side of a right-angled triangle FAB
- We have interpreted the information in the sketch and noticed that FB is 1-b opposite sides of rectangle.
- Perhaps can use Pythagoras
- AB is part of AC. Can calculate the length of BC because BCD is a right angled triangle (P)

3. Carry out the plan

$In\ \Delta BDC\ \ BC^2 = BD^2 - DC^2$✓ (Theorem of Pythagoras)

$BC = \sqrt{(\sqrt{2})^2 - 1^2} = \sqrt{2-1} = 1 = DC$✓✓ $and\ AB = AC - BC = \sqrt{2} - 1$✓

Option 1

$In\ \Delta\ EAB\ \ EA^2 = EB^2 - AB^2$ ✓

$b^2 = (1-b)^2 - (\sqrt{2}-1)^2$ ✓

$b^2 = 1 - 2b + b^2 - (2 - 2\sqrt{2} + 1)$ ✓

$2b = 2\sqrt{2} - 2$✓

$b = \sqrt{2} - 1$✓

Option 2 *Learners may have noticed that* $\Delta ABC\ is\ an\ Isoscele\ \Delta$

$\Delta DBC\ is\ an\ isosceles\ \Delta \rightarrow B\hat{D}C = D\hat{B}C = 45°$ ✓$angles\ of\ a\ triangle\ add\ up\ to\ 180°$

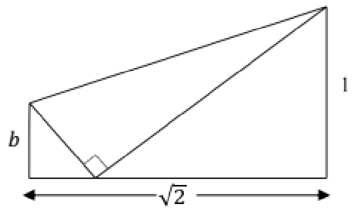
In $\Delta ABF\ \ A\hat{B}F = 180° - (90° + 45°) = 45°$✓ (adjacent angles on a straight line add up to 180°)

$Then\ B\hat{F}A = 45°$
(Angles of a triangle add up to 180°)

$\Delta\ ABF\ is\ an\ isosceles\ triangle$✓
$Thus\ FA = AB\ \rightarrow b = \sqrt{2} - 1$ ✓

Question 3

A rectangular sheet of paper with side lengths$\sqrt{2}$, and 1.The left hand corner has been folded as shown so that it meets the opposite long side as shown. The length b is



A. $2\sqrt{2}-1$ B. $\sqrt{2}+1$ C. $\sqrt{2}-1$ D. $\sqrt{5}-2$ E. $\sqrt{3}-1$

Show all working necessary to support your answer.

(6)

Total (45)

(8)

4. Look Back

$In\ \Delta\ FAB\ \ FA=\ \sqrt{2}-1\ and\ AB=\ \sqrt{2}-1\ and\ FB=1-FA=1-(\sqrt{2}-1)$
$=2-\sqrt{2}$

$If\ we\ apply\ the\ theorem\ of\ Pythagoras\ \ FA^2+AB^2=FB^2$

$The\ LHS=6-4\sqrt{2}\ and\ the\ RHS=6-4\sqrt{2}$

Possible Questions

- *Is it possible to calculate the length ofFD?*
- *If you take any right anlged sheet and fold it over as explained will two right angled isosceles triangle always be form.*

Total (45)

WORKSHEET 6

Name:	

WORKSHEET 4 **GR 9** **Content Area:** 2. Patterns, Functions and Algebra

Topic: 2.4 Algebraic Equations

---

1. Solve for x:

   a) $5x-3=x+29$

   ____

   ____

   b) $2x^2=6^2-4$

   ____

   ____

   ____

[5]

2. Complete the tables below for x and y values for:

   (b) the equation: $y=3x-4$

x	–4	–3	–1	0		5	9	
y					5			41

(b) the equation: $y=x^2+3$

x	–2	–1	0		6		12	
y				19		103		628

[4]

3. John has an unknown number of sweets which he wants to distribute equally amongst himself and 4 of his friends. He and each one of his friends receive 17 sweets with 2 odd sweets left.

   (a) Design an equation whereby you can determine how many sweets John started with.

   ____

   (b) Use the above equation to calculate how many sweets did John start with.

   Hint: Take the unknown number of sweets as x.

   ____

   ____

WORKSHEET 6 (MEMO)

MEMO 4 GR 9 **Content Area:** 2. Patterns, Functions and Algebra
Topic: 2.4 Algebraic Equations

<table>
<tr><th>QUESTION</th><th>TOPIC</th><th>DIFFICULTY</th><th>SPUR</th><th>ANSWER</th><th>EXPLANATION</th></tr>
<tr><td>1</td><td rowspan="4">2.4 Algebraic equations
Equations
• Use substitution in equations to generate tables of ordered pairs
• Extend solving equations to include:
○ Using additive and multiplicative inverses
○ Using laws of exponents</td><td>E</td><td>S</td><td>(a) $4x = 32$ ✓
$\therefore x = 8$ ✓
(b) $2x^2 = 32$ ✓
$\therefore x^2 = 16$
$\therefore x = \pm 4$ ✓ (+4) ✓(−4)</td><td>Solve equations
Using additive and multiplicative inverses
Remember answer can be positive or negative when square rooting</td></tr>
<tr><td>2</td><td>M</td><td>P</td><td><table><tr><td>x</td><td>–4</td><td>–3</td><td>1</td><td>0</td><td>3</td><td>5</td><td>9</td><td>15</td></tr><tr><td>y</td><td>–16</td><td>–13</td><td>–7</td><td>–4</td><td>5</td><td>11</td><td>23</td><td>41</td></tr></table>
<table><tr><td>x</td><td>–2</td><td>–1</td><td>0</td><td>4</td><td>6</td><td>10</td><td>12</td><td>25</td></tr><tr><td></td><td>7</td><td>4</td><td>3</td><td>19</td><td>39</td><td>103</td><td>147</td><td>628</td></tr></table></td><td>✓ (any 4 correct)
✓ (all 8 correct)
Substitute in equations
✓ (any 4 correct)
✓ (all 8 correct)</td></tr>
<tr><td>3</td><td>M</td><td>U</td><td>(a) $\frac{x}{5} = 17\ rem\ 2$ ✓ ✓
(b) $x = (17 \times 5) + 2$ ✓
$\therefore x = 87$ ✓</td><td>Design and solve equation</td></tr>
<tr><td>4</td><td>M</td><td>Olympiad type Question</td><td>Number of books $= x \times y \times x$
$= xyz$ ✓ ✓</td><td>Logic thinking</td></tr>
</table>

WORKSHEET 7

WORKSHEET 7

Grade 9 TERM 3

Task 1 Functions

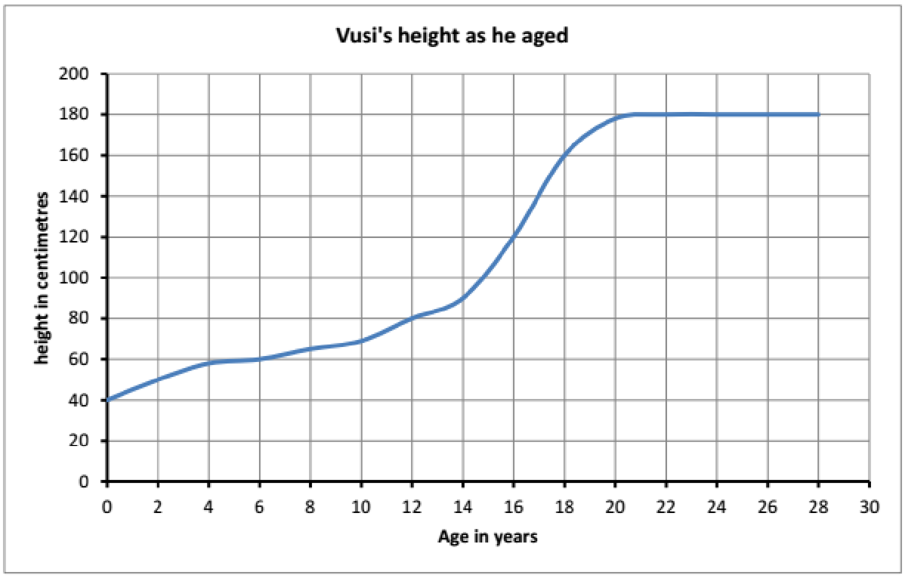
Question 1.

Represent the following function $y = \frac{1}{2}x + 2$ as a

i. Flow diagram
ii. Table
iii. Graph

Question 2

Below is a graph showing Vusi's height as he aged.



Use the graph to answer the following questions:

2.1. At what age was Vusi's height 40 cm?

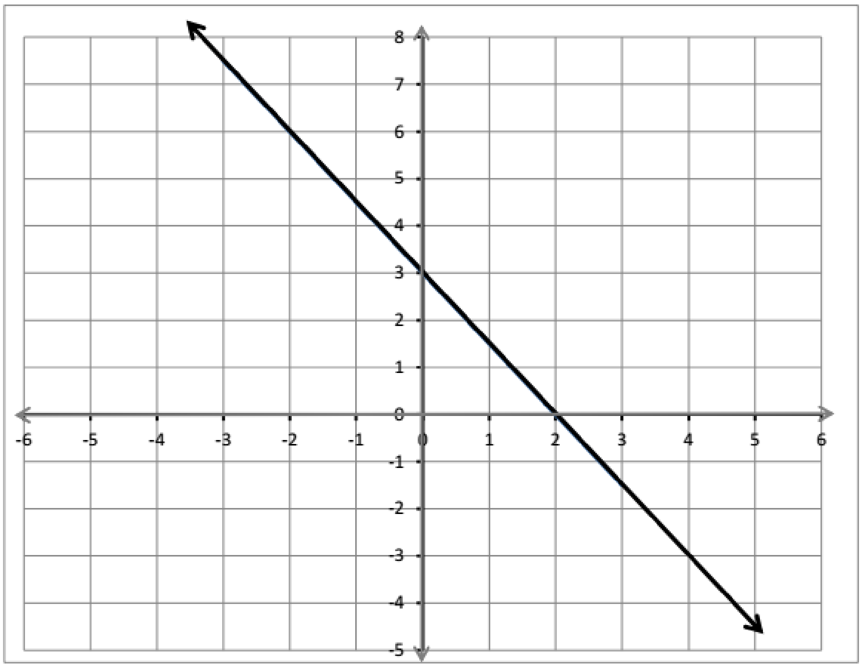
2.2. By how many centimetres did Vusi's height increase from age 18 to age 22.

2.3. During which of the following periods, was the rate at which Vusi grew the fastest? How do you know?

A. 0 to 12 years B. 12 to 16 years C. 16 to 18 years D. 18 to 22 years

Question 3

Consider the following graph



3.1. Complete the following table by reading off coordinates of points on the graph

y	-3	-2	-1	0	1	2	3	4
x	7,5							

3.2. Write down formula for the graph in the form $y = \cdots$

Question 4

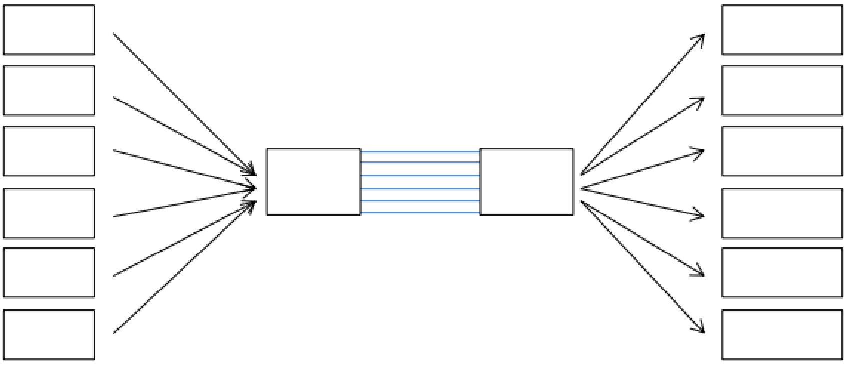
The uneven numbers greater or equal to 1 are written in a pattern as shown:

Row 1:	1						
Row 2:	3	5	7				
Row 3:	9	11	13	15	17		
Row 4:	19	21	23	25	27	29	31
Etc.							

What is the middle number in the 60^{th} row?

Appendix: Question 1

The learners may be given the following diagrams to answer question 1.



WORKSHEET 7 MEMO
MEMO
Grade 9 TERM 3

Task 1 Functions

Aim of the four questions.

Question 1

The formula of a function is given. Learners are asked to do three different representations of the function: A flow diagram, a table and a graph

Question 2

Learners are expected to interpret the graph over different intervals

Question 3

Question 3 is the reciprocal of the question 1. Here a linear function is represented graphically and learners need to gain information from the graph to represent the function as a table and as a formula

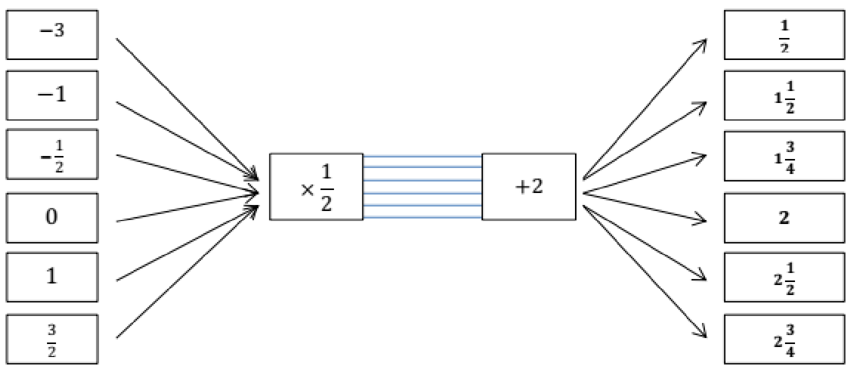
Question 4

This is an Olympiad type of question to challenge learners' mathematical reasoning and thinking and give them opportunity to experience the interrelatedness of mathematics

Question 1.

Represent the following function $y = \frac{1}{2}x + 2$ as a

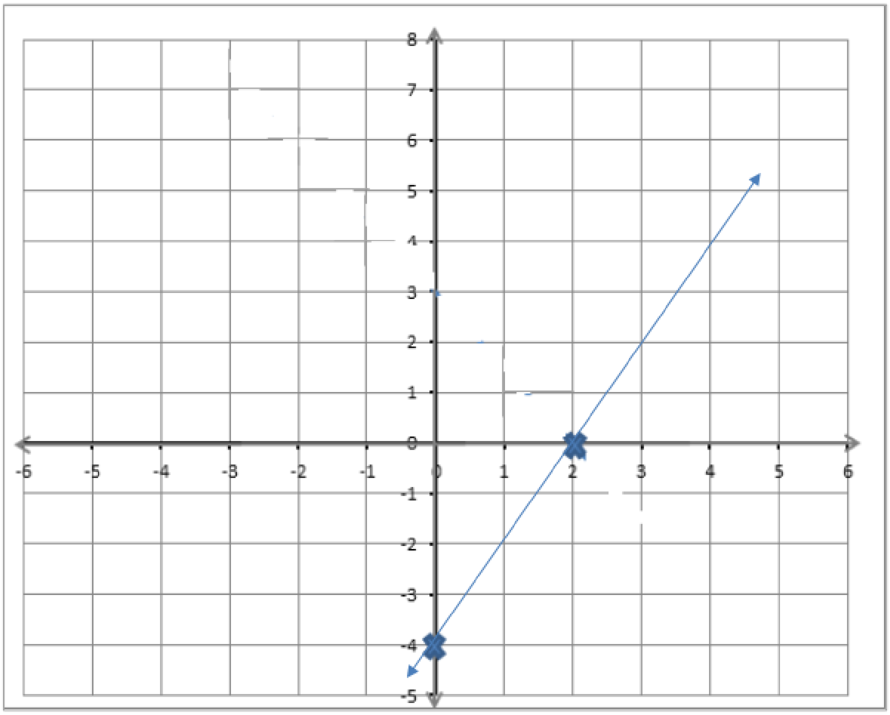
i. Flow diagram



ii. Table

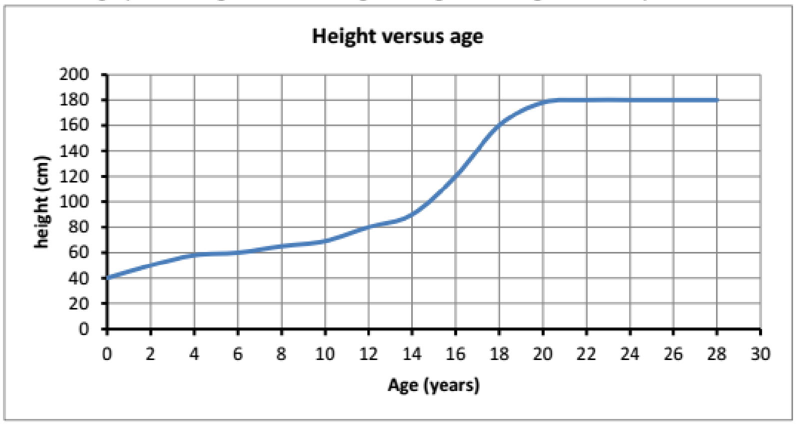
-5	-4	-2	$\frac{1}{2}$	2	4	7	100	25	50
$-\frac{1}{2}$	0	1	$2\frac{1}{4}$	3	4	$5\frac{1}{2}$	52	$14\frac{1}{2}$	27

iii. Graph



Question 2

Below is a graph showing how Vusi's height changed as he aged over 30 years



Use the graph to answer the following questions:

2.1. How old was Vusi when he was 40cm tall.

He was born 40 cm tall

2.2. By how many centimetres did Vusi's height increase from age 18 to age 22.

20 cm

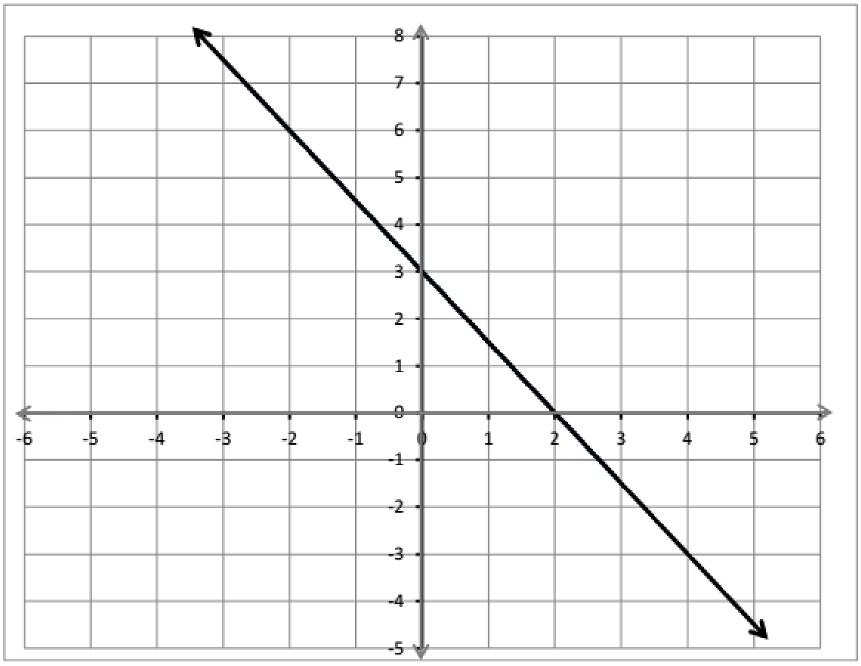
2.3. During which of the following periods, was Vusi growing at the fastest rate? How do you know?

A. 0 to 12 years B. 12 to 16 years C. 16 to 18 years D. 18 to 22 years

Answer : C. Because the graph is the steepest over that time

Question 3

Consider the following graph



3.1. Complete the following table by reading off coordinates of points on the graph

y	-3	-2	-1	0	1	2	3	4
x	**7,5**	6	4,5	3	1,5	0	$-1,5$	3

3.2. Write down formula for the graph in the form $y = -\frac{3}{2}x + 3$

Question 4

The integers greater than 1 are written in a pattern as shown:

Row 1:	1						
Row 2:	3	5	7				
Row 3:	9	11	13	15	17		
Row 4:	19	21	23	25	27	29	31

What is the middle number in the 6 row?

There may be many methods.

Method 1 The learner writes all the rows down.

Method 2 The learner sees the following relationships

First number in a row.	**Middle number.**	**Last number.**	**First number plus last number.**	**Divide the answer/2 and we get the middle number.**
1	**1**	1	2	**1**
3	**5**	7	10	**5**
9	**13**	17	26	**13**
19	**25**	31	50	**25**
33		49		
51		71		
73		97		
.	. . . . .	.	. . . . .	.
801	841	881	1682	841

This method would take more thinking and reasoning but may be less writing You only need to write down the first row and the last row. Many learners may not have use tables but will be able to determine the middle number.

Method 3

1														
3	5	7												
9	11	13	15	17										
19	21	23	25	27	29	31								
33	35	37	39	41	43	45	47	49						
51	53	55	57	59	61	63	65	67	69	71				
73	75	77	79	81	83	85	87	89	91	93	95	97		
99	101	103	105	107	109	111	113	115	117	119	121	123	125	127

Row	Middle number	Rewrite Middle number	Rewrite Middle number
R 1	1	1+0	$1^2 + 0^2$
R 2	5	4+1	$2^2 + 1^2$
R 3	13	9+4	$3^3 + 2^2$
R 4	25	16+9	$4^2 + 3^2$
R 5	41	25+16	$5^2 + 4^2$
R 6	61	36+25	$6^2 + 5^2$
. . . .		. . . . .	
R 21	841		$21^2 + 20^2$

APPENDIX B

EXAMPLES OF FEEDBACK TEMPLATES

(Adapted For Each Worksheet)

FEEDBACK: Theorem of Pythagoras

Name ………………………………………………………………… School………………………………………………………………..

Dear Teacher, please give your feedback/ comments on each question below.

QUESTION	TOPIC	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Numeric and geometric patterns? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1	Solve problems using the Theorem of Pythagoras • Use the Theorem of Pythagoras to solve problems involving unknown lengths in geometric figures that contain right-angled triangles				
2					
3					

4					

*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs?...**

*** ANY OTHER FURTHER COMMENTS:………………………………**

FEEDBACK **Algebraic expressions**

Name …………………………………………………………………. **School……………………………………………………………..**

Dear Teacher, please give your feedback/ comments on each question below.

Algebraic expressions

1. From the students' responses; what do you think they understand / not understand about Algebraic expressions?

2. Based on your responses to questions 1, how would you adapt or change your instruction if necessary?

3. In which way can this specific worksheet support you in addressing individual learner's needs? / address these needs?

*** ANY OTHER FURTHER COMMENTS**

FEEDBACK **Algebraic expressions**

Name ……………………………………………………………………. School……………………………………………………………..

Dear Teacher, please give your feedback/ comments on each question below.

Content Area: Patterns, Functions and Algebra

TASK 1 Topic: **2.3 Algebraic expressions**

	QUESTION	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Algebraic expressions? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1	Algebraic language • Revise the following done in Grade 8: -- Recognize and identify conventions for writing algebraic expressions -- Identify and classify like and unlike terms in algebraic expressions -- Recognize and identify coefficients and exponents in algebraic				
2	expressions • Recognize and differentiate between monomials, binomials and trinomials Expand and simplify algebraic expressions • Revise the following done in Grade 8, using the commutative, associative				
3	and distributive laws for rational numbers and laws of exponents to: -- add and subtract like terms in algebraic expressions -- multiply integers and monomials by: ♦♦monomials ♦♦ binomials ♦♦ trinomials -- divide the following by integers or monomials: ♦♦monomials ♦♦ binomials ♦♦ trinomials -- Simplify algebraic expressions involving the above operations				

4					

*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs? ....**

*** ANY OTHER FURTHER COMMENTS :………………………………**

FEEDBACK : Numeric and geometric patterns **WORKSHEET 1 GR 9**

Name ……………………………………………………………………. School………………………………………………………………..

Dear Teacher, please give your feedback/ comments on each question below.

Content Area: 2. Patterns, Functions and Algebra

Topic: 2.1 Numeric and geometric patterns

QUESTION	TOPIC	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Numeric and geometric patterns? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1	**2.1 Numeric and geometric patterns Investigate and extend patterns** • Investigate and extend numeric and geometric patterns looking for relationships between numbers, including patterns: o represented in physical or diagram form				
2	o not limited to sequences involving a constant difference or ratio o of learner's own creation o represented in tables o represented algebraically • Describe and justify the general rules for observed relationships between numbers in own words or in algebraic language				
3					

4					

*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs?...**

*** ANY OTHER FURTHER COMMENTS:………………………………**

FEEDBACK Algebraic Equations

Name ………………………………………………………………….. School……………………………………………………………..

Dear Teacher, please give your feedback/ comments on each question below.

WORKSHEET 4 GR 9 **Content Area:** 2. Patterns, Functions and Algebra

Topic: 2.4 Algebraic Equations

Question	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Numeric and geometric patterns? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1				

2				
3				
4				

*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs?..**

*** ANY OTHER FURTHER COMMENTS:………………………………**

FEEDBACK; FUNCTIONS TASK TERM 3

Name …………………………………………………………………. School………………………………………………………………..

Dear Teacher, please give your feedback/ comments on each question below.

QUESTION	1. What do you think are the key concepts (principles) that each question addresses?	2. From the students' responses; what do you think they understand about Numeric and geometric patterns? What do they not understand?	3. What feedback would you give to the student/s?	4. Based on your responses to questions 2 and 3, how would you adapt or change your instruction of this topic?
1				
2				
3				

4				

*** In which way can this specific worksheet support you in addressing individual learner's needs? / I. e what actions did you take to address these needs?..**

*** ANY OTHER FURTHER COMMENTS:………………………………**

APPENDIX C

APPENDIX C: QUALITATIVE SURVEY

CATEGORY	OPEN-ENDED QUESTIONS
Background	1. How many years have you been teaching? (Include both part-time and full-time). 2. How many years have you been teaching mathematics? 3. What is your position (designation) in your school? 4. Are you teaching other subjects? (Please specify).
Teaching and Learning	1. Please indicate your degree of confidence in teaching mathematics. High, medium, low, other. 2. If you feel confident, which of the following have contributed to your confidence in using the mathematics achievement objectives (please tick the appropriate boxes).E.g. My knowledge of mathematics, teaching experience, professional development in mathematics, my school has translated the achievement objectives into specific learning outcomes, Other (please state) 3. Please tick which of the essential skills you emphasise in your teaching of mathematics. Put two ticks beside those which you emphasise the most. 4. How do you assess student learning in mathematics? E.g. Assessment Resource Banks, Previous question papers - e.g. ANAs, Investigations, Observation, Peer assessment Practical tasks; Pre-tests/post-tests; Projects Self-assessment. You can choose from this list or other (please specify):
Assessment, Student achievement, Progress, and Reporting	1. What has influenced your formative assessment practices in the last few years? 2. How much has your teaching from the curriculum statements resulted in improved achievement for students? 3. How has each of the following processes influenced decisions about what and how you teach? School /self-review External reviews/evaluations (from outside the school, e.g. ANAs). Please explain how school/ self-review and/or external evaluation have had an impact on your teaching or assessment practices.

APPENDIX C: QUALITATIVE SURVEY

CATEGORY	OPEN-ENDED QUESTIONS
Curriculum implementation and manageability	1. How easy has it been for you to use the curriculum (CAPS) that you teach from? 2. To what extent is the curriculum flexible enough to allow you to plan for and meet individual students' needs and interests? 3. From your experience in implementing the curriculum, how long does it take you to feel confident with the planning, teaching, and assessing aspects of a new national curriculum statement? 4. How do you rate your own content knowledge for the mathematics curriculum statements that you teach from? 5. Teachers have reported that new curriculum requirements (such as in the National Education Guidelines) have had varying impacts on their work. How strong is the impact of each of the following on your work? a) Administration (keeping records): b) External review (e.g. IQMS): c) Assessment/reporting: d) Written planning:
Professional Development	1. In what ways has professional development activities helped/not helped you in your teaching of mathematics? 2. What sources of professional development have been very useful for your teaching of mathematics? (Please tick the appropriate boxes). 3. In what aspects of mathematics would you most like to receive professional development to support your teaching of mathematics? 4. What are the three major challenges you have faced in implementing the mathematics curriculum? (Please give some examples, including ways these have been addressed).

APPENDIX C: QUALITATIVE SURVEY

CATEGORY	OPEN-ENDED QUESTIONS
	5. What teaching approaches/practices would you say have been very effective in improving your students' learning in mathematics? 6. What teaching approaches/ practices would you say have been obstacles in your students' learning of mathematics?

APPENDIX D

APPENDIX D

INTERVIEW SCHEDULE/ PROTOCOL

1. PERSONAL DOMAIN

1.1 Background:

a. How many years have you been teaching? ....

b. How many years have you been teaching mathematics? ....

c. What is your position (designation) in your school? …………………………………..

d. Are you teaching other subjects or grades? (Please specify)………………………..

e. How many learners, on average, do you have in your class? ....

f. What is your highest qualification and where did you study? ....

1.2 Beliefs, Attitudes, Knowledge

a. What is your understanding of 'good' mathematics education? / Why is mathematics important?

…………………………………………………………………………………………………

How do you rate your own content knowledge for the mathematics curriculum statements (CAPS) you teach from?

....

c. What is your understanding of **formative** and summative assessment?

....

d. What do you find are the strengths and /or the weaknesses of developing formative assessment tasks before you teach?

…………………………………………………………………………………………………

2. EXTERNAL DOMAIN

a. How does external assessments, such as TIMMS, ANA's influence your mathematics teaching practice?

…………………………………………………………………………………………………
……

b. To what extent do these examinations influence your teaching *and* assessment practice?

…………………………………………………………………………………………………

APPENDIX D

c. How do you think your practice might change if there were no external assessment? E.g. ANAs

………………………………………………………………………………………………………

d. What external factors influenced your formative assessment practices (classroom-based) in the last few years?

………………………………………………………………………………………………………

3. DOMAIN OF PRACTICE (THE WORKSHEETS)

3.1 Reflection on Formative Assessment (FA) Task Development Activities (worksheets provided by the University)

a. How do you assess your learners' progress on a daily base? ………………………………………………………………………………………………

b. How did you align the (**your own**) assessment with the standard set by your PLC (referring to the standards provided in the memos of each worksheet as discussed during the meetings) in the development process?

………………………………………………………………………………………………………

c. What **resources** did you use to develop or refine the worksheets that aligned with the cognitive complexity of mathematics?

………………………………………………………………………………………………………

d. What were the **challenges** that you recall during the AETL project? ………………………………………………………………………………………………

4. DOMAIN OF CONSEQUENCE

a. How might you refine the worksheets after using it with students and reviewing their responses?

………………………………………………………………………………………………………

b. In what ways did the worksheets allow for job-embedded professional development?

………………………………………………………………………………………………………

c. After administering the assessment to your students and grading their work, what did you learn about what they understand and do not understand in regard to your targeted outcomes? (Refer to the refinement/ comments of individual questions on the worksheets)

……………………………………………………………………………………………………

d. To what extent has your engagement in the development of Formative Assessment tasks led to changes in the following areas? Describe your experiences.

……………………………………………………………………………………………………

i) Valuable professional development opportunities in the use of structured formative assessment instruments

……………………………………………………………………………………………

ii) Quality of classroom instruction

……………………………………………………………………………………………

iii) Attention to lowest performing students.

……………………………………………………………………………………………

iv) Attention to students in the middle (average) range

……………………………………………………………………………………………

v) Attention to highest performing students

……………………………………………………………………………………………

e. What was the single most important skill that you required during the whole formative assessment development process?

……………………………………………………………………………………………………

Thank you so much for taking time to participate in this interview. Your responses will remain confidential.

APPENDIX E

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2015 / 342 G

GDE GROUP RESEARCH APPROVAL LETTER

Date:	13 February 2015
Validity of Research Approval:	13 February 2015 to 2 October 2015
Name of Supervisor/s:	Dr Caroline Long and Dr Johan Engelbrecht
Name/s of Researchers	Van der Nest A. and Meintjies F.
Address of Supervisor:	12 Denbigh Road; Greenside East; Johannesburg 2193
Telephone/ Fax Number/s:	012 420 4175; 012 420 4175; 012 420 4175
Email addresses:	Adri.vandernest@up.ac.za ferdi@edubuilder.co.za; caroline.long@up.ac.za; johann.engelbrecht@up.ac.za
Research Topic:	Assessment enhanced teaching and learning
Number and type of schools:	TEN Secondary Schools
District/s/HO	Tshwane South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

APPENDIX F

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Centre for Evaluation and Assessment

11th November, 2014

The Dean,
Faculty of Education
University of Pretoria
Groenkloof Campus

Dear Professor Eloff,

Re: **Assessment Enhanced Teaching and Learning (AETL) Project**: Research in 10 Tshwane schools

I am requesting permission for the research described below for ethics purposes.

Professor Johann Engelbrecht and I have embarked on a research study which extends the work done by the **Centre for Evaluation and Assessment (CEA)** with the Michael and Susan Dell Foundation (MSDF) on the monitoring of a cluster of schools (six LEAP schools and the Inanda Seminary) over the past four years.

While the initial requirement in this study was simply the administering of a monitoring component, the scope of the project was extended to firstly, providing extensive criterion referenced feedback to teachers and then secondly, to introducing a classroom based formative assessment component. The development of this model was based on the work of Bennett & Gitomer (2009), and Bennett (2010; 2011). The classroom based component consisted of designing formative assessment tasks (with detailed memoranda) for teachers to evaluate, firstly for appropriate classroom use and then secondly to administer. An important aspect of this component was that the teachers engage with the tasks. Here we acknowledge the statement by Bloom et al. (1956), that a requirement for the educational taxonomy to be useful was that teachers could engage with its components, and thereby extend their teaching repertoire to embrace a range of objectives and assessment practices. It was also their hope that the teachers would extend their teaching into the realm of problem solving (Bloom et al., 1956, p. 42).

The plan with the **Assessment Enhanced Teaching and Learning (AETL)** project is that the preliminary work undertaken in the CEA/MSDF project be extended to 10 schools within a 20 kilometre radius of the University of Pretoria.

We have attached a summary proposal for purposes of providing a succinct overview. Two students' have designed their dissertations around this study. **Adri van der Nest (PhD student)** focusses on the professional development component, while **Ferdinand Meintjies (Masters student)** is in the process of designing a diagnostic assessment instrument for the project.

We have two international partners, firstly, **Professor Elaine Simmt** from the **University of Alberta** wishes to replicate the project in Tanzania, and secondly **Jan Berkvens** from the **Curriculum Institute in the Netherlands** will be an interested observer, and advise on curriculum matters.

Regards,

M.b. Lg.

Dr Caroline Long (Senior Lecturer)

Centre for Evaluation & Assessment
10 Years of Research Excellence

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APPENDIX G

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

INFORMED CONSENT: PRINCIPAL

Name of School:...

I hereby give permission to researchers from the Mathematics Education Department of the University of Pretoria, who are working on a developmental project (Assessment enriched Teaching and Learning Programme), to conduct their study with the cooperation and consent of the school.

I am aware that participation in this study is voluntary. If a teacher decides to participate, but changes his/her mind later, the teacher may withdraw from the study at any time. The names and identities of participants in the study will be kept private and confidential. In published reports, there will be no information included that would make it possible to identify the names of schools, or individuals who participate.

I also grant permission to the researchers to conduct interviews and observations with the grade nine mathematics teachers who are willing to participate in the research project.

Signature of Principal ....

Print Name of Principal...

Date.................................

APPENDIX H

APPENDIX H **PARTICIPANT INFORMED CONSENT**

Faculty of Education

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Re: **AETL (Assessment Enhanced Teaching and Learning*)* Project University of Pretoria**

Dear Participant

You are being asked to take part in a research study being conducted by Adri van der Nest, a part-time lecturer and doctoral student at the University of Pretoria.

I am interested in teachers' experiences when refining and implementing a structured formative assessment instrument, based on specific topics of the Grade 9 Mathematics curriculum (CAPS).

By inviting you to share your experiences, I hope to learn more about how grade 9 mathematics teachers engage in formative assessment tasks and if they experience any professional growth from participating in these activities in professional learning communities.

This consent is designed to inform you about the purpose of the study, possible risks and benefits, and provide you with information to contact the researcher should additional questions arise.

What is the purpose of the study?

The purpose of this qualitative study is to learn more about practicing mathematics teachers' experiences and interactions when they develop and implement FA tasks when participating in the AETL Project. The activities will be scheduled within a professional learning community (PLC), which constitutes fellow teachers, researchers from the University of Pretoria and district officials of Tshwane South.

The researcher seeks to better understand how teachers participate in and understand FA, the curriculum and implementation of structured FA tasks. This project is being conducted as a dissertation study for the University of Pretoria, Department of Mathematics, Science and Technology Education.

Why was I asked to participate in the study?

You are being asked to join this study because you are a practicing grade nine mathematics teacher or administrator in the school that is being studied.