Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District

by

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Declaration

I, Mfundo Mondli Khoza, declare that:

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Date

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Dedication

I dedicate this work to the lord, the almighty. Proveb 9:10 Ukuqala kokuhlakanipha kungumesaba uJehova (The fear of the Lord is the beginning of wisdom), Ngiyabonga Nkosi, uthando lwakho lukhulu.

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Abstract

Curriculum reform in the South African education system has faced a number of changes in the post-apartheid era. The changes in the curriculum aimed to redress the imbalances of the past while addressing the challenges of the future. The major curricular reform that has taken place in the past two decades includes the introduction of the subjects of Mathematical Literacy in 2006 and Technical Mathematics in 2016. Technical Mathematics has been piloted and is being implemented across technical schools in South Africa – which means that Departmental Heads (DHs) face a challenge in being ready to implement it. Therefore, knowledge of the experiences of those who have piloted and implemented Technical Mathematics in their schools is essential. The DHs, as curriculum leaders, must demonstrate an in-depth understanding of the subjects they manage. In this qualitative study, three Technical Mathematics DHs in Pinetown District in KwaZulu-Natal shared the duality of their teaching roles while managing the new subject. Using Samuel's (2008) Force Field Model, professional forces were used to analyse this study. These forces enabled or constrained the DHs' implementation, management, and teaching of Technical Mathematics in their respective schools. The conceptual framework used in this study is a modification of Shulman's (1986) pedagogical content knowledge (PCK) and Ball et al.'s (2008) Mathematical Knowledge for Teaching (MKT), which provided clearer lenses for understanding the study phenomenon. Findings revealed that DHs understand what is needed, but this knowledge is not demonstrated all times; their understanding of their roles is more inclined toward teaching rather than managing the subject. The results of this study showed that suitable teachers, continuous evaluation and support, including practical assessment tasks (PAT), and providing professional development for Technical Mathematics teachers were perceived as enablers. Inhibiting factors were the six-year delay in including PAT, a lack of professional development targeting DH management roles, crumbling content, and learners' apathy towards the subject. I argue that DH needs targeted support for their role and capacitation in knowledge of implementing and managing Technical Mathematics in order to execute their roles efficiently.

Keywords: ***Curriculum implementation, Departmental Head, Technical Mathematics*.**

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Appendices

List of Abbreviations

ATP	Annual Teaching Plan
CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Education
DH	Departmental Heads (formely termed as Heads of Departments)
DoE	Department of Education
HCK	Horizon Content Knowledge
IQMS	Integrated Quality Management System
KCS	Knowledge of Content and Students
KCT	Knowledge of Content and Teaching
KZN	KwaZulu-Natal
KMCI	Knowledge of Mathematics Curriculum Implementation
KMCM	Knowledge of Mathematics Curriculum Monitoring
LTSM	Learning and Teaching Support Materials
MKT	Mathematical Knowledge for Teaching
POA	Programme of Assessment
PAM	Personnel Administrative Measures
PCK	Pedagogical Content Knowledge
QMS	Quality Management System
SCK	Specialised Content Knowledge
SMK	Subject Matter Knowledge
SMT	School Management Teams

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Chapter 1
Introduction and background to the study

This Chapter introduces the study, with a description of key terms that are used. Chapter 1 also highlights the aims of the study, its parameters, research questions that drive the research, the intended contribution that the study will make in the research space, and its impact in today's Mathematics classrooms. Lastly, this chapter highlights the anticipated outcomes of the research.

1.1 Introduction

Globally, Mathematics is a subject that has been considered critical because it is a requirement for many careers that are considered to include scarce skills. Similarly, in South Africa Mathematics is considered an important subject, and the drive to ensure that learners are mathematically literate is of the essence. Hence the curriculum of South Africa and in particular that of Mathematics has undergone several changes. While curriculum reform is not the focus of the study, and the researcher will not dwell on it, it is nevertheless important to highlight that many learners drop out of Mathematics at Grade 9 level (Spaull, 2015; Spaull & Kotze, 2015; Van der Berg , Van Wyk, Selkirk, Rich, & Deghaye, 2019). The South African Department of Basic Education (DBE) introduced Mathematical Literacy with the aim of ensuring that all learners study some form of mathematics up to matric level (Bansilal, 2014). Nevertheless, there remains a gap between Mathematical Literacy as used for everyday life and the mathematics needed for scarce skills careers. With many learners opting out of Mathematics after Grade 9 (DBE, 2014b), in favour of Mathematical Literacy, this could be regarded as a crisis. To address the crisis, in 2016 the DBE introduced the new subject of Technical Mathematics. In South Africa, after Grade 9 learners must choose one option from among Mathematical Literacy, Pure Mathematics or Technical Mathematics. The learners with no intention of pursuing mathematics-related careers post-matric generally choose Mathematical Literacy, while those intending to pursue careers in mathematics-related fields now can choose between Pure Mathematics and Technical Mathematics.

As background to the study, in the next section the researcher briefly discusses educational transitions that have taken place in the South African curriculum since the end of apartheid, which have given rise to the changes we see today. Since the study will foreground Technical Mathematics, the section will highlight the differences and similarities between the Pure Mathematics and Technical Mathematics curricula in the South African context.

1.2 Mathematics curriculum changes in South Africa post-apartheid

The preamble of the South African Constitution asserts that it aims to "heal the divisions of the past and establish a society based on democratic values, social justice, and fundamental human rights" (Republic of South Africa, 1996, p.2). Notably, the Constitution acknowledges the human injustices that occurred during the apartheid era, and emphasises giving all citizens equal rights. Apartheid education featured a race-based education system, and specifically the Bantu Education Act, Act No. 47 of 1953 (herein referred to as 'the Education Act') denied opportunities to black persons that would equal those available to whites, Verwoerd (1954) as cited in Christie and Collins (1982, p.68) stating as follows:

> There is no place for the Bantu in the European community above the level of certain forms of labour. Until now he has been subjected to a school system which drew him away from his own community and misled him by showing him green pastures of European society in which he was not allowed to graze. This attitude is not only uneconomic because money is spent for an education which has no specific aim but it is also dishonest to continue it. It is abundantly clear that unplanned education creates many problems, disrupting the community life of the Bantu and endangering the community life of the Europeans.

The National Party government and the Bantu Education Act not only marginalised the black learner, but also ensured that the black girl learner was socially excluded from educational opportunities. Hence girl learners were even more oppressed – not only being seen as belonging to an inferior race but also denied equal access to education within their own race The overall principles and vision of Apartheid were to guarantee no compulsory formal education for black children. (Christie & Collins, 1982; Jansen, 1990).

The Bantu Education Act had further implications for teaching and learning in Mathematics education. The education system ensured that the mathematical skills that are deemed essential in society at large would be beyond the reach of black people. In June 1954, in his Parliamentary address, Dr Hendrik Verwoerd as cited in Harrison (1981, p. 194) asked: "What is the use of teaching the Bantu child mathematics when it cannot use it in practice?", and his regime ensured that learning Mathematics would not be available for blacks. Brink (2018, p. 145) asserted that "Mathematics, therefore, became a contentious subject, even a political one, with the teaching – or rather the non-teaching – of mathematics regarded as one tool of oppression deployed by the apartheid regime". In effect, Mathematics was politicised, so that only whites could make good use of it in their European communities. The forerunner to the current DBE claimed that "Mathematics has often been used as a filter to block access to further or additional learning, not only in Mathematics itself but also in areas and careers related or even unrelated to Mathematics" (Department of Education (DoE), 2003a, p. 62).

The impact of apartheid policies concerning Mathematics education are still being felt, with the implementation of Technical Mathematics being hampered by a shortage of teachers with essential technical skills. Consequently, there are not many teachers who are able to teach Technical Mathematics. The only hope lies in developing teachers in large numbers. Then Minister of Education Kader Asmal had highlighted that overcoming problems in the education sector is vital, as challenges facing South Africa are rooted in our past and will impact the opportunities of the 21st century (DoE, 2001).

1.3 Curriculum changes in education during the post-apartheid era

Once South Africa had achieved democracy, the newly appointed government had a core duty of ensuring that all citizens would be treated equally. For education, this meant equal access to education for all people, irrespective of their gender or race. For Mathematics education, it meant all learners could study the same Mathematics curriculum, irrespective of their ethnic group, including those who had been marginalised. The 1996 South African Constitution stresses the importance of the right to education (Republic of South Africa, 1996), with Section 29 stating that:

> Everyone has the right -
>
> (a) to a basic education, including adult basic education; and
> (b) to further education, which the state, through reasonable measures, must make progressively available and accessible. (p. 22)

The right to education was further promoted in the South African Schools Act (SASA), 1996, which further promoted access, quality, and democratic governance in schools. The democratic

Minister of Education of the 'new' South Africa had to undo more than 40 years of formal apartheid education structures. The first essential initiative was to make provision for compulsory schooling for all children aged 7 to 14 years. All learners would be able to exercise their newly acquired right of equal access to quality education without being subjected to discrimination. Harley and Wedekind (2004) state that the new mission of post-apartheid education would be to unite all South African citizens as equals in a democratic and prosperous society.

1.3.1 Curriculum 2005 (C2005)

Curriculum and administrative changes commenced immediately after the 1994 elections, when the National Education and Training Forum (NETF) began revision and consolidation of the apartheid education syllabi and subject rationalisation. Minister Asmal asserted that the main purpose of this process was to lay the foundation for a single national core curriculum (Asmal, 2002). Changes were made on the basis that the curriculum had to cater for all learners, irrespective of their social or ethnic background. Firstly, the Ministry of Education had to blend and reshape 19 racially and ethnically divided departments to have common goals. Moreover, the NETF had to remove explicitly racist and other insensitive language from existing syllabi. Jansen (1998) argued that Curriculum 2005 (C2005) attempted to purge racist, offensive and outdated aspects of syllabi embedded in the apartheid curriculum. In essence, Fataar (2001, p.21) stated that the Ministry intended "C2005 to be a coherent policy initiative" that was to bring transformation to the nature of schooling. According to Engelbrecht (2006) and Mestry (2014), transformation of education in the post-apartheid era was based on equity and redress, access, quality and democracy, as defined by the government policy.

C2005 was launched on 24 March 1997 by the Minister of Education. The DoE (1997) asserted that the rationale for C2005 was based on redressing the imbalances of the past brought about by the apartheid regime, so that henceforth basic education in post-apartheid South Africa would be outcomes-based curriculum framework. Similarly, the DBE (2014) asserted that in 1997 outcomes-based education was introduced to overcome the curricular divisions caused by the apartheid regime. Chisholm (2005) argued that Curriculum 2005 was significant because of the weight attached to what it could have achieved and the enormity of the practical and symbolic legacy it sought to address. The values that underpinned outcomes-based education were not solely concerned with eradicating apartheid education but also with grooming learners who could participate in a global economy, thus meeting the new global competitiveness imperatives.

Teachers as interpreters of the curriculum have a crucial role in facilitating the curriculum, irrespective of its complexity. Teachers' failure to adapt and dissect the curriculum for their intended audience would make it impossible for learners to attain the intended outcomes. For the DoE (2001), failure in implementing C2005 arose from the fact that for many teachers and teacher educators, the vision was, necessarily far removed from their own experience and habits. Few teachers or educators had first-hand knowledge of an outcomes-based curriculum and the teaching so envisaged; there was a deficit in school management structures and professional capacity to manage such changes (DoE, 2001). Whereas C2005 was intended to democratise the education system in South Africa, it received widespread criticism arising from its implementation and the type of assessment that it entailed. Makhwathana (2007) asserted that the transition to C2005 presented teachers with a challenging and significant paradigm shift. Masondo, Mahlangu and Mclea (2010) affirmed that the curriculum was wide open to different interpretations, and so lacked clarity about what was required of teachers.

In essence, the failures of the DoE and its teachers played a significant part in destroying the hopes of millions of learners who were in the education system (Masondo et al., 2010). Msibi and Mchunu (2013, p. 19) believed that "continued ascription of education failure to the curriculum is misdirected, and rather that curriculum change has been undertaken without sufficiently addressing the issue of teacher professionalism". They contended that within the South African educational framework, the main reason for the curriculum implementation's shortcomings is the DoE's fixation on the curriculum rather than the teachers and their competencies (Msibi and Mchunu, 2013). A similar view is shared by Ball, Hill and Bass (2005, p. 14), that "strong standards and quality curriculum are important but no curriculum teaches itself, and standards do not operate independently of professionals' use of them". Specifically, whereas teachers' content knowledge of Mathematics is important, they also need to also know how to implement the curriculum effectively. The McKinsey report, as cited in Barber and Mourshed (2007), argued that the quality of a schooling system depends on the quality of its teachers, getting good people into teaching to attain a better education outcome. They emphasised that an education system's quality cannot exceed its teachers' quality. In essence, the quality of the education system is directly proportional to the quality of its teachers.

In the post-apartheid era all South African learners had the opportunity to learn Mathematics; indeed, it was made a compulsory school subject for all learners until Grade 9 (from Grade 10 no longer being compulsory). Learners who chose Mathematics had the choice of taking Mathematics at Standard or Higher Grade level. This differentiation of the Mathematics curriculum ended in 2007, when Mathematical Literacy was implemented. The introduction of Mathematical Literacy meant that after Grade 9 learners would have a choice between Pure Mathematics (which would direct them to pursue mathematics- and science-related careers post-matric), or Mathematical Literacy (which precluded further studies in a mathematics- or science-related field). The introduction of Mathematical Literacy was accompanied by the revised curriculum; this later transition eliminated the segregation between Higher and Standard Grade Mathematics in favour of uniform teaching of National Curriculum Statement (NCS) Mathematics. This curriculum reform was an intervention that allowed learners who chose to do Pure Mathematics to have equal a chance of being assessed 'fairly'.

1.3.2 Revised National Curriculum Statement (RNCS)

The failure in implementation of C2005 led to further curriculum revisions in 2000 (Jansen, 1998). As stated by Msila (2007), there have been challenges with South Africa's transition from apartheid to the current educational system. The Revised National Curriculum Statement (RNCS) arose to streamline and strengthen C2005. The RNCS was one of several curriculum waves that did not last long; it was based on the premise of 'fixing' the much-criticised C2005. Nevertheless, it was not long before the RNCS received its own criticism –that it did not equip learners to meet international standards. Many scholars alluded to the RNCS not helping South African learners to compete internationally, highlighting the need for further revision (Bantwini, 2010; Chisholm, 2005; Msila, 2007). It was intended to revise the RNCS by eliminating its weaknesses and leaving in those elements that had worked well (DoE, 2007). This wave of changes in the South African curriculum is hardly surprising, since the DoE had to try to redress the problems associated with the apartheid curriculum, while also trying to meet international standards.

Msibi and Mchunu (2013) view curriculum implementation and development as a process that is interactive, constantly changing, collaborative and intellectually engaging. Essentially, this wave of curriculum revision shifted the South African education system from being content-based to an outcomes-based approach. A content-based syllabus focuses on everyday knowledge that is acquired from different disciplines, whereas the competence-based or outcomes-based syllabus focuses on school knowledge (Hoadley & Jansen, 2013). The educational reforms that took place in South Africa promoted a paradigm shift from a teacher- and content-driven curriculum to an outcomes-based and learner-centred curriculum.

1.3.3 Curriculum Assessment Policy Statement (CAPS)

The multiple curricular changes that South Africa has been subject to indicate that education was seen as a 'weapon of transformation' (Msila, 2007). Further changes to the RNCS were in relation to content, assessment, and learner outcomes, which led to the Curriculum Assessment Policy Statement (CAPS) (Maharajh, Nkosi, & Mkhize, 2016; Moodley , 2013; Nkosi, 2014). The CAPS curriculum was intended to go "back to basics" in addressing challenges simplifying previous complications that had been created by previous educational reforms (Harrop-Allin & Kros, 2014). While many teachers and educational experts (Harrop-Allin & Kros, 2014; Msibi & Mchunu, 2013; Ramatlapana & Makonye, 2012) have criticised the authoritarian nature of the CAPS curriculum, on the basis of its being content-driven with very stringent prescriptions for the sequencing and scope of contents; with some even claiming that the new curriculum has elements of the Apartheid curriculum. The curriculum changes in the South African education system have affected all subjects, specifically Mathematics as one of the key subjects has undergone transitions, with corresponding challenges associated with implementation. In next section the researcher shifts the discussion to focus particularly on the recent evolution of the Mathematics curriculum, because the study will focus on the implementation of Technical Mathematics, which is a recent development in the curriculum transformation of mathematics in South Africa.

1.4 Mathematics curriculum transformation

South African learners in the Further Education and Training (FET) phase were previously deprived of opportunities to learn Mathematics. Sasman (2011) stated that in the past, about 40% of secondary schools in South Africa did not offer any form of Mathematics beyond Grade 9. This meant that many learners at the matric level in South Africa were mathematically deprived. Between 1995–2007 when Mathematics could be studied on either Higher or Standard Grade, Mathematics Standard Grade was of such a nature that it was much easier to teach and learn, while Mathematics Higher Grade was seen as being elitist. Consequently, many learners were left with no option but to take Mathematics Standard Grade. In an attempt to increase the number of learners with greater mathematical skills, in 2006 the division of Mathematics between Higher and Standard Grade was phased out (Nel and Kistner, 2009; Mthethwa, 2013). This meant that all learners doing Mathematics would learn and be assessed on the same concepts. However, this change would not address the challenge of learners not choosing to do Mathematics beyond Grade 9 – so the new subject of Mathematical Literacy was introduced in 2006.

1.5 Mathematical Literacy curriculum

Mathematical Literacy provides learners with an awareness and understanding of the role that mathematics plays in the modern world, as outlined by the DoE (2003b). Thus, Mathematical Literacy is a subject driven by life-related applications of mathematics. It enables learners to develop the ability and confidence to think numerically and spatially in order to interpret and critically analyse everyday situations and to solve problems (DoE 2003b). When implemented, Mathematical Literacy was announced as one of the FET phase designated subjects other than Mathematics; hence learners who do not perceive Mathematics to be necessary for their chosen career path or study direction are now required to take Mathematical Literacy as an alternative.

Mthethwa (2019) states that Mathematical Literacy was implemented as a new subject in Grade 10 in 2006, in Grade 11, 2007 and in Grade 12 in 2008. This allowed learners to choose between Mathematics and Mathematical Literacy, on the basis that one is easier than the other. Learners who were struggling with Grade 9 Mathematics and obtaining less than 60% would generally choose Mathematical Literacy instead. This would, however, preclude them from studying subjects such as Physical Sciences.

The implementation of Mathematical Literacy is one of the interventions by the DoE (later DBE) that brought both successes and failures in teachers' readiness to teach and learners' relatively poorly understanding of the contextualised mathematics problem embedded in the subject (Debba, 2011; Hobden, 2007). Mathematical Literacy was then developed, which could offset the low-level numerical literacy levels among adults in South Africa (Hobden, 2007). This was therefore one of the new subjects in the National Curriculum Statement that forced the department to reskill teachers to teach the subject effectively. Webb et al. (2011) stated that introducing Mathematical Literacy required urgent training of a massive cohort of teachers before implementing the learning area in schools. This then required higher education institutions (HEIs) to devise ways of 'recurriculation', to reskill teachers to teach Mathematical Literacy effectively. HEIs had to develop and deliver Advanced Certificate in Education (ACE) qualifications to capacitate Mathematical Literacy teachers.

These attempts to equip teachers to teach Mathematical Literacy did not, however, address the challenges associated with curriculum implementation – let alone that of having low numbers of learners taking Mathematics post-Grade 9. This brought about the latest intervention to encourage learners to take Mathematics as a subject after Grade 9, when the DBE introduced the new subject of Technical Mathematics.

1.6 Technical Mathematics curriculum

Technical Mathematics was introduced and implemented in schools as a pilot subject in 2016. The intention was to help learners who intended to enter technical career fields like Engineering, which required Mathematics post-Grade 9, but who had no inclination to study Pure Mathematics. The main aim was therefore to ensure that learners who were interested in technical fields had the opportunity to further their studies at FET colleges at an entrance level of N-4, thereby creating an alternative access route to HEIs. This implies that learners would now develop connections to their chosen career path, by learning courses that included Technical Sciences and Technical Mathematics, and other related technical subjects while in the FET band.

The DBE (2011, p. 6) defines the two subjects as follows:

> Mathematics is a universal science language that makes use of symbols and notations for describing numerical, geometric and graphical relationships. It is a human activity that involves observing, representing and investigating patterns and qualitative relationships in physical and social phenomena and between mathematical objects themselves. It helps to

develop mental processes that enhance logical and critical thinking, accuracy and problem solving that will contribute in decision-making. Mathematical problem solving enables us to understand the world (physical, social and economic) around us, and, most of all, teaches us to think creatively.

While Mathematics and Technical Mathematics are two individual subjects, they are grounded on similar goals, and thus the content taught will foreground the same outcomes. However, they do differ to some extent, as illustrated in Table 1.1.

Table 1.1: Comparison of specific aims for Mathematics and Technical Mathematics

Mathematics specific aims	**Technical Mathematics specific aims**
To develop fluency in computation skills without relying on the usage of calculators.	To develop fluency in computation skills with the usage of calculators.
Real-life problems should be incorporated into all sections whenever appropriate. Examples used should be realistic and not contrived. Contextual problems should include issues relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible.	Real-life technical problems should be incorporated into all sections whenever appropriate. Examples used should be realistic and not contrived. Contextual problems should include issues relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible.
To provide the opportunity to develop in learners the ability to be methodical, to generalise, make conjectures and try to justify or prove them.	To provide the opportunity to develop in learners the ability to be methodical, to generalise and to be skilful users of the science of Mathematics.
To promote accessibility of mathematical content to all learners. It could be achieved by catering for learners with different needs.	To promote accessibility of mathematical content to all learners. This could be achieved by catering for learners with different needs, e.g. technical needs.
To prepare the learners for further education and training as well as the world of work.	To provide learners at technical schools with an alternative and value-adding substitute to Mathematical Literacy.

Sourced from Mathematics Grade 10-12 CAPS Document (DBE, 2011. p. 9) and Technical Mathematics Grade 10-12 CAPS Technical Mathematics CAPS Document (DBE, 2014, p. 11)

The common specific aims in the Mathematics and Technical Mathematics curricula place mathematical modelling as one of their focal points. Learners are expected to be fluent in understanding and working with number systems, and need to develop both problem-solving and cognitive skills. The DBE (2011) further states that learners learning pure Mathematics and Technical Mathematics should be encouraged to develop critical thinking skills. This means that instruction should focus more on the "when" and "why" of problem types rather than just the "how".

In Mathematics the specific aims further stipulate that Learning procedures and proofs without a good understanding of why they are important will leave learners ill-equipped to use their knowledge in later life. Whereas the specific aims of Technical Mathematics emphasise supporting and sustaining technical subjects at technical schools. The document specifies that "Technical Mathematics can only be taken by learners offering a Technical subject (mechanical, civil and electrical engineering)" (DBE, 2014a, p. 10). This is to ensure that the subject provides a vocational route aligned with the expectations of labour, in order to ensure direct access to learnerships or apprenticeships (p. 10). Lastly, Technical Mathematics aims to create opportunities for learners to further their studies at FET colleges at an entrance level of N-4, and so facilitates an alternative access route to HEIs (p. 10).

The DBE (2011, p. 58) asserts that:

> for a very long time the majority of learners in most schools did not cope with the current difficult level of the mathematics. Because of this they either took Mathematics Literacy or they achieved such a bad mark that they could do nothing with it.

The new subject sought to give technical learners a good foundation for vocational studies, so they could continue in level N4 in a technical college. The DBE (2011, p. 10) stipulates that

> In the FET Phase, learners should be exposed to technical mathematical experiences that give them many opportunities to develop their mathematical reasoning and creative skills in preparation for more applied mathematics in Higher education institutions or in-job-training.

Technical Mathematics was therefore designed to give Grade 10–12 learners a concrete background of the content that is covered in levels N1 to N3 college mathematics syllabi. In this way, learners could be enrolled in technical colleges without undertaking bridging courses. The DBE (2011, 2014) CAPS documents for Mathematics and Technical Mathematics (pp. 9 and 11, respectively) outlines the main content areas that contribute to the attainment of specific skills, as shown in Table 1.2.

Table 1.2: Comparison of Mathematics and Technical Mathematics content areas

Mathematics	Technical Mathematics
1. Functions	1. Functions and graphs
2. Number patterns, sequences, series	2. Number systems
3. Finance, growth, and decay	3. Finance, growth, and decay
4. Algebra	4. Algebra
5. Differential calculus	5. Differential calculus
6. Probability	6. Mensuration
7. Euclidean geometry and measurement	7. Euclidean geometry
8. Analytical geometry	8. Analytical geometry
9. Trigonometry	9. Trigonometry
10. Statistics	10. Circles, angles and angular movement

While the content covered in the two subjects may seem similar, Technical Mathematics specifically focuses on the technical aspects of mathematics. One such difference stated in the DBE (2014, p.11) Technical Mathematics CAPS document, is the focus on number systems; in Mathematics, this is limited to the real number system, whereas Technical Mathematics has a focus that includes understanding both real and complex numbers (i.e. imaginary numbers), and solving equations involving complex numbers. Technical Mathematics is also distinguished by its focus on angular movement and mensuration and its strong focus on integration, both as a summation function (definite integral) and as converse of differentiation (indefinite integral). In Mathematics, calculus has a narrower focus, with an intuitive understanding of the limit concept, in the context of approximating the rate of change or gradient of a function at a point, and using limits to define the derivative of a function. These differences in content areas make each subject unique in its own way.

1.7 Background and problem examined by the study

In this study the researcher's focus was to explore the experiences of Departmental Heads (DHs) in the implementation of Technical Mathematics in technical schools in the Pinetown District of KwaZulu-Natal. The study aims to understand the extent to which Mathematics DHs understand

and manage the implementation of Technical Mathematics in their departments. Exploring their understanding and practices would also reveal the enabling factors that would sustain the implementation of the new subject as it is rolled out to other schools, as well as any challenges that may have the potential to hinder the sustainability of the new subject.

In the context of South Africa, to be a DH one needs to be a specialist in the subject he/she is managing and have expertise to manage the curriculum. To be a specialist, one is required to have undergone training or preparation to teach the subject and have some experience in teaching it. Bansilal (2002) maintains that well-trained teachers are essential in the educational process, which means that the success or failure of an education system depends on the quality of the teachers. This implies not only the classroom teachers, but also those tasked with managing the curriculum within the school setting.

Technical Mathematics is a new subject that was piloted in a limited number of South African schools in 2016, and since 2018 has been rolled out to other schools. The year 2018 brought the first matric cohort being offered Technical Mathematics in South Africa (DBE, 2018b). However, while the teaching of Technical Mathematics is progressing, little has been done to ensure the quality of those tasked with teaching and managing the curriculum. Motshekga (2013, p. 4) argue that "Most teachers in South Africa currently active in our schools were trained in the old rural colleges which generally provided education of very poor quality". The previous education (apartheid era) of most South Africans included no technical subjects, leading to the current pool of DHs in Mathematics lack the appropriate expertise to teach and manage Technical Mathematics.

Moreover, teacher training institutions have not currently infused Technical Mathematics into their curriculum to produce teachers who are well trained in teaching and managing the new subject, and there are no measures in place from the DBE to ensure that the current pool of DHs is equipped to teach and manage the subject. Hence, the Mathematics DHs are not subject specialists. Having curriculum implementers and managers of Technical Mathematics who are not specialists nor well trained in the subject is contrary to the South African policies on norms and standards (DBE, 2016a). This deficit has been highlighted in the literature (see, for instance, Bansilal, 2002; Ball et al., 2008; Pournara et al., 2015), where authors emphasise the importance of having well-trained teachers and curriculum implementers to ensure that effective teaching can take place in the classroom.

The introduction of Technical Mathematics – in the absence of expert DHs – might negate the whole purpose of implementing the subject, in that the aims might not be achieved. A major challenge arises because DHs are appointed on the basis of having a minimum teaching qualification and more than five years' teaching experience, but Technical Mathematics was implemented in South Africa with little or no training to prepare the DHs and the teachers they lead on how to implement and teach the new subject. Without doubt, DHs might face any number of challenges in relation to curriculum management and providing supervision for teachers, while still assuming their teaching role.

Regarding the teaching of Technical Mathematics, the content knowledge of the DHs is essential – as it is for all other teachers – and should go beyond merely classroom teaching. As curriculum managers within the school, DHs are responsible for supporting other teachers. Accordingly, they must have content knowledge of the subject in order to be able to manage the curriculum effectively while monitoring and supporting the teachers. It is important that their understanding of the content of Technical Mathematics is thorough and that they know the subject well; in other words, that their understanding is unquestionably beyond the level of the learners they teach and the teachers they supervise. Nene (2019) is of the view that DHs should demonstrate superior knowledge and understanding of curriculum supervision, and their practice should be seen to influence curriculum implementation.

The Jika iMfundo campaign introduced in 2015 aimed at addressing the main cause of poor performance in the Senior Phase, which is poor coverage of Mathematics curriculum (Metcalfe, 2018). Lack of curriculum coverage speaks to DHs' lack of curriculum knowledge and skills in managing the curriculum. While lack of teacher knowledge may be the responsibility of an individual teacher, DHs should be experts in their subjects and are expected to provide support to all teachers in the phase and to provide professional development where they identify gaps in teacher expertise related to subject matter knowledge, pedagogical content knowledge or curriculum coverage. However, for a DH to be able perform these duties, he or she first needs to have the required knowledge to teach the subject and to manage the curriculum. Therefore, in terms of these responsibilities DHs are expected to be subject specialists, to ensure the effective implementation of Technical Mathematics. In light of the lack of research conducted to explore the implementation of Technical Mathematics in South African schools, the researcher recognised the need to pursue this study, with the express aim of exploring DHs' knowledge of teaching the subject and the extent to which they navigate their roles in managing implementation of the curriculum in their schools.

1.7.1 Roles and responsibilities of DHs

The Employment of Educators Act 76 (1998) stipulates that the role of DHs includes monitoring the work of educators and learners in their department. The main responsibilities of DHs, as spelled out in the Personnel Administrative Measures (PAM) (DBE, 2016b) document, are to engage in class teaching, oversee the effective functioning of the department, and to organise relevant or related extracurricular activities to ensure that the subject, learning area or phase, and the education of the learners is promoted in a proper manner.

The PAM (DBE, 2016b) defines DHs as school managers who are responsible for certain subject/s stream/s. In South African schools DHs have the important role and responsibilities of ensuring smooth implementation and teaching of the curriculum. Accordingly, as the intermediary between Subject Advisors and teachers, DHs must manage curricular instructions for teachers – which is the core duty that separates them from ordinary teachers. They therefore work hand in hand with the school principal and deputy principal to ensure the smooth running of the subject they manage. Gordin (2013) confirms that DHs establish the appropriate links between their department members and the upper executive of their schools. Muriuki, Onyango and Kithinji (2020) assert that the global understanding of DHs' role in public secondary schools is that they lead, manage and develop standards of excellence in curriculum delivery in their areas of specialisation. Beyond managing the curriculum, they also have to implement it, as mooted by Mashapa (2019); Metcalfe and Witten (2019), who stated that DHs' roles involve the simultaneous management of a department and class teaching. This dual role for DHs, of both administration and teaching, is widely adopted in South African schools. The general understanding is that DHs are required to lead and to contribute to the whole school leadership.

The DBE (2022c) has highlighted key elements of curriculum management that DHs are expected to execute, which include curriculum supervision, evaluation and curriculum monitoring, staff support and resources, capacitating staff with the required skills, creation of relevant learning activities, and providing quality assurance relating to learning and assessment. DHs play an important role in the assessment and development of teachers in accordance with the teacher evaluation system known as the Integrated Quality Management System (IQMS), later referred to as Quality Management System (QMS). The IQMS is an essential tool used for measuring the development and performance of teachers. Southworth (2004) elaborates that the processes involved in the IQMS include DHs' observation of teachers at work and providing them with feedback after visiting their classroom. The DHs then note areas of teacher strengths and weaknesses, while devising plans for improvement for effective teaching of the subject. Therefore, this expectation of DHs means that they should be experts in the field and adequately prepared as curriculum managers to manage and implement the curriculum. Thus, with the introduction of Technical Mathematics without prior training of DHs on how to execute these roles for the new subject, the researcher saw the need for this study to understand the DHs' practices in and knowledge of managing and implementing the new curriculum.

1.7.2 Effects of the Department Head's expertise on learner performance

Poor performance among learners has been attributed in many studies to poor teachers and poor teacher knowledge (for example, Ball et al., 2008; Bansilal et al., 2014; Pournara et al., 2015). Furthermore, Nkabinde (2012) attributed poor learner performance in Mathematics to DHs' lack of skills and knowledge required to perform their roles. He asserts that poor performance of learners may be the result of DHs' perceptions regarding their roles and responsibilities in light of the limited support they are able to offer learners and teachers. Mkhwanazi et al. (2018) attributed the lack of curriculum coverage and poor use of innovative tools to enhance teaching to the DHs' lack of engagement with teachers in professional conversations about curriculum implementation, and the lack of support provided to teachers to ensure their professional development. In the same way, in the teaching and implementation of Technical Mathematics, DHs have a dual role, which includes coordinating all educational activities between the top management of the school and the supervision of post level one teachers' curriculum delivery (DBE, 2015b). This dual role of teaching and management in schools is not widely understood by some teachers and DHs, leading to inactive supervision and implementation of the curriculum at classroom level. The wide scope of responsibilities is alluded by Nkambule and Amsterdam (2018) is arguing that its compromise the quality of support, leading poor learner performance.

According to the South African Schools Act, Act 84 of 1996, and Employment of Educators Act 76 of 1998, DHs are post level two employees. The aim of their job is defined in terms of class teaching, and responsibility for effective functioning of the department (including organising relevant or related extracurricular activities), all to ensure that the subject, learning area or phase and the education of the learners is promoted in a proper manner. Therefore, exploring DHs' practices as curriculum managers and implementers is intended to provide an understanding of the enabling factors or challenges which would inform what professional development needs to be effected to sustain the implementation of Technical Mathematics in South African schools.

1.8 Purpose of the study

The purpose of this study is to explore the knowledge and practices of Mathematics DHs in implementing Technical Mathematics in Pinetown District. In the study the researcher aims to provide DHs with an opportunity to engage in reflective practice through sharing their knowledge and practices concerning various stages of the teaching and implementation of Technical Mathematics in respective schools. Reflecting on their knowledge and practices will show their knowledge of enacting their roles and responsibilities, thereby revealing enabling factors that have the potential to enhance the implementation and teaching of Technical Mathematics, as well as the challenges that might be a barrier to this.

1.9 Rationale for the study

The reasons for undertaking the study were based on personal experience and the aim was to contribute to the field of knowledge.

1.9.1 Personal experience

Improving the quality of and access to education has been a topic of interest for many decades. Being a Mathematics teacher, and having taught in the school where Technical Mathematics was being piloted, the researcher observed the confusion that DHs and teachers encountered regarding implementation of the subject. Noting this confusion that arose with the introduction of Technical Mathematics during the pilot phase, and subsequently seeing the subject being rolled out to other schools with no prior training for DHs before the implementation of Technical Mathematics, with no in-depth research being conducted on understanding the experiences of those expected to implement it, provided the rationale for this study. It is within these parameters that the researcher hopes that the knowledge gained about DHs' know-how and practices would significantly assist policy makers in understanding the challenges and successes of those who are at ground level. This could potentially assist with future planning in providing tailor-made professional development for DHs, so they would be better able to capacitate their teachers for effective implementation of the new subject.

The aim of Technical Mathematics as another branch of Mathematics is to help those learners who are interested in neither Mathematics nor Mathematics Literacy to have fundamental technical mathematical skills. Since the subject is offered as early as Grade 10, learners have to make the life decision of whether to choose Mathematics, Mathematical Literacy or Technical Mathematics at the end of Grade 9, when they are as young as 13 or 14 years of age. The subject Technical Mathematics is classified as a branch of Mathematics, yet it is also classified as a technical subject. This raises questions about who is eligible to teach the subject. Neither the existing DHs nor the pool of teachers who are potential DHs have been exposed to Technical Mathematics at school, because it is a new subject; neither have they been trained to teach it, as it is not yet part of the curriculum of teacher training institutions Indeed, there is an argument that some of the content taught in the Technical Mathematics curriculum has already been offered in schools and in teacher training institutions. However, some topics such as integration, are not part of the normal school curriculum and therefore are not included in the curricula offered by some teacher training institutions. Such topics are generally offered to university students intending to pursue careers in the engineering field (in other words, to those not being trained as teachers). The latter might have a better grounding in the content knowledge of the topics taught in Technical Mathematics, but they lack the pedagogy to teach. Conversely, those trained as teachers are probably not grounded in the subject matter of Technical Mathematics. In view of this discrepancy, it is important that research is conducted to explore how those tasked with the responsibility of implementing, managing and teaching the curriculum navigate these complexities.

During the C2005 implementation I was one of the learners subjected to the curriculum change. As a product of this education transition, I observed and experienced first-hand how the challenges associated with teachers' lack of preparedness for implementing the new curriculum affected their teaching, especially in Mathematics. For example, some new topics, such as linear programming, were simply skipped although it was already in the old NSC HG curriculum. This was confirmed by a study by Brijlall et al. (2011), which found that many mathematics teachers are put in a position where they must implement the syllabus, even though it covers some topics they are unfamiliar with. This reflects Jansen's (1998) earlier caution that teachers had difficulties in implementing the curriculum.

From my experience as a Mathematics teacher who taught in a school where Technical Mathematics was piloted, I observed that technical subjects are frequently taught by teachers who have little or no background of teaching pedagogy, mostly recruited from the private sector or Universities of Technology. Furthermore, implementation of the curriculum for Technical Mathematics may be managed by a DH who is not a mathematics specialist. To such DHs may fall the responsibility of teaching and managing the new subject of Technical Mathematics, without them having the appropriate content knowledge. It is within these parameters that the researcher decided to explore DHs' knowledge and practices when implementing, managing and teaching Technical Mathematics.

1.9.2 Addressing research gap

Technical Mathematics was implemented for the first time in the South African curriculum in the FET phase in 2016. The researcher became interested in knowing more about the DHs' knowledge and practices when implementing the subject, since there is dearth of research in this field. This is especially the case in South Africa, where Technical Mathematics is a new subject. Studies exploring implementation of the curriculum in Mathematics, such as those of Mthethwa (2019), Graven and Venkat (2007) have revealed some of the successes and failures in this topic, which then inform the literature and policy makers on strategies to be undertaken to sustain the implementation of the subject. However, the introduction of each new subject or curriculum will have its own complexities that need to be explored for sustainability. Since Technical Mathematics is a new subject, there is little published in this field of research. The researcher therefore aims to fill the existing gap in the literature and to contribute to knowledge and policy making. This is explored in depth in the next chapter, the literature review.

Over the years, curricular changes and implementation have been understood through the eyes of policy makers rather than those of the DHs and teachers on the ground (see, for example, Bennie & Newstead, 1999; Govender, 2018; Jojo, 2019). While there might be an argument that teachers are the key stakeholders at the ground level, DHs play the dual role of teaching as well as implementing and managing the curriculum; thus the introduction of new subjects demands from them the expertise to teach, implement and manage the relevant curriculum. Therefore, this study exploring DHs' knowledge and practices has the potential to inform policy making and to help other DHs to learn from the experiences shared, in order to understand how they could handle similar problems and consequently improve implementation.

1.10 Objectives

This research aims to explore DHs' knowledge and practices of implementing Technical Mathematics. The following objectives guide the study

1. To explore DHs' knowledge and practices of implementing and managing Technical Mathematics in schools.
2. To examine how Mathematics DHs enact their roles and responsibilities of implementing and managing Technical Mathematics.
3. To understand any challenges and enabling factors encountered by DHs when implementing and managing Technical Mathematics.

1.11 Critical questions

For in-depth engagement with the phenomena of the study, which is DHs' knowledge and practices in implementing, managing and teaching Technical Mathematics, the researcher set out to answer the following research questions:

1. What are the DHs' practices and knowledge in managing, implementing and teaching Technical Mathematics?

2. How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics?
3. Why do DHs enact their roles in the way they do?
4. What factors hinder or enable DHs in the implementation of Technical Mathematics?

1.12 Significance of the study

Technical Mathematics is a new subject that was only recently introduced in South African schools. Therefore, researching DHs' knowledge and practices as curriculum managers and implementers at the school level would have the potential to inform policy involved in the roll-out of the subject to other schools. As they are subject specialists, understanding the experiences of DHs is essential to generate guidelines for the implementation of Technical Mathematics. This suggests that when Technical Mathematics is presented across many more schools in South Africa, they will be points of reference to learn from DHs' shared experiences. School principals, as overall managers in schools, have a huge responsibility to understand the needs of the teachers and learners. When Technical Mathematics has been introduced, principals thus have the responsibility of ensuring that learners receive the intended curriculum to serve the intended purposes. This study about DHs' practices and knowledge would assist principals by highlighting the enabling factors and challenges encountered as they are tasked with the implementation, managing and teaching of the curriculum, thereby helping with planning appropriate immediate interventions, if needed.

1.13 Limitations of the study

According to Kumar (2018), there are limits to all research. A few limitations were present in this study, including the fact that the researcher contacted participants in advance and created a schedule accordingly to minimise the impact of time. There were sometimes conflicts between pre-planned meetings with DHs and other activities and workshops, necessitating rescheduling and adjusting. DHs were sometimes reluctant to admit their shortcomings to conceal their weaknesses in managing and teaching the Technical Mathematics curriculum. The study is limited to three schools within one district, so it cannot provide a substantial basis for comparisons. Therefore, this small sample size makes it difficult to draw general conclusions and principles. Nevertheless, this study aims to understand participants in their natural settings rather than generalizing findings.

1.14 Delimitations of the study

Rule and John (2011) state that by declaring the limitations of a study, the dependability of the study is raised. A limitation of this study is that it is a small-scale study comprising a sample of three DHs at three schools as the primary sources of data generation. This could be seen as a weakness of the study, since the findings should not be generalised. Nevertheless, as Cohen et al. (2011) explain, qualitative studies do not provide generalisable findings, but rather create meaning and understanding. Accordingly, because the sample group is relatively small, the researcher is not intending to generalise the findings, but rather to elicit findings from the DHs in order to inform policy makers and ideally enhance practices of teaching and managing Technical Mathematics.

1.15 Methodology

The study was underpinned by two theories, the theoretical framework being Samuel's (2008) Force Field Model (FFM) and conceptual framework being a modification of Shulman's (1986) Pedagogical Content Knowledge (PCK) needed for teaching, substantiated by Ball, Thames, and Phelps' (2008) Knowledge for Teaching Mathematics (MKT). The theoretical and conceptual frames gave premises in understanding DHs' knowledge and practices, and how DHs enact their roles and responsibilities, while understanding their enabling and challenging factors. This is a qualitative study within an interpretive paradigm, which aims to interpret the enabling factors and challenges from the perspective of the curriculum managers and implementers. The research style that this study uses is case study, with the aim of gaining in-depth knowledge of enabling factors and challenges, as well as a unique insight into Mathematics DHs' implementation of Technical Mathematics. The data will emanate from three methods of data collection: one-to-one semi-structured interviews, focus group interviews, and observations.

1.16 Defination of terms

Curriculum implementation: Curriculum implementation refers to how teachers deliver instruction and assessment through the use of specified resources provided in a curriculum (Nevenglosky, 2018).

Curriculum management: Means the leadership and management of all activities that take place in a school for the purpose of teaching and learning, including all learners and teachers' experiences within the schooling environment which are planned and documented with the intention of developing the learners' general knowledge and skills (Tapala, 2019)

Departmental Head (DH): In South Africa, and the acronym 'DH' is used consistently to refer to Departmental Heads, which has recently been adopted to replace the acronym 'HoD' which refers to Heads of Departments. The PAM (DBE, 2016b) defines DHs as school managers who are responsible for certain subject/s stream/s.

Technical Mathematics: The subject of Technical Mathematics in the Further Education and Training Phase forms the link between the Senior Phase and the Higher Education band. The aim of Technical Mathematics is to apply the science of Mathematics to the technical field where the emphasis is on APPLICATION and not on abstract ideas (DBE, 2014).

Technical School: The term technical secondary school refers to schools that offer a broad range of technical subjects, such as engineering, science, Mathematics and Technical Mathematics. These schools are reminiscent of TVET colleges (Shoba, 2020)

1.17 Outline of the study

Chapter 1 has given an introduction to the study, a statement of the problem, purpose and rationale for the study, the research objectives and critical questions. Chapter 1 also highlighted some underlying reasons why Mathematics DHs' knowledge and practices experienced in the implementation of Technical Mathematics were deemed essential for research.

Chapter 2 focuses on a review of literature related to the introduction of Technical Mathematics as a new subject in the curriculum assessment standard. It highlights theories relevant to the research questions.

Chapter 3 describes the theoretical framework that guides this research.

Chapter 4 details the methodology used in the study. The focus is on the chosen research paradigm, research style, data collection methods, and data analysis, while considering ethical issues and the trustworthiness of the research.

Chapter 5 reports on each of the three cases, according to the data collected from DHs' experiences based on the parameters of this study.

Chapter 6 focuses on the findings concerning DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics.

Chapter 7 discusses the DHs' enactment of their roles and responsibilities to implement and manage Technical Mathematics.

Chapter 8 outlines enabling and challenging factors in DHs' implementation, management and teaching of Technical Mathematics.

Lastly, Chapter 9 presents a detailed summary of the study findings, conclusions, recommendations for further research, proposed framework for effective Technical Mathematics curriculum implementation, study limitations, the contribution of the study and concluding remarks.

1.18 Chapter summary

This chapter has provided an introduction and the background of the study, leading to the statement of the problem. In addition, the purpose and rationale for the study have been outlined. Finally, Chapter 1 also discussed the significance and limitations of the study, as well as its merits.

Chapter 2
Review of the literature

2.1 Introduction

This chapter provides a review of the literature that is of relevance to this study, grounded on previous research findings on the research problem that is examined in this study, to gain insight into existing knowledge and identify gaps in the literature. This chapter begins by exploring the literature pertaining to issues of curriculum implementation and management, discussing factors that enable curriculum implementation and management and associated challenges. This is followed by a review of the literature on the roles of Departmental Heads (DHs) regarding curriculum implementation and management. Since DHs are also involved in teaching, the literature review will explore the relationship between mathematical knowledge for teaching (MKT) and curriculum implementation. Lastly, factors that sustain implementing new subjects in an existing curriculum are explored. The chapter concludes by summarising studies that have been carried out on curriculum implementation and management.

2.2 DHs' curriculum management and implementation

In this section the researcher explores some definitions of curriculum management and implementation, and then reviews the literature on factors that enable or impede DHs' curriculum management and implementation.

2.2.1 DHs' curriculum management

The concept of curriculum management has no encompassing definition (Mitchell & Castle, 2005). International studies recognise 'curriculum management' as 'instructional leadership', and 'leadership for learning' as terms that define the process of leading or managing teaching and learning in a school setting. Hallinger (2005) argued that stress on the term 'instructional leadership' prevailed in the 21st century, due to the rising need for school leaders to account for learners' performance in their schools. Hallinger (2005) suggested that the emergence of the accountability movement at the beginning of the twenty-first century led to a growing emphasis on the educational achievements of both learners and schools. The Values and Principles of Education and Training Policy in White Paper 1, Chapter 4, Section 17 (Department of Education,

1995) states that restoring the culture of teaching, learning, and management requires the creation of a culture of accountability. The notion of accountability is closely associated with curriculum leadership/ management, and there is a compelling need for leaders to meet this expectation of accountability (Valle et al., 2015).

In South Africa, the widely used term is 'curriculum management' (Bush & Glover, 2009; Bush et al., 2010) which is essentially leadership of teaching and learning. Research often indicates that leadership/management is a core duty of school principals (Bush et al., 2010; Kyahurwa, 2013; Murphy, 2018; Southworth, 2002), who in fact oversee the curriculum implementation, management and teaching through DHs, who are middle managers. Bush et al. (2010) opine that principals have the potential to influence classroom teaching by taking a proactive stance and assuming the role of "instructional" leaders. In South Africa, principals are not directly involved with the management of curriculum. Bush et al. (2010, p. 6) affirm that "their instructional leadership is often confined to checking that work has been completed rather than making informed judgements about the quality of teaching and learning" – hence the DHs are the main drivers of curriculum implementation and management. This positional view was also echoed by Ogina (2017), asserting that instructional leadership extends beyond just principals to include heads of departments. Similarly, Kalane and Rambuda (2022) contend that the management and leadership of the school are no longer solely the responsibility of the principal, but rather a collective obligation shared by the team, primarily comprised of middle managers who are also DHs".

The above views suggest that DHs as middle managers have a critical role when it comes to teaching and learning in their schools. It is within the understanding of the critical role that DHs need to play when it comes to teaching and learning that the researcher decided to explore the knowledge and practices of DHs in implementation of the Technical Mathematics curriculum since its introduction in 2016. In line with the phenomena of the study, it is critical to provide an overview of the definition of curriculum management and implementation in the context of South Africa.

The DoE (2000) defines curriculum management as instructional leadership, which ultimately mean the process of leading teaching and learning. The DBE (2011) further states that education/curriculum management is the day-to-day organisation of teaching and learning, and the activities that support teaching and learning. Moreover, it is emphasised that the professional management of public schools is the responsibility of the head of the institution, who is also the manager of the school (principal), and other members of the School Management Team (SMT). Hence, the SMT (Principal, Deputy Principal and DHs) carry out the management responsibilities in schools. In particular, DHs are middle managers responsible for supervision and control of the teachers in their departments, to ensure that teaching and learning takes place, and the curriculum is implemented (Shaked & Schechter, 2017; Tapala, Fuller & Mentz, 2022). The DBE (2011, p. 43) defines monitoring as "The systematic collection and recording of information in order to track progress towards the achievement of the objectives of an intervention and identify the need for corrective action." For DHs to monitor the curriculum effectively, they need to have expertise in the teaching and learning of the subjects they manage. This study adopts the term 'curriculum management' on the basis that it is conducted in South Africa, and the acronym 'DH' is used consistently to refer to Departmental Heads, which has recently been adopted to replace the acronym 'HoD' which refers to Heads of Departments.

Not contradicting the DBE (2011) definition, Tapala's (2019, p. 191) definition encompasses leadership and management, and he defines curriculum management as

> the leadership and management of all activities that take place in a school for the purpose of teaching and learning, including all learners and teachers' experiences within the schooling environment which are planned and documented with the intention of developing the learners' general knowledge and skills.

He argues that the management of the curriculum should focus on learners, teachers, and the school environment. In his definition he explicitly articulates that DHs are the key drivers of curriculum management and implementation. His holistic view of curriculum management challenges DHs and the SMT to have knowledge of the three dimensions that contribute to effective curriculum implementation: management, implementation, and teaching. As part of their management role, DHs have to monitor the implementation and teaching of the curriculum in their respective departments.

2.2.2 DHs' curriculum implementation

Dorgu (2015) stated that translating curriculum content and instructional guidelines into classroom practice can be termed as curriculum implementation. It essentially involves the process of the actual teaching and assessment of the content that is taught. Of the same view, Nevenglosky (2018, p. 17) states that "curriculum implementation refers to how teachers deliver instruction and assessment through the use of specified resources provided in a curriculum." She asserts that "Curriculum designs generally provide instructional suggestions, scripts, lesson plans, and assessment options related to a set of objectives" (2018, p. 17). However, it is teachers who need to implement it in the classroom.

In the context of South Africa, the DBE designs the curriculum, provides suggestions of the pacing through the annual teaching plan (ATP), with teaching resources (lesson plans), learning resources (textbooks), assessments, a programme of assessment (POA), and curriculum monitoring tools (school-based assessment (SBA) moderation tools). Once the design is in place, it is delegated to schools to be implemented. However, over and above the classroom implementation, curriculum implementation also involves monitoring (Ntuli, 2018). Bush et al. (2010) posit that effective curriculum implementation requires professionals (for example, teachers and managers) who are hands-on in delivering the curriculum, and to be hands-on requires that they possess the necessary knowledge and skills of the curriculum. Dorgu (2015) is of the view that a teacher is the sole implementer of the curriculum in the classroom, arguing that for effective curriculum implementation, teachers need to be abreast of knowledge of teaching the curriculum. In the South African context, DHs have the dual role of being both a teacher and curriculum manager, and thus have to manage, implement and monitor the curriculum. For the DHs to perform their roles and responsibilities diligently, they need to know more than their teachers do so that they are able to monitor and leverage teaching and learning.

2.3 Factors that enable curriculum management and implementation by DHs

The curriculum management and delivery strategy of the KwaZulu-Natal (KZN) DoE (2020) states that one of the strategic issues in the implementation of a curriculum is strong curriculum leadership and management. To strengthen curriculum leadership and management, the SMT and especially the DHs (as curriculum managers in their disciplines) must ensure that the following conditions are met (KZN DoE, 2020, p. 30):

- Collaborative curriculum planning;
- Curriculum coverage in all subjects;
- Monitor regular learner assessment;
- Provide guidance and mentorship in different subjects;
- Strong supervision of learners' progress; and
- Monitor effective curriculum implementation.

In the context of this current study, curriculum management and implementation require Technical Mathematics DHs to assume their management roles to their best ability. For effective management of the curriculum, I discuss important factors affirmed by international literature (see, for example, Brown, Rutherford & Boyle, 2000; Rudhumbu, 2015; Zepeda, 2016) and South African literature (see, for example, Chikoko, 2009; Madonsela, 2017; Nkadimeng, 2017; Reddy, 2021).

2.3.1 Mathematics Departmental Heads' knowledge and expertise

In this study context, DHs are subject managers and Technical Mathematics teachers. Therefore, they need to possess a deep understanding of the subject they teach and manage. Importantly, the management role with respect to knowledge and expertise requires them to be abreast of the latest trends and developments in the subject they manage, as it is newly implemented. They need to know more than their teachers do. As argued by the American scholar Zepeda (2016), it is difficult to supervise and then provide developmentally appropriate professional learning opportunities without the knowledge that the standards offer. The above view suggests that for DHs to be able to manage, monitor and implement Technical Mathematics, they need to be expert in terms of pedagogies to teach the subject, and be competent in the subject matter as well as the curriculum knowledge. In the South African context, DHs' knowledge and expertise requires them to have a deep understanding of the Curriculum Assessment Policy Statement (CAPS), and to be able to unpack it, so that they can effectively guide their teachers when they monitor its implementation (Govender, 2018; Mbatha, 2016). Knowledge of the curriculum implies that they understand the social dynamics of the education system and the challenges that still exist in the teaching and learning of Mathematics in general. Knowledge of the subject premises that the DHs understand effective teaching methods (pedagogy) that could be applied in different topics that could enhance learners' attainment of knowledge.

In essence, Mathematics DHs need to possess the major categories of teacher knowledge advocated by Shulman (1986) and Ball, Thames and Phelps (2008), which encompass general pedagogical content knowledge (PCK) and Mathematical Knowledge for Teaching (MKT), respectively. For Technical Mathematics DHs to monitor the curriculum, I argue that the specialised content knowledge (SCK) enables the DHs to know whether teachers are able to unpack the mathematical knowledge for their learners, identifying common errors that students have and how they are addressed by teachers during their class visits and moderation of tasks. The DHs also need to have knowledge of content and students (KCS), which is a domain of knowledge that is useful in understanding the Mathematics content and the learners doing Mathematics. When teaching and managing Mathematics, it is of paramount importance to know the level of learners' understanding (strengths and areas where they are challenged), in order to devise tasks and assessments that will address their possible errors and misconceptions. When DHs possess this type of knowledge, they are able to know whether teachers are able to address common errors that the learners have. According to Ball et al. (2008) several teaching demands call for knowledge linking learners and content. Being familiar with possible common errors can allow the DHs to make informed management decisions on the professional development workshops that the teachers need for capacitation. In section 2.6 below, a detailed discussion of DHs' expertise in terms of knowledge needed for effective curriculum management and implementation is presented.

2.3.2 Mathematics Department Heads' collaboration and liaison with teachers and stakeholders

DHs are micro-managers who work hand in hand with subject advisors, the SMT, teachers and learners. Chikoko (2009) emphasises decentralised decision making, suggesting that schools managers need to have collegial relationships with the teachers they manage, and support them in their roles by providing mentorships. He argues that a lack of collegial relationships promotes hierarchical relationship divides that make teachers feel like subordinates who are not able to make contributions, which ultimately demotivates teachers from executing their roles.

Ali and Botha (2006) suggest that DHs should work with teachers to create departmental improvement plans. Thus, DHs' collaboration with education stakeholders is essential for their effective curriculum management. In schools, DHs should work together to ensure that curriculum needs are met, through collaborative curriculum planning practices. DHs also need to collaborate with their subject teachers. This could be achieved by holding regular meetings with teachers so that they could team up in planning lessons and discussing challenges that they encounter in their practice. The study conducted by Mulford (2003) on school leaders' challenging roles and the impact on teachers and school effectiveness suggests that when collaboration foregrounds educational matters, it has the potential to enhance teaching and learning. Thus, while administrative matters are important to enable the management and implementation of the curriculum, teaching and learning should be foregrounded. Alviz's (2019) study on the roles of DHs showed them to be key to school improvement and also affirmed that they played a crucial role in influencing the teachers in a specific subject. Therefore, to elevate the standard of teaching and learning, the DHs should capacitate teachers to unpack the knowledge for the benefit of the learners (Alviz, 2019).

2.3.3 Mathematics Departmental Heads' understanding of aspects of curriculum coverage and monitoring

In the context of this study, DHs' roles are to oversee teachers' curriculum coverage, and they are also responsible for implementation of the Technical Mathematics curriculum. The Employment of Educators Act 76 (1998) states that the role of the DH is to oversee the work of teachers and learners in their department/s. Southworth (2005, p. 76) posits that "monitoring enables leaders not only to keep in touch with colleagues' classrooms, but also to develop, over time, knowledge of teachers' strength and development needs." Bush et al. (2010) posit that an effective DH is one who oversees teaching and learning through monitoring curriculum coverage. In a study conducted in the province of KZN, Mkhwanazi et al. (2018) argue that monitoring curriculum coverage should not be driven by issues of compliance only, but rather by DHs' understanding of the curriculum as a whole and appropriate use of monitoring tools. For example, in the context of South Africa, they need to understand CAPS and the correct use of monitoring tools such as the ATP and POA. Of the same view, Mthiyane, Naidoo and Bertram (2019) mooted that DHs as curriculum monitors need to be knowledgeable on curriculum implementation and monitoring tools in order to be effective in their roles. Drawing from the above studies, it is imperative that when the new curriculum is being implemented, DHs as curriculum managers are equipped with the necessary skills and knowledge to execute their duties. It is therefore within these parameters that the current study aims to explore DHs' knowledge and practices of managing and implementing Technical Mathematics in some schools in South Africa.

2.3.4 Management of learning and teaching support materials

To effectively manage teaching and learning, DHs must ensure that learning and teaching support materials (LTSM) are available for teachers to use to teach and for learners to learn (Bush et al., 2010; Phakathi, 2015). This means that their role in management of LTSM is primarily working closely with subject teachers to decide on the textbooks they recommend for effective teaching and learning. Also, when resources are available, DHs need to ensure that proper records of LTSM are kept and maintained (Marishane & Motona, 2016). Studies point to a short supply of LTSM negatively affecting learners' achievement. For example, Jansen (2005) insists that persistent lack of both human and physical resources impedes teaching and learning. Myende (2014) reaffirms that schools' efforts to raise academic achievement are threatened by the ongoing lack of LTSM. Extending the argument in their study conducted in 14 schools in KZN on Mathematics curriculum coverage, Mkhwanazi et al. (2018) point out that lack of LTSM is often cited as a cause of quality problems in education. This suggest that DHs as curriculum managers tasked with monitoring and implementation of Technical Mathematics also need to manage the distribution and retention of LTSM in their schools. However, Sithole (2020) is of the view that it is not just the availability of school resources that needs to be managed, but also how those resources are utilised. Knowledge of management and utilisation of LTSM is mooted as essential for effective teaching and learning to take place (Reddy, 2021).

Lumadi (2012) argues that by DHs providing adequate LTSM, they enable subject teachers to provide quality teaching and learning, yielding quality teaching and learning in the classroom. Ntuli's (2018) study revealed that when the SMT provides adequate LSTM, teachers are able to utilise these effectively with the guidance of the DHs. The study affirms that accessibility of relevant LTMS relies on adequate management, which then ensures sustainability of resources. Nkadimeng's (2017) study had similar findings, that the provision of high-quality LTSM enables

DHs and teachers to guide and pace teaching and learning in their classrooms. The role of DHs as curriculum monitors is eased by uniformity of learning materials distribution, and there is syllabus completion across the grades as teachers are able to adhere to the teaching plan, which ultimately improves teaching and learning. His findings revealed that LTSM is an enabling factor that allows for effective curriculum management, teaching and learning in schools, while a lack thereof retards curriculum management and implementation. Mkhasibe et al. (2020) also regard LTSM as an enabler for successful curriculum implementation, and affirm that availability of and access to LTSM facilitates curriculum presentation since there are tangible materials. Their study revealed that LTSM is crucial to achieving the teaching and learning objectives.

2.3.5 Continuous monitoring, evaluation, and support

Continuous evaluation is an ongoing process that involves the systematic and regular assessment of teacher performance. Southworth (2005) characterises evaluation as a diagnostic assessment of pedagogic skills, strengths, and talents. The focus of DHs should be on identifying what teachers are doing well and what areas they need to improve in. According to Southworth (2005), monitoring classrooms is now a recognised component of leadership. Similarly, Marais and Meier (2004) argue that the purpose of continuous evaluation is to provide teachers with feedback on their strengths and weaknesses, identify areas for improvement, and support them in their professional development. Continuous evaluation can also help schools to identify areas where additional support may be needed, such as training or resources.

In the United Arab Emirates, Al-Husseini (2016) noted that frequent classroom observations and feedback from DHs improved teachers' classroom practices and learners' performance. In the United Kingdom, Wise (2001) reported that some teachers were against the idea of being evaluated in their classrooms, and leading conflicting role as middle managers. Wise (2001) argues that although teachers do not welcome evaluation of their practice, lack of frequent monitoring compromises DHs' ability to conduct curriculum reviews.

In South African schools, SMTs use the QMS, which is a management tool designed to appraise teachers and ensure that they perform their duties to the best of their ability (De Clercq, 2008; Myende, 2014). The DBE in the QMS (2013, p. 7) states that the DHs' role is to "conducts Performance Appraisals for educators under his/her supervision, including classroom observations, and keeps records thereof'. DHs use the QMS as an enabling tool for teacher assessment during classroom observations, or appraisal and development of teachers. The feedback should be constructive, specific, and focused on areas for improvement (Bush, 2013).

Naidoo's (2021) study on the instructional leadership roles of SMTs revealed that classroom visits are the most effective means of assessing an educator's capacity, so that effective guidance and support may be offered. She further states that there is always debate about whether there should be more or less supervision, where teacher unions do not allow frequent classroom visits unless embedded in the QMS formal observation. Continuous evaluation enables DHs to understand the challenges and devise intervention strategies to help teachers improve their practices (Naidoo, 2021). He alludes to evaluation as important in accounting for learners' performance in their departments. Ntuli (2018) argues that DHs must regularly review teachers' work to assess their progress and decide what kind of support they need. According to Smith, Mestry, and Bambie (2013), many DHs have limited training in evaluation and feedback, which can make it difficult for them to provide meaningful support to teachers. The researchers suggest that it is essential that DHs are properly prepared, supported, and given time to perform core teaching and learning leadership functions.

The debate around evaluation and support is ongoing, while others contend that reducing supervision can foster autonomy (Pearson & Moomaw, 2006) and creativity, and taking ownership of their work (Öztürk, 2011). Some contend that increasing supervision can encourage accountability (Mette, 2019; Zepeda, 2016) and improve teacher performance (Nel & Luneta, 2017) and growth (Oliveras-Ortiz & Simmons, 2019). The increased accountability means that everyone takes accountability for effective implementation and management of the curriculum with his/her classroom, thus making the DHs' roles more manageable (Zepeda, 2016).

2.4 Challenges with curriculum management and implementation

Curriculum management is an important aspect of education, and the role of the DHs in ensuring effective curriculum management cannot be overstated. In secondary schools in the United Kingdom, Brown, Rutherford and Boyle (2000) identified lack of time, space, specialist teachers, personnel management, staff morale, and homework policy as key challenges to curriculum management. Feza (2014) in South Africa identified social class, teacher morale, mathematics knowledge, and curriculum instability as key challenges. What both studies allude to is the fact that curriculum management goes beyond what takes place in the classroom, and that other external factors need to be managed to ensure effective curriculum management and implementation. For example, Mkhwanazi et al.'s (2018) study revealed external factors such as continuous change of teachers and teacher and learner absenteeism as challenges that impeded curriculum implementation and coverage. To extend the argument, in his study Tapala et al. (2021) revealed several barriers experienced by DHs when enacting their roles, which include but are not limited to lack of training and development, workload, lack of time, school culture and environment, and lack of resources and facilities. The next section elaborates on some of the challenges alluded to in the literature.

2.4.1 Lack of training to execute the roles and responsibility

In his study, Mulford (2003) posits that DHs need to foreground education matters when managing the curriculum; however, according to Jaca (2013), DHs have no formal training to supervise Mathematics instruction and some lack subject matter expertise and content knowledge. The lack of subject matter knowledge (SMK) meant that DHs themselves are not capable of implementing the curriculum they are expected to manage. Madonsela (2017) argues that taking informed decisions on different challenges encountered by DHs requires various skills and knowledge of managing the curriculum to overcome these. She conducted a study on DHs' role in managing curriculum in a secondary school in KZN, and asserts that the challenges that DHs experiences start on the first day of their appointment. Madonsela (2017) argues that DH's failure to enact their roles effectively is ascribed to a lack of training for their new demanding roles of managing curriculum, and there is no support and mentoring after induction and follow-up training. Similarly, Seipobi (2012) argues that newly appointed DHs' induction and training and development are not sufficient in addressing daily challenges they face. The lack of SMK was further echoed by Malinga and Jita (2016), who assert that most DHs are constrained in their ability to manage the curriculum by their own inadequate training and weak qualifications in the subject they are expected to manage. They discovered that DHs struggle with two crucial facets of their jobs: establishing their professional credibility and providing classroom support. Stephenson (2010) in New Zealand reported a similar viewpoint, stating that there were no professional development initiatives intended to help DHs serve as curriculum leaders. Similarly, du Plessis and Eberlein's (2018) study found that DHs of multi-subject departments face particular difficulties, because they must be responsible for subjects which they may not have formal training in, and find themselves burdened with a heavier workload than those in departments focusing on a single subject (Dube-Xaba & Makae, 2022; Mthiyane et al., 2019).

DHs’ poor support for teachers is a serious concern that impedes curriculum implementation; this alludes to a common criticism of the DBE for holding irregular professional development workshops focused on CAPS effectiveness. Ajani (2021) recommends that DHs should receive extensive training for delivering CAPS and training their teachers. As subject specialists, DHs are responsible for unpacking the curriculum document for teachers on every topic or task prescribed by the DBE (Ajani, 2021). They must also monitor the implementation process (Bush et al., 2010; Nene, 2019), provide feedback to teachers as needed (Jaca, 2013), and provide teachers with professional development (Bambi, 2013) on curriculum changes or updates. In this study context, introducing Technical Mathematics requires DHs to be informative regarding new developments, so that teachers and learners receive information timeously.

2.4.2 Lack of adequate learning and teaching support materials in schools

Literature highlights availability of LTSM as an enabling factor when it comes to curriculum management and implementation, as discussed in the above sections. However, a lack or shortage of LTSM is considered a challenge. Tsakeni, Munje, and Jita (2021) moot that opportunities for teaching and learning Science and Mathematics are limited by a lack of resources such as human resources and physical resources. Similar sentiments were discussed in a study conducted by the Education Labour Relations Council (ELRC) (2016), which showed that limited school resources are a significant impediment to effective curriculum management, especially in Science and Technology subjects. The lack/shortage of resources impedes curriculum management because it makes it difficult for teachers to pay individual attention to learners and to ensure that the curriculum is taught effectively (ELRC, 2016). In the South African context, there has been an outcry concerning the shortage of LTSM; for example, the DBE’s (2020) revised National 5-year Strategic Plan (Strategic Plan 2020–2024) states that access to books still falls short of the ideal of 100% for all learners. Shortage of books negatively impacts curriculum implementation, and makes it difficult for DHs to monitor the implementation. The negative impact of a shortage of LTSM on curriculum management and implementation was also reported on in early studies of curriculum implementation. For example, Jansen (1998) pointed out that unless materials and resources improve, implementation of the curriculum would be impractical in South Africa. Velupillai, Harding, and Engelbrecht's (2008) study concurs that that without teaching materials, the teaching of Mathematics is compromised.

2.4.3 Lack of qualified Technical Mathematics teachers

According to Machisi (2023), CAPS introduction has presented severe challenges to in-service Mathematics teachers due to new topics that require new teaching methodologies. Technical Mathematics is one of the new subjects with new topics. As alluded to by Machisi (2023), the introduction of Technical Mathematics has created significant challenges for both in-service and pre-service Mathematics teachers, because it introduces new topics that call for new teaching approaches. Not only does it present challenges for teachers, it presents challenges for DHs, because DHs have a core duty of assigning teaching roles to teachers who have knowledge and expertise. Therefore, with a shortage of teachers with expertise to teach Technical Mathematics, DHs' core duty is compromised, making it difficult to manage curriculum implementation effectively.

The shortage of qualified Mathematics teachers is a global issue, as alluded to by Tsakeni et al. (2021). While the assumption might be that qualified Mathematics teachers are equipped to teach any mathematical topics, this is not necessarily true. However, qualified teachers do have the necessary expertise to manage teaching even when new topics are introduced. Technical Mathematics is a new subject, and while it has some topics that qualified Mathematics teachers would have been exposed to, there are a number of topics that have not been part of the school curriculum for Mathematics, but rather were covered under technical subjects. This means that teachers teaching the subject have either been exposed to and are competent in technical topics, or in Pure Mathematics topics, leaving a gap regarding being qualified to teach the subject holistically. The shortage of qualified teachers to teach new subjects or topics makes it difficult for DHs to manage and implement the curriculum, because teachers lack specialised expertise and knowledge. The shortage of teachers with expertise results in learners' having compromised learning experiences, as they may not receive adequate support in acquiring the required knowledge and skills. Furthermore, the lack of qualified teachers limits learners' ability to fully comprehend the extensive subject matter, which hinders their ability to master it (Taylor, 2019).

According to Tachie (2020) practical experience is required for Technical Mathematics to be taught successfully in a classroom. In South Africa, teachers that are teaching Pure Mathematics or trade subjects are recruited to teach Technical Mathematics. While some concepts taught in Pure Mathematics are also found in Technical Mathematics, there are new topics such as mensuration, number system (complex numbers), integration and angular movement that have been accommodated instead of sequences and series, probability, and statistics (DBE, 2014a; Machisi, 2023). This means that while teachers are qualified to teach Mathematics, there are aspects of Technical Mathematics which they are not equipped to teach. What is missed is the deep knowledge needed in artisanship; Mathematics teachers lack practical experience of working in the trade industry, such as welding, plumbing, carpentry, or electrical work. With these knowledge gaps among teachers teaching Technical Mathematics and DHs themselves, it is possible that curriculum management and implementation become a challenge. As alluded to by Jansen (1998), unless teachers' content knowledge is improved, curriculum management is impractical. Kundema (2016) also makes the case that teaching Mathematics is difficult when one lacks competence, and this impacts on curriculum implementation.

2.4.4 Lack of time

Several curriculum management studies (Bambi, 2013; Malinga, 2016; Malloy, 2017; Tapala et al., 2021) have cited lack of time as a challenge that militates against effective curriculum management practices of DHs in most schools. Bambi's (2013) study revealed that DHs needed more time to manage the curriculum since they also had a full duty load as teachers. He found DHs' lack of time to fulfil their duties to be one factor contributing to ineffective implementation. Malinga and Jita (2016) contend that DHs do not get enough time to enact their roles and responsibilities. She asserts that sometimes DHs take time away from their teaching duties to focus on administrative work and to fulfil their leadership obligations (Malinga, 2016). Malloy's (2017) study findings suggest that given that DHs are also teaching a full duty load, they do not have enough time to carry out their roles and responsibilities effectively. A similar argument shared by

Tapala et al. (2021), who cited that DHs' workload in teaching timetables does not give them sufficient time to enact administrative duties and deal with their heavy instruction burden. Tapala (2019) found that DHs work after hours, over the weekend, on public holidays, and even during school holidays. The result is often fatigue which may lead to underperformance of the DHs. To overcome these barriers is not easy as most of them are not self-inflicted but are external to the DH control.

Another issue related to lack of time is the fact that DHs' variety of competing priorities all crave their own attention, despite the time constraints (Tapala et al., 2021). Several studies reviewed in this section have shown that time is a key constraint for DHs in enacting their management and leadership roles. They have demanding managerial responsibilities to fulfil in addition to their teaching duties, which leaves them with little time for strategic planning. As alluded to by Bambi (2013), issues such as unstable curriculum, lack of time to fulfil their duties, insufficient professional development, a lack of opportunities at the departmental level, no clear direction and vision from the SMT and ineffective communication between senior department managers are factors which contribute to ineffective implementation of the curriculum.

2.4.5 Role ambiguity and conflict

The role of DHs is dual-faceted: they manage subjects in their departments and are also expected to teach subjects in the classroom setting like the teachers they manage (Lumadi, 2012; Stephenson, 2010; Wanzare, 2012). Stephenson (2010, p. 16) asserts that DHs often encounter role conflict that derives from role ambiguity, claiming that "ambiguity arises from their dual identities where they are neither wholly a senior management team member nor solely a teacher". Siskin (1993) also expresses this view when he describes the DHs' role as 'hermaphroditic' and an amalgam of many roles. Stephenson (2010) supports this assertion, arguing that at both the operational and hierarchical levels, the position of a DH is fraught with conflict and problems. Zepeda and Kruskamp (2007) hold that DHs' role conflict arises when they are uncertain whether they are coaching or judging teachers in evaluation. DHs are managers in their departments in schools, which positions them above teachers in terms of their level of importance (Malinga & Jita, 2016) – but they also work as teachers (Leithwood, 2016) and must be on par with their peers. Stephenson (2010) further articulated that DHs move up and down the structural continuum according to the situation and context they are operating in at any given time. DHs must balance the requirements of both their managerial and teaching roles, which can be difficult and cause conflict between quality assurance and threats to collegiality within their departments (Stephenson, 2010). This is supported by Lumadi (2012), who argued that the DHs must carry their roles and responsibilities effectively and efficiently to maintain a delicate balance between the demands of parents, teachers, and the DBE, which are frequently at odds with one another. Wanzare (2012) clarifies that DHs are expected to visit classrooms, demonstrate lessons, provide guidelines, and provide helpful feedback to teachers to improve teaching. However, one critique of DHs' dual role (Tapala et al., 2021) is the absence of professional credibility (Malinga & Jita, 2016). The authors support their assertion with their finding that DHs are constrained in their ability to assist and develop their teachers by their insufficient training and weak professional credibility in the subjects they manage.

2.5 DHs' roles and responsibilities in curriculum management and implementation

The Personnel Administrative Measures (hereafter referred to as the PAM document) of the DBE (2016, p. 36) states that the primary objective of a DH in a school is to engage in classroom teaching, ensure effective department functioning, and organise related extracurricular activities that promote the subject, learning area, or phase of education for students in a proper manner. Implementing a curriculum and managing its implementation is a crucial responsibility for DHs, ensuring it meets learners' needs and complies with the DBE's envisioned curriculum implementation goals. According to Bush et al.'s (2010) study, in managing teaching and learning DHs should:

- Regularly meet with educators to develop collaborative plans for teaching and learning;
- Attend classes to observe and practice good techniques;
- Regularly monitor teachers and provide feedback to improve teaching and learning;
- Evaluate student performance to drive classroom instruction; and
- Monitor student performance and teacher planning.

In the subsections below, DH roles and responsibilities concerning curriculum management and implementation, as stated in the PAM document as well as in the literature, are discussed.

2.5.1 Mathematics DHs' teaching roles and responsibilities

DHs' teaching roles and responsibilities speak to the implementation of the curriculum. The DBE's (2016) PAM document defines the core duties and responsibilities of DHs, which vary depending on the needs and approaches of individual schools, and include teaching. DHs' role as a subject teacher entails creating a conducive learning environment, organising and implementing lessons, and monitoring and reporting to parents on learners' academic progress (PAM document; DBE, 2016b). DHs as subject teachers are expected to design, administer, mark, moderate, and report on assessment tasks and learner progress. The roles also entail using various teaching techniques and drawing on learners' experiences and context to develop lessons that are relevant to the learners' lives.

The CAPS document emphasises the inclusion of real-life examples in the teaching of Mathematics. With specific reference to Technical Mathematics, it specifies that "real life technical problems should be incorporated into all sections whenever appropriate" (DBE, 2014a, p. 10). The above statements from CAPS suggest that in the process of implementing the Technical Mathematics curriculum, practical and real-life problems should not be relegated to outside the classroom. The same argument is raised by Tachie (2020), who posits that practical experience and practical knowledge is required to teach Technical Mathematics effectively. Therefore, teachers should not shy away from incorporating practical knowledge when teaching Technical Mathematics. In their role as subject teachers, DHs need not only to be competent in solving mathematical problems, but in exposing learners to practical experience related to Technical Mathematics in order to ensure effective curriculum implementation. DHs have an essential role in enabling their learners to comprehend abstract knowledge and its application in the technical field of mathematics ideas by implementing the relevant pedagogy of teaching Technical Mathematics (DBE, 2016b). With the introduction of the new content, Jojo (2019) asserts that DHs as teachers of Technical Mathematics in Grades 10–12 encountered new concepts like integration, complex numbers, and trigonometry for the first time. Therefore, for effective implementation, being competent in their mathematical knowledge for teaching Technical Mathematics is necessary in executing their roles as teachers as well as curriculum managers.

2.5.2 Mathematics DHs' managerial roles and responsibilities

The DBE's (2016) PAM document stipulates that the DH is responsible for a subject, learning area, or phase. The DH must collaborate with teachers to develop policies for the department they manage. The ELRC (1998, p. 66) states that DHs are to "develop curriculum related policies, control the work of teachers and learners, appraise subordinates, and manage subject work schemes". They must also coordinate all department subject evaluations, assessments, homework, composition, and so on. They must demonstrate leadership and provide and coordinate guidance to department teachers. As curriculum leader, the DH ensures that all stakeholders understand the curriculum's objectives, explains the implementation procedures, and facilitates stakeholder collaboration. In essence, DHs serves as a liaison between the DBE policymakers, the faculty who teach the curriculum, and the students who are the intended audience for the curriculum. In the Mathematics curriculum DHs and subject advisors work in hand to help Mathematics teachers with content mastery, through content and pedagogy professional development workshops. The KZN DoE (2020) Curriculum Management and Delivery strategy emphasises the need for SMTs to: a) regularly oversee the implementation of the curriculum, b) understand the significance of efficient curriculum and instructional practices, and c) assess the quality of assessment materials used in schools by observing classes, monitoring lessons, and evaluating assessments. Therefore, since the DH is part of the SMT and is a curriculum manager within the school, it is their responsibility to manage curriculum implementation.

Scholars emphasised that implementing the curriculum in the classroom must be effectively monitored by DHs as part of their managerial responsibilities, through providing constructive feedback to teachers and learners (Mpisane, 2015; Mthiyane et al., 2015; Tsakeni et al., 2021). For curriculum implementation to be successful, Smith et al. (2013) argue that monitoring and evaluations are necessary. Monitoring includes tracking learners' progress, measuring the quality of teaching and learning, and identifying areas for improvement. To ensure that teachers deliver the curriculum effectively, DHs should provide support and guidance in the teaching and learning process and give teachers feedback (Nel & Luneta, 2017). Furthermore, the literature suggests that given their pedagogy and subject area expertise, DHs' role is to mentor low-performing teachers by guiding them on instructional issues (Nel & Luneta, 2017). However, the study by Jato, Okemasisi and Alari (2022) on DH mentorship roles of newly deployed/transferred teachers in

Kenyan secondary schools shows that the DHs put in minimal effort to monitor teachers' work and build their professional capacity. Similarly, in South Africa it was found by Seobi (2015) that DHs' involvement in instruction leadership often consists of reviewing teachers' final reports rather than regularly collaborating with them to improve instruction, suggesting that while roles are stipulated, they are sometimes not practised by the DHs. Technical Mathematics is a new curriculum introduced in 2016 in South Africa; therefore DHs as curriculum managers as well as implementers, as they also teach, need to be abreast of their roles to ensure effective management and implementation of the technical curriculum. It is within these parameters that the current study explores DHs' knowledge and practices of managing and implementing the Technical Mathematics curriculum.

2.5.3 DHs' personnel management roles and responsibility

According to the DBE's (2016) PAM document, DHs are expected to be involved in agreed-upon school/teacher appraisal processes to help improve the school's teaching, learning, and management quality. Their role is to monitor and provide support to their teachers (Jaca, 2013; Mthiyane et al., 2019; Munje, Tsakeni & Jita, 2020; Tsakeni et al., 2021). Inevitably, the school's achievement relies on the accomplishments of its departments, and any inadequacy in one can impact the entire school system. Therefore, effective DHs can coordinate teaching teams by networking and collaborating on agreed, common curriculum goals (Nkosi, 2000). Within their personnel management roles, DHs are responsible for orienting new teaching staff (Iordanides & Vryoni, 2013), ensuring an appropriate allocation of teaching responsibilities, and properly timetabling all subjects within the department (Ntuli, 2018; Sengai, 2021). The orientation of staff and appropriate allocation of teaching responsibilities is one of the fundamentals when it comes to curriculum implementation. A part of the orientation of new staff is pairing them with experienced teachers for professional growth, and avoiding leaving them to figure things out independently (Shava, Heystek, & Chasara, 2021).

Moreover, DHs are responsible for helping principals to recruit teachers who are suitable for identified positions in their departments (Bambi, 2013; Mutuku, Arasa & Kinyili, 2021; Tapala, 2019), because they know the content and pedagogy. In relation to the current study, it means it is the DHs' role to recruit suitable teachers to teach Technical Mathematics, to ensure effective curriculum implementation. The PAM document also stipulates the second personnel role of DHs, which is to allocate work equitably among department staff members (DBE, 2016b; Maja, 2016; Smith et al., 2013). According to Tapala et al. (2021) DHs also require personnel management and curriculum leadership expertise, which can help them when enacting the responsibility of assisting the principal in identifying suitable teachers, and monitoring and evaluating teachers' work using the QMS.

2.5.4 DHs' general or administrative role and responsibilities

The PAM document (DBE, 2016b) stipulates that DHs' general/administrative duties include assisting with the planning and managing of school stock, textbooks, and equipment for their departments. Furthermore, they ensure that resources are allocated appropriately, that the necessary supplies are ordered on time, and that the classroom environment is conducive to learning. It is the DHs' responsibility to communicate with their subject teachers about their departmental needs, which enables their principals to allocate budgets accordingly. Bennetts (2021) explains that DHs are physically closer to teachers than principals are, since they share a workspace. Hence DHs can provide timely support to teachers in their everyday activities. Other than communicating with teachers in the respective departments or schools, DHs need to develop communication channels with all stakeholders. Stakeholder communication is essential for successful curriculum implementation and management. There are various stakeholders within the school, but in the context of curriculum management and implementation, the DBE, parents and learners are the main stakeholders. Dinham (2007), du Plessis and Eberlein (2018), and Vermaak (2021) agree that DHs are essential intermediaries between stakeholders and classroom instructors. The DBE (2016) specifies in the PAM document that DHs should work with colleagues to maintain good teaching standards and administrative efficiency. Vermaak (2021) supports this assertion, indicating that DHs' interactions with the personnel under their command or lack thereof can make or break the department and lead to poor performance.

According to the DBE's (2016) PAM document, the primary responsibility of DHs is to ensure a high standard of teaching and learning among learners in their department (Sengai, 2021). Their roles involve collaborating and cooperating with colleagues within the department and the school to foster administrative efficiency (Schlebusch, 2020; Vermaak, 2021). DHs also collaborate with educators from other schools to conduct extracurricular activities and develop their departments. DHs, as professionals, must meet with parents to discuss their children's progress and conduct and participate in departmental and professional committees, seminars, and courses to update their professional views (Bipath & Nkabinde, 2018). In addition to providing support to learners, Ntuli (2018) asserts that informing all stakeholders, especially parents, is essential when learners are being assessed. The PAM document further states that DHs should also maintain contact with further and higher education institutions to support learners' records, performance, and career opportunities. Additionally, DHs are expected to establish and maintain contact with sporting, social, cultural, and community organisations as well as the public on behalf of the principal.

2.6 Competencies DHs need in order to manage and implement curriculum

As discussed in the above sections, DHs as curriculum managers and implementers are expected to be specialists in the subject they manage and teach, because they are expected to provide support and mentorship to other teachers. The focus of this study is not teacher knowledge but on curriculum management and implementation; however, curriculum implementation means that one is competent to teach the subject. Therefore it was deemed critical to explore the knowledge that DHs need in order to manage and implement the curriculum.

In the context of teaching, the literature articulates aspects of teacher knowledge that are needed. For example, Shulman (1986) argued that teachers require special knowledge or expertise for their work, which he referred to as pedagogical content knowledge (PCK). In Shulman’s (1986, 1987) perspective, PCK is a unique type of knowledge that teachers possess. Shulman (1986) and Ball (1990) indicate that teacher effectiveness correlates with the teacher’s knowledge of the subject matter and teaching practice. Other authors who support this assertion include Ningsih and Juandi (2020), who describe PCK as a blend of teaching material knowledge (content knowledge), coupled with knowledge of teaching (pedagogical knowledge) that a teacher needs to possess. Similarly, Nadas (2019) argues that teachers must have good SMK and make it accessible to their learners while being sensitive to learners’ prior knowledge and misconceptions. Therefore DHs as curriculum managers and implementers must be knowledgeable in teaching Technical Mathematics in order to support teachers (Mosala, 2019).

When talking about knowledge required to teach, Ball et al. (2008) delineate the components required in the teaching of Mathematics topics, which they termed mathematical knowledge for teaching (MKT). According to Ball et al. (2008) MKT encompasses the complete scope of Mathematics knowledge required for teaching a particular subject, distinct from the mathematical knowledge necessary for other professions that use maths for different purposes. de Souza Pereira Grilo and Cerqueira Barbosa (2022) contend that specific MKT is a prerequisite for effective Mathematics instruction. Ball et al. (2008) emphasise that teachers require a unique set of mathematical knowledge and skills tailored to the demands of teaching mathematics to learners. In this section below, the researcher discusses how the literature positions and uses MKT constructs to align curriculum implementation.

2.6.1 Subject matter content knowledge

Subject matter knowledge (SMK) covers the fundamental mathematical knowledge that all Mathematics teachers should have. According to Stols et al. (2015) teachers' SMK is critical for effective curriculum implementation, because the lack of such knowledge hinders their ability to apply what they know in the classroom. The above assertion means that DHs who are also Mathematics teachers need to have well developed content knowledge for the subject they teach, such as Technical Mathematics, to effectively implement the teaching in the classroom for the benefit of the learners. However, DHs are not just teachers, they are also curriculum managers, and therefore – as alluded to by Mampane (2018), that Mathematics teachers need to be professionally developed and provided with ongoing support to enhance their SMK – it is the DHs who are supposed to execute such roles. Therefore, it is imperative that their SMK is well developed for curriculum management and implementation. Due to the critical roles placed on the shoulders of DHs concerning curriculum management and implementation, education stakeholders should support DHs in planning, organising, supervising and implementing professional development to equip Technical Mathematics teachers with the necessary knowledge and skills (Mampane, 2018). In so doing, teachers may develop confidence in their in-depth knowledge for preparing and developing lessons in various methods that the students will grasp (Mpungose, 2019).

2.6.2 Horizon content knowledge

Ball et al. (2008, p. 403) define horizon content knowledge (HCK) as "an awareness of how mathematical topics are related over the span of mathematics included in the curriculum". HCK involves understanding how Mathematics developed, the proponents of various theories, and their application to daily life (Ball et al., 2008). According to Brijlall (2014), the HCK category highlights the need for teachers to understand the connections between the many mathematical concepts covered by the curriculum. He argues that Mathematics teachers must understand what happens in the lower grades, in order to lay a firm foundation to help learners connect their knowledge and what they will learn in the upper grades and beyond. This affirms Ball et al.'s (2009) proposition that HCK is neither common nor specialised, but rather is concerned more with understanding the discipline's broader mathematical (disciplinary territory) context. As Jakobsen, Thames, and Ribeiro (2013, p. 8) argue, "a content area can be related to a different topic outside the immediate curriculum, with a different purpose and not directly connected to the other topic". The researchers suggest that teaching specific content will be more effective if teachers know how disciplines handle the content at different stages. Therefore, DHs' understanding of HCK is imperative in order to assist teachers in identifying aspects of Mathematics which they teach which are relevant to the different trade industries/fields in the case of Technical Mathematics. This is so that they can align the curriculum with practical, relevant skills needed in the vocational route aligned with labour, and ensuring direct access to learnerships and apprenticeships (DBE, 2014a). As mooted by Mosala (2019), DHs are responsible for integrating topics in the Mathematics curriculum and improving teaching strategies in the classroom by taking the lead in making connections across topics.

2.6.3 Specialised content knowledge

Specialised content knowledge (SCK) refers to the mathematical skills that enable teachers to demonstrate concepts and procedures related to Mathematics (Ball et al., 2008). Teachers possess SCK, which is used to impart mathematical content knowledge to learners, so they must develop strategies to solve the same problems (Brijlall, 2014). According to Jakobsen et al. (2013), SCK enables a teacher to engage in tasks specific to teaching, including analysing error patterns, or developing strategies to solve the same problems. A similar assertion is made by Ndlovu, Amin and Samuel (2017), who argue that SCK is a fusion of teachers' knowledge, understanding, diagnosis, and action for learners' engagement and errors. The authors affirm that strong SCK enables teachers to identify whether learners' errors are minor, concepts are misunderstood, or they cannot connect concepts to solve problems (Ndlovu et al., 2017). DHs, as subject specialists, should possess SCK in order to communicate mathematical concepts to the teachers and learners appropriately (Mosala, 2019). Lack of such knowledge therefore means that some aspects of the curriculum might not be managed appropriately, for example, assisting teachers in developing remedial teaching strategies or themselves as teachers developing appropriate remedial instructional strategies to remedy learners' errors.

2.6.4 Knowledge of content and students

Knowledge of content and students (KCS) involves the teacher's ability to relate the mathematical content to the learners' ability levels and meet each learner's needs. Shulman (1986) argues that teachers need to know learners' learning abilities and the common mistakes they make, in order to provide instruction. DHs' responsibility as instructional leaders is to ensure that the curriculum, instruction, and assessment align and meet the DBE's standards for learners to succeed (Mafuwane, 2011). Through continuous classroom visitations, DHs can gain a deeper understanding of what happens in classrooms, understand some of the challenges teachers and learners face, address instructional issues from a practical perspective rather than their teaching perspective, and build a foundation to support the improvement of teaching and learning through curriculum decisions (Mafuwane, 2011). Marishane and Motona (2016) recommend that DHs take responsibility for ensuring close links between teaching, learning, and assessment to achieve good results. Mudaly and Mpofu (2019) suggest that a shift from being ritualistic to exploration could strengthen mathematical discourse. Mudaly has cited on many occasions (Mudaly, 2021; Mudaly & Fletcher, 2019; Mudaly & Mpofu, 2019) that having a multifaceted approach to solving Mathematical problems enhances understanding, by using multiple representations which helps in catering for learners different learning styles (Khoza, 2019; Mudaly & Naidoo, 2015; Mudaly & Singh, 2016). DHs could then help teachers to use the multiple ways of solving a problem. For example, in Mudaly and Naidoo (2015), master teachers draw on their teaching experience and PCK to help learners understand abstract mathematical concepts by providing real-life contexts and situations. They also use concrete and representational visual tools to facilitate learners' comprehension of abstract concepts and develop mathematical relationships.

2.6.5 Knowledge of content and teaching

Ball et al. (2008) describe knowledge of context and teaching (KCT) as the most effective representation of ideas, analogies, illustrations, examples, explanations and demonstrations. KCT combines pedagogy and mathematics content knowledge (Ball et al., 2008; Lestari & Juniati, 2018; Santarone, Abney & Samples, 2020). Brijlall (2014) recommends that teachers introduce a topic based on learners' prior knowledge, and sequence lessons in a way that reinforces and facilitates learning of new concepts. KCT gives teachers premises to know and select strategies, approaches, teaching and learning materials, assessment tasks and methods that are meaningful to learners (Lestari & Juniati, 2018). Thus, KCT is the teacher's ability to use relevant teaching approaches for all Mathematics concepts and skills. Mosala (2019) argues that DHs are regarded as instructional leaders and immediate supervisors of teachers, and are therefore in a position to help Mathematics teachers develop effective strategies and skills that will improve learners' understanding of the subject. As experts in Mathematics, adequate KCT can be used as the rationale for planning sequence-specific content, deciding examples to use to introduce the content that will deepen learners' understanding, and using teaching approaches that help to convey a specific idea or concept in an engaging, meaningful way (Ramaligela, Ogbonnaya, & Mji, 2019). Similarly, Martensson (2019) argues that KCT allows teachers to plan and teach Mathematics by selecting appropriate tasks, representations, and materials, coordinating the mathematical content, and asking learners the right questions. The DH is responsible for engaging teachers in pedagogical dialogue about the viability of different instructional models in Technical Mathematics (Ní Shúilleabháin, 2016).

2.7 Sustainability of new subjects implemented within the existing curriculum

In Kaur's (2019) opinion, the best curriculum at present is the curriculum that provides a broad range of learning experiences for all learners. Stoll (2006) argues that educational change aims to benefit learners. Technical Mathematics was introduced on the basis that the existing curriculum (Pure Mathematics and Mathematical Literacy) did not fully integrate the practical experience that is essential in the trade industry or vocational field. The DBE (2014) stipulates that Technical Mathematics aims to apply the science of Mathematics to the technical field, emphasising *application* and not abstract ideas. Nevertheless, crucial factors that influence the sustainability of emerging subjects may be overlooked due to existing challenges of poor leadership, deficient resources, or lack of understanding among role players (Miedijensky & Abramovich, 2019). Fischbach (1993, p.5) states that "apprenticeship is the process of learning a trade by practical experience under the tutelage of skilled workers in a craft", and suggests that Technical Mathematics instruction must enforce the mathematics skills needed in craftsmanship. Fischbach (1993) argues that indirect instruction is based on the teacher using extensive input from learners rather than just a few inputs, using group problem-solving involving all students, assessing learners' understanding during guided practice, and giving them hints when they make mistakes.

According to Miedijensky and Abramovich (2019), implementing sustainable change in schools requires a comprehensive curriculum prioritising sustainability and professional development opportunities for teachers. Daily management strategies and self-evaluation are also crucial (Chapman & Sammons, 2013). As in the case of Jika-iMfundo, DHs need tools and training to enact their curriculum monitoring role (Metcalfe, 2018). According to Metcalfe (2018), to improve curriculum coverage it is imperative to monitor curriculum coverage, report any issues at the appropriate level where corrective measures can be implemented, and provide supportive measures to address curriculum coverage-related challenges. For learning outcomes to be sustained and long term, Metcalfe (2018) finds it necessary that DHs establish routines and patterns of support within departments. De Clercq et al. (2015) emphasise the need for collegial professional practice, where stakeholders collaborate to sustain the implementation of the curriculum. Mucavele (2008) argues that successful curriculum changes require all stakeholders to engage in a collaborative and critical approach that allows them to implement the change, thus reducing the inevitable gap between theory and practice.

Success depends on factors such as motives for change, stakeholder involvement, specific actions, and ongoing efforts to improve the process. In order to achieve the long-term benefit of curriculum implementation, each stage of the process must be carried out in a thorough way. Stabback (2016) argues that effective curriculum implementation places clear expectations on learners, teachers, and schools. Miedijensky and Abramovich's (2019) study revealed that an exemplary school's implementation of the new curriculum was a gradual and structured process that executed many actions at each stage, and where the principal, DHs, and teachers were well-qualified and fully committed. By interacting with other schools, practitioners can build lateral capacity and become system thinkers in action, which can change the context in which they work. Fullan (2006) argues that systems thinking fuses theory and practice, integrating the disciplines. It is essential for sustainability to cultivate and encourage a fundamentally new kind of leadership (Fullan, 2006, 2007, 2014).

Sustaining a new subject like Technical Mathematics suggests that DHs as curriculum leaders must foster and promote innovation and focus on sustainable practices in order to ensure long-term success. There is a challenge with sustainability, in that it occurs after a curriculum has already been developed and implemented, and may not be implemented in the way that was intended. Fishman et al. (2011) described sustainability as a continuous intervention to improve curriculum quality. This means that curriculum implementation is not a once-off process, and continual support is needed to support the DHs and ensure sustainability of the implementation of Technical Mathematics. Several studies (Jaca, 2013; Madonsela, 2017; Malinga & Jita, 2016) allude to the need for continuous professional development targeted at DHs as professional leaders/managers and some to teachers, as they are primarily implementers of the curriculum in the classroom. DHs must enact their essential role in teacher development by providing instructional leadership and being change agents in their departments (Mthiyane et al., 2019). However, Fullan (2015) posits that the fundamental element of change is the individual, and change can only happen with sufficient knowledge and skills; therefore teachers should have knowledge of curriculum implementation or be willing to change entrenched beliefs and practices (Kisa & Correnti, 2015).

2.8 Studies on curriculum implementation and management

Several studies focus on curriculum management and implementation. For example, Mandukwini's (2016) study investigated the experiences and challenges faced by school stakeholders, particularly SMTs and educators, in implementing curriculum changes in selected high schools in the Eastern Cape Province of South Africa. The qualitative research method was used, and data was gathered through open-ended interviews and document review to provide a detailed description and explanation of the challenges faced by SMTs and teachers in managing curriculum implementation in their contexts. The study found that poor teacher capacitation and lack of the necessary resources were some of the factors contributing to the challenges faced by SMTs and teachers in implementing curriculum changes. Additionally, the study identified other significant curriculum challenges, such as inadequate training and heavy workloads. The study recommended measures to limit these challenges, such as ongoing support and training for SMTs and teachers to enable them to execute their duties effectively. Furthermore, the study highlights the importance of effective leadership in schools and the need for ongoing support and training to implement curriculum changes successfully.

Another study conducted by Tapala, Van Niekerk, and Mentz (2020) identified several barriers that hinder secondary school DHs in executing their curriculum leadership roles; these included a lack of training, experience, work skills and knowledge, workload, lack of time, school culture and environment, and lack of resources and facilities. Based on their findings Tapala et al. (2020) recommended that DHs receive continuous in-service training and support from the DBE to overcome these challenges. Lack of support from principals, logistical barriers, lack of resources, and underutilisation by principals were identified as other factors that diminish DHs' efforts, thus rendering them incompetent. The above study highlights the need for better communication and training from principals to support DHs in performing their duties effectively. To extend the argument, Mashapa (2019) examined the instructional leadership role of Mathematics heads of department (DHs) in secondary schools in Limpopo. The findings revealed that DHs play an essential role in learners' academic success, but are ill-prepared to execute the role of instructional leader. The study further revealed that the DHs faced role ambiguity as well as workload, and administration challenges.

In contrast, Mogashoa's (2013) study showed that SMT members, including DHs, felt empowered by the training they received when it came to curriculum management – but the actual implementation posed a challenge due to a shortage of resources. This means while DHs felt empowered to execute their role in curriculum management, external forces hindered the implementation. In New Zealand, Craggs' (2011) study investigated challenges and opportunities experienced by middle managers (DHs) in implementing the revised New Zealand curriculum in secondary schools. Data was collected from various secondary schools in the Northland region, with interviews conducted in three schools. Several barriers to effective curriculum implementation were found in the study, and DHs' interpretations and practices differed widely. The researcher revealed that DHs' responses were primarily managerial rather than leadership-based, raising questions about their preparedness to implement a significantly different curriculum without extensive support and guidance from government agencies and school leadership. In order to facilitate curriculum change, strong school leadership and government support are essential to provide DHs with more training and development opportunities. The study suggests several ways in which the curriculum implementation could be better undertaken at various levels, to utilise middle leaders more effectively during future curriculum changes. Craggs' (2011) study emphasises that DHs must receive more support and guidance to ensure the effective implementation of the new national curriculum in New Zealand. Finally, the study highlights the importance of strong school leadership and government support in supporting curriculum change in secondary schools, emphasising the role of middle leaders. Although the above studies were conducted in different contexts, what all of the studies revealed is that for DHs to manage and implement curriculum effectively, continuous support should be provided.

Mucavele's (2008) study examined the factors influencing new curriculum implementation in schools in Mozambique. The study also evaluated the progress of the new curriculum and identified factors that were critical for its successful implementation. The study employed quantitative analysis using a survey questionnaire to gauge educators' and learners' opinions. Based on the findings of the study, ensuring the presence and maintenance of all necessary conditions for successfully implementing the new curriculum depends greatly on school leadership. Furthermore, the study findings suggest that strong school leadership and capacity building are essential for successful implementation, with innovative classroom practices identified as crucial for maintaining teachers' confidence. In addition, factors such as learners' expectations, learning opportunities and outcomes, subject preferences, and a friendly and supportive school environment were also highlighted as necessary. Mucavele's (2008) study also provides a critical analysis of the implementation of the new curriculum. It contributes to the current literature on new curriculum implementation by presenting empirical evidence of the importance of school resocialisation, which involves restructuring and re-culturing.

The aforementioned studies revealed what is needed to ensure effective curriculum management and curriculum implementation, as well as factors that negatively impact on curriculum management and implementation. However, the studies do not provide a nuanced analysis of DHs' knowledge and practices of managing and implementing a new curriculum, which the current study focuses on.

2.9 Conclusion

In this chapter the concepts of curriculum management and implementation in South Africa were defined, and relevant literature related to the study phenomenon was reviewed. The review included a discussion of enabling and challenging factors in curriculum implementation and management, and DHs' roles and responsibilities in this regard. Furthermore, the relationship between MKT and alignment with curriculum implementation was explored, along with factors that sustain the implementation of new subjects within an existing curriculum. To conclude, the studies on curriculum implementation and management were summarised.

Chapter 3

Theoretical framework

3.1 Introduction

Chapters 1 and 2 outlined the background to the problem and the literature that informs this study, respectively. The aim of this chapter is to detail the theoretical and conceptual frameworks that underpin this study, posited by the selected theoretical orientation. This chapter describes Samuel's (2008) Force Field Model, which interrogates and explores the influence of professional forces, such as biographical, contextual, institutional, and programmatic forces arising from different perspectives and experiences, which may push and pull the Departmental Heads' (DHs') implementation, teaching and managing of Technical Mathematics. The Force Field Model may be used as a lens through which we may understand how DHs reconcile the different professional forces that influence them when enacting their roles in implementing the new Technical Mathematics curriculum. Hence it was deemed appropriate for this study. In addition to the theoretical framework, the conceptual framework is discussed. It is developed using the constructs of Shulman's (1986) framework of pedagogical content knowledge (PCK) and some of the constructs of Ball et al.'s (2008) framework of mathematics knowledge for teaching (MKT), which is in essence a modification of Shulman's (1986) model of knowledge needed for teaching in general. This modified model was used to gain a conceptual understanding of how DHs as Technical Mathematics teachers execute mathematical curriculum implementation (MCI) and mathematics curriculum monitoring (MCM) in their schools.

3.2 Theoretical and conceptual frameworks

A theoretical framework is defined as a system of concepts, assumptions, expectations, beliefs, and theories that support and inform a study (Robson, 2002). Thus, a theoretical framework is an important component of research, because in providing theoretical underpinnings it indicates the appropriate way for the researcher to conduct the research (Phakisi, 2008). Accordingly, in the context of this study the theoretical framework refers to interrelated concepts related to the phenomenon under study that inform this research. Moreover, it builds on previous studies in articulating the same theories used to investigate issues of implementation and management of curriculum. Mohajan (2018, p. 6) affirms that "In qualitative research there is a close relation between the researcher's goals and the researcher's theoretical frames." In this way, theoretical frameworks play a large part in framing a qualitative study, and in guiding data generation and its analysis (Collins & Stockton, 2018; Mohajan, 2018). A similar view is shared by Yin (2014), who posits that strong theoretical propositions and frameworks enable a researcher to pave the way for strong guidance in determining data collection methods and strategies for data analysis. Maxwell (2005), as in cited in Hennink, Hutter and Bailey (2020, p. 34), articulates that "a major function of incorporating in the research design is to provide a model or a map of why the world is as it is, and to provide a conceptual view or simplification of what the world looks like". Maxwell (2008, p. 217) emphasised that "research questions should have a clear relationship to the goals of your study and should be informed by what is already known about the phenomena you are studying and the theoretical concepts and models that can be applied to these phenomena." Drawing from the perspectives of Maxwell (2008), Yin (2014) and Mohajan (2018), it is clear that if chosen correctly theoretical frameworks help the researcher and the reader to understand the phenomenon through clearer lenses.

The term conceptual framework as a "concept that refers to a mental image or abstraction of a phenomenon" is defined by Lauffer (2011, as cited in Saunders et al., 2015, p. 39). Leshem and Trafford (2007, p. 94) also point out that "the problem of understanding theoretical and conceptual frameworks is compounded by the fact that there is a lack of a common language regarding the notions of theoretical and conceptual frameworks". Based on Miles and Huberman (1984), a conceptual framework can be described as a map of the territory under study drawn by the researcher. In my understanding, conceptual framework is the analytical framework used by the researcher to analyse the data of the current study, comprising the pre-existing theoretical frameworks or researcher-constructed frames that provide lenses through which the phenomenon is studied. This is supported by Maxwell (2008, p. 222), who clarified that the conceptual framework is "the system of concepts, assumptions, expectations, beliefs, and theories that supports and informs your research". In essence, it explains the phenomenon to be studied in detail.

This study explores DHs' knowledge and practices of implementing the Technical Mathematics curriculum. Since DHs have a double role, being both teachers and curriculum managers, it was deemed important to use a conceptual framework to delineate the two roles. In exploring DHs' knowledge and practices of implementing the subject of Technical Mathematics, the works of Shulman (1986) and Ball et al. (2008) were combined to form constructs to understand knowledge of teaching and implementing Technical Mathematics. Furthermore, constructs of teachers' implementation of curriculum are explored, since the study is about DHs' incorporated mathematics curriculum management and implementation. Maxwell (2008, p. 223) affirms that the conceptual framework "incorporates pieces that are borrowed from elsewhere, but the structure, the overall coherence, is something that you build, not something that exists ready-made".

Hennink et al. (2020, p. 37) briefly summarised several reasons for researchers to use conceptual frameworks in both qualitative and quantitative research; they state that "a conceptual framework:

- provides focus and structure to the study;
- provides clarity to the concepts that are being investigated in the study;
- provides a way to further refine research questions;
- reflects the theoretical assumptions and concepts adopted in the study;
- reflects the expected relationships between the concepts that will be explored".

The purpose of a conceptual framework is thus to promote meaning-making of concepts related to the phenomena in the research study. In this study it is used to describe and understand the concept of DHs' knowledge and practice in implementing Technical Mathematics. The aim is to give meaning to the phenomena as well as provide a context for analysing data. Leshem and Trafford (2007) concur that a conceptual framework should drive meaning-making in a study.

Both theoretical and conceptual frameworks are terms used in this study to gain more understanding and facilitate analysis of the phenomena. Because the two terms are often used interchangeably or without differentiation, the two types of frameworks should first be distinguished from each other. In this regard, Kumar (2011) views a conceptual framework as the base for a research question. Kumar (2011, p. 53) states that

> conceptual framework stems from the theoretical framework and usually focuses on the section(s) which become the basis of your study. Whereas the theoretical framework consists of the theories or issues in which your study is embedded. The conceptual

framework describes the aspects you selected from the theoretical framework to become the basis of your enquiry.

The rationale for using two frameworks (theoretical and conceptual) in this study was to facilitate a close and careful observation of numerous echoes around the phenomenon under investigation, which is the understanding of DHs' practices, knowledge and experiences of implementing Technical Mathematics. I believe that through the use of multiple frames, the debate around DHs' enactment of their roles may be observed and stirred through different lenses. Hence, different resonances of the phenomenon are studied intently as opposed to using only one theoretical framework.

3.3 Theoretical framework for the study: Samuel's Force Field Model

Samuel's (2008) Force Field Model posits that teacher development and schooling context could be understood as potentially vibrant spaces that can be activated by different charges. These charges may conflict with each other and with the DHs' surroundings. Teachers' roles and identities, according to Samuel (2008, p. 11), are influenced by different forces, which then "push and pull teachers' roles and identities in different directions". He argues that teachers' identities are shaped by several forces that promote or devalue their autonomy in the school setting. The roles of DHs as teachers and curriculum managers are then defined by the forces that are exerted in the school. These ultimately shape how the DHs perceive themselves in teaching and managing the curriculum. Keiler (2018, p. 3) states that "teachers' roles refer to what teachers do in classrooms and teachers' identities refer to the ways that teachers think about themselves and their classroom roles." She argues that radical changes in the environment in which teachers work ultimately affect how they define their identities and their approaches to teaching. In the same way, Cohen (2008, p. 80) also argues that "teachers' identities are central to the beliefs, values, and practices that guide their engagement, commitment, and actions in and out of the classroom".

The ideas above mean that when a new force is experienced, these teacher beliefs become either stagnant or redefined. In the context of this study, DHs perception of their roles and identities are challenged during the new curriculum implementation. The roles that DHs held for years are challenged, to be restructured and redefined in the quest of maximising success in the implementation of Technical Mathematics. Another issue to consider is the management of teachers with similar identity issues. In this regard, Miller (2009) mooted the premise that identity understanding would be continuously changing and not static. She argues that identity is considered "as relational, negotiated, constructed, enacted, transforming, and transitional" (p. 174). Likewise, Grier and Johnston (2009, p. 5) maintain that "Teacher identity is based upon the core beliefs one has about teaching and being a teacher that are constantly changing and evolving based upon personal and professional experiences". These charges (influences) could constrain the mobility or actions of the teacher. Samuel (2005), as cited in Pillay (2009, p. 21), states:

> The teacher's conception of their role and identity as an electron within a forcefield. The direction that the individual electron moves within the forcefield is influenced by both the pull or push exerted by external forces in that field, but also by the stored potential energy that the electron itself has (its charge). The trajectory of the electron is directed by both internal and external sources which enable or constrain its mobility or actions.

In the context of this study, DHs' perceptions of their roles and identities have been challenged during the implementation of the new curriculum. To effect maximum success in the implementation of Technical Mathematics, the roles that DHs have held for years are challenged; that is, they are restructured and redefined. Walbrugh (2016) argues: "Although this model does not explicitly state that it is a temporally embedded process, there are clear associations with the past, present and future within in each force". Furthermore, Walbrugh (2016, p. 25) cites Samuel (2008) as insisting that "researchers need to understand lives of teachers in order for teachers to understand their own profession and develop accordingly, this is by means of understanding the forces that pull and push them in different directions.

Against this background, this study aims more to understand than to criticise DHs as they enact their important roles in teaching, implementing, and monitoring the Technical Mathematics curriculum. The Force Field Model articulates teachers' roles and responsibilities. Although this study explores DHs' experiences not only of teaching but also of implementing and managing the curriculum, their primary role is that of being a teacher in the classroom. Thus, the model was deemed appropriate for this study.

The narratives of DHs' daily experiences are constructed in this research with the aim of understanding how and why they implement the new curriculum as they do, through observing their execution of their roles and responsibilities during their professional practice. Samuel's

(2008) Force Field Model is used in this study to understand how DHs reconcile the different forces that operate in the sphere of implementation and teaching of Technical Mathematics in their schools. Henceforth, challenging such reconciliation may be indicated by the increased need for DHs to be autonomous when enacting their roles in the force field, but within the very prescriptive CAPS curriculum. Accordingly, the study also explores the extent to which different forces impinge on DHs' autonomy within the school context.

In this study the Force Field Model is used to understand the forces that enable or hinder the DHs' knowledge and practices in the implementation and managing of the Technical Mathematics curriculum. The model is extended, as illustrated in Figure 3.1, which shows the constructs of the Force Field Model.

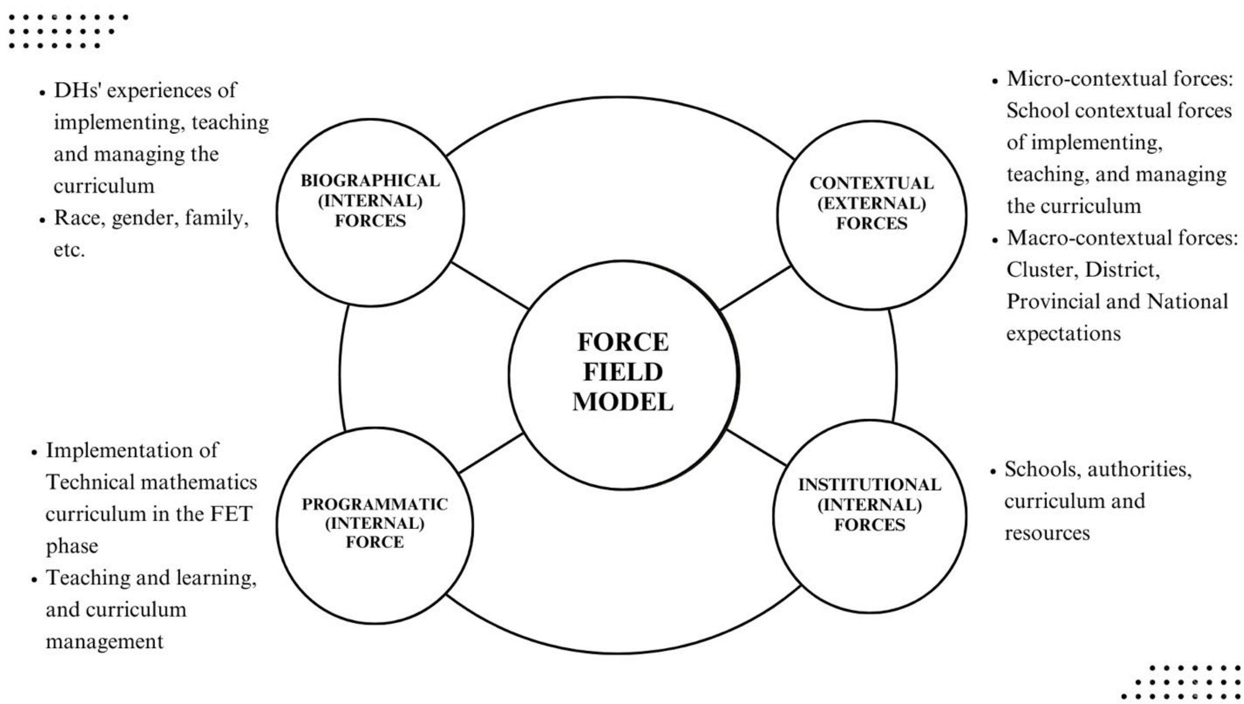


Figure 3.1*: Modification of Samuel's Force Field Model to understand DHs' knowledge and practices in implementing and managing Technical Mathematics.*

The Force Field Model (Figure 3.1) shows the relationships between professional forces that act on an object – in this case the DHs. These forces push DHs' roles and identities in different directions. The pushing forces promote, while pulling forces constrain or impede the use of DHs' knowledge and practices in successfully implementing and managing the Technical Mathematics curriculum. Drawing from Newton's third law of motion, forces can influence each other in several ways. If two objects are in contact, with one pushing on the other with a positive force, then the other object would also be pushing back on the first with an equal and opposite force. In this analogy, for teaching, implementation, and management of Technical Mathematics to be successful, the driving forces pushing towards a desired outcome must be strengthened, while the restraining forces pushing against it must be weakened by developing strategies to promote positive change.

Figure 3.1 also shows the cyclical nature of the Force Field Model, at it premises that the professional forces are constantly influencing one another, while also interacting with one another. It is noteworthy that, depending on the condition or school context in which the DHs operate, some forces may be more dominant than others, and their relative sizes determine the outcome. Also, with the differences in school contexts, as reflected by the DHs' biographies, the forces that dominate in some contexts may be less influential in others, which means that the forces do not necessarily play out in the same way in every situation.

Samuel's (2008) Force Field Model is used in this study to understand both of the DHs' identities – in their management and teacher roles – within the schooling system in which they operate. Samuel (2008) argues that a teacher's role and identity are shaped by the various forces that exist within the educational system and the curriculum. In the context of this study, the Force Field Model is used as a tool to understand the DHs' role and identity within the South African schooling system. The intuitive understanding of the DHs' identities in this study is based on the premise that various professional forces are influencing the DHs' roles and identities within a force field (schooling system). As explained above, the DHs may be seen as 'electrons' within a force field, that is the vibrant space causing electrons to move in different directions. The electrons (DHs), who are curriculum managers and teachers implementing, managing and teaching Technical Mathematics, are pushed by driving forces or pulled by restraining forces.

For the purpose of this study, leveraging the driving forces allows the DHs to understand themselves and to propel them towards professional growth. This means that they are then able to be innovative and effective. Driving forces such as participation in professional growth and continuous professional development initiatives, both within and outside the school, may shape DHs' roles and identities so they become more committed to learners attaining the necessary skills for success in Technical Mathematics. Furthermore, as curriculum managers, DHs have a significant and central role that may influence successful implementation of Technical Mathematics. Their influence may be on the teachers they manage, learners they are responsible for and teach, principals who are responsible for allocating necessary resources, as well as subject advisors in Technical Mathematics.

In contrast, restraining forces may also inhibit the teachers' role and identity development. The demands on DHs concerning administrative duties, lack of support from both the school management team and subject teachers, political agendas, DBE expectations, and parents or society at large, are some of the factors that may impinge on DHs' fulfilment of their professional roles. I argue that, in the context of curriculum implementation, restraining forces may include lack of resources, teachers' inadequate knowledge of the curriculum, lack of school management support, or resistance from teachers. Samuel (2008) asserts that other restraining factors are internal, and have the potential to influence the DHs' roles and identities; these may include lack of support, role ambiguity, and fatigue. Samuel (2008) posits that when teachers recognise and address such restraining forces, they are more likely to curb their impact on learners' learning and wellbeing. In the context of this study, when DHs recognise and address these restraining forces, they can eliminate those that impede the successful implementation of the Technical Mathematics curriculum. In this way, Samuel's (2008) Force Field Model can help DHs to identify the forces that are currently influencing their role and identity, and to develop strategies to promote positive change. As noted above, Samuel argues that teachers' roles and identity may evolve and change throughout their career.

Samuel's Force Field Model has been used as a framework in other studies. De Villiers (2021) used it in his study that sought an in-depth understanding of the pushing and pulling factors that influence professional practices. De Villiers (2021) stated that the four forces are not static and influence one another. Some forces will be at play simultaneously, and they are continuously influenced by different factors. In the context of this study, the forces that have an influence on the attributes of DHs are their experiences, and their perceptions of the curriculum and its implementation. Singh (2011) also used Samuel's Force Field Model to understand the role of staff development programmes in capacitating in-service teachers. She asserts that school contexts are vibrant, dynamic spheres, in which there are continuous changes in education policies and particularly in the curriculum. Singh (2011) argues that for teachers to reduce the effect of the challenges embedded in such changes, they need to adapt by engaging with professional development initiatives that aim to close the gaps that are brought up by time and change. In this study, the Force Field Model was used to provide a multidimensional understanding of DHs' experiences in implementing a new intervention.

In the next section I provide a detailed description and account of each construct behind the professional forces.

3.3.1 Biographical forces

According to Samuel (2008), the lived experiences that are significant in shaping teachers' identities include biographical forces. Walbrugh (2016, p. 27) indicates that forces of biography refer to "how one's history of teaching and learning provides rich experience and a great foundation for one's identity and ensued agency." Samuel (2008) contends that different teachers have unique experiences, personalities, and interpretations of the curriculum and their roles. Hence, DHs draw their energy from the biographies of their unique life experiences. Similarly, Cohen (2008, p. 80) argues that "role identities have different salience for individuals often, but not always, depending on how highly the individual values the role and how often she or he enacts it", while De Villiers (2021, p. 4) argues that forces of biography are internal forces which are seen as "authentic, unique and personal". DHs, as the central focus of the study, may thus experience biographical forces as they draw energy from their personal life experiences.

The inertial nature of biographical forces could be understood as being the 'safe world' into which teachers often retreat when under pressure from other forces; it gives teachers a degree of comfort and stability. Whereas a teacher's view and understanding of education is habitually influenced by their identity, these biographical forces are neither stable nor unitary. Samuel (2008, p. 140) states that biographical forces

> include the different individuals' (shifting) cultural, racial, ethnic, religious identities which predispose them to think, act or behave in particular ways with learners, school authorities, and with school subjects with similar or different biographical heritages (school principals, mentors, novice teachers and learners) come to inhabit the specific teaching /learning context.

In the context of this study, I used the Force Field Model to understand the extent to which biographical forces influence DHs' constructs, their teaching, and their interactions with learners, teachers, principals and the subject. Such forces may predicate the DHs' choices in the implementation and enactment of their roles in Technical Mathematics.

In this study, the researcher examines the biographical forces that influence DHs when enacting their roles. According to Samuel (2008), the powerful forces of biography play a substantial role in teacher identity. Teachers' rich store of experiences are rooted in their racial, cultural, religious and socially situated experiences that shape their acquired lived experiences and their unique life history of schooling, from which they draw energy. Samuel (2008, p. 12) also believes that the meaning they draw about "what it means to be a teacher is gleaned through their biographical history".

Experience is a powerful dimension shaping one's daily practice and agency in the classroom. On this theme, the national policy framework for teacher education and development in South Africa (DoE, 2007) acknowledges that practising teachers' lived experiences are deeply connected to their personal biographies and influence the daily execution of their roles. Ramawtar (2010, p. 14) argues that:

> Teachers' personal histories which arise from socializing within a particular family, culture and community as well as the forces of one's institutional training and the forces of the institutional ethos within which one is teaching, all collectively influence how one identifies who she is and what role she plays within the present education system.

Similarly, Miller (2009, p. 175) insists that biographical forces or identities cannot be isolated from teachers' professional duties; they play a significant role in how teachers enact their roles and responsibilities:

> thinking, knowing, believing, and doing are enacted in classroom contexts in a way that cannot be separated from identity formation. What teachers know and do is part of their identity work, which is continuously performed and transformed through interaction in classrooms.

Nelson (2013) concurs that teachers' biographical forces are increasingly believed to have a significant bearing on their classroom behaviours and practices. I therefore argue that the manner in which teachers conduct themselves in the classroom is influenced by their personal biographical forces, which draw energy from their professional and life experiences.

3.3.2 Contextual forces

Samuel (2008) states that the second major set of forces influencing teacher behaviour are the contextual forces, which relate to the school environment in which that teacher generally operates and are influenced by factors embedded in the schooling environment. General factors like cultural and political dynamics have an enormous impact on teachers' daily enactment of their roles; hence the effectiveness of the teacher within their school is dependent on the context of the environment. In support of Samuel's view of contextual forces, Shaked and Schechter (2013) alluded to DHs, as school leaders, facing a number of challenges, which are directly dependent on the particular context and local needs of their school environment. In this way, the social behaviour and meaning making of the DHs is reliant on their context. I believe that this research will reveal how DHs make sense of the context in which they work and its subsequent influence on how they enact their roles.

Samuel (2008) articulates that teachers are both products and processors of their history. He argues that the contextual forces may be regarded as the uniqueness of the macro-social, political, and cultural environment within which the teacher finds himself or herself. DHs' macro-environment transformation in education is affected by changes in the education curriculum and policy goals. Furthermore, Samuel (2008, p. 14) concludes that "such contextual forces may be more site specific and include the policy regulating teacher education curricula or policies at the specific school micro-contexts where adherence or divergence from the macro-context may be at play".

This study is about curriculum implementation. Understanding the complexity of inhibiting or enabling contextual factors on DHs requires a clear lens, as provided by the framework espoused by the Force Field Model. Barnett (2000), as cited in Anakin et al. (2018) argued that an institution's curriculum changes are characterised as complex processes involving interactions within and between various institutional social contexts. Among the findings of Anakin et al. (2018) on the contextual nature of curriculum change is that the nature of curriculum change is highly context-dependent. This suggested that the contextual forces for the present study should be identified in order to understand their influence on Technical Mathematics implementation. The school context has competing beliefs, ideas, and interests which require that DHs adapt and respond to them to ensure successful implementation, teaching and management of Technical Mathematics. De Villiers (2021) states that in terms of the Force Field Model the contextual South African forces are the external macrosocial, political, and historical forces.

3.3.3 Institutional forces

Institutional forces draw on the lived biography of institutional settings, as explained by Samuel (2008). Different institutions may have a different ethos, which would tend to change in differing historical periods. Hence, the quality of teaching and learning may change in response to the setting of the time. Samuel (2008, p. 13) argues that "teachers who either teach or learn within institutional settings are infused with a vibe of the institution and its ethos, and this influences their conception of self, role and identity as members of that institutional community". In this way, DHs' institutional setting will shape their identity and consequently influence their enactment of their roles. This means that characteristic conceptions of professional teachers and DHs in the context of this study are the result of the force of their institutional expectations. To be specific, DHs' values and goals concerning the pedagogy and implementation of the Technical Mathematics curriculum are most likely to be shaped by the very prescriptive CAPS curriculum that they are required to implement.

In understanding institutional forces, the fundamental scholar Scott (1995, p. 33) states as follows: "Institutions consist of cognitive, normative, and regulative structures and activities that provide stability and meaning to social behaviour. Institutions are transported by various carriers – cultures, structures, and routines – and they operate at multiple levels of jurisdiction." In principle, he describes the forces as regulative, normative, cognitive activities and structures that provide meaning and stability to social behaviour. In a way, institutional theory is concerned with the issues pertaining to rules that exist in the school environment, and the social and administrative routines to which DHs must adhere. These would be general norms and standards for educators – the rules by which they must abide, which deliberately prescribe for teachers their behaviour as social actors, their schemas, and the structures within their institutions. In support of this claim, Hanson

(2001) maintains that teachers' institutions are influenced by a number of factors that he calls relations and networks, predominantly their beliefs, attitudes, and behaviours.

Stromquist et al. (2013) assert that institutional factors emanate from individuals' cultural beliefs, gender roles and expectations in the work environment, that are predetermined by their social context. Their study exposed number of dynamics that account for institutional forces from male counterparts that restrain women in Liberia from becoming teachers. In this context, where women are generally destined to become resources for their husbands' families, the study reveals that those women who reject such social norms and become teachers receive insufficient support from the institutions in which they work. Drawing from these findings, DHs' roles are subject to the institutions in which they operate. The holistic understanding of the way in which such factors and social imbalances impinge on teachers' execution of their roles in different schools might affect the way they enact their roles and responsibilities in implementing and managing Technical Mathematics.

The study phenomenon concerns DHs' knowledge and practices when implementing, teaching, and managing Technical Mathematics. It is therefore important to highlight the institutional forces that may influence DHs in their practices as related to the schools in which they work; the authorities in the DBE, that is mainly subject advisors; the Technical Mathematics curriculum and the availability of resources for DHs to facilitate the teaching and learning in classrooms. In this regard, DHs are required to plan for recruitment of learners and teachers in the subject. They also need to ensure that teaching and learning resources are available for effective curriculum delivery, and must communicate with relevant authorities to ensure that teachers are trained to meet the demands of the subject in terms of content knowledge and pedagogy. These institutional forces may challenge DHs if the provision of resources is inadequate, and may enable them if they are catered for in their respective school contexts. Hence these may push or pull the DHs' role in different directions.

3.3.4 Programmatic forces

Different constituencies of the curriculum create programmatic forces, according to Samuel (2008). In this sense, programmatic forces can be understood as curriculum interventions that give direction on what should be taught and how it should be taught. Samuel (2008, p. 13) describes programmatic forces as "an explicit charge which declares the sequence, content and direction that the teaching/learning practices will follow". Programmatic forces that structure teachers' professional identities encompass both the formal and hidden curricula.

The formal or intended curriculum is essentially a plan that includes instructional objectives, learning experiences, content (what is taught), and resources (lesson plans, worksheets and learners' activities and assessment). In the context of South African education, the Curriculum Assessment Policy Statement (DBE, 2011) is very prescriptive in terms of the range of potential educational and instructional practices that are embedded in the curriculum, which need to be implemented in different grades. This includes the standardised assessment for which teachers prepare their students in order to compete at the national state examination in Grade 12. Accordingly, the intended curriculum goes beyond simply the planned teaching and assessment, and includes the pedagogy by incorporating instructional guidance and lesson planning for teachers for their learners.

The hidden curriculum, as described by Bieber (1994) and Nagy (2023), is made up of the non-taught, unwritten, non-spoken social rules and behavioural expectations that teachers promote in their daily teaching practice. Henceforth, in this work programmatic forces will be taken to encompass the transmission of social norms and beliefs that are learned in a school context without the intention of a teacher; that is, they are 'unintended'. This subjects teachers to implicit demands in the Technical Mathematics curriculum that may be beyond their expectations of what education should be, and often they experience implementing such aspects as challenging.

The idea of programmatic forces reinforces the notion that teachers' ability to improve their expertise in their daily practice reflects the sum of their learned experiences over years. This suggests that whatever they have acquired as learners during their own schooling experience, together with what they have learnt over years as lifelong practitioners, will mould their professional identities. Samuel (2008) emphasises that these experiences shape teachers' professional identity consciously, subconsciously or even unconsciously.

The Force Field Model is used in this study to understand the multidimensional nature of DHs' experiences that impact their enactment of their roles in the implementation of Technical

Mathematics. Notably, these forces do not operate in isolation; they are interwoven. The institutional forces could be understood as directly influencing contextual forces. This means that DHs' lived experiences and their unique life history is informed by the setting of the institutions in which they teach and manage.

For this study all of the forces are important in understanding the phenomenon; they encompass all of the dimensions that influence the DHs' enactment of their roles and responsibilities. By using the Force Field Model, the forces that push or pull DHs in different directions are understood through clearer lenses. The framework identifies the constraining and enabling forces that predetermine the way in which DHs implement the Technical Mathematics curriculum; that is, the way in which their identities influence their thinking about themselves as curriculum managers and their roles as classroom teachers. All of the forces – biography, context, institutional and programmatic – interact in a potentially vibrant space, continuously changing and being activated by different charges.

In support of Samuel's theory, Lewin's (1951) Force Field Analysis theory of change also helps to understand the change process that the DHs in this study find themselves in. It is a useful model to analyse behavioural changes and the level of occurrence. Lewin's theory states that there are driving and restraining forces that promote or hinder change, which in this context is the implementation of a new intervention. Driving forces promote effective implementation of the curriculum, while restraining forces act against the proposed change. Hence, Force Field Analysis emphasises that a change becomes increasingly difficult to implement when the restraining forces are stronger than the driving forces. Accordingly, in the context of this study, effective curriculum implementation requires that the restraining forces need to be weakened and the driving forces need to be strengthened. Lewin (1951) asserts that a state of equilibrium is reached when the two forces exert the same strength. Kaminski (2011, p. 1) summarises the theory as "force field analysis offers direction for diagnosing situations and managing change within organizations and communities. Lewin assumed that in any situation there are both driving and restraining forces that influence any change that may occur".

The constructs of Lewin's Force Field Analysis theory of change are used in this study, rather than the theory as a whole. Thus it is possible to extend the lenses of Samuel's Force Field Model to better understand the knowledge and practices of DHs in implementing and managing the

Technical Mathematics curriculum. The theoretical framework used in this study allows exploration of the different forces within the forcefield, whether they restrain or promote implementation of the Technical Mathematics curriculum. Samuel (2008) emphasises that all these forces influence teachers strongly in their daily practice. Implementation of the curriculum demands that DHs' experience and expectations in executing their teaching and administration is fuelled by different forces that act on their force field. For effective curriculum implementation, the demands need renegotiation to ensure equilibrium is reached between opposing forces. Notably, the Force Field Model suggests that the four professional forces can each have positive and negative influences.

3.4 Conceptual framework underpinning this study

Teachers' curricular knowledge informs pedagogical decisions they make concerning teaching. Shulman's (1985) early work indicates that an effective teacher needs an understanding of knowledge that is broad and organized. The knowledge that Shulman (1985) refers to is that required to 'teach' an area of specialisation. His view emanated from his understanding of the types of knowledge that teachers ought to have. Shulman (1987, p. 8) affirms that the type of PCK that teachers should possess "represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction." Shulman's ideas are the foundation of modern thinking, and have been developed further by others.

Ball et al.'s (2008) framework arises from Shulman's (1986) model. Its emphasis is on mathematics knowledge for teaching (MKT). Its emphasis is on expounding variables that had been neglected in Shulman's model, to more specifically apply in mathematics teaching. Figure 3.2 shows the modification of Shulman's (1986) PCK and Ball et al.'s (2008) MKT framework, giving rise to the conceptual frame for this study. The reasons for the modifications are then outlined.

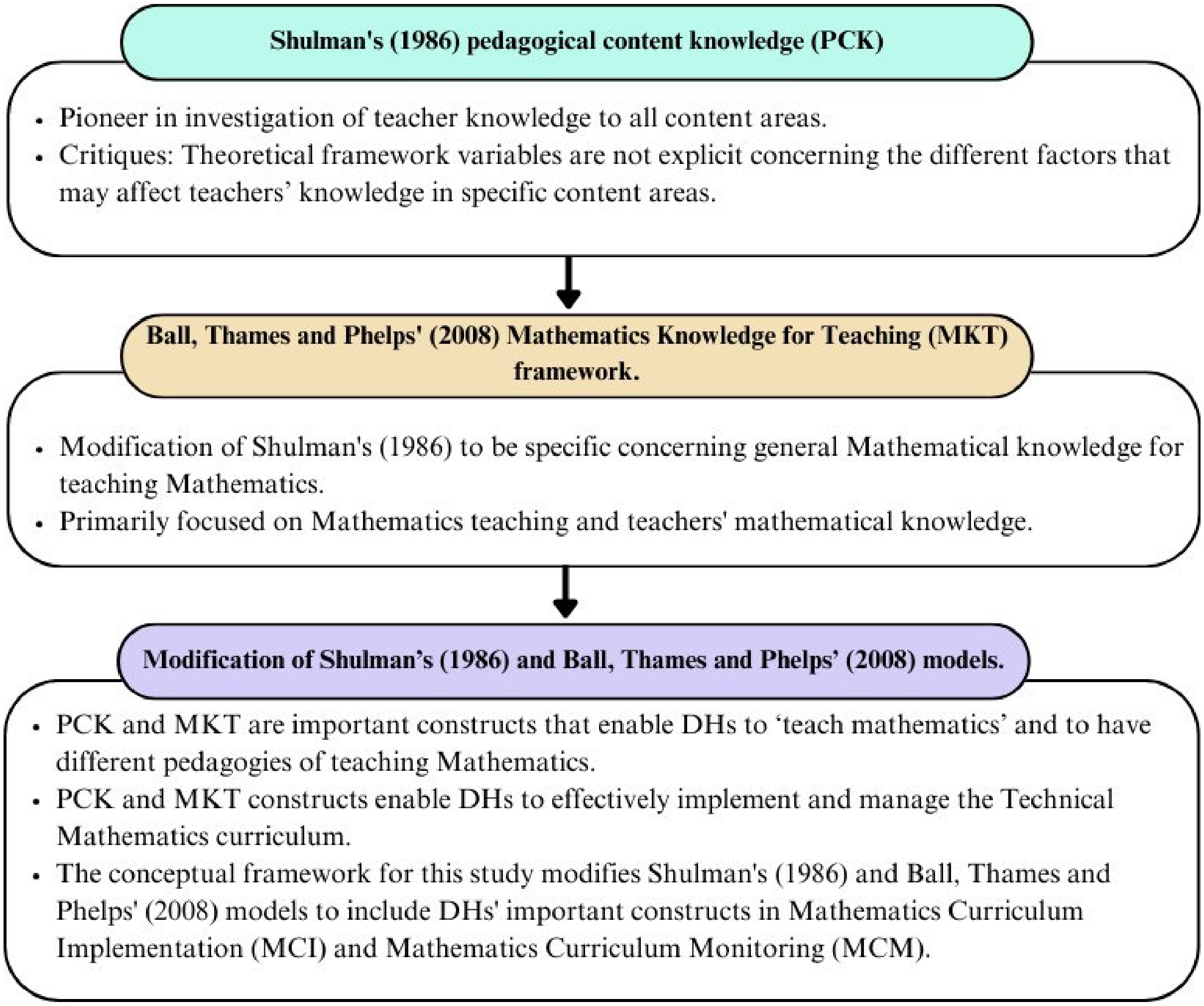


Figure 3.2. *Modification of Shulman's (1986) and Ball, Thames and Phelps' (2008) models.*

In this study the researcher used an existing theory developed by Shulman (1986) as a baseline conceptual framework. However, because his model was underpinned by general knowledge for teaching and was not specific to Mathematics teaching, it did not fully address the research questions of this study. Shulman's (1986) theoretical framework was therefore modified for this study. The researcher also used the Ball et al.'s' (2008) model and adjusted its constructs to give rise to a more pertinent conceptual underpinning. Accordingly, as shown in Figure 3.3, the model of Ball et al. was modified to structure the present study and provide a lens for data analysis. Hence, MKT goes beyond pure mathematical content knowledge to also include PCK for Mathematics teachers.

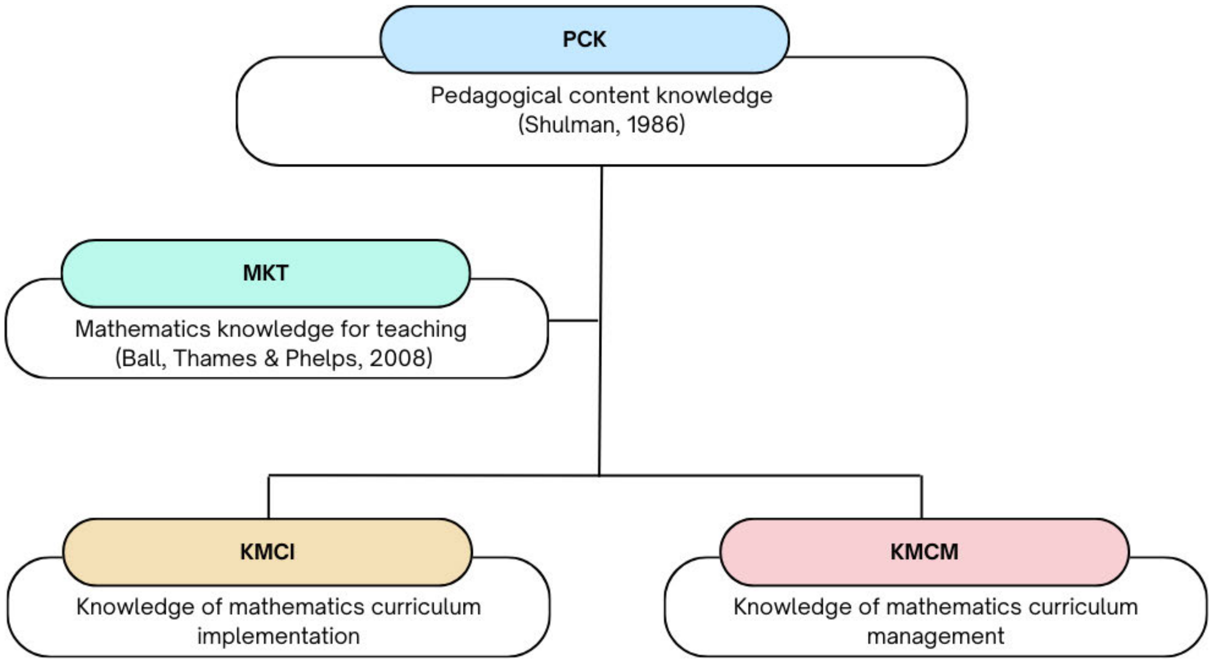


Figure 3.3. ***Conceptual framework developed by the researcher for this study.***

PCK includes constructs that enable DHs to have knowledge of what they teach and how they teach it, and while MKT is embedded in PCK, MKT represents the specific knowledge of teaching Mathematics that Mathematics teachers should possess for their subject area. In the context of Technical Mathematics as a new subject, DHs ought to have specialised trade knowledge that promotes practical components of Mathematics relevant to the trade industry. I then argue that to execute their management role, DHs need to have knowledge of implementing the Technical Mathematics curriculum in their schools. I refer to this type of knowledge construct as knowledge of mathematics curriculum implementation (KMCI). I argue that it sets out standards that are expected in the implementation of a Technical Mathematics curriculum. Part of the DHs' management role encompasses knowledge for monitoring the curriculum implementation. Hence, curriculum monitoring knowledge is necessary for DHs to understand how the curriculum could be continually improved, putting them in a better position to understand any implementation shortfalls for the subject. I refer to this second construct as knowledge of Technical Mathematics curriculum monitoring (KMCM), which aims to understand knowledge, strategies, and tools that are used by DHs to evaluate the curriculum, self-evaluate, and evaluate the teachers that they manage. These two constructs give a holistic view of DHs' enactment of their roles and responsibilities to ensure effective curriculum implementation, management, and teaching of Technical Mathematics. In Weber's (1996) instructional leadership model, these two constructs are encompassed in one term: knowledge to manage curriculum and instruction.

3.4.1 Pedagogical content knowledge (PCK)

Shulman (1987, p. 4) articulates that PCK "represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction." Banks, Leach and Moon (1999) state that through increased teaching experience, teachers' PCK gradually increases. In the same way, it is an assumption in this study that DHs would tend to be more effective as they gain confidence in executing their roles. Aminah and Wahyuni (2018) summarised Shulman's (1986) PCK domains, listing seven knowledge domains that teachers need to master, which are: subject matter knowledge, general pedagogical knowledge, PCK, curriculum knowledge, learning knowledge and characteristics, knowledge of teaching strategies, and knowledge of the learning context. These domains still point out that Mathematics teachers need to know more than ordinary mathematicians, in that having adequate knowledge of Mathematics content and facts is not sufficient if there is minimal understanding of the pedagogical knowledge. Mathematics teachers need to know 'what to say' and 'when to say it' whenever this is advantageous in enhancing learners' understanding of abstract Mathematics concepts. The current study explores DHs' knowledge and practices of implementing, teaching, and managing the Technical Mathematics curriculum. The implementation is anchored in their expertise to teach the subject, which encompasses both content knowledge and PCK of the subject. Managing the curriculum requires DHs to provide academic and professional support to other teachers who are teaching the subject, thus drawing on their expert knowledge of teaching and curriculum.

3.4.2 Mathematical knowledge for teaching (MKT)

Whereas Shulman defines knowledge for a general teacher, Ball et al. (2008) define knowledge that is specific to the teaching of mathematical subjects. According to Ball et al. (2009), MKT refers to the knowledge needed to teach mathematics. This is therefore the knowledge needed for effective teaching of Mathematics. MKT needs to be unpacked for learners to understand abstract ideas entailed in the mathematical knowledge. The authors alluded to the fact that MKT enables Mathematics teachers to decompose abstract Mathematics ideals into knowledge that is attainable by the learners. Ball and Bass (2003, p. 12) state that "another important aspect of knowledge for teaching is its connectedness, both across mathematical domains at a given level, and across time as mathematical ideas develop and extend". This means that Mathematics teachers should be able to link topics, so that learners understand the connection in the content they are learning, and do not to see it as isolated factual knowledge. Thus, teachers need to acquire and generate appropriate MKT in order to facilitate learning of Mathematics.

MKT was developed to fill in the gap in Shulman's PCK. Hence, the focus of MKT is on ensuring that teachers' knowledge of Mathematics is transferable to learners through effective instruction methods – this is what separates general mathematicians from Mathematics teachers. Knowledge of Mathematics and knowledge of teaching Mathematics are two constructs that are used in this study, derived from Ball et al. (2008). Unlike the Shulman's (1985) generic knowledge for teaching, Ball et al. (2008) emphasised 'Mathematics' knowledge as a discipline which is significant and more specific to knowledge that is important for Mathematics teachers.

This study explores DHs' knowledge and practices of implementing, teaching, and managing Technical Mathematics. DHs are teachers as well as curriculum managers, and their expertise includes possessing adequate knowledge of the subject they teach and manage. MKT incorporates different strands, which are subject matter knowledge (SMK) and PCK. SMK is divided into two sub-strands, which are common content knowledge and specialised content knowledge. PCK is divided into three strands: knowledge of content and students (the latter termed learners in this study), knowledge of content and teaching, and knowledge of content and curriculum. Since DHs have dual roles as teachers and curriculum managers, they need to be competent in all of these strands, hence the inclusion of MKT in the conceptual framework to understand DHs' knowledge and practices of implementing, teaching, and managing Technical Mathematics is vital.

Beyond the DHs' roles of curriculum implementation and managing, there is curriculum monitoring and evaluation, which led to modification of the model, as illustrated in Figure 3.3. The development of Shulman's (1986) model is necessary in understanding the additional professional knowledge that Mathematics teachers ought to have when implementing and monitoring the curriculum. In contrast, the understanding of Ball et al. (2008) is grounded on the blend of content and pedagogical knowledge that is required for teaching Mathematics, since there is enormous pressure on teachers to develop content that is relevant and can be understood by the learners. This is also important when then it comes to enhancing learners' understanding of Technical Mathematics. The MKT construct is a practice-based approach that focuses on knowledge of teaching Mathematics. DHs have an obligation to ensure that they and their teachers transform their Mathematics knowledge into meaningful instructional knowledge that learners can easily understand, in order to execute their roles effectively.

3.4.3 Knowledge of mathematics curriculum implementation (KMCI)

Mathematics curriculum implementation has been changing from time to time with respect to society's needs to fulfil education reform. As stated in the introductory chapter, South African education has experienced numerous curricular changes since 1990; nevertheless implementation at school level has barely achieved intended outcomes. The DBE (2018a, p. 11) proclaims that

> the teaching and learning of Mathematics in South African schools is not yielding the intended outcomes of South Africa's education policies and curricula. This is evident from research from many studies conducted by the Department of Basic Education (DBE), universities and other research agencies in South Africa.

Implementation of Technical Mathematics in South Africa is not unique in terms of educational developments, but the DHs carry the burden of ensuring that it runs smoothly. Also, one cannot describe curriculum implementation without inclusion of the holistic development of the learners, who are the receivers and the main individuals that the curriculum is intended for and aims to enhance. Learners tend to be exposed to different curriculums in their schooling lives, and their learning experiences tend to evolve as the country evolves, especially in the context of South Africa as a developing country that needed major education reforms. These reforms come with a package of teaching practices and curriculum requirements, which often do not coincide with the traditional, existing teaching approach often used by Mathematics teachers in the classroom. In Weber's (1996) models this incorporates one's ability to monitor classroom practices, provide resources and provide support to enhance classroom practices. DHs as curriculum implementers and managers who monitor curriculum implementation have a central and critical role in ensuring that curriculum demands are met in the classroom practices. Thus their beliefs and theoretical perspectives are crucial through all of the stages of curriculum implementation. According to Ernest (1989), curriculum implementation is fundamentally dependent on the teacher's beliefs and view of the nature of mathematics. Without teachers ploughing their efforts into understanding and interpreting the curriculum in the way intended by curricular developers, it will be impossible for the curriculum to reach its target audience.

3.4.4 Knowledge of mathematics curriculum monitoring (KMCM)

Rossi and Freeman (1989, p. 170) define curriculum monitoring as "the systematic attempt by evaluation researcher to examine program coverage and delivery. Assessing program coverage consists of estimating the extent to which a program has reached its intended target population". The curriculum needs focal lenses that guide its implementation: thus, DHs as first-hand monitors need to make sure that curriculum needs are met. The DoE (1997, p. 1) asserts that the curriculum is the centre of the education and training system, and that "It is imperative that the curriculum be restructured to reflect the values and principles of our new democratic society". For DHs to enact their roles effectively they need to have monitoring knowledge, and need to constantly work with their teachers and learners to establish a common understanding on what needs to be taught and learned. The DBE proposed a number of interventions that capacitate DHs with monitoring tools in Technical Mathematics (Metcalfe, 2018). These interventions sought to enable DHs to give leadership support to the teachers they manage in curriculum implementation.

In their study, Mthiyane, Naidoo and Bertram (2015) used the theory of change underlying Jika iMfundo to examine the role of DHs in curriculum coverage to balance monitoring and support. Mthiyane et al. (2015) argue that DH are important structures that assure effective curriculum monitoring from different stakeholders. They also asserted that stakeholders need to work together, so that the roles and responsibilities of the DHs are eased. In playing their central role in curriculum implementation, teaching, and management (monitoring), DHs engage with many different stakeholders: teachers, the SMT, principals, circuit managers, subject advisers, and other district officials (Mthiyane et al., 2015). I argue that for effective Technical Mathematics curriculum implementation, all stakeholders ought to work together to support the DHs in executing their roles.

For the knowledge of Technical Mathematics curriculum monitoring construct to be effective, I argue that DHs need adequate PCK to monitor curriculum implementation, MKT, and KMCI. Curriculum monitoring requires specific skills that are aligned with the subject matter. In the CAPS evaluation report, the DBE (2009) noted that there are elements that hinder curriculum monitoring and implementation. DHs have an obligation to provide opportunities for professional support to the teachers they manage, and it is expected that they support the teachers with ongoing and new developments in the relevant subject area. Exposing themselves and the teachers they manage to professional development workshops designed to support curriculum implementation is essential. This could strengthen their curriculum monitoring skills.

The end-goal in this new curriculum is to ensure that all teachers can monitor their own teaching practice through self-assessment. Weber (1996) emphasised the need for instructional leaders to be conversant with current teaching and learning methods, curriculum policies and curriculum trend, in order to provide informed guidance to teachers, so that they can improve their instructional practice. This suggests that before DHs are able to carry out monitoring, they need to be knowledgeable about the Technical Mathematics curriculum and what is needed in order for it to be implemented, and to provide proper guidance to all teachers in the school.

3.5 Conclusion

This chapter described the theoretical framework that underpins this study. Samuel's (2008) Force Field Model was used to understand how DHs reconcile the different forces that influence their implementation, teaching, and management of Technical Mathematics. The conceptual framework used in this study is an amalgamation of different frameworks: the PCK of Shulman (1986), who is the pioneer in generic teaching knowledge and insisted that teachers need to have set of cognitive knowledge for teaching, and that of Ball et al.'s (2008) on MKT. The researcher included the constructs of knowledge of mathematics curriculum implementation (KMCI) and knowledge of Mathematics curriculum monitoring (KMCM), borrowed from the work of Weber (1996), to anchor discussions around the research phenomenon.

The next chapter discusses the methodology used in this study, and details the guidelines followed in responding to the research questions. This includes discussion of the research design, data collection plan, how the data was generated, the research instruments used, and validity in ensuring that the research questions are fairly addressed. Issues relating to sampling, ethical clearance, trustworthiness and the limitations of the study will also be discussed.

Chapter 4

Research methodology

4.1 Introduction

The previous chapter described the theoretical framework that underpins this study. This chapter discusses the methodology that was used to carry out the study, including the research plan and design deemed appropriate to explore DHs' knowledge and practices of implementing Technical Mathematics. Research design encompasses guidelines that a researcher needs to follow in responding to research questions, and the methodology provides a plan, structure, and strategy for research. Pandey and Pandey (2021) state that the methodology is the blueprint to oversee the research process; in other words, it acts as a map to navigate the study. Accordingly, this chapter provides an in-depth account of the research design, methodology, methods, and sampling techniques that were used to generate data for the study, and methods of data collection used to answer the research questions. The sampling method and selection criteria used to determine inclusion or exclusion of research participants are outlined, with a detailed outline of how the data generated by the study were analysed. Finally, this chapter addresses how ethical considerations, including issues of validity and reliability were addressed.

Research design is defined by McMillan and Schumacher (2001) as the plan that describes the conditions and procedures for collecting and analysing data. Similarly, Mason (2002) defined a research design as the logic through which a researcher addresses the research questions. Mackenzie and Knipe (2006, p. 197) state that "methodology is the overall approach to research linked to the paradigm or theoretical framework while the method refers to the systematic procedures or tools which are used for collection and analysis of data". Cohen and Manion (2000), highlighted that research design is a structured approach to collecting data from a specific population to comprehend a phenomenon and generalize findings to a broader population.

The aim of this study was to explore DHs' knowledge and practices of implementing Technical Mathematics in schools in Pinetown District in KZN. The reason for sampling DHs who are also teaching the subject was to incorporate their experiences as curriculum implementers and as the most important SMT team member in terms of oversight of the curriculum, from both the department point of view and according to teachers' perspective.

Cohen, Manion, and Morrison (2017) stated that the purpose of the study is an important element in deciding on the research methodology and design. The general perception is that the purpose of the research helps both the researcher and the reader to understand what is intended to be accomplished in terms of the chosen phenomenon and why the research is conducted in the way it is. Creswell and Creswell (2017) affirm that a researcher need to identify a single central phenomenon and present an initial definition of the phenomenon when writing a qualitative purpose statement. In this study the researcher aimed to provide DHs with an opportunity to engage in reflective practice on various stages of their teaching, implementation, and management of Technical Mathematics in their schools by sharing their knowledge and practices. DHs' reflections on their knowledge and practices would indicate their experiences of enacting their roles and responsibilities, thus revealing enabling factors with potential to enhance the implementation and teaching of Technical Mathematics as well as challenges that might hinder this. This study has the potential to inform discussion around the implementation of Technical Mathematics in schools offering the subject.

As indicated in Chapter 1, the following research questions were posed in this study:

1. What are the DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics?
2. How do DHs enact their roles and responsibilities to implement and teach Technical Mathematics?
3. Why do DHs enact their roles in the way they do?
4. What factors hinder or enable DHs in the implementation of Technical Mathematics?

In accordance with the research questions, an interpretive research methodology and qualitative analysis using multiple methods of data collection were deemed most appropriate for investigating the phenomena under study. The methods of data generation used in this study are one-to-one semi-structured interviews, focus group interviews, observations, and document analysis. In this qualitative study, the researcher aimed to gain an in-depth understanding of DHs' knowledge and practices of implementing Technical Mathematics.

4.2 Ontology, epistemology and methodology

The three major dimensions that guide each research study, as outlined by Terre Blanche, Kelly and Durrheim (2006), are ontology, epistemology and methodology, each of which is discussed below.

Ontology looks at what constitutes reality and Guba and Lincoln (1989, p. 39) emphasise that it is concerned with "what kind of world we are investigating, with the nature of existence, with the structure of reality as such". Creswell and Creswell (2017) express that it depicts the nature of reality as seen in everyday life and what we can understand about the world. It relates to the types of realities (one verified truth, multiple, and socially constructed) that researchers ascribe to (Patton, 2002). In my view, the assumption is that DHs will be able to voice their opinions, and the study creates a space where they can share their perspectives, which will reveal the ontological perspective. This study aims to understand DHs' shared experiences and practices around their implementation as it occurs in their daily routine. As a researcher I anticipated that I would gain an insight into the context from which the data emanates, as Creswell and Poth (2016) argue that data generation occurs in participants' workplace and where they live. I hold certain views about the implementation and teaching of Technical Mathematics, as I am a Mathematics teacher, but I intend to avoid allowing my personal views to interfere with the research findings. Creswell and Creswell (2017) emphasised that within this worldview it is important for researchers to indicate where their beliefs and values may have interfered with findings.

Epistemology is a theory about the nature of knowledge and how it is generated (Bryman, 2011). It is a philosophy about ways of knowing, how we acquire knowledge, getting to understand the nature of knowledge, 'how people construct knowledge', and knowing how we know what we know (Patton, 2002). Likewise, Crotty (2020, p. 3) defines it as "a way of understanding and explaining how we know what we know". In the context of this study, the interpretive epistemology is subjective as it based on many interpretations, since DHs' experiences and practices may vary as they are unique to each individual. Moyo (2017, p. 288) explained that interpretivist epistemology is

> more subjective in that it is anchored on the ontological notion that reality is not an absolute or objective phenomenon, but rather it is subjective to the extent that what constitutes

reality varies from person to person, depending on the meanings that they attach to the world around them.

The interest of this research is in understanding DHs' knowledge and its impact on their implementation and management. My understanding of the ontological and epistemological perspectives with regard to the interpretive paradigm is that it discards the notion of a single objective reality and affirms that there are many subjective realities (Cohen, Manion, & Morrison, 2011).

The terms methodology and method of data collection are used interchangeably. In this study I adopted the meaning shared by Mackenzie and Knipe (2006, p. 197) that "methodology is the overall approach to research linked to the paradigm or theoretical framework while the method refers to the systematic procedures or tools which are used for collection and analysis of data". This study is a qualitative study, where the researcher focuses on how people make meaning of their own world in their natural setting – in this context, DHs in their schools (Creswell & Poth, 2016). Their own worldview is of paramount importance in establishing discussion around the phenomenon in question (Marshall & Rossman, 2014), and qualitative research allows multiple truths regarding a subject. These authors argue that participants are allowed to view reality based on their own perspective; hence, to answer questions from one's point of view allows flexibility, in that there is no right or wrong answer. Participants will not be judged by the researcher since everything is based on their experiences. In a nutshell, participants may feel that their opinions are valued, and that they could make a meaningful contribution to the world outside of the context in which they operate (Marshall & Rossman, 2014).

In this interpretivist study, the ontological, axiological and epistemological assumptions are that there are multiple realities, which allows me as a researcher to understand DHs' worldview of their knowledge and practices, without conforming to the assumption that they need to give certain views to make the research more valid. Creswell and Poth (2016) affirm that within the interpretivist worldview, multiple realities exist; hence it is subjective, since meaning is constructed and shared within the community. In the same way, Creswell and Creswell (2017) contend that ontological assumption within interpretivism is based on many different understandings or meanings, which prompts the study participants and researcher to broaden their reflective practice, as meaning is not confined to a single idea. It is anticipated that complex philosophies will emerge from the responses of the DHs, triggered by open-ended questions. These will reveal the complexity of views within the phenomenon studied by this research. Hence, the interpretivist nature of this study is likely to impact on how knowledge of teaching, implementing, and managing Technical Mathematics is constructed, as experts experienced in the subject engage in reflective practice and develop subjective meanings related to their experiences.

4.3 Research paradigm

A research paradigm is the set of assumptions that explains the researchers' ontology (view of reality) in which they want to position their study (Choongwa, 2018), There are different views on the understanding of paradigms. The early work of Creswell and Creswell (2017) classifies four different paradigms that researchers use when conducting their research: post-positivism, social constructivism or interpretivism, participatory action research, and pragmatism. Kumar (2018) emphasises three main research paradigms, namely post-positivism, interpretivism, and the critical paradigm. The interpretive paradigm was determined to be the most relevant for this research, and was chosen as the paradigm underpinning this study.

4.3.1 Interpretivism

Interpretivism assumes that there is more than one truth. Maree (2016) argues that researchers within the interpretive paradigm aim to understand the subjective meanings and interpretations individuals ascribe to their social world. An interpretive researcher examines how individuals construct their realities and the context in which those constructions occur (Maree, 2016). Cohen, Manion and Morrison (2018) state that the interpretive paradigm is centred on understanding individuals' view of their natural setting. Their perception of the world around them is of paramount importance in gaining insight into their day-to-day experiences. Creswell and Creswell (2017) emphasise that researchers within this paradigm often discuss their interactions and make sense of meanings with participants in the specific context in which they live and work. In the current study, the researcher aims to explore DHs' experiences in the quest to understand the implementation of Technical Mathematics through the eyes of curriculum implementers. This aim is aligned with the interpretivist understanding that individuals' interpretations of the world they live in is drawn from inside and outside (Cohen et al., 2018). Creswell and Creswell (2017) contend that within the interpretive paradigm the researcher views reality as it is observed in everyday life.

Taylor and Medina (2013) view the interpretive paradigm as a humanistic approach aimed at understanding other people's experiences and cultures. Cohen et al. (2017, 2018) affirm that interpretivism roots from the constructivist view that reality is a social construction of the mind. I contend that gaining knowledge of DHs' experiences requires them to speak their minds and to engage in a reflective practice. I argue that without participants' self-introspection, it would be difficult or impossible to gain access to the valuable information they hold. Framing this study within the interpretive paradigm aimed to reveal the subjective experiences of DHs and their perceptions within their social contexts.

As a researcher I anticipate that using the interpretive paradigm to investigate the phenomenon might yield different experiences from the DHs. Cohen et al. (2011) as well as Creswell and Poth (2016) are of the view that research within the interpretive paradigm believes that there are multiple truths, and this study aim to understand the multiple truths that DHs hold about the implementation of Technical Mathematics.

Scotland (2012) raised some critiques around the interpretive paradigm, stating that the knowledge it generates is often fragmented and lacks cohesiveness, thereby limiting its applicability across different contexts. In my view, this study does not aim to generalise its findings. I believe that DHs in different schools have their own unique experiences in implementing the new subject. It is learning about others' experiences that could inform wider implementation. As Cohen, Manion and Morrison (2007, 2017) asserts, interpretivism offers researchers a framework to explore and comprehend individuals' beliefs, values, interpretations, experiences, attitudes, and self-reflection. Unlike in the post-positive paradigm, the researcher aims to understand the phenomenon from the perspective of the curriculum managers and implementers. Moreover, unlike in the critical paradigm, the research is not planning to emancipate or influence the participants' views concerning the status quo, but rather to understand from their perspective the practices of implementing, teaching and managing Technical Mathematics.

Cohen et al. (2011) assert that according to the interpretive paradigm, the world is dynamic, and it is individuals who attribute meaning to specific situations. Cohen et al. (2011) further articulate that understanding how people make sense of the contexts in which they live and work can be gained through interpreting the world according to their experiences. Among the naturalistic approaches which this study adopts to gain these views are observations and interviews (Angen, 2000).

This qualitative study aims to gain DHs' understanding and their experiences when enacting their roles. My rationale for positioning the study in this paradigm was based on my view that the study sought to explore human behaviour which then needs to be understood and interpreted within its context. I concur with Merriam and Grenier's (2019, p. 5) understanding of the interpretive position: "exploring how individuals experience and interact with their social world, and the meaning it has for them, is based on an interpretive (or constructivist) perspective embedded in qualitative approach." The conscious choice of an interpretive- orientated study confers that the research aims to reveal multiple understandings, with no absolute truth expected to emerge from the researcher and participants' interactions.

Limitations of the interpretive paradigm are outlined by Terre Blanche, Durrheim and Painter (2008), who argue that interpretivists acknowledge that they cannot be seen as independent observers in their research, as they tend to be involved in the meaning-making process through their research, thus imposing pre-existing structures onto the data they generate. Creswell and Creswell (2017), Robson (2002) and Coates (2021) believe that it is important that researchers restrict their own assumptions so that the enquiry process and the participants' worldviews and assumptions are clearly expressed.

It was important for this study phenomenon to be understood in relation to the school contexts within which the DHs operate, to understand the factors that may impact their practice, and the interpretive paradigm was deemed suitable for its qualitative results. Taylor and Medina (2011) and Mohajan (2018) conclude that qualitative and quantitative methods are legitimate forms of enquiry, and that a limitation attached to each is the interpretation of findings. I was keen to use qualitative methods in this study in order to give the participants a voice, as it sought to understand their experiences and practices. In this qualitative study DHs would be motivated to gain knowledge through their experience, and I intended to gain an understanding of their experiences and practices through their own narratives.

4.4 Qualitative approach

A qualitative case study within the interpretive paradigm was adopted to explore the knowledge and practices of implementing the new subject of Technical Mathematics in some technical schools in South Africa. Creswell (2003, p. 4) states that qualitative research is

> a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The process of research involves emerging questions and procedures. Data typically collected in the participant's setting. Data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data.

Myende (2011, p. 32) affirms that "in qualitative research meaning is interpreted as embedded in the social context and in the people who live in that context." Whereas quantitative research tries to generalise its findings, this qualitative study seeks an understanding of the phenomenon from participants' natural settings.

Cohen et al. (2018) and Cheryl and Creswell (2018) state that quantitative research, qualitative research, and mixed method research are the three dominant approaches used by researchers when conducting their studies. They assert that researchers generally choose the research approach that is compatible with their studies, that will pave the way to answering the research questions. Maree (2016) argue that qualitative research aims to understand a phenomenon in its natural setting. In line with this view, this qualitative study aims to understand and interpret DHs' perspectives, feelings, and beliefs in their natural situations. Kumar (2018, p. 171) expresses that

> study designs in each paradigm are appropriate for finding different things. Study designs in qualitative research are more appropriate for exploring the variation and diversity in any aspect of social life, whereas in quantitative research they are more suited to finding out the extent of this variation and diversity.

This qualitative study adopts an inductive approach, meaning that all conclusions that are made are based on the data collected. Merriam and Grenier (2019) state that one of the important characteristics of qualitative research is that it is inductive, rather than deductively deriving a hypothesis to be tested (as in positivist research). I intend to gain a rich and complex understanding of DHs' experiences in implementation of the new subject of Technical Mathematics in technical schools. Creswell (2013, p. 185) asserts that to obtain meaningful qualitative data, "researchers need to gather information by actually talking directly to people and seeing them behave and act within their context". This study was conducted in schools where the researcher directly interacted with research participants in their natural setting to understand the complexities involved in implementing and managing Technical Mathematics. Denzin and Lincoln (2008, as cited in Bansilal, Mkhwanazi and Brijlall, 2014, p. 39) used the same reasoning in their qualitative study, and affirmed that "qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them".

This qualitative research adopts multiple ways of exploring and understanding the phenomenon. The researcher uses individual interviews, focus group observations and document analysis to understand the phenomena through the eyes of the participants. Qualitative data emanates from a variety of methods, such as case studies, key informant interviews, discourse analysis, narratives, ethnography and participant observation (Jensen, 2020; Msomi, 2020). Babbie and Mouton (2006) concur that qualitative research attempts to study human action from the insider's perspective. Myende (2011, p. 32) stresses the need for research participants with the relevant experience, and citing Babbie (2007) who affirms that "Participants in qualitative research are valued and regarded as people who are informed about their context (insiders)." Hence this study selected DHs as they are believed to be experienced in teaching and managing the curriculum, and are trusted by the DoE to ensure implementation of the new subject.

Robson (2002) stated that qualitative research is flexible in that it unfolds and develops as the study unfolds. Hence, the nature of qualitative research is to provide a rich, contextualised illustration of a social phenomenon, as it seeks to understand the type of data collection methods and the underpinning reasons why they were deemed essential for the study. Qualitative research examines human behaviour in the social, cultural, and political contexts in which they occur, and in this study should ensure that the data generated provide a rich description of DHs' accounts in their school contexts. Larkin, Shaw and Flowers (2019) affirm that this approach is beneficial when researchers aim to understand the nature, quality, and context of interventions. Service (2009), in the book review of Strauss and Corbin (1998), elaborates that that through qualitative research, researchers can capture participants' inner experiences of the phenomenon, with meanings formed through natural settings rather than testing variables.

Kumar (2018, p. 59) affirms that "in qualitative research these attributes (specificity, dissection, precision and focus) are deliberately kept very loose so that you can explore more as you go along, in case you find something of relevance". He believes that researchers need to be open-minded and must not 'bind themselves' with restrictions that may limit the ability to explore the phenomenon in its entirety. Neuman (2014, p. 172) encourages adaptive reasoning when one conducts a qualitative study, since

> Flexibility in qualitative research encourages us to continuously focus throughout a study. An emergent research question may become clear only during the research process. We can focus and refine the research question after we gather some data and begin a preliminary analysis.

This study sought to investigates the phenomenon from the participants' perspective in their natural setting, and it might indeed be the case that DHs might want to share more than what I have presumed to be important, that will later inform narrative statements. Hence my choice of positioning my research in a qualitative approach.

Ochieng (2009, p. 14) listed several assumptions of qualitative designs, and these are also used as guidelines in conducting this qualitative study:

1. Qualitative researchers are concerned primarily with process, rather than outcomes or products.
2. Qualitative researchers are interested in how people make sense of their lives, experiences, and their structures of the world.
3. The qualitative researcher is the primary instrument for data collection and analysis. Data are mediated through this human instrument, rather than through inventories, questionnaires, or machines.
4. Qualitative research involves fieldwork. The researcher physically goes to the people, setting, site, or institution to observe or record behaviour in its natural setting.
5. Qualitative research is descriptive in that the researcher is interested in process, meaning, and understanding gained through words or pictures.
6. The process of qualitative research is inductive, in that the researcher builds abstractions, concepts, hypotheses, and theories from details.

This qualitative research is based on extracting DHs' meaning of their own knowledge and practices. As Merriam and Grenier (2019, p. 40) argue, "Qualitative researchers are interested in knowing how people understand and experience their world at a particular point in time and in a particular context". A similar view is shared by Khoza (2019, p. 40), as cited in Creswell (2013) and Maxwell (2018), who asserts that "for the meaningful data on a qualitative research, researchers need to gather information by actually talking directly to people and seeing them behave and act within their context".

In this qualitative study I interacted directly with DHs to understand their practices and knowledge of the phenomenon being studied within its natural setting. This was done through engaging in a conversation with them during the interview process and observing them in the school setting in which they operate, in the classroom in which they teach, to understand how they enact their roles. I chose a qualitative approach with the understanding that DHs have a voice, in order to share their experiences, challenges, and successes. The commitment to give a voice to the participants is dominant in qualitative research; this suggest that its findings may be more inclined to a specific context and cannot be generalised, which again conforms with its principles.

4.5 Research design

According to Kumar (2018), a research design refers to a researcher's procedural plan to formulate and answer questions objectively, accurately, and economically. The research design in this study sets out the specific details of the research enquiry, and describes how the answers to the research questions will be arrived at. In this study, in principle the research design was used as a platform to explain how the researcher generated data from the participants, how the research participants were selected, and how the data generated was analysed and reported to reach the conclusions that emanated from this study.

Bertram and Christiansen (2014) argue that when researchers plan research design, they must decide which research style and data collection methods are most suitable to answer the research question.. Kumar (2018, p. 41) asserts that "the main function of a research design is to explain how you will find answers to your research questions" (p. 41), including the procedures to be used in undertaking the study. The current study sought to apply these principles by developing an inquiry to extract the knowledge and practices of the participants. The research design was used as a guideline that ensured that the research questions were adequately addressed, by scrutinising the questions that were asked of the research participants to generate valid data. In essence, the research design guided the researcher to arrive at trustworthy findings, comparisons, and conclusions. The method of data inquiry used in this study is a case study of three Technical Mathematics DHs who were studied in their schools in the Pinetown District.

4.5.1 Case study

Bertram and Christiansen (2014) assert that there is a range of research styles that could be used when conducting a study. They articulate that the research questions, research objectives, data collection methods and research paradigm are predetermining factors that influence the choice of research style. Informed by the research paradigm, approach and research questions, case study was deemed the appropriate style for this study. Simons (2009, p. 10) outlined core elements of a case study as follows:

> A case study is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, program or system in a 'real life' context. It is research-based, inclusive of different methods and is evidence-led. The primary purpose is to generate in-depth understanding of a specific topic, programme, policy, institution or system to generate knowledge and/or inform policy development, professional practice and civil or community action.

The same was advocated by Yin (2014, 2018), who argued that qualitative study was developed to gain an in-depth understanding of experiences and involvement of real cases in real contexts and situations. In this study, the aim was to gain an in-depth understanding of the DHs' knowledge and practices of implementing Technical Mathematics in their schools. Furthermore, in this study it is of particular interest to understand how and why DHs execute certain practices in the managing and implementation of Technical Mathematics. Yin (2014) also asserted that this approach is more viable when a study seeks to answer the 'How?' and 'Why?' questions.

Cohen et al. (2018) maintained that a case study provides a unique example of real people in real situations. Through exploring the knowledge and practices of DHs implementing Technical Mathematics, this study sought to provide unique insight into their experiences of the teaching, managing and implementing of the new subject since 2016. DHs are deemed to have in-depth knowledge of the enabling factors and challenges, and thus their experiences would not only benefit other DHs and teachers but also the DoE in terms of planning appropriate professional development to ensure the sustainability of the subject in schools.

Kumar (2018, p. 123) believes that the selected 'case' in a case study design becomes the "basis of a thorough, holistic and in-depth exploration of the aspect(s) that you want to find out about". In my understanding, the selected cases ought to offer a deep insight into the phenomenon in question. Hence, exploring three cases of DHs was considered significant, as the research focuses on extensively exploring and understanding individual cases in order to be more precise, as opposed to confirming and quantifying the data.

Cohen, Manion and Morrison (2002, p. 184) listed a number of important strengths and weaknesses embedded in the use of case study. They state that the strengths of case study are that:

- "The results are more easily understood by a wide audience (including non-academics) as they are frequently written in everyday, non-professional language.
- They are immediately intelligible; they speak for themselves.
- They catch unique features that may otherwise be lost in larger scale data (e.g. surveys); these unique features might hold the key to understanding the situation.
- They are strong on reality.
- They provide insights into other, similar situations and cases, thereby assisting interpretation of other similar cases.
- They can be undertaken by a single researcher without needing a full research team.
- They can embrace and build in unanticipated events and uncontrolled variables."

Some of the weakness they pointed out about the use of case study as a research design were that:

- "The results may not be generalizable except where other readers/researchers see their application.
- They are not easily open to cross-checking, hence they may be selective, biased, personal and subjective.
- They are prone to problems of observer bias, despite attempts made to address reflexivity." (Cohen, Manion & Morrison, 2002, p. 184).

In this qualitative study, the researcher understands the benefits of using case study as the research design, and the advantages outweigh the disadvantages. Nevertheless, the disadvantages mentioned were addressed, in that the researcher does not intend to generalise the findings, but to understand the phenomenon from the viewpoint of the participants and their context, which could provide insights to understand what is happening in other contexts. While it might not be possible to entirely limit biasedness – since the researcher is a Mathematics teacher and was teaching in South Africa at the time of piloting Technical Mathematics – adopting a case study approach would be useful to foreground participants' views and opinions and not my own. Different data collection methods were used to obtain enough information to understand and interpret correct inferences from the perspectives of the participants. This cross-checking of participants enhances triangulation of data. Rephrasing questions may yield a better understanding of participants' point of view, which ultimately reduces biasedness in reporting findings, and henceforth restricts false generalisation. Hence, the aim is to gain the richest possible, in-depth understanding of the three cases under investigation with regard to the phenomenon of this study.

4.5.1.1 Multiple case studies

Yin (2014, p. 16) states that case study is "An empirical inquiry that investigates a contemporary phenomenon (e.g., a 'case') within its real-life context, when the boundaries between phenomenon and context are not clearly evident". His understanding is that it seeks to unfold the phenomenon in its natural setting. In this study, using the cases of three DHs helped me to understand the phenomenon from different perspectives or in different contexts, making the findings more compelling, in that their shared experiences and practices might be different or similar, which ultimately adds to the credibility of this study. Stake (2013) argues that multiple cases start with the phenomenon (quintain), which embeds all cases to be studied – which in this study is the three DHs – and to gain a better and deeper understanding, the researcher studies similarities and differences.

Stake (2013) emphasised the importance of paying attention to each case, so that reasonable inferences are drawn. Gustafsson (2017) posits that a case study can be characterised as an in-depth examination of an individual, a group of individuals, or a unit to draw generalizations across multiple units. While in this study the aim is to study a group of people (that is, DHs), the researcher by no means intends to generalise the findings, and thus does not adopt Gustafsson's (2017) view. I am of the view that generalising conclusions is not primarily what a case study aims to achieve in a study. and thus adopt some prominent case study methodologists' (Creswell, 2014; Stake, 2013; Yin, 2014, 2018)) views that in using a multi-case study the aim is to gather an in-depth knowledge of the phenomenon being studied. This study is more concerned with particularising the cases in their contexts than in generalising the embedded cases. Yin (2018, p. 98) averred that there are "general lessons learnt from studying the case(s)".

Creswell (2013) states that a multiple-case design is an exploration of several instrumental, bounded cases by means of in-depth data generation using different sources of information. In this study, the researcher uses different cases to gain a holistic understanding of the phenomenon. In the same way, Merriam (2015) argues that a case study involves providing a comprehensive description and analysis of a defined and limited system. Patton (2015) and Yin (2018) affirm that multiple case study has the added advantage of analysing the generated data in minor cases and across embedded cases. This study allows the researcher to understand and interpret each situation (individual DHs in their context) and across situations (all DHs in their contexts). Gustafsson (2017, p. 4) opines that

> The researcher can choose to make a single case study with embedded units. This means that the researcher is able to explore the case with the ability to analyse the data within the case analysis, between the case analyses and make a cross-case analysis.

The use of multiple case study is also affirmed by Chiesa et al. (2007, p. 10), who state that "Multiple-case study methodology is regarded as more robust than single case study, since cross-case comparisons allow a more vigorous explanation building process and understanding of contextual variables' effects". Urbinati et al. (2019) concur with the use of multiple cases, arguing that it allows the researcher to explore the same phenomenon in different contexts, and thus provides tangible information.

In the context of this study, qualitative case study was employed with three DHs carefully chosen on the premise that they hold a deep understanding of Technical Mathematics implementation, which is the area that this study sought to unravel. The experiences of DHs accounted for understanding the transition phase, where they were introduced to the new subject and expected to implement, teach, and manage it. Samuel's (2008) theoretical framework was used in this study to provide lenses for understanding the DHs' contextual understanding of their agency, hence questioning how they execute their roles. As a new subject, Technical Mathematics needed to be explored in its entirety, through the eyes of the implementers, teachers and managers of its curriculum. The study intended to get an in-depth understanding of the phenomenon (Kumar, 2018), while being sensitive to the DHs' shared experiences.

As stated above, this study was guided by the theoretical framework of Samuel's (2008) Force Field Model, which helped in gaining a multidimensional understanding of DHs' experiences of implementing, teaching, and managing the new intervention. The conceptual framework of the study developed by the researcher was drawn from Shulman's (1987) pedagogical content knowledge (PCK) and Ball et al.'s (2008) mathematics knowledge for teaching (MKT) framework. I then proposed the mathematical curricular implementation (MCI) and mathematics curriculum monitoring (MCM) constructs, to anchor discussions around the research phenomenon of DHs who are teachers and managers of curriculum. The conceptual frame gave lenses for the DHs' cases to be studied holistically. Rule and John (2011, p. 21) affirm that multiple cases are "amenable to study within a common theoretical framework". Understanding of DHs' knowledge and practices afforded me the prospect of unfolding the MKT, PCK, MCI and MCM they possess in their teaching, monitoring, and implementing of the Technical Mathematics curriculum.

4.6 Sampling and sampling methods

In this study, sampling refers to the criteria used to select the population for the study. Sampling of DHs aimed at obtaining the richest possible sources of information to answer the research questions. Cohen et al. (2007) explain that four key factors must be considered in sampling, namely the sample size, the representativeness and parameters of the sample, access to the sample, and the sampling strategy to be used. Gentles et al. (2015) defined sampling as the act, process or technique of selecting a representative part of a population for the purpose of determining characteristics of the whole population. This study employs purposive sampling, which first looked at the subjects that schools offered. Very few schools in Pinetown District offer technical subjects. In the quest of generating in-depth data from the research participants, purposive sampling was deemed appropriate (Ehri et al., 2006).

While Technical Mathematics has been introduced at other schools, the three schools chosen participated in the pilot project for implementing Technical Mathematics, and the three DHs were already working in the selected schools when Technical Mathematics was piloted. The research participants are therefore considered to have in-depth knowledge of the implementation of Technical Mathematics. In this study, I made specific choices regarding people to involve, which was only DHs who have engaged with Technical Mathematics since 2016. It was imperative that only schools which were also involved in the first lot of the implementation phase were selected, because they were deemed to have rich information about the phenomenon being studied as it has evolved since its inception. Johnson, Adkins, and Chauvin (2020, p. 141) insisted that "Qualitative researchers recognize that certain participants are more likely to be 'rich' with data or insight than others, and therefore, more relevant and useful in achieving the research purpose and answering the question at hand". The participants chosen for this study are deemed to have more insight than others, since they were involved with implementing and managing Technical Mathematics since its pilot stage to date.

Omona (2013) asserts that purposive sampling means that the researcher makes specific choices about which people, groups, or objects to include in the sample. Similarly, Creswell and Clark (2017) state that purposive sampling necessitates that the researcher selects the most appropriate groups or individuals with the necessary experience, who are knowledgeable about the phenomenon that the study seeks to investigate. In the same way, Johnson et al. (2020) argue that in qualitative research, sampling design is not random but intentionally structured to encompass the most appropriate participants within the most relevant contexts for addressing the research question.

Hence, this study samples three DHs who are also teaching Technical Mathematics. They were purposively selected in relation to their management position, their teaching role, and experience of implementing Technical Mathematics. Creswell et al. (2011) affirm that researchers need to establish firm inclusion and exclusion criteria that will guarantee the selection of a suitable target population that is phenomenologically relevant to their study. It is important to note that in order to get an in-depth understanding of the experiences of the implementation of Technical Mathematics, this study needed DH participants who are teaching Technical Mathematics and managing the curriculum, and not teachers who are not DHs.

4.7 Methods of data collection

Methods of data collection refers to the instruments and measures used to collect data. This qualitative study uses multiple data collection methods, which are individual-based one-to-one interviews, focus group interviews, observations, and document analysis. Cheryl and Creswell (2018, p. 98) argue that

> A hallmark of a good qualitative case study is that it presents an in-depth understanding of the case. In order to accomplish this, the researcher collects and integrates many forms of qualitative data, ranging from interviews to observations, to documents, to audio-visual materials.

Cheryl and Creswell (2018) felt that relying on one source of data is not sufficient and does not establish in-depth data. Cohen et al. (2018, p. 469) state that

> selecting the instrument(s) for data collection, like deciding on methodologies is not a matter of preference, arbitrary or automatic decision making, but, like other aspects of research, is a deliberative process in which the key is the application of the notion of fitness for purpose.

The methods that were used in this study correlate with the qualitative approach underpinning it. The aim was to generate data which is contextualised in DHs' natural settings. Hence, the data collected was primary data that I collected from three Technical Mathematics DHs in their different schools. Contrary to the method used in this study, secondary data emanates from studies that have been done in the past, which is distinctive in that the researcher is not part of the meaning-making process. Hence, generating 'first data' allowed me to choose data collection instruments deemed appropriate for this qualitative multi-case study.

4.7.1 Interviews

An interview is a conversation between a researcher and participant/s on a subject of interest to both. It is used to unearth in-depth data, unveiling participants' views on the phenomenon that the researcher seeks to explore. A well-structured interview allows for meaningful conversation, where the participants introspect about their behaviour and innermost feelings on the subject. Pickard (2007, p. 117) alludes to the fact that "interviews are used when the researcher is seeking qualitative, in-depth, descriptive data and when the nature of the data may be too complicated to be asked and answered easily". The explicit drive is to gather specific information from the participants (Singh, 2014). In this study, face-to-face interaction was used to probe answers from the research participants, which allowed me to ask follow-up questions about responses that were ambiguous or open to many interpretations. This ensured that I understood the views or opinions expressed and captured as intended by the participants.

Kothari (2004, p. 97) makes a distinction between a personal interview and telephonic interview (which these days could be through conference video calls on different platforms such as Zoom, Microsoft Teams, and Skype), asserting that

> Personal interview method requires a person known as the interviewer asking questions generally in a face-to-face contact to the other person or persons. (At times the interviewee may also ask certain questions and the interviewer responds to these, but usually the interviewer initiates the interview and collects the information.)

Hence, one of the mainstay data generation tools used in this study was personal interviews, where participants were asked questions by the researcher both individually (one-to-one) and as a group (focus group), also face to face (Babbie, 2013).

Cohen et al. (2007), Gugiu and Rodríguez-Campos (2007), Patton (2015) and Yeong et al. (2018) refer to the importance of the interview protocol in qualitative data, affirming that researchers need to align interview questions with the research questions, and construct an inquiry-based conversation. Yeong et al. (2018, p. 2701) assert that "an interview protocol increases the effectiveness of an interview process by ensuring comprehensive information is obtained within the allocated time". I adhered to the interview protocols to ensure that better understanding was gained about issues related to the participants' experiences, and critical factors attributed to the phenomenon could be identified. Several interview techniques help to facilitate discussion of the researcher's topics, and the type of interview technique used in this study was the semi-structured interview.

4.7.1.1 Semi-structured interviews

During the initial phase, all three participating DHs were interviewed in their schools in the first phase, using semistructured one-on-one interviews. Interestingly, the interview in School A was conducted over two days, exceeding the initially allotted 45 to 60 minutes because the DH needed more time to discuss the issues.

The researcher used semi-structured interviews, which were formulated from open-ended questions (Appendix H). This allowed the researcher to ask questions that the researcher deemed suitable to probe DHs' knowledge and practices of the implementation of Technical Mathematics, while being sensitive to the unknown experiences that they hold. This also enabled the research participants to expand on, clarify and rectify assumptions that may be misinterpreted in the absence of open-ended questions. Cohen et al. (2018, p. 511) assert that the semi-structured interview is "an open situation, having greater flexibility and freedom". It was necessary to develop questions that were standard for all participants, while at the same time allowing some flexibility. Cohen et al. (2018. p. 511) believe that in a semi-structured interview "the topics and questions are given, but the questions are open-ended, and the wording and sequence may be tailored to each individual interviewee and the responses given, with prompts and probes". The aim is to ensure that research participants share valuable information and perceptions without being limited by any constraints. For example, if they were to write down responses they might be careful of their wording, to suit a standard that they might presume the researcher expects. A similar view is shared by Creswell (2014), that formulating questions that are standardised enhances the trustworthiness of the findings.

In this study I asked open-ended questions to maximise the opportunity for DHs to share their knowledge and practices comfortably while being comfortable to express themselves. Drever (1995) and Ruslin et al. (2022) view semi-structured interviewing as a very flexible technique for small-scale research. The authors argue that it is not suitable for studies involving large numbers of people, but is most helpful in mini-studies and case studies, as used in this qualitative study. This study focuses on the cases of three DHs who were deemed appropriate for eliciting unconscious and deep underpinnings related the phenomenon. Hence, the method of data collection used was semi-structured interviews and participants were interviewed using both one-to-one and focus group interviews.

4.7.1.2 Focus group interviews

Birmingham and Wilkinson (2003, p. 90) define a focus group as a "form of qualitative method used to gather rich, descriptive data in a small group format from participants who have agreed to focus on a topic of mutual interest. The emphasis is on understanding participants' experiences, interests, attitudes, perspectives and assumptions". A holistic understanding within the context of DHs' experiences was gained through conversations with participants in the focus group discussion. The aim of the focus group interviews with DHs was to elicit their first-hand experiences of piloting and implementing the new subject in the FET phase in their respective schools. Unlike the semi-structured interviews that were conducted one-on-one, focus group interviews allowed for shared meaning and shared experiences, which further elicited the experiences of DHs from different school contexts. In this study, focus group interviews were conducted after one-on-one interviews, classroom observations, and document analysis to ensure a comprehensive exploration of the research topic. As a result of this approach, the study findings were deepened and contributed to a more robust analysis of the study results.

Vaughn, Schum and Sinagub (1996) and Sim and Waterfield (2019) argue that focus groups are conducted to ascertain participants' point of view. They assert that the goal of focus groups is not explicitly to reach consensus between participants, but rather to find out each participant's point of view. In this study, participants were encouraged to express their unique experiences so that different points of view were heard, not necessarily to weight the strength of each point of view expressed by each participant. The focus group discussion gave them a platform to share their experiences among each other. The group consisted of three DHs from selected schools, and the idea of choosing a small group was to allow each participant to feel comfortable to share their experiences in a meaningful and honest way. Creswell (2005, p. 215) argues that focus groups can be used to "collect shared understandings from several individuals as well as to get the views from specific people". The focus group interviews were recorded, transcribed and analysed, as discussed in the data analysis section (DiCicco-Bloom & Crabtree, 2006).

4.7.2 Observations

The third method of data generation that was used in this study is observations. Cohen (2011, p. 456) states that "observations is about looking and noting systematically people, events, behaviours, settings, artefacts, routines and so on". Kothari (2004, p. 96) affirms that "Observation becomes a scientific tool and the method of data collection for the researcher, when it serves a formulated research purpose, is systematically planned and recorded and is subjected to checks and controls on validity and reliability". The observation method requires a researcher to seek information by observing the participants directly, without asking questions, or to seek clarity about occurrences. This method challenges the researcher to be autonomous and record findings as they are.

The second phase involved three participating Technical Mathematics DHs, so a total of three lessons were observed, in School A (Grade 11-Evaluating trigonometric expressions), School B (Grade 12-Complex numbers), and School C (Grade-Application of logarithm laws). Through observations I was able to observe the participants in their natural setting. In this way, I gained an explicit understanding of the day-to-day practice of the participants. I anticipated that DH's knowledge of Technical Mathematics might inform what their role and classroom practices. I used an observation schedule that I developed, that was aligned with the research questions and objectives and the theoretical and conceptual framework of the study. This was also intuitively guided by the research design. Classroom observations were used to generate qualitative data about DHs' actual daily practices when teaching Technical Mathematics. The DHs were also observed in enacting their management role, through their social interaction with members of staff and the SMT.

4.7.3 Document analysis

Bowen (2009, p. 27) defines document analysis as "a systematic procedure for reviewing or evaluating documents both printed and electronic (computer based and Internet transmitted) material". In this study (Third phase) I examined DHs' files which they use to conduct their daily routine of managing and teaching Technical Mathematics. The document analysis in the study involved scrutinising various administrative and instructional documents, including the DHs' files, curriculum monitoring tools, meeting minutes, learners' files, Programme of Assessment, and teachers' files. Document analysis in this study aimed to gain insights into leadership decisions, curriculum alignment, institutional (school) priorities, learners' performance trends, assessment practices, and instructional strategies. By systematically examining these documents, the study sought to inform decision-making processes and identify areas for improvement in implementing the Technical Mathematics curriculum.

Document analysis was used to triangulate the findings that emanated from other data sources (interviews and classroom observations) used in this study. Mackieson, Shlonsky and Connolly (2019, p. 4) affirm this, stating that the aim of triangulating by combining other data collection methods with document analysis is "to supplement and corroborate findings across different data sets with a view to reducing the impact of the potential biases in a study". The aim was to devise a comprehensive understanding of DHs' management and implementation of the curriculum. Documents in the DHs' and teachers file included the annual teaching plan (ATP), programme of assessment (POA), and school-based assessment (SBA) moderation tools. Bowen (2009, p. 29) concurs that "the rationale for document analysis lies in its role in methodological and data triangulation, the immense value of documents in case study research, and its usefulness as a stand-alone method for specialised forms of qualitative research". The challenge with document analysis was that DHs were reluctant to share essential documents like minutes of meetings, arguing that this was for protection of critical information that should not be in the public domain. These documents could have helped in gaining a deeper understanding of the issues pertaining to curriculum implementation, whether reflecting negative or positive experiences.

4.8 Data analysis

Cheryl and Creswell (2018, p. 100) state that in case studies, the data analysis integrates thematic and contextual information, explaining that

> when multiple cases are chosen, a typical format is to provide first the detailed description of each case and themes within the cases, called a within-case analysis, followed by a thematic analysis across the cases, called a cross-case analysis, as well as assertions or an interpretation of the meaning of the case.

The assertions in the context of this study include both instrumental and intrinsic ones, which are derive meaning from the case or learn about unusual situations, respectively. Data analysis in this study was informed by Cheryl and Creswell's (2018) understanding, drawn from different scholars who contributed to meaning making in qualitative data (Merriam, 1998; Merriam & Tisdell, 2015; Stake, 1995; Yin, 2009, 2014). Each case study was analysed to illustrate its merits and draw out prevailing themes. Thereafter themes across all cases were analysed with the aim of understanding common issues across different contexts.

My understanding of data analysis is that it is a process of understanding the data emanating from the research, that serves to organise and interpret the information in a way that readers are able to follow. In this study, thematic analysis, case and cross-case analysis and framework analysis were used to understand the research findings. The research questions were used to formulate initial themes, that were used to analyse and interpret the data. Other themes and subthemes emerged from the data that was generated from the interviews, observations and document analysis. This allowed me to be flexible and ensured that I did not leave out data that may not have been directly relevant to the research questions I initially posed. Theoretical and conceptual frameworks provided lenses through which to understand the DHs' PCK, MKT, MCI and MCM derived from the literature review, as established in Chapters 2 and 3. Hennink et al. (2020, p. 45) affirm that

> Qualitative research provides opportunities to locate the genesis of a phenomenon, explore possible reasons for its occurrence, codify what the experience of the phenomenon meant to those involved, and determine if the experience created a theoretical frame or conceptual understanding associated with the phenomenon.

Hence, the steps taken to analyse the data were to transcribe and code the data and categorise it into themes.

4.8.1 Data transcription

Classroom observations and interview data that were in the video recording were transcribed, meaning that the visual data was changed to textual data, providing a detailed account of what transpired. The data was then categorised into themes that emerged. I watched videos and listened to the interviews repeatedly to capture and validate what transpired. My engagement with transcribing the data gave me an opportunity to understand more about the experiences shared by the DHs, consequently helping me to generate themes. I thus agree with Lester, Cho and Lochmiller (2020, p. 99), who indicate that "transcription serves as an opportunity to become familiar with a data set. This familiarity deepens a researcher's understanding of the participants' perspectives and supports them in understanding the data set in a way that accelerates analysis later on." These authors assert that researchers need to generate their own data transcripts so that they can become immersed in the data emanating from their study.

4.8.2 Coding the data

Williams and Moser (2019, p. 45) state that "coding in qualitative research is comprised of processes that enable collected data to be assembled, categorized, and thematically sorted, providing an organised platform for the construction of meaning." They assert that coding is a key structural procedure that enables the researcher to analyse the data and move one step closer to achieving the study's aims. The data generated through one-to-one interviews, focus group interviews, classroom observations and document analysis were coded into distinct categories that emerged from the data transcripts.

Hennink et al. (2020) view codes as issues, topics or concepts that are present in the data, and affirm that from a methodological perspective, developing codes allows you to identify the issues raised by participants and give these issues a name (or code), thereby capturing the emic perspective of the research issues. They add that "From a practical perspective, developing codes helps you break-up data into smaller but meaningful parts for analysis" (Hennink et al., 2020, pp. 218-219). I had to read and listen to the interview transcripts repeatedly to ensure that the coded data correlated with the transcribed data. I then used computer-assisted qualitative data analysis software program NVivo to organise and match the developed codes with themes.

4.8.3 Categorising data into themes

Tatira (2020, p. 91) states that "thematic analysis is a common form of data analysis in qualitative research which attempts to pinpoint, examine and record notable patterns within a data set." In this study, themes related to the research focus were generated from the analysed data. Kumar (2018, p. 36) explained that "when analysing data in qualitative research, you go through the process of identifying themes and describing what you have found out during your interviews or observation rather than subjecting your data to statistical procedures". Generation of themes in this study was also guided by the literature review and theoretical framework. Themes that emerged from the interviews and observations were categorised. The data analysis was enhanced by use of NVivo software. Silverman (2017, p. 356) highlights the advantages of using qualitative data analysis software tools: "The tool allows you to organize and inspect data, and record your own thoughts about it, in ways that would be very time consuming, perhaps even impossible, with manual methods". Like Yin (2014), who emphasises that NVivo does not do the analysis on its own, Silverman (2017) states that having qualitative data analysis software tool does not mean that it will do the analysis for you. The researcher must still carry out analysis to give meaning to the data. Therefore, the tool was adopted to enhance the generation of codes and themes developed by the researcher after engaging with the data.

My understanding of a theme is that it seeks to capture emerging patterns that are deemed important in the study to answer the research questions. Weber (1990, p. 15) states that thematic analysis "is a process by which many words of a text are classified into fewer categories/themes". Interviews were analysed inductively, which allowed the data to speak through the themes that emerged from them. Thematic analysis made it possible to code the data and then combine related codes into themes. Themes allowed the voluminous data to be reduced, to capture only meaningful specifics that allowed the study objectives to be reached while acknowledging emerging themes.

In this study I used the qualitative software program NVivo (Figure 4.1) to identify themes and phrases that matched, to extract the DHs' shared experiences. I then looked for patterns and matching codes to formulate themes or issues that were then applied across all cases. Analysing the data was through description of the individual DH's cases, and thereafter by means of cross-case analysis (Cheryl & Creswell, 2018). More details on how the data analysis process unfolded are provided in Chapter 5.

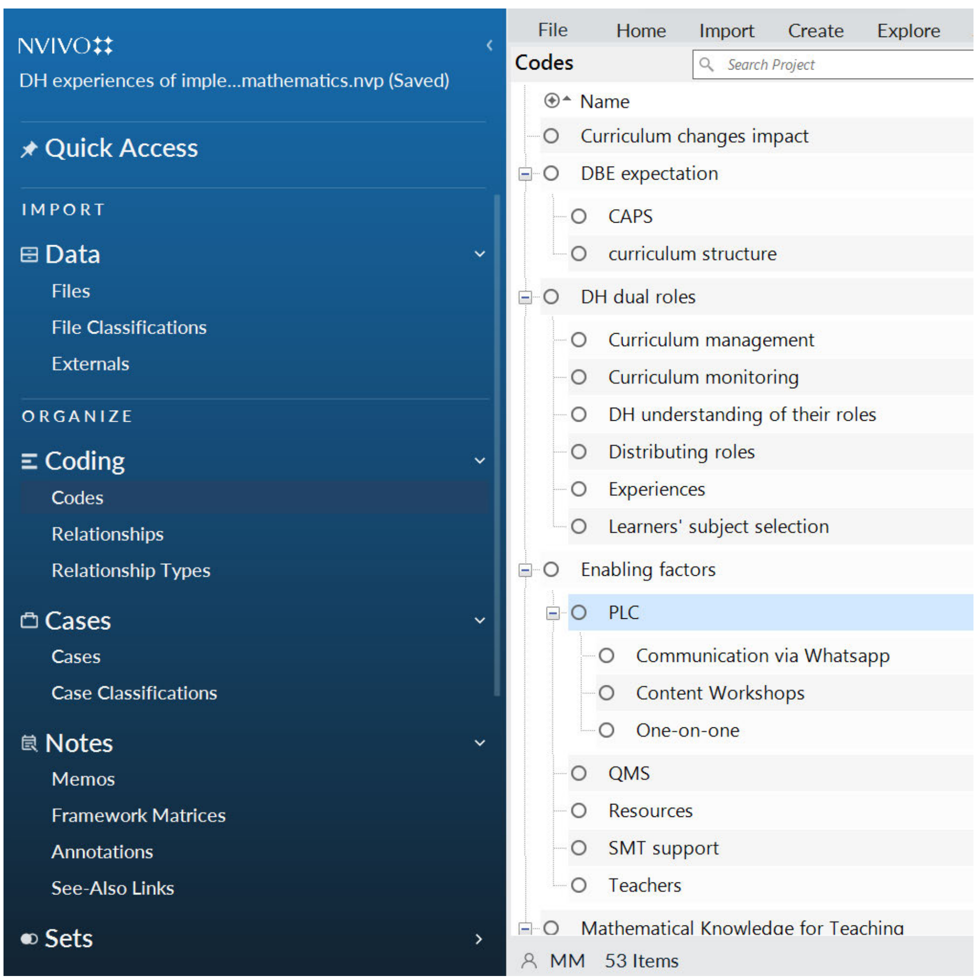


Figure 4.1. ***A screenshot of the interface for the NVivo software.***

4.9 Ethical considerations

Ethical considerations are a control mechanism of what is acceptable and not acceptable when carrying out research. They thus inform the researcher of boundaries that needs to be set between the researcher and participants, and the acceptable behaviour expected of the researcher when conducting a study. In this way, they safeguard the research participants from any harm or discomfort. The participants are guaranteed the freedom to withdraw from the study at any point, should they wish to do so. Cohen et al. (2011, p. 112) state that "Educational researchers must take into account the effects of the research on participants; they have a responsibility to participants to act in such a way as to preserve their dignity as human beings". To protect the identity of participants and the research sites, pseudonyms were used in the reporting of findings; this ensured that participants' confidentiality was guaranteed in this study (Cohen et al., 2011). School principals, DHs, learners and parents or guardians were guaranteed anonymity, and this was disclosed in the letters to the gatekeepers.

Israel and Hay (2006, p. 132) affirm that "researchers need to protect their research participants; develop a trust with them; promote the integrity of research; guard against misconduct and impropriety that might reflect on their organizations or institutions; and cope with new, challenging problems". In this study all protocols for conducting research and ethical considerations were adhered to. The researcher identified confidentiality, anonymity and informed consent as important ethical aspects that needed to be addressed (Creswell, 2014), to ensure that fairness was established before the researcher gathered information. The researcher made participants aware of their rights and that their confidentiality and anonymity were guaranteed.

Creswell (2014) also emphasises that personal disclosure, authenticity, and credibility of the research report need to be maintained and protected. He asserts that "attention needs to be directed toward ethical issues" in different stages of the research, that is, "prior to conducting the study; beginning a study; during data collection and data analysis; and in reporting, sharing, and storing the data" (p. 132). Creswell (2014) stresses the need for researchers to anticipate ethical issues that may arise during course of their studies. Hence, there were different stages in the process that I undertook to get permission from the gatekeepers, as outlined below.

First, I sent a formal letter to the KZN DoE to request permission to conduct my research in their institutions. Approval to collect data was duly granted (Appendix A). I then sent a request to the University of KwaZulu-Natal Humanities and Social Sciences Research Ethics Committee (HSSREC) for ethical clearance (Appendix B). The HSSREC granted full approval after careful consideration of the study proposal (protocol reference number: HSSREC/00003217/2021).

Next, I purposively selected the study contexts, which are three schools in Pinetown District. The school principals were then sent a request for permission to conduct the study in their schools. Each granted permission for the study to be conducted (Appendix C). I then approached Technical Mathematics DHs to voluntarily participate in the research, through informed consent letters that I sent to them (see Appendix D). All three DHs voluntarily agreed to participate in the study. I explained the nature of the study, and that it involved audio-taped interviews, videoed observation of their classes with learners, and document analysis.

Informant assent forms were then sent to learners, for them to give permission for me to observe the teaching and learning in a Technical Mathematics lesson that they were present in (see Appendix E). Learners gave permission for the researcher to conduct the study. Although learners were not participants in this study, it was deemed necessary to seek their consent since the researcher was going to be in their space while observing DHs' enacting their roles in the classroom.

Lastly, I sent a parental consent form to the parents/guardians of the learners to request permission for their child to participate in the research. Their permission was necessary as learners are minors, and their parents' consent safeguarded the learners. Parents agreed for their children to participate in the study (see Appendix F).

Confidentiality of participants' inputs was explained; it was guaranteed that inputs would not be attributed to individuals, but reported only as a population member opinion. Participants were informed that their involvement or participation in the study was purely for academic purposes, and that no financial benefits were involved. The research participants attested to the fact that the information presented to them about the nature of the research and expectations was simplified and understandable, with details of procedures explained to their satisfaction.

4.9.1 Rigour and trustworthiness

I used Lincoln and Guba's (1986) construct to detail how rigour and trustworthiness were ensured in this study. They suggested that for qualitative research to be trustworthy, it should encompass the four criteria of credibility, transferability, dependability, and confirmability. Using diverse sources, cross-checking and verifying sources of information ensures trustworthiness in this qualitative research (Hayashi Jr, Abib, & Hoppen, 2019). Similarly, this study employed diverse data collection methods. Bertram (2008, p. 69) states that "trustworthiness and rigor are important at both the level of data collection and description, and at the level of data analysis". She asserts that trustworthiness of data collection could be guaranteed using recorded interviews, which this study incorporates. Moreover, following up on interviews for clarification on concepts shared by DHs and the use of member checks assisted in strengthening the trustworthiness of the study (Cohen et al., 2011). Figure 4.2 is a model that shows the criteria for determining trustworthiness in a qualitative study, adapted from Murphy and Yielder (2009), who refined Lincoln and Guba's (1992) model. Murphy and Yielder (2009, p. 66) argue that trustworthiness is reflexive, maintaining that it is "more appropriately displayed as a circular dynamic process, rather than the traditional linear representation … enables the researcher to gauge each part both during and after the study (reflexivity)". I intuitively used this model to ensure that the criteria of trustworthiness were met in this study, as discussed in the sub-sections that follows.

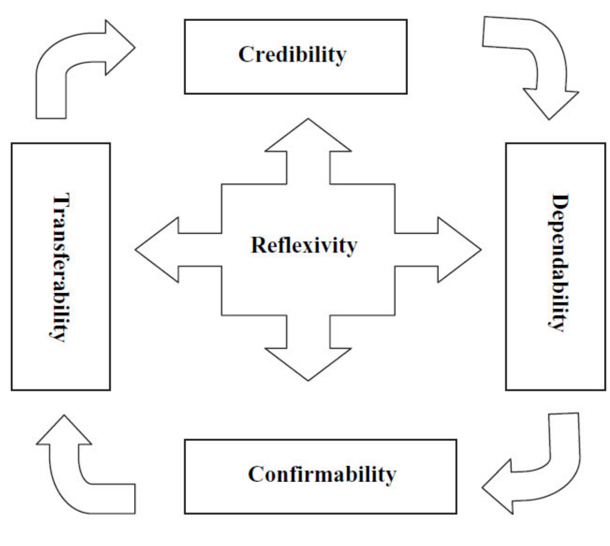


Figure 4.2. *Murphy and Yielder's (2009) Proposed model for the assessment of trustworthiness in qualitative research (adapted from Lincoln & Guba,1985).*

4.9.2 Reliability and credibility

Macnee and McCabe (2008) defined credibility as the extent of truthfulness in the research findings, and Lincoln and Guba (1985) assert that it indicates how plausible the conclusions are that are drawn from the research participants' point of view. Stahl and King (2020, p. 26) concur that its seeks to answer the question of "How congruent are the findings with reality?". Lincoln and Guba (1985), Noble and Smith (2015), and O'Kane, Smith, and Lerman (2021) claim that to establish trustworthiness in a research study, credibility needs to be ensured by the researcher. Cope (2014, p. 89) suggests that "Credibility is enhanced by the researcher describing his or her experiences as a researcher and verifying the research findings with the participants". The researcher needs to establish his or her engagement with the research and clearly state the methods used in data generation, while accounting for any shortfall in the research. Terre Blanche et al. (2006) believe that credible and believable findings are generated by credible research. Flick (2018) and Mayer (2015) reject the understanding of reliability as frequently repeated data collection leading to the same data and results. Similarly, Mohajan (2018) and Wiersma and Jurs (2009) argue that qualitative research is conducted in participants' natural settings, and hence it is less probable for findings to be replicable. I agree with Flick's (2009, p. 387) opinion that "if this form of reliability is used it may be more convenient to mistrust rather than to trust the dependability of the data".

Whereas reliability is ensured in this study, there are elements of qualitative data that are tricky to replicate. The researcher therefore used member checks, where research participants were involved in verifying that the data captured was what they intended to share, and eliminated the researcher's voice in interpretation of data. As Creswell (2009, p. 191) clarified, "the final report or specific description or themes are taken back to the participants". I followed the same procedure where participants confirmed that the reported data captured their shared thoughts and experiences. This was also congruent with what Loh (2013) refers to as ensuring 'verisimilitude', where the researcher provides a detailed analysis of transcripts and interpretation/s for them to verify and remark on whether the presented information is articulated correctly, while correcting misinterpreted information. This correlates with the objectives of doing member checks, with Anney (2014, p. 277) stating that

> the aim is to eliminate researcher bias when analysing and interpreting the results. This means that the analysed and interpreted data is sent back to the participants for them to evaluate the interpretation made by the inquirer and to suggest changes if they are unhappy with it or because they had been misreported.

In this study, I made efforts to ensure that the phenomenon under investigation were depicted accurately, which was done by using triangulation. Cohen et al. (2011) and Daniel (2019) assert that credibility could be ensured by using triangulation in a qualitative study, which refers to generating data from multiple sources. Stahl and King (2020, p. 26) add that "one method of promoting credibility is through the various processes of triangulation. Roughly stated, triangulating means using several sources". In this study I used three data generation methods: interviews (one-to-one and focus group), observations and data analysis.

Yin (2014) attests that the goal of reliability is to minimise the errors and bias in a study. The researcher has to be precise in conducting the study and reporting the findings, such that if another researcher has to follow the same guidelines for the same or a similar study, similar findings could be drawn. Moreover, this study was conducted in three different contexts, which are three technical schools in Pinetown District. This was to ensure that the researcher gained sufficient information on the implementation of Technical Mathematics in schools within the same district. Stahl and King (2020, p. 26) affirm that environmental triangulation assures credibility in qualitative study, and is about "using more than one situation or context to study the intended focus". Khoza (2019, p. 49) asserts that

> measuring understanding is complex in its nature because it is within the individual and who holds information decides when and how it can be voiced out. In essence, reliability is relative, mainly because the interpretation of data may vary from researchers to researchers. This implies that they lack objectivity and are dispassionate, thus this violates the credibility of the research.

I concur that whereas credibility in qualitative study is a delicate subject to sustain, there are measures that the researcher has engaged in this study to ensure that it is maintained.

4.9.3 Transferability

Lincoln and Guba (1985, p. 4) define transferability as "the degree to which the results of qualitative research can be transferred to other contexts or settings with other respondents. The researcher facilitates the transferability judgment by a potential user through thick description".

Huberman and Miles (2002, p. 52) view generalisation as "the extent to which one can extend the account of a particular situation or population to other persons, times, or settings than those directly studied". In this qualitative study I provided a full account of the study data collection methods, including the research context, inclusion and exclusion criteria used to select research participants, participants' background and the reasons for their selection. This view is supported by Hammarberg, Kirkman and de Lacey (2016), who affirm that transferability ascertains the applicability construct in a qualitative study, with the notion that other researchers are able to verify and apply the research findings to other contexts.

Since the study was conducted in Pinetown District, the use of the Technical Mathematics CAPS ensured that the DHs had the same guidance tool as used in different contexts outside the district. They are all expected to use CAPS in their implementation of Technical Mathematics. Districts also share the same ATP and POA, and schools thus follow a uniform, standard procedure in teaching the subject. Nevertheless, the study includes the experiences of the curriculum implementations, and experiences may differ as they are relative to individual school context and other factors relating to the DHs' attributes. As articulated by Stahl and King (2020, p. 27), the transferability proposition "is somewhat tricky, given that by design qualitative research does not (cannot) aim for replicability". Whereas this was the case in this study, I proposed that the data emanating from it could be used to understand the implementation of Technical Mathematics, and that it was essential that the results of this study found a good use in other school contexts, where they can relate to the challenges and enabling factors embedded in the implementation of Technical Mathematics.

Kyngäs, Kääriäinen, and Elo (2020) distinguished transferability and generalisation, in that the terms cannot be used interchangeably in a qualitative study. They assert that "transferability is also concerned with how readers will extend the results to their own situations, whereas generalisation covers the extension of results from a sample to a broader population" (p. 47). This study does not aim to generalise its findings to other contexts, but to understand the uniqueness of the DHs' experiences in their contexts. Nevertheless, the experiences learned from research participants could be used to inform discussions around the implementation of Technical Mathematics in other contexts.

4.9.4 Data dependability

Moon et al. (2016, p. 2) define dependability as "the consistency and reliability of the research findings and the degree to which procedures are documented, allowing someone outside the research to follow, audit, and critique the research process". This understanding of dependability is shared by Denzin and Lincoln (2005), that qualitative research uses dependability in conjunction with reliability to ensure a valid inquiry audit. Amankwaa (2016, p. 122) cited Lincoln and Guba (1985), who state that "The purpose is to evaluate the accuracy and evaluate whether or not the findings, interpretations and conclusions are supported by the data". This means that the researcher provides and explains all instruments used for scrutiny by other researchers, to ensure that the conclusions are supported by the findings emanating from the generated data.

Whereas the aim of inquiry audit is not entirely on repeating the study in the same context, the general assumption is that if the same research procedures are followed by different researchers, they must yield the same conclusions. Consequently, I strengthened the dependability of this study by providing a detailed research design that was adhered to, for other researchers to follow if they intend to carry out similar studies and to scrutinise the current study. Chiororo (2020, p. 80) cites Tobin and Begley (2004), who affirm that "the rigour and dependability of qualitative research involves demonstrating a logical understanding of how the research was conducted, including the chosen methods and, most importantly, the need for the research".

According to Maree (2016), the reliability and validity of qualitative data depend on the data's trustworthiness, the methodology itself, and how it is executed. This study involved member checks and triangulation of the data collection methods. Also, the extent to which research procedures are formulated and followed by the researcher strengthens the dependability of the research findings. In this study I constantly involved the input of the supervisor to ensure that the research structure strictly adheres to qualitive research protocols. This was done at the stages of the research proposal, proposal review committee, research design, data generation and reporting and data analysis. The main objective was to safeguard accuracy throughout the research process, and increase the transparency of this study. Flick (2009) also affirms that dependability is checked through the process of auditing, where the researcher ensures that findings are grounded by the data by selecting appropriate sampling.

4.9.5 Confirmability

Confirmability is the degree to which any other researcher could easily draw similar conclusions given the same data and research context (Lincoln & Guba, 1985; Tuval-Mashiach, 2021). Cope (2014) views confirmability as a process that is concerned with whether the findings mirror the experiences and ideas of the participants, and ensuring that the position of the researcher does not influence the findings. According to Haven and Van Grootel (2019, p. 238), "confirmability regards whether the analyses of the data was coherent and whether the interpretations based on that data were fair". They concur with Lincoln and Guba's (1985, p. 290) understanding of confirmability, that it seeks to answer question of "are the findings a product of participants' responses and not the researcher's biases, motivations, interests, or perspectives?". This means that the research findings solely express the views of the research participants, and the researcher does not impose their view or opinions on the subject. This requires researchers to be objective when reporting on the findings. In this study the researcher gave a full account of the cases of three mathematics DHs', where direct quotations were used to indicate participants' views and details of one-to-one and focus group interviews were captured word for word (Merriam & Tisdell, 2015). Classroom observations were cross- validated by the research participants to confirm that the researcher captured what transpired in the classroom. Nowell et al. (2017, p. 8) suggests that the researcher needs to keep records about the "development and hierarchies of concepts and themes" to ensure that confirmability is established.

The data presented in this study was derived from participants' responses to questions they were asked during data collection. I used triangulation to ensure that conclusions arrived at are compatible with the generated data. As mentioned earlier, member checking was also used to guarantee confirmability, where participants were given their interview transcripts to verify that the data that was captured expressed their original views on different subjects, thus confirming the accuracy of my interpretation. In addition, interview questions were asked in different ways to ensure that participants' responses were consistent. Observations enhanced confirmability, in that the researcher was able to understand whether the DHs' responses matched what transpired during classroom observations, and not given to impress the researcher. In this way, triangulation was used to cross-validate generated data. Cohen et al. (2017) assert that in the study of a certain aspects of human behaviour, two or more methods of collecting data should be used to confirm the authenticity of the research findings.

4.10 Conclusion

This chapter discussed the interpretivist research paradigm in detail and why it was deemed essential in this study, and then outlined the nature of qualitative research and why it was used. This chapter detailed the design and the methodology used to answer the research questions, and explained the use of the case study design and how it relates to this study. The purposive sampling of three mathematics DHs as the research participants was detailed. Methods of data generation by means of semi-structured interviews, focus group interviews, observation and document analysis were discussed. This chapter also explained the sampling method used to select the context of the study and the research participants, and the process of gaining access to the gatekeepers. The method of thematic analysis used to interpret the data was discussed, with application of NVivo as a computer-assisted qualitative data analysis software program to identify themes and phrases that matched, in order to extract the DHs' shared experiences. How trustworthiness was ensured in this research study was also explained.

Chapter 5

Presentation and analysis of the data

5.1 Introduction

The previous chapter discussed the choice of using a qualitative approach and the interpretive research paradigm. It further elaborated the methodology that paved a way to answering the research questions. Chapter 4 also outlined the choice of data collection methods, including the selection and exclusion criteria used to identify ideal participants for the study. The context of the study was detailed, and purposive sampling of three mathematics DHs was explained, including selection of the school context. Ethical considerations were detailed, outlining how participants' autonomy was safeguarded by the researcher.

This chapter seeks to provide an in-depth presentation and analysis of the data emanating from the one-on-one interviews, focus group interview, classroom observations and document analysis. Data generated from this study using one-on-one interviews are reported verbatim, to ensure that participants' shared experiences capture their feelings about the phenomenon in question. This chapter presents a comprehensive thematic analysis of the data from the interviews, which were audiotaped and transcribed, and then coded. Responses of DHs from three different schools were grouped according to themes that emerged from analysis using NVivo.

The main aim of this study, as detailed in Chapter 1, was to explore DHs' knowledge and practices of implementing Technical Mathematics.

The following critical research questions were explored:

1. What are the DHs' practices and knowledge of managing, implementing and teaching Technical Mathematics?
2. How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics?
3. Why do DHs enact their roles in the way they do?
4. What factors hinder or enable DHs in the implementation of Technical Mathematics?

5.2 Participants' biographical information

Biographic information of the research participants is presented in Table 5.1, including age, teaching experience, experience as a DH and teaching qualification/s. The aim was to understand the DHs' background information, including their school context and experience as Technical Mathematics teachers.

Table 5.1 Participants' bibliographical information

	Participant A	**Participant B**	**Participant C**
Participant (pseudonyms)	Mr Alpha	Mrs Beta	Mr Gamma
Age (years)	52	45	49
No. of years as DH	14	7	9
No. of years teaching Technical Mathematics	6	6	5
School quantile	5	4	4

In South Africa, all schools are divided into five groups, known as quintiles, largely to allocate financial resources. A school's quantile is determined by measures of average income, unemployment rates, and literacy levels in its area based on the socioeconomic status of its community (Dieltiens, & Motala, 2014). A non-fee-paying school in Quintile 1 to 3 receives more government funding per learner than a fee-paying school in Quintile 4 or 5 (Ogbonnaya & Awuahu, 2019).

5.3 School context

Three technical schools were selected as study contexts, on the basis that offer Technical Mathematics and their DHs are teaching the subject. The criteria used by the researcher were then subjected to scrutiny and three schools were conveniently selected based on their access and proximity. Bertram and Christiansen (2014, p. 59) state that "sampling includes making decisions about which people to include in the study. Researchers need to decide how many individuals, groups, or objects (such as schools) will be observed". Dodgson (2019) alludes to the fact that the choice and selection of the study context allows the researcher to identify an applicable and relevant environment suitable for the study. In the chosen school context, the portion of population selected is suitable to represent the wider range of the population (De Vos et al., 2010). Cohen et al. (2011) concur that it is important to set the case of a case study within its context. The study context, which is the three schools selected, termed School A, School B and School C, is discussed below.

School A is one of the high-performing schools in Pinetown District, and specialises in technology subjects. The school has a total population of 1050 enrolled learners served by 45 teachers, making the learner to teacher ratio 24:1. School A falls under quantile level 5 and learners are expected to pay for their school fees. This school is located in an urban area. This is a Section 21 school, meaning it is allocated finances by the DoE and is responsible for ordering stationery, textbooks, paying water and lights accounts and undertaking its own maintenance (SASA, 1996). School A is one of the schools in which Technical Mathematics was piloted and implemented in 2016.

School B caters for about 1170 learners served by 49 teachers, giving a learner to teacher ratio of 49:1 School B is a fee-paying school under quantile level 4. The school offer ordinary subjects and technology subjects, including Technical Mathematics. School B is a Section 21 school, meaning that it is allocated finances by the DoE and is responsible for ordering stationery, textbooks, paying water and lights accounts and undertaking its own maintenance. Apart from Technical Mathematics, the DH also manages Manufacturing, Engineering, and Technology. There is also a DH who manages Physical, Mathematical, Computer and Life Sciences. The school offers about 23 subjects in the FET phase.

School C is a comprehensive high school in Pinetown District, which is a fee-paying school in quantile 4. School C is not under Section 21, meaning that the school budget is administered by the district office of the DoE. The school caters for 1400 learners and 49 teachers, giving a learner to teacher ratio of 29:1. The school offers a dynamic curriculum and is situated in one of the biggest townships in KZN. There are 20 subjects offered in the FET phase, that includes technical subjects, which are Technical Mathematic, Technical Science, Civil Technology, Engineering Graphic and Design. The schools also cater for core subjects that other schools generally offer, including Mathematics, Mathematical Literacy, Physical Sciences, and so on. The school is dominantly made up of isiZulu-speaking learners and the medium of instruction is English. The DH manages technology and science and mathematics subjects.

5.4 Generating and analysing data

Data generated from the interviews, observations and document analysis was transcribed. At this stage, the elicited data was captured without looking at the relevance of the participants' responses to the research questions that this study sought to answer. The researcher listened to the interview recordings several times to ensure that the data was transcribed without missing any valuable information shared by the participants. The unabridged presentation of data guaranteed authenticity in the findings and conclusion of this study. Examination of the transcripts ensured that there was correlation between what transpired in the observations and interviews. NVivo was used to code the transcripts and themes that emerged from phrases in the DHs' shared experiences. These were cross-checked by the researcher to ensure that the software did not deviate from the themes that emerged from participants' responses.

5.4.1 Generating one-on-one interviews

The researcher engaged with the DHs in their respective schools by asking them semi-structured questions that aimed to answer the research questions one, three and four (see Appendix H). The interviews took place during school hours and therefore the researcher was sensitive to the time that the DHs had to spend responding to the semi-structured interview questions, limiting it to 45 minutes. In School A the semi-structured interview took more than the estimated time, and the researcher had to reschedule another day to engage with the DH. The DHs shared their experiences of implementing Technical Mathematics in their schools. A number of issues raised by the DHs were then organised into themes in order to report the findings according to the research questions. Some concerns that were raised but were not relevant to the current study were left out. The data collected in the one-on-one semi-structured interviews were triangulated with that gained from document analysis, classroom observation, and the focus group interview. Analysis of interviews was foregrounded by principles of the interpretive paradigm that guided this study. Moreover, analysis of the one-on-one interviews was cognizant of the research questions and the theoretical and conceptual frameworks underpinning this study.

5.4.2 Analysis of one-on-one interviews

During one-on-one interviews with department heads, 18 themes emerged, providing insights into their roles in Technical Mathematics curriculum management and implementation. These themes encompassed DHs' roles in curriculum implementation, the implementation of practical assessment tasks, support from the Department of Basic Education (DBE), participation in personal development workshops, engagement with professional learning communities, DHs' management of Technical Mathematics, their understanding of the curriculum, challenges faced, learners' selection for Technical Mathematics courses, the mathematical knowledge required for effective teaching, recruitment of suitable teachers, pedagogical content knowledge, continuous evaluation and support, challenges in teaching Technical Mathematics content, learners' attitudes towards the subject, collaborative efforts within and across subjects and schools, the inclusion and timing of practical assessment tasks within the curriculum, and concerns about the complexity and density of Technical Mathematics content.

5.4.3 Generating document analysis

The researcher analysed documents that are used by the DHs when executing their roles in their schools, when teaching, monitoring and implementing Technical Mathematics (see Appendix J). Hence, this content analysis was based on the content that was covered in the documents that were analysed, and the extent to which the DHs kept records of all necessary documents needed for their department, particularly in Technical Mathematics. The researcher used document analysis to triangulate the research findings from the participants' interviews and observations. Consistency was the key element that drove conclusions based on what the DHs were saying and doing and what they keep in their files. Hence, patterns were recognised in the documents of the three DHs participating in this study. The DHs' monitoring tools helped to understand whether they were following and monitoring the ATP, POA, personal development plan, and pre- and post-moderation reports. For teaching, the documents that were analysed were lesson plans, resources used, learners' exercise books, portfolios, and recording of marks on the marksheet. DHs' management documents that were analysed were their files, which contained the CAPS document, subject policy, subject improvement plan, school-based moderation tool, and minutes of meetings where they discuss curriculum issues. Triangulation by using documents was based on the motive of ensuring a full understanding of the phenomenon.

5.4.4 Analysis of documents

Based on the document analysis, 15 distinct themes emerged from the data to capture the breadth of discussion. These themes included continuous evaluation and support for teachers, department heads' management of teaching and learning resources, the content and sequence of Technical Mathematics instruction, personal development workshops, the Department of Basic Education's expectations regarding curriculum, planning, and assessment, curriculum monitoring, evaluation, and classroom observations, as well as discussions on learner attendance and performance. Additionally, themes covered content and pedagogy workshops, assessment monitoring, new curriculum developments, quality management systems, and learners' records of work. Each theme was meticulously coded to extract relevant insights and patterns from the data, contributing to a comprehensive understanding of the educational context under study.

5.4.5 Generating classroom observation

The researcher observed the three DHs' classrooms when they were teaching Technical Mathematics (see Appendix G). Classroom observation allowed the researcher to understand how the DHs carried out their teaching roles and the learners' attainment of knowledge in the classroom setting. The duration of the lesson varied from 45 to 50 minutes, as per school timetables. The researcher made field notes based on the lesson observations. The aspects covered were classroom environment, lesson introduction, resources and media used by the DHs, learner involvement in the lesson and in lesson activities, assessment, and enabling and challenging factors that promoted/hindered DHs in teaching the lesson. The researcher used field notes and recorded videos of the three lessons that were observed, to preserve the observations for analysis. Videos of the lessons were further analysed to eliminate any vagueness that might have transpired during the actual observation of the DHs' lessons. The end goal was to understand how DHs enact their teaching role and their actual implementation of the subject, by identifying themes and patterns observed in relation to the study phenomenon. This was necessitated by the DHs' dual role of being a teacher and a curriculum manager – hence the need to see how they implement the curriculum in the classroom and enact their roles of being a teacher and a curriculum manager.

5.4.6 Analysis of classroom observation

During classroom observations, 11 distinct themes emerged, encapsulating various facets of the teaching and learning environment. These encompassed aspects such as teaching and learning dynamics, the depth of department heads' subject knowledge, the availability and utilization of teaching resources, assessment practices, and challenges encountered, particularly in navigating complex Technical Mathematics content and facilitating factors. Additionally, observations shed light on department heads' execution of dual roles, their interactions and experiences with students, including learners' attitudes towards Technical Mathematics, and the effectiveness of curriculum implementation.

5.4.7 Generating focus group interview

The researcher engaged all three DHs in a group setting, where they all shared their thoughts on different aspects of the subject's implementation (see appendix I). The DHs' views were also coded and used to answer the research questions. The semi-structured interviews were conducted via Zoom, as some participants were still reluctant to meet with others in the midst of the COVID-19 pandemic. Nevertheless, the DHs were exposed to different scenarios that speak to their management role in curriculum implementation. The focus group interview lasted for about 30 minutes, and there were four questions. The three participating DHs were given leeway to respond to the questions freely, to the best of their knowledge. The research questions informed the discussion, as all scenarios that were presented aimed to answer these. The researcher perused the transcribed data and analysed the responses by placing them into themes as they emerged from the data.

5.4.8 Ananysis of focus group interview

The focus group interviews uncovered a comprehensive array of themes surrounding teaching and learning in the Technical Mathematics classroom and the roles and responsibilities of DHs in curriculum management. These themes can be categorised into four main areas: Knowledge and practices, Enacting roles and responsibilities, Enabling factors, and Constraining factors.
Under knowledge and practices, six themes emerged: strong knowledge of CAPS documents, DHs' sound content knowledge, and collegial professional conversations. Setting weekly meetings with teachers, Managing the teacher's files, Curriculum implementation and teaching, Knowledge of unpacking curriculum, Meeting with teachers to draw up lesson plans and create resources, DH to support the teacher and help learners, Planning course selection, Understanding of DH roles, Unsatisfactory professional knowledge.

Enacting roles and responsibilities knowledge like DH workshops teachers on areas that are not taught in Mathematics, Distributive role in mentoring, Suggesting that the teacher gets the CAPS document, setting up a mentoring programme for teachers, Inviting subject advisor to advise, guide and mentor Technical Mathematics teacher, Providing opportunities for the teacher to attend workshops, Assigning CAPS document, ATPs, POAs, textbooks and available resources, Developing and checking of daily forecast, lesson plans, marking and assessments, Providing and help to create mechanisms to ease teaching curriculum.

Enabling factors included Getting the right teachers to teach, Seasoned teachers' PCK and content knowledge, Parents meeting – checking with prospective universities if they recognise Technical Mathematics, Career guidance –course selection, Availability of teaching resources, i.e., textbooks, Subject expectations: ATPs, POAs, teacher guidelines Grades 10-12, Sharing responsibilities with seasoned teachers, Subject advisor – Unpacking curriculum, Liaise with teachers, mentors, SMT and advisors, Professional learning community (PLC) in schools and neighbouring schools, Practical assessment task component assists in promotion.

Constraining factors include Poor alignment of CAPS and its application in Technical Mathematics, New teachers' inability to teach the entire syllabus, Challenging sections poorly explained, Higher education institutions not offering Technical Mathematics, No training for specialised Technical Mathematics teachers, No DH specialised training, DH lack of expertise, DH reluctance to use new teachers, Learners are lazy to do challenging mathematics, Majority of learners drop out, DBE progression policy – learners' perception of the automatic pass, Rejection of Technical Mathematics learners in universities, Challenging exam questions, Technical Mathematics learners' unequal access to universities with Pure Maths learners, Technical Mathematics is difficult.

5.5 Generating themes

Thematic analysis of data in this study involved searching for themes by collating and sorting broadly similar extracts from the transcripts. Themes that specifically related to the research questions were categorised into respective main themes, and the other emerging themes were also grouped. These themes were reviewed and modified into sub-themes, that allowed the coding to be done systematically. The researcher ensured that the coded themes were concise and presented logically, while providing a holistic picture of the DHs' experiences. The researcher then used the

NVivo computer-assisted qualitative data analysis software program to organise and fit the developed codes in and match them with themes. Thematic analysis made it possible for the data to be coded and arranged into themes to represent all of the data sources.

5.5.1 Phases of data analysis

The phases of thematic data analysis undertaken in this study are shown in Figure 5.1.

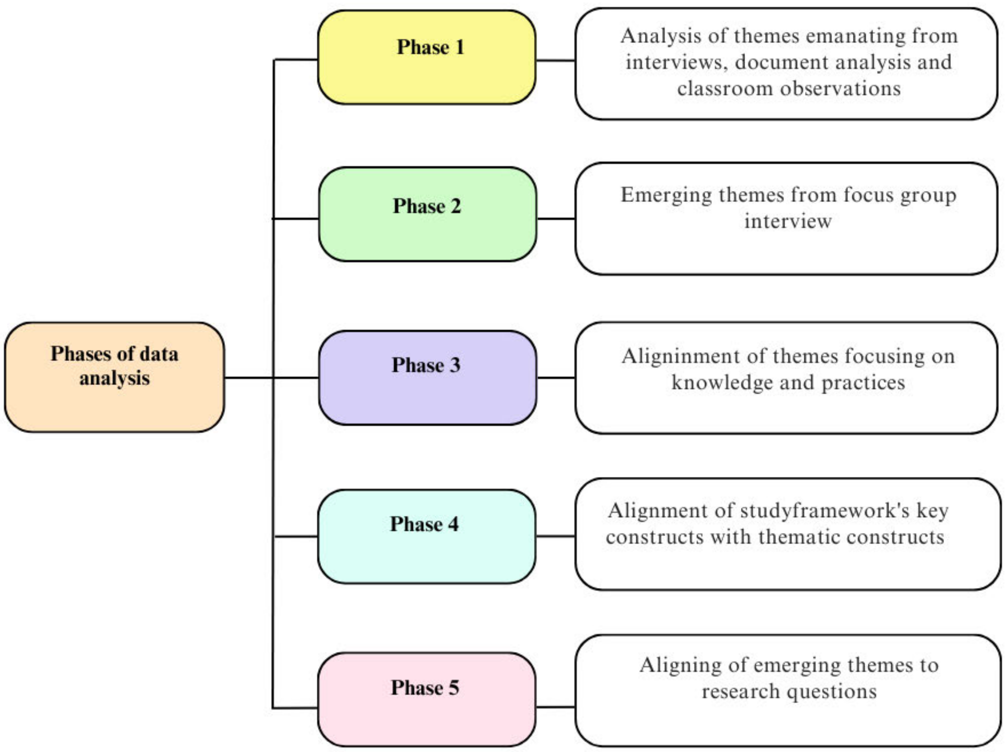


Figure 5.1. *Data analysis phases.*

5.5.1.1 Phase one

During the first phase of data analysis, the researcher extracted common themes from transcripts that were coded using NVivo. In the coding process, nodes were collapsed and expanded while keeping the codes as close as possible to the transcripts from the one-on-one interviews, document analysis and lesson observation transcripts. Words that appeared frequently in each participant's transcript guided the first attempt at creating nodes and codes. Line-by-line coding was used to analyse data into preliminary codes, that were later collapsed and expanded. This was guided by dominant coding stripes and a number of references were used to formulate codes that were used in the analysis. The analysis of data involved sorting, categorising, grouping, looking for similarities and differences, developing categories, and finding codes that encapsulated what was relevant to the study phenomenon. Combining and abstracting similar codes was used to formulate individual case themes. Codes that did not speak to research questions were not used, and were therefore collapsed. Figures 5.2a, b and c show the analysis of themes that emanated from the data generated from the one-on-one interviews, document analysis and classroom observation. These are presented for each participant from each school separately.

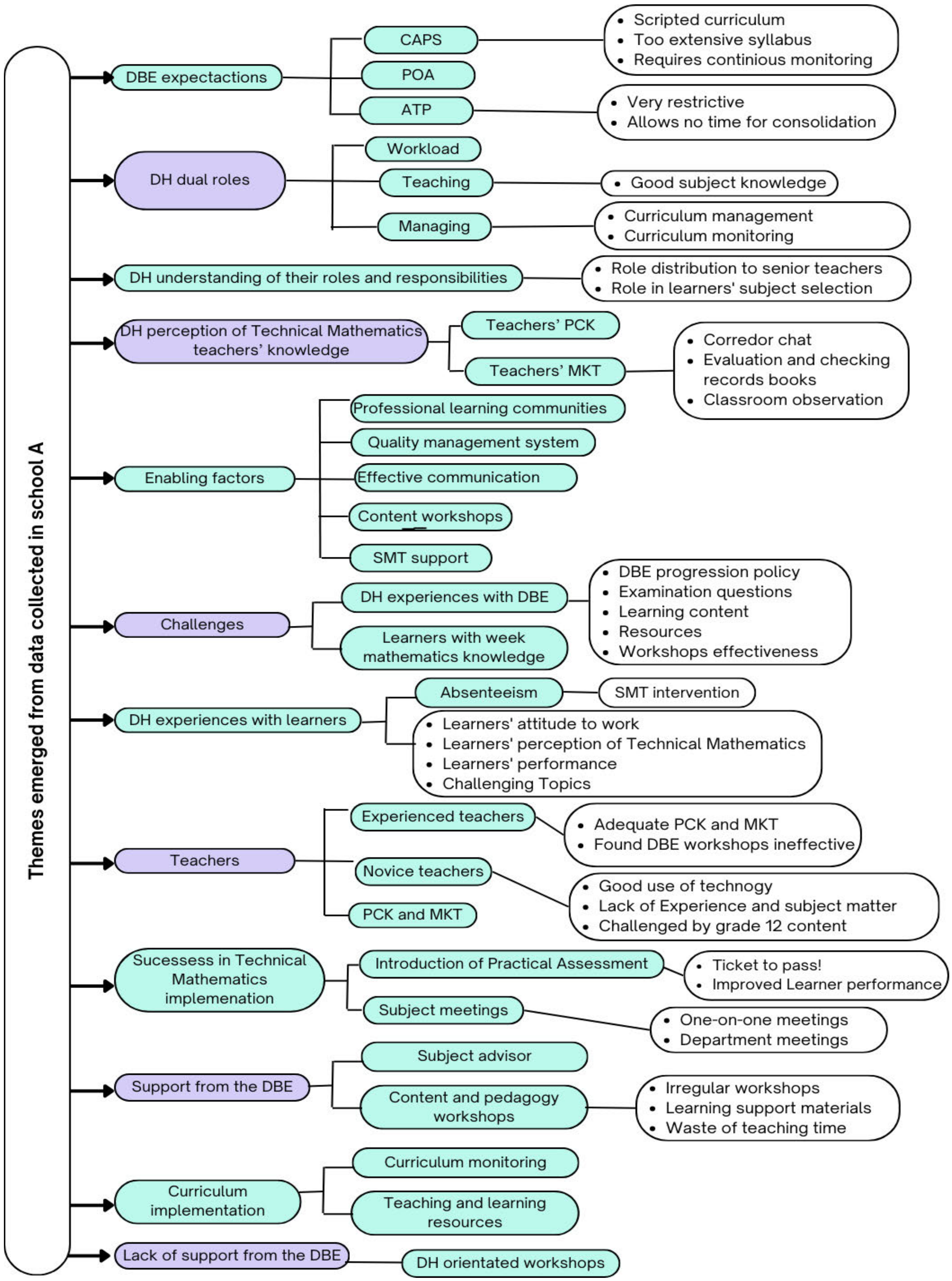


Figure 5.2 a. *Themes that emerged from the one-on-one interviews, document analysis and classroom observation at School A.*

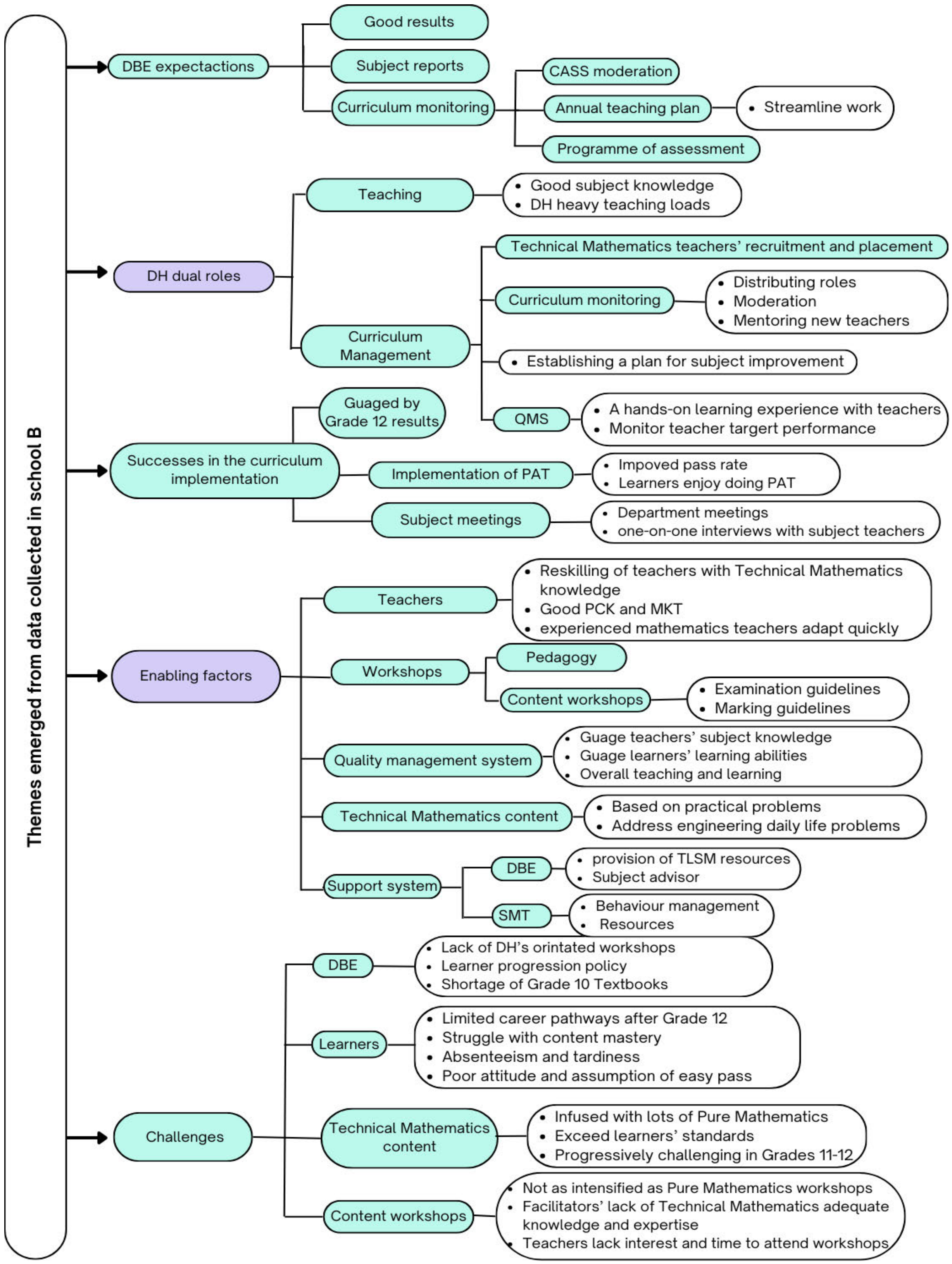


Figure 5.2 b.*Themes that emerged from the one-on-one interviews, document analysis and classroom observation at School B.*

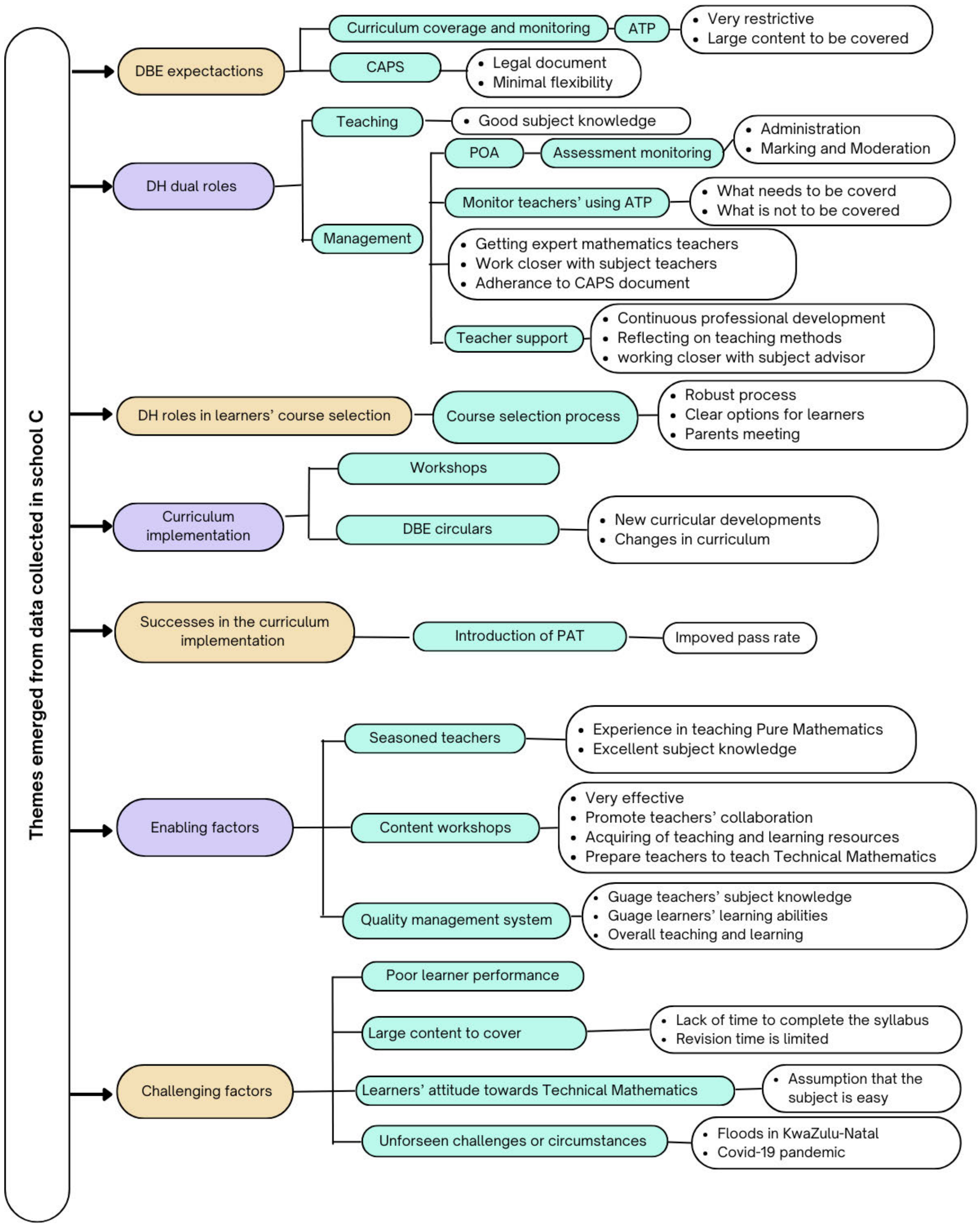


Figure 5.2. c. *Themes that emerged from the one-on-one interviews, document analysis and classroom observation at School*

5.5.1.2 Phase two

The second phase was the analysis of the focus group interview, which involved extracting common codes and themes and clustering them together. NVivo was used to organise the coded transcript into common codes and themes. Text from transcripts of parent and child nodes/codes, which is coding within the codes, was used to further analyse the transcript. This was done by creating typologies, subthemes, and broader themes. The code book was then formulated and summarised in table form to show how themes clustered by word similarity fitted into each construct. In this phase the focus was on dissected themes that emerged from focus group interviews, which are presented in Table 5.2. The four constructs, namely knowledge and practices, enacting roles and responsibilities, enabling factors, and constraining factors, were aligned with the research questions and the study phenomenon. Case classifications were used to store different attributes of interview responses of different participants. It also showed demographic information for each participant, to keep track of their responses.

Table 5.2:Alignment Themes that emerged from the focus group interview

Knowledge and practices	**Enacting roles and responsibilities**	**Enabling factors**	**Constraining factors**
• Strong adherence to CAPS document • DH sound content knowledge • Collegial professional conversations • Setting weekly meetings with teachers • Manage the teacher's files. • Curriculum implementation and teaching • Knowledge of unpacking curriculum • Meeting with teachers to draw up	• DH workshops teachers on areas that are not taught in Mathematics • Distributive role in mentoring • Suggest that the teacher gets the CAPS document • Setting up mentoring programme for teachers • Inviting subject advisor to advise, guide and mentor Technical Mathematics teacher • Providing opportunities for	• Getting the right teachers to teach • Seasoned teachers' PCK and content knowledge • Parents meeting – checking with prospective universities if they recognise Technical Mathematics • Career guidance – course selection • Availability of teaching resources, i.e. textbooks • Subject expectations: ATPs, POAs,	• Poor alignment of CAPS and its application in Technical Mathematics • New teachers' inability to teach entire syllabus • Challenging sections poorly explained • Higher education institutions do not offer Technical Mathematics • No training for specialised Technical Mathematics teachers • No DH specialised training

lesson plans and create resources • DH to support the teacher and help learners • Planning course selection • Understanding of DH roles • Unsatisfactory professional knowledge	the teacher to attend workshops • Assigning CAPS document, ATPs, POAs, textbooks and available resources • Developing and checking of daily forecast, lesson plans, marking and assessments • Providing and help creating mechanisms to ease teaching curriculum	teacher guidelines Grades 10-12 • Sharing responsibilities with seasoned teachers. • Subject advisor – Unpacking curriculum • Liaise with teachers, mentors, SMT and advisors • Professional learning community (PLC) in schools and neighbouring schools • Practical assessment task component assists in promotion	• DH lack of expertise • DH reluctance to use new teachers • Learners are lazy to do challenging mathematics • Majority of learners drop out • DBE progression policy – learners' perception of automatic pass • Rejection of Technical Mathematics learners in universities • Exam questions • Technical Mathematics learners' unequal access to universities with Pure Maths learners • Technical Mathematics is difficult

5.5.1.3 Phase three

The third phase organised the themes that emerged from the three participants, which were clustered in a horizontal multi-level hierarchy to show the link and relationship between themes that emerged from the data. The themes that were common and had the same meaning from all three data sources were grouped together, formulating common themes in relation to DH knowledge and practices. The emerging themes were again clustered according to the research topic main constructs, which are DHs' knowledge and practices, as presented in Figure 5.3a and 5.4b, respectively. The aim of assembling data into two distinct categories was to understand the two main constructs, which are knowledge and practices.

Figure 5.3a presents organisation of the themes that emerged on DHs' knowledge of teaching, managing, and monitoring Technical Mathematics curriculum. Figure 5.3b presents the themes that emerged on DHs' practices of teaching, managing, and monitoring Technical Mathematics curriculum.

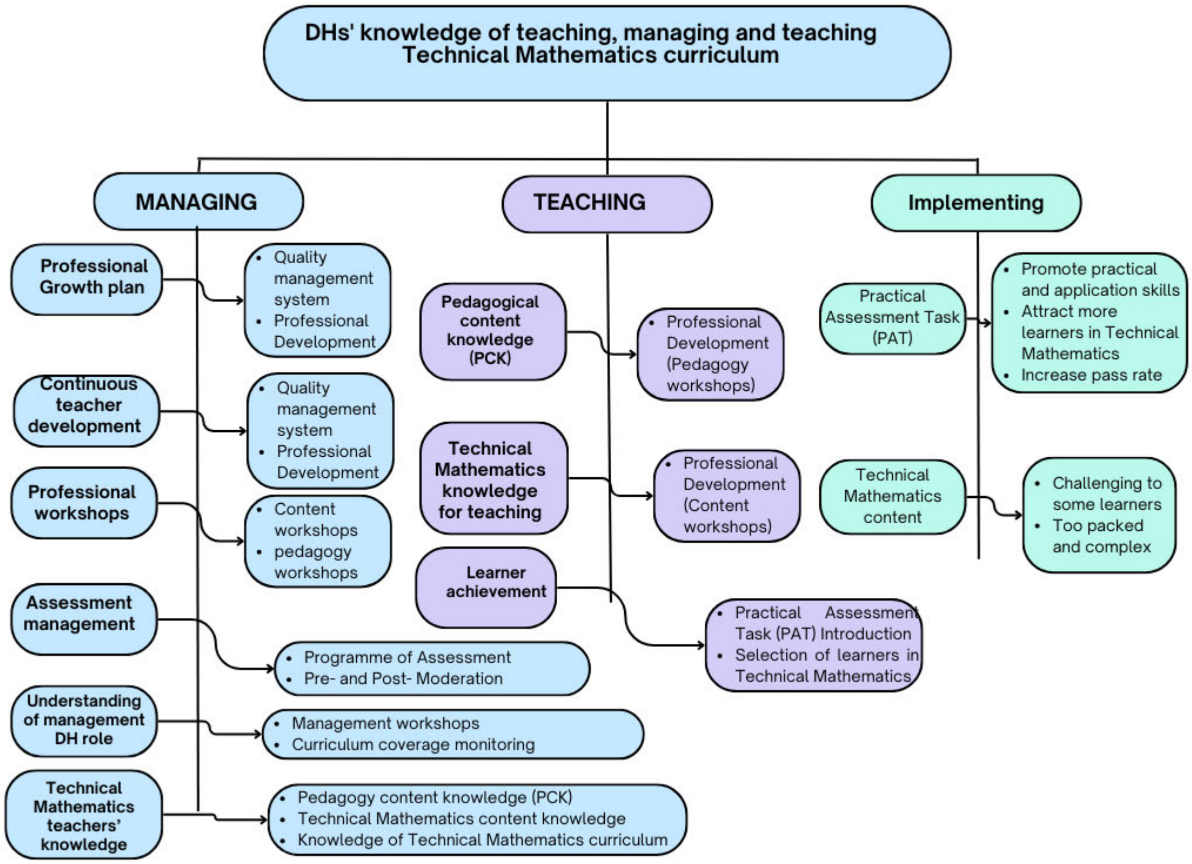


Figure 5.3 a. *Themes that emerged on DHs' knowledge of teaching, managing, and monitoring Technical Mathematics curriculum.*

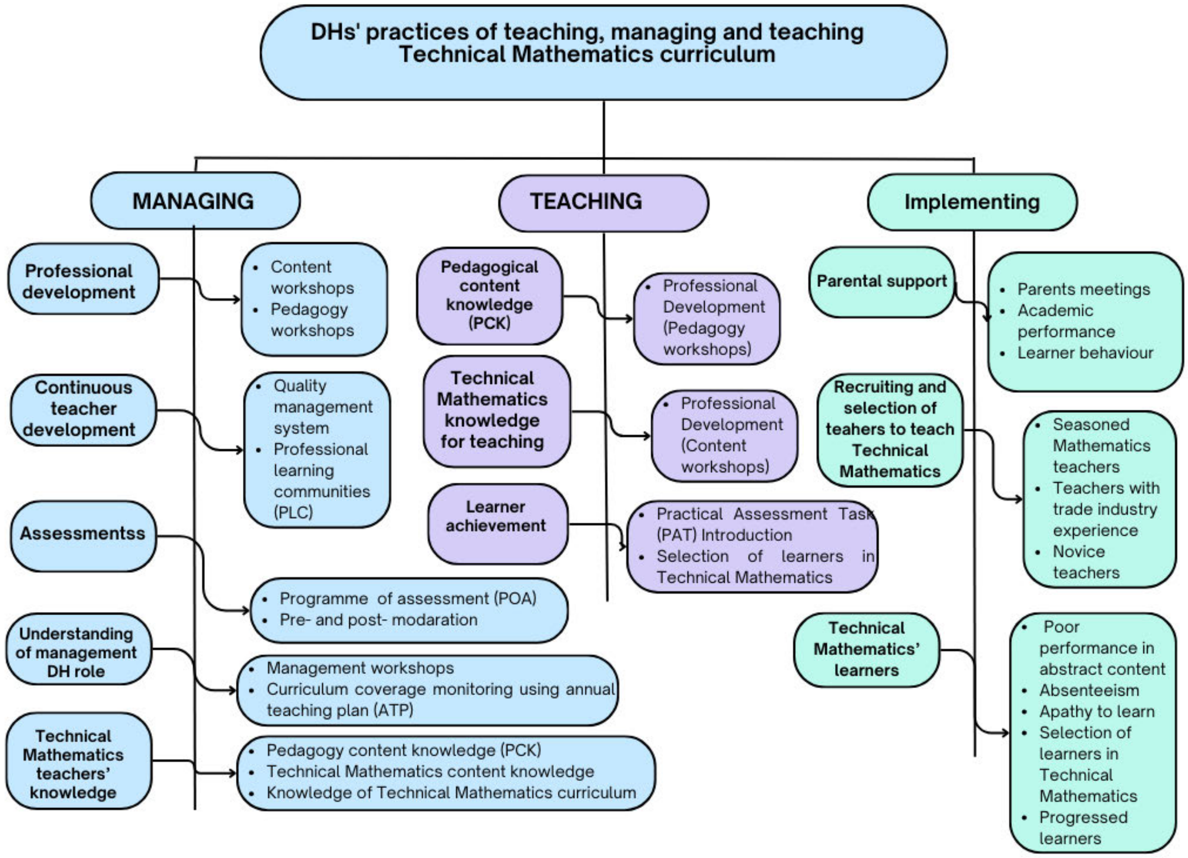


Figure 5.3 b. *Themes that emerged on DHs' practices of teaching, managing and monitoring Technical Mathematics curriculum.*

5.5.1.4 Phase four

In the fourth phase, themes were further assembled to show alignment of framework key constructs with thematic constructs emerging from the data (Table 5.3). All themes that were deductively and inductively formulated were further narrowed down and aligned with the study theoretical and conceptual framework. The study theoretical framework, Samuel's (2008) Force Field Model constructs were matched with themes that emanated from the data. The theoretical constructs are professional forces, biographical, contextual, institutional, and programmatic forces, and were used to analyse and unpack DHs' knowledge and practices emanating from the data sources. The conceptual framework construct that was drawn from Shulman's (1986) pedagogical content knowledge (PCK) and Ball et al.'s (2008) mathematical knowledge for teaching (MKT) were infused with the DHs' Mathematics curriculum monitoring (MCM) and Mathematics curriculum implementation (MCI) knowledge that the study aims to understand.

Table 5.3: Alignment of framework key constructs with constructs emerging from the data

Literature-based themes	Themes emerging from the data	Theoretical framework				Conceptual framework			
		Bio.	Con.	Inst.	Prog.	PCK	MKT	MCM	MCI
Curriculum management	DHs' management of teaching and learning resources	✓	✓	✓					✓
Factors enabling curriculum management	Support from DBE			✓					✓
Challenges with curriculum management	Lack of DHs' management-orientated workshops		✓	✓		✓	✓		
DHs' roles in curriculum management	DHs' understanding of management of Technical Mathematics curriculum	✓					✓	✓	✓
	DHs' management of Technical Mathematics				✓		✓		✓
	DHs' management of human resources – Teachers								
	DHs' enactment of roles and responsibilities								✓
	Reasons why DHs enact their roles in the way they do	✓	✓						✓
Curriculum implementation	DHs' implementation of Technical Mathematics		✓				✓		
Factors that enable implementation	Implementation of practical assessment task		✓		✓				✓
	Personal development workshops			✓	✓		✓		✓
	Professional learning community			✓		✓	✓		
Challenges with curriculum implementation	Learners' selection in Technical Mathematics course	✓	✓						✓
	Continuous evaluation and support		✓	✓					✓
	Challenges teaching Technical Mathematics content	✓						✓	
	Learners' attitudes towards Technical Mathematics		✓		✓				✓
DHs' roles in curriculum implementation	DHs' roles in curriculum implementation			✓	✓				
	Getting the right teachers to teach Technical Mathematics				✓				✓
Sustainability of Technical Mathematics implemented within the existing curriculum	Teaching and learning in Technical Mathematics classroom	✓				✓	✓		
Mathematical knowledge for teaching	Technical mathematical knowledge for teaching		✓		✓	✓	✓		
Alignment between MKT and curriculum implementation	Pedagogical content knowledge	✓				✓			
	Technical Mathematics content and sequence of teaching and learning				✓		✓		

Theoretical framework constructs: Bio. = biographical force; Con. = contextual force; Inst. = institutional force; Prog. = programmatic force.

Conceptual framework constructs: PCK = pedagogical content knowledge; MKT = mathematical knowledge for teaching; MCM = Mathematics curriculum monitoring; MCI: Mathematics curriculum implementation.

5.5.1.5 Phase 5

The final phase of data analysis was based on aligning themes that emerged from the data to the research questions. The themes that related to DHs' knowledge and practices were aligned with research question one: What are the DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics? The themes that were related to the roles and responsibilities were associated with research questions two and three How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics? and Why do DHs enact their roles in the way they do? The last themes, that are related to the enabling factors and challenges in curriculum implementation, were viewed through the lens of the research question four: 'What factors hinder or enable DHs in the implementation of Technical Mathematics?'.

Using implicit knowledge to code has the potential of hiding the process of why certain codes were coded in the way they are from interested parties. It was important for the researcher to expose all phases of the data analysis, including the methods of coding employed by the researcher. Since the researcher collected the data, it became easier to use implicit knowledge, but listening to, transcribing, and reading the transcripts from all data sources made the researcher be more aware of the codes and themes that emanated from the data.

The final phase of the data analysis thus involved collapsing themes and constructs and aligning them to the research questions. This was done with the purpose of ensuring that the discussion of findings is guided by the research questions. The discussion of findings is presented in the following three chapters, Chapter 6, Chapter 7, and Chapter 8, as outlined in Table 5.4.

Table 5.4: Aligning emerging themes to research

Research questions	**Generated themes**
Chapter 6 RQ 1: *What are the DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics?*	• DHs' understanding of management of Technical Mathematics curriculum. • DHs' role in implementing and managing the curriculum. • Pedagogical content knowledge • Technical MKT • Technical Mathematics content and sequence of teaching and learning • Teaching and learning in Technical Mathematics classroom
Chapter 7 RQ 2: *How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics?* RQ 3: *Why do DHs enact their roles in the way they do?*	• DHs' management of Technical Mathematics • DHs' implementation of Technical Mathematics • DHs' management of human resources – Teachers • Learners' selection in Technical Mathematics course • DHs' management of teaching and learning resources • DHs' enactment of roles and responsibilities • Reasons influencing DHs to enact the roles in the way they do
Chapter 8 RQ 4: *What factors hinder or enable DHs in the implementation of Technical Mathematics?*	• Getting the right teachers to teach Technical Mathematics • Continuous evaluation and support • Inclusion of PAT task in the Technical Mathematics curriculum • Collaboration within and across subjects and schools • Delaying inclusion of PAT in the Technical Mathematics curriculum. • Lack of professional development for DHs' management and implementation • Content to be taught is too packed and complex • Learners' attitudes towards Technical Mathematics

Chapter 6

Departmental Heads' knowledge and practices of managing and implementing Technical Mathematics

6.1 Introduction

In this chapter the aim is to discuss the findings concerning DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics. Samuel's (2008) Force Field Model was used to understand programmatic forces that influence DHs' teaching, learning and curriculum management. The programmatic forces of Samuel's (2008) Force Field Model were explored in research question one. Programmatic force, as explained in Chapter 3, can be understood as conceptions of curriculum forces which influence how the teaching takes place. In the context of this study, programmatic forces declare how the DHs should implement, teach and manage the curriculum. Samuel (2008, p. 13) explains that

> programmatic forces is a more explicit charge which declares the sequence, content, and direction that the teaching/learning practices will follow. This declaration is not only espoused, but also enacted in everyday practices to reinforce the quality of teaching and learning. Teachers who come under the influence of these programmatic charges come to interpret their role and identity in unique ways.

In schools, DHs conform to a very prescriptive curriculum, which is capsulated in the CAPS document. Programmatic forces inform the programmatic content that 'pushes and pulls' DHs as teachers and curriculum managers to strictly follow CAPS specifications in all South African schools. The study's conceptual framework unpacked the DHs' understanding of pedagogical content knowledge (PCK) and their mathematical knowledge for teaching (MKT) of Technical Mathematics. The programmatic forces and DHs' PCK and MKT were used to understand and interrogate their practices and knowledge under the following themes:

- DHs' understanding of management of Technical Mathematics curriculum
- DHs' role in implementing and managing the curriculum
- Pedagogical content knowledge
- Technical Mathematics knowledge for teaching
- Technical Mathematics content and sequence of teaching and learning
- Teaching and learning in Technical Mathematics classroom.

6.2 Departmental Heads' understanding of management of Technical Mathematics curriculum

One of the DHs' central roles is to manage the curriculum effectively and ensure that the implemented curriculum is improved. According to the Personnel Administrative Measures (PAM) document issued by the DBE (2016, p. 27), the primary aim of DHs is

> To engage in class teaching, be responsible for the effective functioning of the department and to organize relevant/related extra-curricular activities so as to ensure that the subject, learning area or phase and the education of the learners is promoted in a proper manner.

This means that part of DHs' role includes not only teaching but also managing subjects in their departments. In response to the question 'What is your understanding of managing and implementing Technical Mathematics curriculum?' during the one-on-one interview with the DHs, the DH from School B, Mrs Beta, stated that in her department there are certain standards that she drew up, that help her to manage the Technical Mathematics curriculum and other subjects that she manages. To further elaborate on her she had the following to say:

> **Mrs Beta:** *My understanding is that teachers need to be workshopped and trained in the new subject in terms of the content, examination guidelines, marking guidelines etc. this is because they are new topics that are not taught in Pure Mathematics. As a result, there needs to be reskilling of teachers that are teaching the subject for the first time.*

From the above extract it could be deduced that Mrs Beta's understanding of curriculum management is based on capacitating teachers and providing resources needed for planning and teaching. She further stated that:

> *Moreover, I have measures in place to ensure that teachers should go to class, prepared, and teach ensuring that they cover the work prescribed in the annual teaching plan. Secondly, I ensure that every teacher is comfortable teaching any section of the syllabus, and, in the event that this is not the case, it is the teacher's responsibility to bring this to my attention, so I can help or refer the matter to the SMT, so that the teacher may be assisted with inside or outside support. My management role also requires that I look after the needs for teachers and provide support that is needed for the teachers to perform maximally.*

Drawing from the above extract, it is further evident that Mrs Beta's management practices of implementation of Technical Mathematics involved ensuring that teachers do go to classes to teach and ensuring that they are prepared to teach the content stipulated in the annual teaching plan (ATP). Other than ensuring teaching, she understand that part of her role is to provide support to teachers or seek support on behalf of teachers.

What Mrs Beta expresses is similar to what Tapala, van Niekerk and Mentz's (2021) study of DHs' perceptions on curriculum leadership roles reveals. The authors emphasise the importance of reskilling teachers through professional development initiatives. In the same way, Aldosemani (2019, p. 46) states that "Teachers' professional development programs are critical to sharpen their knowledge, skills, attitudes, and self-efficacy for transformative practice". The need for teacher training cannot be overly emphasised, especially when a new curriculum or subject is being implemented. Hence, the DHs' understanding of managing the curriculum depends on adequate training of in-service teachers so that they are capacitated, and they become familiar with the DBE's expectations on teaching and learning of Technical Mathematics. For the DHs to look after the needs of teachers and provide support, the DHs need to be well versed in the subject expectations and demands. Tapala et al.'s (2021) study looked at curriculum leadership barriers experienced by DHs in South African schools, and recommends the need for the DBE to capacitate DHs for their management roles and provide continuous support through coherent workshops. However, it could be noted that while Mrs Beta considers reskilling of in-service teachers to teach Technical Mathematics, she does not seem to consider it important for herself also to be reskilled. Her priority is the reskilling of post level 1 teachers.

Contradictory to Mrs Beta, Mr Alpha from School A emphasised the need for DHs to be trained for their roles as DH when the new subject is being introduced. He stated that they have been trained as Mathematics teachers to teach Technical Mathematics. He mentioned that the DBE set up a number of workshops that were sufficient for him to understand and assume his role, as reflected in the following statement:

> **Mr Alpha:** *Firstly, I want to put this out there. We have been trained, okay. As much as we are math teachers, we have been trained in this particular learning area. We also have a lot of assistance from the Department of Education where they introduced a number of workshops that are assisting us.*

The DH's statement reflects that as DHs among other Mathematics teachers, they were trained when Technical Mathematics was introduced in their schools. He commends the DBE for providing a lot of support in terms of equipping teachers for the demands of Technical Mathematics. Mr Alpha's understanding of his role seemed to be inclined towards teaching of Technical Mathematics than its management. He did not show adequate understanding of managing and implementing Technical Mathematics curriculum in his response, other than the training and support offered by the DoE to him and the Technical Mathematics teachers. This might be the intuitive priorities that the DH set for implementation of the new subject, and the overall expectation he has for the DoE to provide support to teachers. I noted that when he responded to questions he often spoke as a teacher more than as the manager of the subject, which might impact his understanding of his role as the DH.

Mr Gamma, the DH from School C, understands the dual role of being a DH in his school. This was evident in his response, as he placed great emphasis on having the content knowledge for teaching Technical Mathematics, so that he models the knowledge to the educators he manages and the learners he teaches. He understands that for him to manage the curriculum well, he needs to be an expert in the field, thus articulating the need to have in-depth content knowledge of the subject.

> **Mr Gamma:** *In my general opinion, obviously I need to have knowledge of the subject, the syllabus and the content that has been covered, and obviously work closely with the Mathematics educators and Technical Mathematics educators and the ATP that we have in place in order to ensure that the curriculum needs are met.*

As mentioned by Mr Gamma, as the DH he needs to have knowledge of the subject in order for him to interpret the curriculum correctly for his teachers. This view is substantiated by Ogina (2017), who argues that for teachers to be promoted to DH, they need to be informed in their subject area. In the same way, Tapala et al. (2021, p. 2) affirm that DHs need to be "knowledgeable and competent in the subject under the DHs' control". The DHs avow to the frequency of workshops that help them to master the Technical Mathematics content knowledge, as reflected in the following statements.

> **Mrs Beta:** *Every year there are workshops that take place, other workshops are scheduled over the entire weekend, Friday, Saturday, Sunday.*

Mr Gamma: *The Department of Education set a number of workshops that teachers are required to attend, there are also webinars that teachers attend online.*

In the context of Technical Mathematics, the DHs participating in this study voiced that they have received numerous content workshops that allowed them to gain knowledge of Technical Mathematics. I argue that only having the knowledge of the subject does not equip DHs with management skills in order to execute their role, and thus initiatives to capacitate DHs in their management role must be put in place for them to assume their roles and responsibilities adequately.

The DHs participating in this study did not mention any training offered to them specifically for their management role, suggesting the need for them to be capacitated with curriculum management skills. The DHs need ongoing workshops that could improve their practice, making them more aware of the subject expectations of the DBE and how best they could manage the subject in their schools. Seobi and Wood's (2016) study on improving the instructional leadership of DHs in under-resourced schools in South Africa revealed that DHs' instructional leadership was limited to checking teachers' final report of the work covered, rather than being actively involved in improving instruction practice on an ongoing basis. Seobi and Wood (2016, p. 1) refer to this practice as "final checkers of teachers' reports of work covered". This suggests that their roles are subjected to approving what the teachers have done, and not prominently advising on what should be done and how it should be done. Tapala, Fuller and Mentz (2022) observed that DHs use intuition when executing their roles, and noted that DHs lack training to manage their subjects.

As could be noted from the sentiments of the DHs participating in this study, they need capacitation so that they are equipped to execute their role of being curriculum managers. Tapala et al, (2022) argue that lack of training has the potential to stimulate a distorted perception of their roles, which then contradicts the DBE's expectations regarding how DHs should execute their roles and responsibilities. Thus, training for DHs is essential to homogenise what is expected of them in managing Technical Mathematics.

6.3 Departmental Heads' role in implementing and managing the curriculum

In the context of South Africa, there is a performance management system called the Quality Management System (QMS), which was designed to evaluate the performance levels of individual teachers. What is clear is that the QMS holds that DHs are to oversee the curriculum implementation. To illustrate the extent of the importance of the QMS in managing and implementing the curriculum, one DH had this to say:

> **Mr Alpha:** *I'm going to be honest with you, I am guided by the QMS. We monitor the teaching of Technical Mathematics, but in most of the sections, our subject advisors working together with other learned personnel are providing us with teaching and learning material in terms of lesson presentation, lesson preparation.*

Notable from Mr Alpha's comment is that while he has the document that guides him on how to manage the Technical Mathematics curriculum, most of the work is done by subject advisors. It could be then argued that while Mr Alpha's role is to manage the implementation of the curriculum, it seems that this role is not entirely within his control, as it is more subject advisors-driven.

In the same way, Mrs Beta comments regarding QMS, based her reflection on observation of teachers, that teaching of Technical Mathematics requires teachers' awareness of learners' worldview. This means that application problems that are presented in the classroom should incorporate learners' social context. The DH pointed out that through using the QMS she was able to identify challenges that learners and teachers face daily. She attested that one of her teachers' curriculum deliveries was compromised by an inability to relate the subject matter to learners' context. This is where the teacher finds it difficult to articulate his knowledge to learners who are not English first language speakers. This is reflected in the following comment:

> **Mrs Beta:** *Examples that do not speak to learners' contexts hinder their understanding of the subject matter, and the QMS has helped me to speak with the teacher and suggest that he needs to learn more about his audience, to know what their environment is like, so that it is easier to bring the subject matter into context…. language barrier and soft tone were another issue that the teacher had to address. Learners had to lip-read the teacher to understand what he was saying. Through the QMS I was able to ask the teacher to reflect on the issues I pointed out and his teaching is gradually improving.*

What transpired from Mrs Beta is that she uses the QMS to understand other teachers' practices, besides knowing what happens in her own classroom. The use of QMS apprises DHs about areas in which teachers need to improve in their teaching and implementation of the Technical Mathematics curriculum (Malloy, 2017). The identified needs speak to understanding the learners' context, which means that teachers need to incorporate subject matter using learners' context or worldview.

Of the same view, Mr Gamma raised that the QMS allows him to be aware of his teachers' knowledge of Technical Mathematics. He states that through the QMS monitoring he can identify learners' learning abilities:

> **Mr Gamma:** *The QMS observation sheet allows us to gauge teachers' subject knowledge, gauge pupils' learning abilities, and basically look at the teaching and learning that takes place. Obviously, if you have high-quality teaching, you will expect high-quality learning.*

According to Mr Gamma, persistence in assigning experienced Mathematics teachers to teach Technical Mathematics has yielded high-quality learning in the Technical Mathematics classroom. He believes that his teachers possess adequate knowledge of Technical Mathematics and have experience of meeting curricular demands. Mr Gamma's beliefs about high-quality teaching afforded by seasoned teachers makes the DH shy away from his role of providing mentorship to new teachers. The DBE (2018a) indicates that DHs often neglect using younger teachers in their schools, that little attention is paid to new teachers, with the DHs rarely providing mentorship and trusting them to teach in the FET phase.

DHs have a responsibility to ensure that teaching and learning in Technical Mathematics is maintained. Bush et al. (2010, p. 2), mooted that DHs have direct responsibility for the quality of learning and teaching and pupils' achievement, and state that "This implies setting high expectations and monitoring and evaluating the effectiveness of learning outcomes." Mr. Gamma's use of the QMS does not appear to address teachers' needs, support, or continuous growth; he assumes that having high-quality teaching ultimately means the expectation of high-quality teaching, neglecting that a teacher can have good knowledge of content but may not have the relevant pedagogical capacity; hence with no accountability on him as the DH.

In contrast, Mrs Beta raises the point that Pure Mathematics and Technical Mathematics are not the same; thus being experienced in teaching Pure Mathematics does not necessarily mean one is equipped to teach Technical Mathematics:

> **Mrs Beta:** *If teachers have done Mathematics, it is then taken for granted that they can teach Technical Mathematics. In as much as Technical Mathematics has mathematical content, there are very few teachers that get to be exposed to the technical environment. The majority of teachers are exposed on the academic path and can hardly relate with the trade application problems that are predominant in Technical Mathematics curriculum … Up to this day there is not even a student teacher who comes from university to teach Technical Mathematics, who has been trained particularly on Technical Mathematics. This then requires me as the DH to mentor teachers, even those experienced in teaching Pure Mathematics, but to guide them when it comes to Technical Mathematics.*

What can be deduced from Mrs Beta's comment is that teaching Technical Mathematics should be guided by examples drawn from the trade field. She argues that Mathematics teachers should not assume that the two subjects should be taught in the same way, as the focus is on application rather than on the abstract knowledge emphasised in Pure Mathematics. This implies that DHs should play a pivotal role in mentoring Technical Mathematics teachers to understand and implement the subject, with more attention paid to the application of Mathematics, as intended by the DBE.

6.4 Importance of Departmental Heads' knowledge of Technical Mathematics for implementation and managing the curriculum

DHs are, first and foremost, teachers; thus, the implementation of the curriculum encompasses the classroom practices of a teacher. To speak of DHs' understanding and practices of implementing the curriculum therefore requires one to also explore DHs' understanding of the knowledge components needed in the teaching of Technical Mathematics.

6.4.1 Departmental Heads' conception of pedagogical content knowledge

As explained by Shulman (1986), PCK refers to the teaching methods that teachers use to ensure that learning takes place in their subject areas. Shulman's PCK specifies that in addition to knowledge of content, teachers' effectiveness is backed up by their ability to teach the content. Hence, PCK blends content knowledge and pedagogy, and thus requires teachers to have knowledge of their subject area and be familiar with the teaching methods specific for each topic. In essence, Technical Mathematics as a technical subject requires different teaching approaches compared to the teaching of Pure Mathematics or Mathematical Literacy, although these subjects are from the same strand of Mathematics. When teachers plan for their lessons, they need to bear in mind the subject aims and frame their lessons to meet the demands of the subject accordingly.

Mashapa (2019) argues that the subject vision should clear and transparent to all the stakeholders, especially learners, parents, teachers, and the SMT. Hence, DHs' PCK is essential in ensuring that their teachers differentiate their teaching approach to meet the subject demands, and for them to monitor they need to have sufficient knowledge of and model their practice in the teaching of Technical Mathematics. By the same token, when DHs lack PCK they would struggle to monitor their teachers' teaching of Technical Mathematics, and ultimately it will be difficult to meet subject goals (Jaca, 2013; De Clercq, Shalem, & Nkambule, 2015). I therefore argue that deep understanding of Technical Mathematics would mean that DHs and teachers have a deep understanding of the subject, and that their teaching is informed by applying specific pedagogy suited for a specific topic. In addition, Romylos (2018, p. 13) states that "The capacity to be critical of subject matter and pedagogical skills is important, especially in a South African context where teachers work with learners from diverse cultural groups". He affirms that teachers' pedagogy should not only focus on the subject matter, but also be sensitive to learners' context.

In response to the question 'What is your understanding of pedagogical content knowledge in Technical Mathematics', participants were of the view that PCK is essential knowledge in Technical Mathematics that they themselves as DHs and teachers need to have. Mrs Beta from School B indicated that the pedagogy of teaching the Technical Mathematics curriculum is different from the Pure Mathematics curriculum:

> **Mrs Beta:** *Pedagogy of teaching Technical Mathematics is slightly different from that of Pure Mathematics, because its content helps learners to deal with things that engineers face on a daily basis. Most of the questions should be based on things that arise from the field of engineering.*

Mrs Beta's response affirms that whereas the content of Technical Mathematics and Pure Mathematics has similarities, its teaching is "slightly different". Her response indicates that the nature of the subject determines the teaching approach that is needed for learners to attain knowledge. She advocates that there is a need for learners to be exposed to real-life problems that aim to improve technical mathematical skills for artisans.

In contrast, Mr Gamma's emphasis was based on the QMS observations; he pointed out that teachers need to adhere to the ATP, and added that he is constantly checking if his teachers' knowledge of teaching aligns with the content spelled out in the CAPS document. He believes that CAPS and the ATP must be followed strictly, while aligning their pedagogy with the content they are teaching. His understanding of PCK in Technical Mathematics is framed on adhering to the ATP and professional conversation about teaching the subject:

> **Mr Gamma:** *Being the head of the subject and being a Science and Mathematics person, my understanding of it is based on what I see in the ATP and my conversations I have with my Technical Math educators. They have a good understanding and good knowledge of it because it is Mathematics-based, and obviously some content, some topics may be different, but it is something that they can cover.*

Drawing from Mr Gamma's response, he states that his teachers have adequate knowledge of the subject and PCK. He argues that seasoned Mathematics teachers are able to apply their knowledge and skills in teaching Technical Mathematics; whereas some topics may be different, his teachers easily relate to the new subject. My position is that Pure Mathematics teachers also need to renegotiate their teaching practices pedagogy to suit the needs of Technical Mathematics. This is also supported by Romylos (2018, p. 65) in her study, where she affirms that "Experienced teachers' content knowledge may increase, but they may not always take cognisance of new developments in pedagogical strategies, and therefore this domain may remain undeveloped". This calls for continuous professional development in teachers' pedagogy.

In cognisance of Romylos' (2018) opinion, Mr Gamma advocates for continuous professional development, and encourages his teachers to continuously reflect on their practice. Technical Mathematics teachers especially need to engage in personal professional development that is outside of the school and that caters for their individual needs. He added that content workshops set by the DoE are helpful to an extent, but will not address all the teachers' personal professional needs:

> **Mr Gamma:** *We always talk about continuous professional development and keeping their best by reading up and always reflecting on their teaching methods, and so forth. Also working collaboratively with other educators. As I said, we are working closely with the Technical Mathematics subject advisor to ensure that we know what needs to be covered, what is not to be covered, and how they* [teachers] *cover the required content to the best of their ability.*

The DH argues for the need for Technical Mathematics teachers to continuously advance their PCK, and suggests that reading up on new developments in the subject might equip teachers with the necessary skills. Mr Gamma suggests that working with the subject advisor also helps in knowing the subject expectations, in terms of the content that needs to be covered during the year. While the DH's suggestions are helpful in terms of gaining external support, he seemed not to offer any support within the school. One of the expectations that did not transpire in the DH's response how he provides support to the teachers teaching Technical Mathematics, which is a critical component of DHs' managerial responsibility as curriculum managers.

Mr Alpha believes that PCK is essential in the teaching of Technical Mathematics. He argues that both seasoned and novice Technical Mathematics teachers' practices should be informed by the CAPS document in their teaching. In response to the question 'What is your understanding of PCK and MKT in technical mathematics?', Mr Alpha stated as follows:

> *As much as we are Maths teachers, remember, the Technical Maths is a watered-down syllabus of Pure Maths. Certain sections that we teach in Mathematics, we do not teach in Technical Maths. But we have a document that guides us in terms of knowing what we teach and what not to teach, it's called the CAPS document. Like, if you have to consider, like a Bible in terms of what to teach and what not to teach. I think as educators, we've got to be constantly looking at it, especially if you are a new educator. You know, for us, we have been teaching Mathematics for many years right now, but as much as we have been teaching it, it is our reference document that we must continuously check.*

Mr Alpha's understanding of PCK is based on ensuring that teachers know about the subject matter as stipulated in the CAPS document. Programmatic forces depicts that the DH conforms to the prescribed curriculum and therefore influences teachers that he manages. He refers to the CAPS document as the ‘Bible’, which is an expression that subjugates and deprofessionalises his DH role. The emphasis on strict adherence to CAPS neglects the pedagogy which is equally important for learners to attain knowledge. Romylos (2018, p. 10) insists that “Teachers need to make choices about what content to teach, how to teach it, and to what extent they should emphasize and expand certain aspects of knowledge.” Content that is dictated and overly emphasised may result in teachers’ loss of identity within the profession. I therefore argue that whereas the CAPS guides the knowledge that learners need to attain, it should not be used as a tool to limit teachers’ instruction. Teachers need to understand their learners and identify knowledge gaps and multiple intelligences, then devise mechanisms to support them.

I found that the autonomy of this Technical Mathematics DH did not prevail in his understanding of PCK. In addition, his understanding of PCK is grounded on meeting the expectations of covering the content to be taught or describing the difference in the Pure Mathematics content and Technical Mathematics content, not necessarily articulating the methods needed in the teaching of Technical Mathematics. DHs are tasked with implementing and managing the curriculum; thus, if their conception of the PCK needed for Technical Mathematics is not aligned with the conventional understanding, it has a huge impact on their implementation of Technical Mathematics.

The obsession with the CAPS document limits the DHs’ agency in the classroom, and ultimately influences the identities of the novice teachers and seasoned teachers. Msibi and Mchunu's (2013, p. 21) study on the knot of curriculum and teacher professionalism in post-apartheid South Africa argues that perceived overcompliance with the CAPS document indicate “signs of creating a ‘teacher-proof’ curriculum (through CAPS) and instead promote teacher professionalism”, and that “Lowering expectations and de-professionalizing teaching simply converts schools into factories where the workers (teachers) simply have to follow a set manual (curriculum) to produce a particular product (learners).” They maintain that the teaching profession is more than complying with the prescribed curriculum (Msibi & Mchunu, 2013). The researchers insist that overemphasising the scripted curriculum limits teachers’ agency and “undermines the teachers’ pedagogical content knowledge and positions teachers as people who need expert guidance in executing their jobs” (p. 25).

In the same way, Samuel (2008), on teacher identities and the Force Field Model, argues that the teaching career is increasingly deprofessionalised. In the context of this study, this calls for DHs to perceive themselves as change agents, especially in the context of the new curriculum: "It is likely therefore that when the ethos of a school-learning environment is dull and boring, routinised and ritualized without adequate critical reflection, this might predispose the individual teachers in that setting to 'switch off'" (Samuel, 2008, p. 13). I concur that DHs' re-professionalisation by simply adding an element of flexibility in the teaching of the Technical Mathematics subject they manage could increase teacher autonomy and their PCK. Teachers' restriction through the prescriptive CAPS does not help learners to become autonomous either they are sandwiched within the boundaries of the curriculum, as are their teachers.

6.4.2 Departmental Heads' understanding of Mathematical Knowledge for Teaching Technical Mathematics

Technical Mathematics knowledge for teaching advances MKT (Ball et al., 2008) and PCK (Shulman, 1986). As elaborated in Chapter 2, Ball et al. (2008, p. 4) define MKT as "the mathematical knowledge that teachers need to carry out their work of teaching", which they extend to say that this is the "mathematical knowledge needed to perform the recurrent tasks of teaching mathematics to students" (p. 399). MKT is what differentiates other mathematicians from Mathematics teachers (Carrillo et al., 2013). MKT was based on research carried out in the United States of America (USA) by researchers who were concerned about knowledge that Grade K–8 teachers required for teaching Mathematics. Also in the USA, the Conference Board of the Mathematical Sciences (2001, p. xi) argues that "Knowledge for teaching mathematics is unacknowledged". They reasoned that Mathematics teachers need to have a solid understanding in order to develop coherent, sense-making lessons. They argue that MKT has a close connection with teachers' classroom practice. In this study DHs were asked: What is your understanding of the pedagogical content knowledge and the mathematical knowledge for teaching in terms of technical mathematics?

> **Mr Gamma:** *Being the head of the subject and being a science and mathematics person, my understanding of is based on what I see in terms of the ATP and my conversations I have with my technical math educators. They have a good understanding and good*

knowledge of it because it is math based. And obviously some content, some topics may be different, but it is something that they can cover.

As explained by the participant, PCK encompasses the specialized knowledge required to teach Technical Mathematics. The DH recognises that Technical Mathematics has a distinct focus compared to pure Mathematics, and PCK involves knowing what to teach and how to teach it effectively within this context. The participant emphasizes the importance of continually referring to the CAPS document, which guides educators in aligning their teaching with curriculum standards. As for MKT, the participant did not explicitly mention it in his response, neither did the participant address it. This suggests that the DH lack understing of the MKT.

Mrs Beta: *The Pedagogy of teaching technical mathematics is slightly different from pure Mathematics because its content helps learners deal with things that engineers face on a daily basis. Most of the questions should emphasise engineering-related topics.*

Mrs. Betas' understanding of PCK in Technical Mathematics involves tailoring teaching methods to the specific needs and challenges of teaching technical mathematics, particularly in relation to the content that aligns with engineering practice. Mrs. Beta recognises that the pedagogy of Technical Mathematics differs somewhat from that of pure mathematics due to its focus on preparing learners for real-world engineering applications. Similarly to Mr. Gamma, Mrs. Beta lacks a comprehensive understanding of what MKT means when it comes to teaching Technical Mathematics.

In this study, the focus is on DHs' knowledge and practices of implementing and managing the Technical Mathematics curriculum, and therefore their MKT of Technical Mathematics is critical in this process, since their primary role is to teach. I argue that MKT necessitates that teachers have the ability to give explicit justification to their learners as to 'why it is so and why not so'. This then allows for deep or concrete understanding of the concept to be instilled (Bansilal et al., 2014). This calls for practising teachers to rethink their mathematical knowledge in application, rather than as abstract problem solving.

6.4.3 Departmental Heads' perception of their knowledge and Technical Mathematics teachers' knowledge

DHs as curriculum managers in schools are to oversee teachers' knowledge of the curriculum and subject implementation in the classroom. It is their core duty to understand teachers' challenges so that can devise strategies to enhance improvement of curriculum delivery. The DHs in this study were of the view that some of their teachers possess adequate knowledge of the subject, while others fall short in content knowledge and/or PCK of Technical Mathematics. What seems be the challenge is that teachers who have been teaching Pure Mathematics for a longer period are adjusting well, whereas those who have not been teaching Pure Mathematics find it difficult to relate to the Technical Mathematics content. Even so, teachers not exposed to Grade 12 content are challenged by content at that grade level. This is reflected in Mr Alpha's comments:

> **Mr Alpha:** *The content and pedagogy workshops are done for Grade 12's educators, once a year. But they've invited Grade 10 and 11 educators to those workshops. But you see the challenge of educators who are not teaching Grade 12, when facilitators are doing the presentations and giving pre-test which has Grade 12 as part of it is. So, a Grade 10 educator who has not taught Grade 12 is challenged. Yeah! Especially a new educator. If you have got an educator who is seasoned, who knows the stuff, he will get away with it.*

The DH points out that some teachers that have been teaching Pure Mathematics struggle with the Grade 12 content, as they have not been exposed to the Grade 12 Technical Mathematics content. For teachers to be challenged by Grade 12 Technical Mathematics content suggests that they do not have sufficient content knowledge for the subject they are teaching. Ultimately, one would expect that learners taught by these teachers are also at this level of understanding of Technical Mathematics content. Similar findings are reported by Bansilal et al. (2014) in their study, where they explored common content knowledge that Grade 12 Mathematics teachers possess. Of the 253 Mathematics teachers who wrote certain sections of a Grade 12 Mathematics examination paper that the learners they teach wrote, and still performed extremely poorly, with an average of 57%. Bansilal et al. (2014, p. 34) revealed that "it was found that on average teachers obtained 29% on questions which were at the problem-solving level, raising concerns about how these teachers would mediate tasks that are set at high cognitive levels, with their Grade 12 learners". Pournara et al.'s (2015) study examined the extent to which professional development programmes improve teachers' understanding and their learners' attainment of knowledge, and revealed that there was low learners' attainment of knowledge; moreover, the researchers noted the under-preparedness of Grade 10 learners for the next grade of Mathematics.

Mrs Beta, the DH from School B, noted that novice teachers often struggle to understand and teach Technical Mathematics content. She acknowledges that seasoned teachers easily relate to the content and teaching of Technical Mathematics:

> **Mrs Beta:** *The teachers that are experienced in teaching Mathematics fit in very quickly, only teachers that struggle a bit are teachers that are teaching for the first time, maybe that have not been exposed to teaching for a long time. But as I have said, teachers that have been teaching for quite a while do not take too long to get to grips with the subject.*

Mr Gamma, the DH from School C, concurs with the statements above, and seemed to have no issues related to teachers' knowledge of teaching Technical Mathematics. All of the Technical Mathematics teachers in his school are seasoned teachers with many years of experience:

> **Mr Gamma:** *I've got two seasoned educators that teach Technical Mathematics. One educator has been teaching for 38 years, the other has been teaching for over 23 years. So, they have an excellent subject knowledge of it, as they are also Pure Mathematics educators. They are doing the job to the best of their ability because they have extensive knowledge.*

Mr Gamma was of the view that teachers who are seasoned Mathematics teachers can relate to the content of Technical Mathematics and its teaching. Importantly, this DH attests that he is well-informed with regard to the knowledge for teaching Technical Mathematics, as he is an experienced Mathematics teacher. This was also evident during classroom observation, where the DH used unique ways of teaching Technical Mathematics.

Mrs Beta alluded to the fact that the teaching of Technical Mathematics requires that one knows more than just the content and has the ability to engage learners:

> **Mrs Beta:** *My teacher' knowledge is adequate. Although as a teacher I have the knowledge for Mathematics, there are few factors that hinder the effective teaching. As a teacher I need to scale down to meet learners' level of understanding.*

Mrs Beta alluded to the fact that her knowledge of the subject is substantial. She points out that learners' knowledge of the subject seems to be minimal at entry-level in Grade 10 through to Grade 12. She asserts that she 'scales down' to reach learners' level, in order for them to understand the content she teaches. As the DH, Mrs Beta is responsible for knowing that her teachers possess sufficient knowledge for teaching Technical Mathematics. In her observation, she indicates that her teachers possess adequate knowledge of the subject, which enables them to teach Technical Mathematics fluidly. The importance of strong knowledge for teaching Mathematics ultimately led to improved learners' performance, while lack of teacher knowledge of Mathematics results in poor performance by learners. Ball et al. (2008) concur with this, asserting that teachers' effectiveness requires high levels of Mathematical knowledge and pedagogy. They noted a strong link between the two constructs, contributing to teachers' effectiveness. DHs as the subject heads have an obligation to ensure that they and their teachers are exposed to professional development workshops that promote high-quality teaching.

Mampane's (2018, p. 193) study on DHs' roles in ensuring professional development of teachers in Mathematics raises a concern about DHs and their leadership role, stating that "There is a need to affirm the leadership role of the HoDs in Teacher Professional Development (TPD) to allow HoDs to acquire knowledge and skills that will enable them to perform their role effectively". He states that DHs must identify teachers' needs, while noting their development, and asserts that presently teacher professional development programmes are not speaking to teachers' needs adequately. Mampane (2018, p. 138) argues that "Teachers who attend workshops that do not address developmental needs, do so to comply with departmental circulars". His study raised the need for DHs to have concrete pedagogy and content knowledge in order to lead instruction and knowledge in their respective schools effectively. Whereas there is a concern with MKT for Technical Mathematics, the departments has an obligation to adequately plan and ensure that teachers improve their teaching practice for successful content delivery.

6.5 Observation of the Departmental Heads presenting lessons in their classrooms

Each of the three DHs who participated in this study was observed in their classroom to understand their teaching practices related to Technical Mathematics fully. In the following section, I present observations of DHs in the classroom as they enact their teaching duties.

6.5.1 Observation of Mr Alpha's Technical mathematics lesson

Mr Alpha's teaching of how to evaluate trigonometric expressions was well planned, and the objectives of the lesson were clear and spelled out to the learners. His reliance on the textbook was minimal, and instead he used his own examples and asked learners to present their own problems that related to the lesson:

Mr Alpha: *I am doing the section called reduction formula. For Technical Mathematics there is only three reductions, and the reductions we will be doing are absolutely easy. The first one is 180 degrees. The reason I am not reviewing that homework exercise is because there is less than half of you. So, I will review that exercise when all of you are here.*

This is the $sin\ (180° - \theta)$, $cos\ (180° - \theta)\ and\ tan\ (180° - \theta)$. *We will look at the first three and then follow the similar pattern ... We are supposed to know this by a difficult process, but I am saying to you, you do not have to do it that way. This is what you need to do, let's take the* $sin\ (180° - \theta)$.

This question here is guaranteed to come out in your next assessment, it is guaranteed to come out in the third control test, it is guaranteed to come out in the final examination. The mark scheme for this here, the minimum is 6 marks; of the 6, you can get 4 without knowing Mathematics. I am showing right now how you can get those marks. All you have to do is to listen and follow the instruction. Let's take the $sin\,(180° - \theta)$, *for the fact that you are working with* $sin\,\theta$ *then you are going to write* $sin\ (180° - ..)\ and\ put\ 10°$ *instead of* θ. *All you have to do is to take your calculator and sneak in this value and tell me your answer.*

Learner 1: 0, 1736.

Mr Alpha: *All I am interested in, is it negative or positive?*

All learners: *Positive.*

Mr Alpha: *All of you understand that? Did you all get that? So, we will leave this as positive:* $sin(180° - \theta) = sin\,\theta$. *Let's see the next one, what is the next one telling us?* $Cos\ (180° - \theta) and\ we$ *will knock this* θ *off and put 10.* $Cos\ (180° - 10)\ and$ *I want to know what the sign of the answer is going to be! Do that for me.*

Learners: *Negative.*

Mr Alpha: *The answer will be the negative value. Is that so?*

Learners: *Yes!*

Mr Alpha: *All you have to do is to write a negative* $cos\ (180° - \theta) = -\ \ cos\,\theta$.

Let's do the next one: $tan(180° - \theta)$. *What will the next one be equal to? We all know half the answer,* $tan\ (180° - \theta) =\ \dots\ tan\,\theta$. *So, you will knock this* (θ) *off and put 10. And the answer is* $tan\ (180° - \theta) =\ -tan\,\theta$.

Now, the other three ratios, unfortunately there is nothing we can do with co-ratios. But we can use what we already know with the signs of each reciprocal function. So, the next one is: $cosec\ (180° - \theta)\ \ =\ +cosec\,\theta$

$\sec\ (180° - \theta) = -\sec\theta$

$\cot\ (180° - \theta) = -\cot\theta$

We know that this [ratios] *matches with this* [co-ratios] *and the signs are going to be the same. Now this is the reduction formula. Take this down.*

Table 6.1: ***Reduction of*** $\mathbf{180° - \boldsymbol{\theta}}$

Fundamental ratios	**Reciprocals (co-ratios)**
$\sin\ (180° - \theta)\ =$ $\sin\ (180° - \theta) = \sin\theta$	$\mathrm{cosec}\ (180° - \theta)\ =\ \mathrm{cosec}\,\theta$
$\cos\ (180° - \theta) = -$ $\cos\ (180° - \theta) = -\ \ \cos\theta$	$\sec\ (180° - \theta) = -\sec\theta$
$\tan\ (180° - \theta) =\ -$ $\tan\ (180° - \theta) =\ -\tan\theta$	$\cot\ (180° - \theta) = -\cot\theta$

DH chatting with the researcher while learners were engaged in the task:

Mr Alpha: *Khoza, have you ever seen this done this way?*

Researcher: *No, I have not. It seems like an interesting way and makes it easy to find reductions.*

Mr Alpha: *I said I will show you something, I may be wrong. But I think I am the only educator in the province who is teaching this in this way. I shared this with other lot, other educators when we had our content workshop. Because by the time you work out that old school ASTC (All Students Take Coffee), they lost it.*

Researcher: *Okay, this is great!*

Mr Alpha went back to the chalkboard and continued with his lesson.

Mr Alpha: *For the next two reductions* $(180° + \theta)$ *and* $(360° - \theta)$, *you don't need my help.*

Table 6.2: ***Reduction of*** $\mathbf{180° + \theta}$

Fundamental ratios	**Reciprocals (co-ratios)**
$\sin\ (180° + 10°) = -0{,}173648..$ $\sin\ (180° + \theta) = -\sin\theta$	$\text{cosec}\ (180° + \theta)\ =\ -\text{cosec}\,\theta$
$\cos\ (180° + 10°) = -\ 0{,}98480..$ $\cos\ (180° + \theta) = -\cos\theta$	$\sec\ (180° + \theta) = -\sec\theta$
$\tan\ (180° + 10°) = 0{,}17632..$ $\tan\ (180° + \theta) =\ \tan\theta$	$\cot\ (180° + \theta) = \cot\theta$

Mr Alpha: *Now you do the next one!*

Learners completed the task independently, and Mr Alpha walked around to check if they were doing the task and marking learners' exercise books. He then wrote the solutions on the chalkboard:

Table 6.3: ***Reduction of*** $\mathbf{360° - \theta}$

Fundamental ratios	**Reciprocals (co-ratios)**
$\sin\ (360° - 10°) = -0{,}1763..$ $\sin\ (360° - \theta) = -\sin\theta$	$\text{cosec}\ (360° - \theta)\ =\ -\text{cosec}\,\theta$
$\cos\ (360° - 10°) = 0{,}9848..$ $\cos\ (360° - \theta) = \cos\theta$	$\sec\ (360° - \theta) = \sec\theta$
$\tan\ (360° - 10°) = -0{,}17632..$ $\tan\ (360° - \theta) =\ -\tan\theta$	$\cot\ (360° - \theta) = -\cot\theta$

Mr Alpha: *Now many of you are coming here without calculators, and you cannot do this without a calculator!*

Now comes the application, let's do this together!

$\frac{\sin(180°+\theta).\sin(180°-\theta)}{\cos(180°+\theta).\tan(360°-\theta)}$ *Call out the reductions for each for each trigonometric ratio.*

$= \frac{-\sin\theta.\ \sin\theta}{-\cos\theta.-\ \tan\theta}$ … *Reductions for each for each trigonometric ratio.*

$= \frac{-\sin\theta.\ \sin\theta}{-\cos\theta.-\frac{\sin\theta}{\cos\theta}}$ … *Writing* $\tan\theta$ *in terms of* $\frac{\sin\theta}{\cos\theta}$.

$= \frac{-\sin\theta.\ \sin\theta}{\cancel{\cos\theta}.\ \frac{\sin\theta}{\cancel{\cos\theta}}}$ … *Divide* $\cos\theta$ *by* $\cos\theta$ *in the denominator.*

$= \frac{-\sin\theta.\ \sin\theta}{\sin\theta}$ … *Simplify.*

$= \frac{-\sin\theta.\ \cancel{\sin\theta}}{\cancel{\sin\theta}}$ … *Divide* $\sin\theta$ *by* $\sin\theta$ *in the numerator and denominator.*

$= -\sin\theta$ … *Our final answer is going to be* $-\sin\theta$

Learners were confident in applying reduction formulars that Mr Alpha presented, and they were relating to his teaching methods. Their application of reduction highlighted that lesson objectives were achieved. DH's unique method of teaching reduction formula showed that he possesses strong content knowledge of Technical Mathematics, and that he is aware of the questions that examiners are frequently focusing on. The DH prepares his learners to answer in the expected way in tests and examinations. Whereas most learners were out of the class, because of the homework they did not do, he was going to repeat the lesson when they were all present. This suggests that time is wasted, especially for learners who already attended the lesson. Mr Alpha lost teaching time as a result of learners' apathy to do their homework, which suggests that he was falling short on the time stipulated in the ATP, which does not allow such flexibility. The observation of Mr. Alpha's teaching of reduction formulas in Technical Mathematics highlights his proficiency to some degree in both Pedagogical Content Knowledge (PCK) and Mathematics Knowledge for Teaching (MKT).

Classroom observations revealed an exam-driven approach to teaching Technical Mathematics, emphasising content coverage and test preparation over conceptual understanding. DHs predominantly relied on rote teaching methods, focusing on memorisation of abstract mathematical concepts. However, literature suggests that this approach may hinder the development of deeper mathematical understanding. Skemp (1978) argues for fostering rational understanding, emphasising comprehension of both "what to do" and "why" it is done. The prevalence of instrumental understanding in Technical Mathematics classrooms indicates a need for instructional approaches that promote deeper conceptual understanding among students, underscoring the importance of enhancing both PCK and MKT among educators in the field.

6.5.2 Observation of Mr Gamma's Technical Mathematics lesson: Complex numbers

The purpose of this lesson was to recap learners on different complex numbers and introduce complex equations. This was done to prepare learners to answer related exam-type questions. There were 21 learners in the Grade 12 classroom, in a traditional classroom set-up.

> **Mr Gamma:** *What we are going to do in this lesson is to recap on one of the main sections, which is complex numbers. Part of complex numbers is complex equations. Now the reason why I am saying we are going to do complex numbers and complex equations together, if we have to take past exam papers, it is one of the common questions – almost every past paper has a complex equation of some sort in it. So, if we can know that we can answer these questions correctly in the paper, it is going to help us to get to our pass mark and the mark that we want to achieve. Remember, I always tell you that we want to go above our pass mark. This is one of the sections that will come out, as I said, in in your exams and again complex equations is there when you look at your N-courses as well. When you are doing N-4, you do complex numbers again, and you find that complex equations are part of it. That is for learners who will go to TVET colleges after this …and do your trade and artisans and things like that.*
>
> *Now complex equations, our main aim when we look at complex equations today is to establish rectangular form on both sides. Our real part and imaginary part. We are not going to focus on taking things from the right-hand side to the left-hand side or from the left-hand side to the right-hand side (transposing), we are going to be looking at the basics for now:* $x + yi = a + bi$

We will keep what is on the right on the right and what on the left on the left, but at the end of the problem we want to bring it back to the rectangular form on both sides. Our main aim once we get to rectangular form on both sides is to then equate real terms. Remember, real terms are the ones that don't have an i *in it, imaginary terms are the ones that have an* i *in it. We can equate real terms and we can equate imaginary terms. So that our aim here, we are going to say, is to:*

- *equate real terms.*
- *equate imaginary terms (*i).

So, if I were to make up a problem here, just as an example. If I want to say:

$x + yi = 2 - 3i$

$x = 2 \quad y = -3$

This becomes easy for me, my real number on the left is x *and my real number on the right is* 2*, and my imaginary number on the left is* y *and my imaginary number on the right is −3.*

Example 2: $2a + 3bi = 10 + 12i$

If you look at this, it is slightly different form the first one we have done. The only difference is that we don't have a single term, we have got two terms: 2a and 3b. It is the exact same methodology we are going to use from what we did there, we are going to repeat it here. What is your real number on the left?

Learners: *2a*

Mr Gamma: *And your real number on the right?*

Learners: *10*

Mr Gamma: *So, we are going to equate those. We are going to say,* $2a = 10$*, and this is something we have been doing from Grade 8 now, how do I solve for a?*

Learner: *Divide by 2.*

Mr Gamma: $\frac{2a}{2} = \frac{10}{2}$ *so, if I divide by 2 on the left, I must divide by 2 on the right-hand side.*

$a = 5$

So, we are going to do the same thing for my imagery number on the left, which is $3b$, *and my imagery number on the right is 12, and remember it is positive 12 and it works even better, we have* $3b = 12$, *and how do we solve for b again?*

Learners: *We divide by 3 both sides.*

Mr Gamma: $\frac{3b}{3} = \frac{12}{3}$

$b = 4$

Now, that's the basic for complex equations, once we get rectangular form on the left, rectangular form on the right, we just equate real parts and equate imaginary parts. This rectangular form is $z = a + bi$, *there you have clear real part and the clear imaginary part. This is both, real part, and imaginary part*: $2a + 3bi = 10 + 12i$.

Remember, we have gone through this, the only two forms you get is rectangular form: $z = a + bi$ *and you get polar form which is* $z = cos\theta$, *or you can write in short* $z = r + \theta$. *So those are two forms that we get for complex numbers, and we must be able to change between the two. We will go again in another lesson through the conversion from one from to another.*

Exercise 1: Solve for x and y

Mr Gamma: *Let's say if I make up problem here, in the sense that I am solving for x and y, on this side I say:* $x + yi = (2 + 4i)^2$

If we look at this problem, at the start of our lesson we said my aim is to get rectangular form on both sides. Right now, we have rectangular form on the left side, on the right side it is not in rectangular form. This left-hand side is fine $(x + yi)$, *I can leave it as it is, I will just continue carrying it down to a point I can equate it. What should I do on this side?*

Learners: *Open two brackets.*

Mr Gamma: $RHS = (2 + 4i)^2$

$= (2 + 4i)(2 + 4i)$

What will be my next step?

Learner 1: *Use FOIL method*

$= 4 + 8i + 8i + 16i^2$

$= 4 + 16i + 16i^2$

Mr Gamma: *FOIL method, you are right, you are going to use the FOIL method from here, and remember you have to take it to both the terms. I'm saying this because prior to this I had my Grade 11 class that was here and we were doing exponents, we had a similar problem.*

$x + yi = 4 + 16i + 16i^2$

$x + yi = 4 + 16i + 16(-1)$

We are going through this again, yes? Let's go through this again just to clear up if there is any misunderstanding. Are we all okay with me replacing i^2 *with -1?*

Learners: *Yes.*

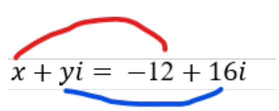
Mr Gamma: $x + yi = -12 + 16i$

So, 16 times -1 = -16, and remember I have a plus 4 which is equal to -12. I can't do anything with these two ($-12 + 16i$)*. There is real and imaginary number. I can only add real number to real numbers, imaginary numbers to imaginary numbers. Okay, that will be my solution for that particular problem. Then we are going to take an exam question and its instruction is going to be the same, we going to solve….*

Learner 2: *Sir, we are not done with this problem.*

Mr Gamma: *Okay, sorry, we are not done with this, you are right, we were solving for our x and yi, we didn't complete this problem. So, when we are at this point, what is my real number on this side?*

Learners: *x*



Mr Gamma: *So, I am going to say, x = -12 and y= 16, and remember we don't put an i there. So, we finish with this particular problem. As I said, the main thing with this, we want rectangular form on the left-hand side and rectangular form on the right-hand side as well. Once it is in this form (I am just doing this again), we equate real terms with real terms and imaginary to imaginary. As I said, learners, these are the questions that I know will come out in your exams, which is why I want you to be able to get them right. The questions will be similar, with different values. I don't know what values will be there, how they will phrase the* *questions, that I don't know. But you must get a complex equation in your exam ... So, the same instruction for the next one, solve for x and y, and I am taking this from a 2019 DBE paper 1. I am going to put it up in the board, and we are going to quickly try it out, then we are going to do the solution for it.*

So, what it says here is, it says $x + yi = \frac{3-4i}{2+i}$

Learners work independently and in pairs discussing the solution, as the DH walks around checking learners' exercise books.

Mr Gamma: *Learners, do we have anyone who is willing to share his or her solution?*

Learner 3: *I will try, I don't know if it is right.*

Mr Gamma: *We will see if it is right or wrong. Learners, please pay attention to his solution.*

Learner 3: [Silently writing his solution on the chalkboard]

$$x + yi = \frac{3 - 4i}{2 + i}$$

$$x + yi = \frac{3 - 4i}{2 + i} \times \frac{2 - i}{2 - i}$$

Mr Gamma: *Learners, are you watching what he is doing, because that is 100% correct so far, he is using his FOIL method. When you multiply out that is what you get.*

Learner 4: *Can you explain what you are doing?*

Mr Gamma: *Minenhle* [pseudonym], *would like you to explain?*

Learner 3: [Writing and explaining the solution on the chalkboard in English and isiZulu.] *We are using FOIL method to expand the terms.*

$$x + yi = \frac{(3 - 4i)(2 - i)}{(2 + i)(2 - i)}$$

$$x + yi = \frac{6 - 3i - 8i \ + 4i^2}{4 - 2i + 2i + \ i^2}$$

$$= \frac{6 - 3i - 8i\ + 4i^2}{4\ - 2i + 2i - i^2}$$

$= \frac{6-3i-8i\ +4(-1)}{4\ - 2i + 2i\ -(-1)}$ *. substitute* -1 *for* i^2*, u-2 no 2 baya-cancelana*

$$= \frac{6 - 11i - 4}{4\ + 1}$$

$$x + yi = \frac{2 - 11i}{5}$$

Learner 3: *Sesiyahlanganisake amaLike terms, ilike term ka 6 no -4, mase siwa adder kuphuma u 2. Mase si-adder u -3i no -8i, kuphume u -11i, isign yethu isazoqhubeka ibe u minus.*

$$= \frac{2 - 11i}{5}$$

Mase la ngenzansi kwidenominator u 4 – (-1), kufana nokuthi si thaymza ama sign u-negative (-) no-negatiive (–) kuphume u-positive (-). Kushuthi lana kuzoba u 5, mase sithola i-answer,

$x + yi = \frac{2}{5} - \frac{11i}{5}$ *Masesiyahlukanisake lempahla*

$x = \frac{2}{5}$ $\quad yi = \frac{11i}{5}$ *Ama like terms*

[Learner 3 forgot to write a negative on $y = -\frac{11i}{5}$ and the DH reminded the learner to write a negative sign.]

Mr Gamma: You forgot something there, a negative: $yi = -\frac{11i}{5}$

Learner 3: I am sorry sir, yes, $yi = -\frac{11i}{5}$ and the final answer is $x = \frac{2}{5}$ $\quad y = -\frac{11}{5}$

Learners*: Clapping*

Mr Gamma: *So, remember, learners, again, we get better with practice. I can tell you for a fact that he is practicing the problems given in class, and that is the reason he is getting it right now. Let's do this one more time, I think you did a good job explaining it as well. As I said, I'm just going to run through this one more time because these are common questions* *that you get from exam papers. As you can see, this one, I took it straight from the exam paper that I found in my booklet, the first one I put up on the board.*

Again, remember you must get a mark there.

$x + yi = \frac{3-4i}{2+i} \times \frac{2-i}{2-i}$ ... *Conjugate is 1 mark*

Once again, anything over itself is 1, if you multiply anything by 1 you are not changing the number, you are just introducing something that will help you to solve it.

$= \frac{(3-4i)(2-i)}{(2+i)(2-i)}$ .... *Then you use the FOIL method:*

$$= \frac{6 - 3i - 8i + 4i^2}{4 - 2i + 2i + i^2}$$

Remember, I am not going to go through every term that is there. I am just highlighting the point where you are going to get your marks for it. Remember, every time when you substitute for i^2, if you replace it with -1 you get your mark. There is also something called Consistence Accuracy (CA) marks when it comes to your Mathematics, that is provided you are doing your own work. That's one thing we encourage learners to do, do your own work, even if you get the answer wrong, but if your method is right, you can still get some part marks for it.

Then you substitute i^2 for -1,

$= \frac{6-3i-8i+4(-1)}{4-2i+2i-(-1)}$ ……………. *substitute -1 for i^2* (1 mark)

Then at this point you can only add real terms to real terms, the real terms, I had 6 and 4 times -1 will be -4, that will give me a 2. Now $-3i$ and $-8i$ will give me $-11i$. And once again, $4-(-1)$, the two negatives become positive when you add at the same time and will give you 5.

$= \frac{2-11i}{5}$

Once we are at this point, as we said, we bring this down [left-hand side of the equation]

$$x + yi = \frac{2 - 11i}{5}$$

Equate your real terms to real terms and imaginary term to imaginary term. Don't forget that negative sign; the reason I asked him if he is missing something, is because I saw it in his answer in the book and he forgot to write it on the chalkboard. As I said, sometimes when we are rushing we make mistakes.

$x = \frac{2}{5}$ $yi = -\frac{11i}{5}$

$x = \frac{2}{5}$ *... Value of* x *(1 mark)* $y = -\frac{11}{5}$ *... Value of* y *(1 mark)*

What we are going to do is, I am going to give you another problem that I want you to try out in the meantime, and again I am taking this problem from a past exam paper. And the reason that I am taking these problems from exam papers is so that we work on the same level of what you are going to be tested on. The whole country is going to write the same paper, so if we work with different past papers, they are all going to be based on the same guidelines, layout, sections. But it will be different styles; remember, every examiner will have a slightly different style of setting a paper. If you get used to multiple styles, whatever comes out in your final paper, you should be able to attempt it, you should be able to get it right.

Okay, so what I want you to do is attempt this problem, I am going to give you a little head start to this. Remember on this side you have your real number and imaginary number and that's okay, what you need to do is to work on the right-hand side, then come to a point where you bring the left-hand side down and equate with the right-hand side. Remember, try this in class, because in class it is not for marks – whatever mistakes, you make them in class – but don't make them in exams where its counts for marks.

Just a humble appeal, for the learners who were doing Grade 12 last year, if you can reach to them, if they want to donate [book] *it back to the school, they can. What I can do with it, I can give it to you for you to use, and again we can recycle again for next year's matrics, or if we get a new lot of books, then we can use those with more recent papers in it. But again, it is a good book, and it has lots of papers in it.*

What I am going to do is give you another problem that I want you to do in the meantime, and again I am taking this problem from an exam paper, I am taking it from September 2019 Paper 1 Technical Mathematics. Once again, same instructions, solve for x and y.

Learners worked on the problem and the DH was walking around checking if learners were doing so. Most learners had shown the DH their solutions and some asked the DH to help them with the first few steps, as they were unfamiliar with the type of problem presented to them.

Mr Gamma: *I am getting a small request to get you started first step, because this problem looks slightly different from the problems we have done. What I am going to do here, is the FOIL method,* LHS = $3x(2) + 3x(i) - i(2) - i^2$

$$= 6x + 3xi - 2i - i^2$$

The lesson ended and learners were given the problem as homework, along with selected similar problems from various question papers.

In the observed lesson led by Mr. Gamma, while there are notable strengths in his PCK and MKT, there are also areas where negative aspects of these competencies are apparent. Negative MKT is observed when there is a lack of differentiation in instruction, potentially hindering learners' engagement and progress due to unmet diverse learning needs. Negative PCK manifests in the insufficient explicit connection to prior knowledge, which may impede learners' ability to build upon foundational concepts effectively. S imilarly to Mr. Alpha, Mr Gamma frequently used rote learning as their primary instructional approach, emphasising rote memorisation of abstract mathematical concepts and preparing learners for tests. Furthermore, the lesson could benefit from a stronger emphasis on mental construction, as Skempt (1978) advocated strategies to promote deeper understanding and independent learning among students. Based on the classroom observation, it was evident that DHs' classroom implementation of Technical Mathematics was exam-driven and based on covering the content, where learners were drilled on answering exam questions and not on conceptual understanding, on which Technical Mathematics is grounded. Moreover, the DH was challenged by contextualising the application of Technical Mathematical problems and demonstrating their relevance to the learner's real-life context and, importantly, in the artisan field they are preparing for.

6.5.3 Observation of Mrs Beta's Technical Mathematics lesson

Mrs Beta's lesson was on the application of logarithms laws, and the purpose was to link previous work on basic rules and definitions associated with logarithms. These involve intuitive understanding of changing exponential form to logarithm form. The DH made use of an e-textbook that she displays on the overhead projector from her laptop. There were 20 Grade 11 learners in the Technical Mathematics class. The lesson was taught in a traditional classroom setup, in the science laboratory. The DH supplemented learning content by using examples drawn from learners' textbooks, and she continuously asked probing questions to engage learners. The activities of the Mrs Beta during the lesson included displaying and explaining the content on the whiteboard. She explained the first three examples, with learners participating, and thereafter gave out the lesson activity with six more complex examples for learners to work on independently to complete the task.

She walked around engaging students and challenging them to do more, similar problems. The DH possessed good teaching ethics; she knew her learners well enough to make them co-operate during class. Behavioural challenges and learner work apathy did not prevail in the DHs' classrooms.

Mrs Beta: *Okay, lets' start, ukhona umsebenzi ongamakiwe before siqale, if ukhona asiqale ngawo* [is there any work we have not marked before we start, lets' start with that].

Learners: *No.*

Mrs Beta: *I am waiting for everybody to confirm that all the work is marked. Is all your work marked?*

Learners: *Yes.*

Mrs Beta: *Now close your books, put your pens down, now pay attention.*

Learners closed their books and listened attentively to the DH.

Mrs Beta: *Okay, tell me the important information that you know now about logs, anything, we have discussed a lot about logs. Hands up. Please speak up, ophakamise isandla akhulume kakhulu …* [the one with a hand up, speak louder!]

Learner 1: *A log of a number with a certain base is equal to 1.*

Mrs Beta: *What else? We spoke about logs laws, we spoke about definition, and so on and so forth, there is a lot. I even shared with you about four definitions. What did you learn last week about logs? And it was in table form. We were using a table. Speak up so that everyone can hear you.*

Learner 2: *Changing from log form to exponential equations, and vice versa. Right! That's what we did.*

Mrs Beta: *What are the four definitions we spoke about? There are four definitions that we discussed. If you are given log this, you must know the answer is this. Yes, girl!*

Learner 3: *A log of a negative number, the answer is undefined!*

Mrs Beta: *Yes! A log of a negative number is undefined. That's number one. What else?*

Learner 4: *Log 1 is equal to 10.*

Mrs Beta: *No! Good try though. Log 1 is not equal to 10. Yes, boy!* [Pointing to another learner]

Learner 5: *Log 100 is equal to 10.*

Mrs Beta: *No! Log 100 is not equal to 10,*

Learner 6: *Log 10 is equal to 1.*

Mrs Beta: *Yes! Log 10 is equal to 1. Carry on from there!*

Learner 6: *Log 100 is equal to 2.*

Mrs Beta: *Right, log 100 = 2, carry on.*

Learner 6: *Log 1000 = 3*

Mrs Beta: *And log 1000 is equal to 3.*

Right, and what is log 1 equal to? you said log 1 is equal to 10, we discussed it. What is log 1 equal to?

Few learners: *Log 1 is equal to zero.*

Mrs Beta: *Log 1 is equal to zero, not 10; So, these are important definitions that we discussed, we also discussed about base, exponents and so on … so, if I give you log 2, what is the base of log 2?*

Learner 5: *The base is 10.*

Mrs Beta: *If there is nothing written there, it means that the base is 10, always remember that! If I give you* $log_2 3$*, what is the base now?*

All learners: *2*

Mrs Beta: *2 is a base, please remember this. Okay, now we are going to start applying the laws that we have written down. Remember, there are different laws, there is a law of addition, subtraction, multiplication, and division. All these laws are based on bases, that is how we do it with exponents, we say when we are multiplying exponents with the same bases, we add exponents. Nalana* [and here] *it works like that, most of the time we work with the same bases. Multiplication goes with addition or vice versa, division goes with subtraction or vice versa. Okay! ... We have done all this. We didn't do this* [going through textbook examples].

I want us to start with this, the question is saying 'Simplify each of the following using appropriate log properties'. The question says do not use a calculator. One of the most important laws when we are doing this simplification is this law, log of a base a, or let me use another letter; log of t base t is equal to what? Checker ilaw emi kanjena ukuth ikhona yini, and tell me the answer [I want you to identify the law and tell me the answer]. *The laws are in your exercise book, you wrote them, check your exercise book.*

Learner 7: *The answer is 1.*

Mrs Beta: *Very good, my friend. The* $log_t t$ *= 1, there is a law, check it! Well done! So, these are questions that we are simplifying. Trying to simplify, but it is not always a case that this law will apply. Alright, then the next thing I want us to look at is, how else can I write the log of 5 to the power* x*,* $log_5 5^x, u\ x$ *ungabi I exponent* [But x should not be an exponent]. *Check that law njengamanje* [right now]. *It is in your exercise book! Look for that law, it is there, in your exercise book. Yes, girl!*

Learner 6: $xlog_5 5$

Mrs Beta: *Yes! there is a law that says you can rewrite log 5 to the power x (*$log_5 5^x$ *) as* $xlog_5 5$*. So those are the laws we are using here in this question. Okay, let me look for an example that we can use to apply these two laws … If I want to change the log of 125 base 5 (*$log_5 125$*). If I simplify the log of log of 125 base 5, what do I do? I try and make this number to be the same as 5. Do you follow?*

Learners: *Yes.*

Mrs Beta: *So I will change this number ngiyibhale* [write] *as 5, uzoba ubanike u 125 mangiwubhale nge base ewu 5?..* [what will 125 be in exponential form, such that the base is 5?]

Learners: *5 to the power 3… (*5^3)

Mrs Beta: *I base yami yala ubani? u5* [What is my base here? its 5], *5 to the power 3, sengizosebenzisa lama laws awu 2* [I will now use these 2 laws], *Ile ebishiwo uwena* [this is the one said by you, pointing to learner 6] *nale ebishiwo uwena* [and the law said by you, pointing to learner 5], *Siqale ngale ebishiwo uwena ithini ilaw yakho?* [Starting with your law, what does it say?]. *How will I change this? Sebenzisa ilaw lo ongitshele yona* [Use the law you just told me].

Learner 5: *3 log 5 base 5 (*$3\,log_5 5$)

Mrs Beta: *Excellent! 3log 5 base 5, sesiya kwilaw yakhoke manje* [we now use your law, pointing to learner 5]. *I am waiting for you, we have 3log 5 base 5, what did you say t base t equal to (*$log_t t$*)?*

Learner 5: *It is equal to 1.*

Mrs Beta: *So, what is log 5 base 5 equal to? (*$log_5 5 = ?$)

Learner 5: *It is equal to 1.*

Mrs Beta: *Good, so this is the same as 3 log 5 base 5, which is 3 multiplied by 1, which is equal to 3. That is what we are doing.*

$log_5 5^3$

$= 3log_5 5$

$= 3(1)$

= *3*

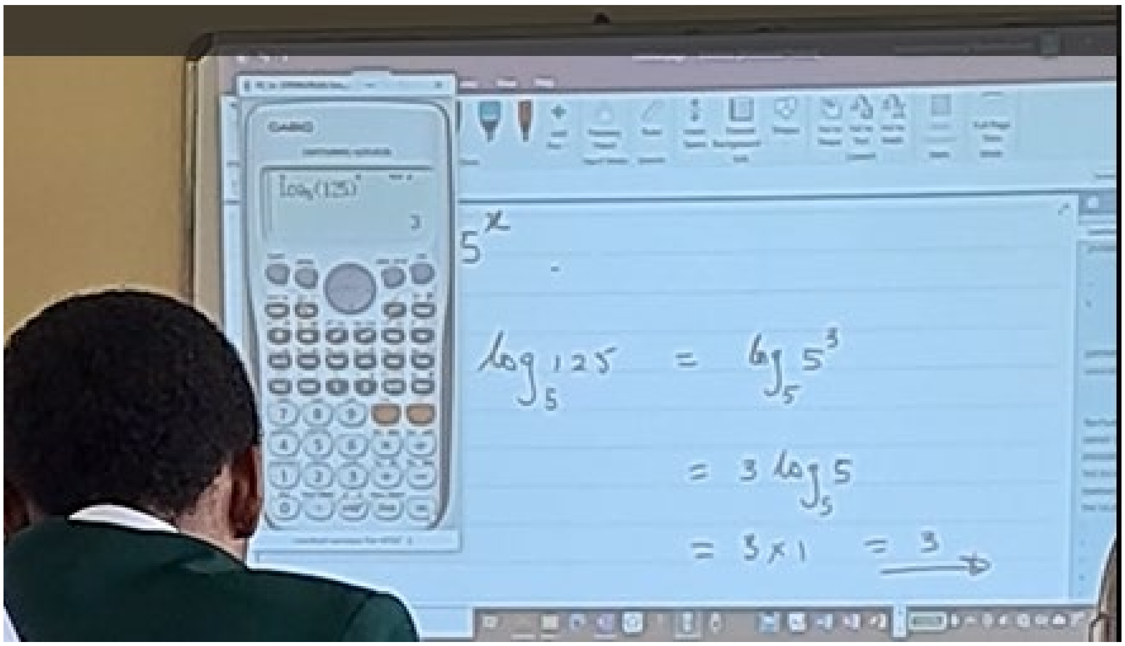


Figure 6.1. *DH Mrs Beta's presentation of the solution using the whiteboard.*

Mrs Beta: *So now, check using your calculator. So, if you check using a calculator, remember you go to this mode here, khona ulog onebase bese kuba khona ulog ongenayo ibase, ibase yakho u 5 inumber yakho u125* [in your calculator, there is a log without a base and where you need to put log base, your base in this case is 5 and the number is 125]. *Remember you can't go and put log 125 base 2. You need to show lamasteps ebesikade siwenza* [these steps which we were doing]. *So, what will be the answer for the next question (c) without doing any work? By inspection, meaning by not using a calculator. What will be* $log_{10} 10^5$*?*

[Learner 8 is using a calculator.]

Mrs Beta: *No! I said by inspection, without using a calculator! Ngokubuka!* [By inspection!] *What will be the answer?*

Learner 8: *Ngokubuka kwami ianswer kuzoba u 4.* [The way I see it, the answer will be 4.]

Mrs Beta: *No! That is not correct… Yes, girl, what will be the answer?*

Learner 9: *It will be 5.*

Mrs Beta: *Good!* $log_{10} 10^5 = 5$*; Let's see if you can tell the answer for (b) by inspection, without using a calculator! What will be the answer for* $log_4 81$*, hands up if you know the answer. Yes Nana* [pseudonym].

Learner 6: *The answer is 4.*

Mrs Beta: *Very good,* $log_4 81 = 4$*, that is what we are doing here! Now, what we were doing mentally, you must now show it when you are writing it down and working it out. Okay, Sizoqala ngalezi engathi zilula mase siza ngalezi ezinzima* [we will start with the easy ones then move on to the difficult problems]. *Do not forget, it all revolves around base trying to be the same as the number. Do a, b and e, you have 5 minutes, your topic will be 'Application of log laws'. As soon as you finish, come and let me check your work.*

Learners started to work independently; as soon as they finished, they lined up at the DH's desk for her to mark their work.

Mrs Beta: *Oseqedile unumber 1 akeze ngiwubone*. [Whoever has done with number 1 must come and show me.] *I said, if you are done with the first question, come and let me check it.*

The DH marked the learners' exercise books and discussed each learner's solution. Almost all of the learners had written the correct answers. The DH was commenting on some learners skipping some steps, and after checking learners' exercise books, she continued by introducing more examples.

Mrs Beta: *Right, that was just a warm-up, after that you simplify these six problems, note that the answer will not always be a number. I am introducing other examples now; I want you to try them. Try to make the base to be like a number.*

[The siren goes and the DH assigns the task as homework.]

The predominant use of an overhead projector as the primary teaching tool in the observed Mrs. Beta Technical Mathematics classrooms reflects a deficiency in both PCK and MKT. Unlike the innovative approaches demonstrated by master teachers in Mudaly and Naidoo's (2015) study, where visuals and tangible objects were utilised to deepen learners' understanding of mathematical concepts, the observed classrooms relied heavily on traditional methods characterized by ‘chalk and talk.’ This limited use of instructional aids and interactive teaching strategies may indicate a lack of PCK, as educators may not be sufficiently equipped to effectively integrate content knowledge with pedagogical practices that promote meaningful learning experiences. Additionally, the failure to capitalise on alternative teaching methods, as highlighted in Mudaly and Naidoo’s research, suggests a potential deficit in MKT. This limited use of instructional aids and interactive teaching strategies may hinder learners' ability to grasp abstract mathematical concepts and develop a deeper comprehension of the subject matter. Skemp (1978) emphasises the importance of fostering rational understanding in mathematics education, advocating for instructional approaches that transcend mere transmission of information to encourage students to comprehend the underlying principles and reasons behind mathematical procedures. Therefore, the observed reliance on an overhead projector as a mere ‘textbook on the wall’ and a calculator may not effectively promote the kind of conceptual understanding advocated by Skemp and demonstrated by Mudaly and Naido’'s master teachers, underscoring the need for teachers to enhance both their PCK and MKT to facilitate more profound learning experiences in Technical Mathematics classrooms.

6.6 DHs’ Technical Mathematics content and sequence of teaching and learning

The sequence of teaching and learning declares the content (specified in the CAPS document), pace (ATP) and assessment of subject content (POA and assessment guidelines). DHs and subject advisors follow standard procedures when monitoring the Technical Mathematics curriculum which, according to Jojo (2019, p. 131) is enabled by the structured curriculum as “the mathematics content to be taught is explicitly delimited, paced, and sequenced with prescribed mathematics textbooks that points out certain examples”. Part of the DHs’ role encompasses monitoring of the sequence of teaching and learning using the ATP and POA, which they themselves have to adhere to, and monitoring if their teachers comply with these tools. Mogari (2014) argues that the CAPS that is preferred in South Africa is helpful in the teaching of low-achieving learners; he further attests that in a more structured curriculum, teacher-directed instructions allow low expectations from both teachers and learners.

The DHs were asked about their conformity to the syllabus and the flexibility that they have in terms of what they have to teach and assess. Mr Alpha called for flexibility in the Technical Mathematics curriculum and stated that its teaching content, lesson planning and exercises, and assessment do not allow them to be flexible and perhaps design their own elements that are suited for their students' needs:

> **Mr Alpha:** *This learning area doesn't allow us a lot of flexibility. What we teach, the exercises given in lessons, and all our tests are designed by the Department* [DBE]. *But the Practical Assessment Task (PAT) allows you a little bit of flexibility, where you can guide learners, but all other assessment tasks do not allow us to guide them. All our school-based assessment (SBA) tasks are more like examination-based, where you give the question paper and learners are expected to work on their own. So that's the challenge. For example, let us say we are teaching a section called Mensuration, where you are dealing with cubes; it doesn't allow them to build a model and give them marks. It doesn't allow the flexibility. But had it allowed for the flexibility, where we build the model and then test the volume, area, surface area and all of this, where we're giving 50% for the project and 50% for content, we know that the learner will pass it because he is building the model. So that's the lack of flexibility that we have. A lot of it is content orientated and content driven. Our assessment, our examinations, everything is based on the content.*

Mr Alpha's comment suggest that the DH is restricted as to what he can teach and assess. He asserts that a lack of flexibility in Technical Mathematics, which is a subject based on application and not on content, makes it hard for learners to attain the learning goals, especially for tasks where they can be hands-on. Mr Alpha views Technical Mathematics as a subject that incorporates practical work and should have a practical component, where learners actively construct models relevant to the content they are learning. Nevertheless, the DH commends the PAT, in that it does allow them to be a bit flexible in terms of guiding learners on what they are supposed to do, as opposed to other formal tasks like assessment where learners work independently without getting assistance from the teacher.

In contrast, Mrs Beta acknowledges that the ATP provided by the DBE gives them direction on when tasks should be administered. She asserts that the ATP is also used for standardisation in their cluster and all schools across the province. She commended the PAT as helping learners to gain confidence in Technical Mathematics, and says that they enjoy engaging with practical problems:

> **Mrs Beta:** *The ATP helps us a lot in terms of streamlining our work, it also guides us when we need to give certain tasks, and most of those tasks are provided by the DBE. Also, PAT has helped to improve the performance of the learners, because it is practical, and learners enjoy it lot.*

Mrs Beta comments that the ATP helps her as a DH to unpack the content to be taught each day, as she indicates that it helps to streamline Technical Mathematics content accordingly. In this way, other than referring to the CAPS document and dissecting the content according to weeks and days, the ATP helps to minimise this task for teachers. She also highlights the fact that the assessment dates are stipulated in the ATP, which helps with organisation of the content topics which teachers need to focus on in preparing learners for upcoming assessment tasks. The DH distributes the ATP to both teachers and learners, so they can conform to the provincial dates during teaching and learning. She comments that the practical component (PAT) that is entailed in Technical Mathematics not only improves results, but also increases learners' apathy in the subject, as they prefer doing practical work.

Mr Gamma holds strong sentiments regarding adhering to the CAPS document. He asserts that as a legally binding document, he conforms to it and advises his teachers to do the same. Whereas the DH alludes to the fact that while there is minimal flexibility in terms of what he and his teacher teach and assess, he ensures that he and his teachers are guided by the ATP in order to conform to the CAPS document. He echoed similar sentiments to Mrs Beta:

> **Mr Gamma:** *CAPS document is the legal document provided by the Department, so we have to conform to it and follow through. The flexibility is very minimal, because of the amount of contents that need to be covered. There is very little flexibility, and we teach according to the CAPS document.*

Mr Gamma emphasises the importance of strict adherence to the CAPS documents in his department, that it is a legally binding document, and dictates the content and pace that he and his teachers need to follow when teaching Technical Mathematics. The ATP provides them with the sequence and plan for the year, which they need to follow regarding the CAPS document. The DH mentions that since these measures are in place, he and his teachers have minimal flexibility over what they teach, meaning that they cannot deviate from the prescribed curriculum to teach sections they feel to be important at the grade level.

Mr Gamma's views match those of Silver (2015, p. 16) in his articles in the AMESA Newsletter, where Mathematics teachers raised the same concern alluding to their experiences in implementing the CAPS, stating that "There is a lot of content to cover in a restricted time". Essentially the DHs and teachers' conformability to the CAPS is exam-driven, as they ensure that all content is covered before learners are exposed to the state examinations.

The DHs and teachers conform to the syllabus and the flexibility they have over what they teach and assess seems very limited. The DHs participating in this study argue that they must conform and encourage teachers to conform, or they will not have enough time to finish the syllabus. The DHs felt that their learners will fail provincial assessments that speak to the CAPS document, ATP and examination guidelines if they do not conform. Drawing from excerpts from the three DHs, it appears that their practices to implement the curriculum as teachers are restricted in terms of what they wish to do by the prescribed syllabus. As Mr Alpha and Mr Gamma put it:

> **Mr Alpha:** *The restricted curriculum also affects the way they manage the curriculum in their respective schools. All our school-based assessment tasks (SBA) are more like examination-based, where you give the question paper and learners are expected to work on their own.*
>
> **Mr Gamma:** *We have to guide teachers to teach according to the CAPS document.*

The DHs who participated in this study alluded to strictly following the prescribed curriculum, where their mandate as the DH is constrained in terms of what should be taught, how it should be taught, and when it should be taught and assessed. Their comments agree with the call by Samuel (2008) for teacher independence regarding what they teach and what their learners learn; this author maintains that autonomy helps teachers to find themselves in their profession.

As noted above, the three DHs who are teaching Technical Mathematics seem not to have the autonomy to implement and manage the curriculum. However, whereas their teaching of the prescribed curriculum impinges on their autonomy as professionals and leaders, it also takes away the burden of having to plan for each subject they manage. Some DHs highlighted that a lesson plan provided by the DBE has too much content to cover in a single 45–60-minute lesson, and one lesson takes about two to three lessons to implement. The lessons are not free- flowing, as suggested in the Learner Support Document, which constitutes prescribed lesson plans and activities provided by the DBE. As a result, DHs and teachers find themselves teaching for examinations; they do not have sufficient time to cover the content and do revision to prepare the learners for examinations. Some participants felt that modifying assessments to suit learners' needs can also improve learners' results and will relieve the pressure on teachers to race to complete the syllabus.

Mr Alpha alluded to the fact that the learning content of Technical Mathematics is as demanding as that for Pure Mathematics. He asserts that learners' perception of the subject is a challenge, as they seek to get an easy pass without putting the necessary effort into their work. He commented on the nature of Technical Mathematics as a demanding subject that is abstract- driven, like Pure Mathematics:

> **Mr Alpha:** *The challenges that we have encountered is the type of learners that we receive or that choose to do Technical Mathematics, some of the learners think it easier than Pure Mathematics. When you look at it carefully, it is not actually easier, it is different content that is covered in Pure Mathematics and in Technical Mathematics. The learners that take the subject with the aim of an easy pass, you find that they are struggling. They find that it is the same thing that is done in Pure Mathematics.*

What is cemented by Mr Alpha is that the Technical Mathematics content has been presented to learners as a subject which emphasises application, whereas in fact the subject does not allow for the development of hands-on experience – which is what Technical Mathematics should allow. Rather, it is taught and assessed like Pure Mathematics is, which is abstract-driven. Also, Mr Alpha commented that most learners choose Technical Mathematics with the idea that it is easier than Pure Mathematics, only to find that the subjects are equally difficult. He noted that these learners do not have a strong foundation of Mathematics and hardly understand the content being taught:

> **Mr Alpha:** *... what must be borne in mind is that the weaker learners are doing Technical Math, it is not the easiest of syllabus, and it's very challenging for learners to get good results.*

6.7 Conclusion

Chapter 6 discussed findings concerning DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics The focus was on DHs' roles and their understanding of their management roles. The study revealed their knowledge and practices of implementing and managing Technical Mathematics in their respective school contexts. The DHs' PCK and MKT was revealed, as well as their perceptions on selecting teachers to teach the subject. The DHs participating in this study noted that as prescriptive as it may be, using CAPS helps by providing the ATP, POA and examination guidelines as curriculum management and implementation tools. The DHs noted that these documents are helpful in providing a structure to follow, especially for new teachers. However, the DHs found the ATP to be impractical to follow, in that it neglected challenges that DHs and teachers experience when teaching the content and with the allocated teaching time.

The next chapter will discuss the findings concerning DHs' enactment of their roles and responsibilities of implementing and managing Technical Mathematics.

Chapter 7

Departmental Heads' enactment of their roles and responsibilities to implement and manage Technical Mathematics

Whereas Chapter 6 focused on the findings concerning DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics, Chapter 7 discusses the findings concerning DHs' enactment of their roles and responsibilities of implementing and managing Technical Mathematics. The researcher used the theoretical framework for this study, Samuel's (2008) Force Field Model, to frame analysis of the data. The Force Field Model stems that were used are contextual forces (macro-social, political, historical context) and institutional forces (micro-contextual) that influence DHs' implementation and management of the Technical Mathematics curriculum in their schools' context. DHs mediate the institutional and contextual forces within their schools, and their agency is important in knowing what to adapt, adopt or neglect when these forces are in play. Thus, managing and implementing the curriculum need DHs to be autonomous, to ensure that they adapt the curriculum to suit their learners' and school's needs.

The following themes emerged from the data with respect to the study framework:

- DHs' management of the Technical Mathematics curriculum
- DHs' implementation of Technical Mathematics
- DHs' management of human resources – teachers
- Learners' selection in Technical Mathematics course
- DHs' management of teaching and learning resources
- DHs' enactment of roles and responsibilities
- DHs' understanding of management of the Technical Mathematics curriculum
- Factors enabling DHs to enact their roles.

Each of these is discussed individually next, followed by a brief overview of Technical Mathematics classrooms in the three schools under this study and cases of DHs' instructional leadership styles that they use to enact their roles and responsibilities.

7.1 Departmental Heads' management of the Technical Mathematics curriculum

For effective curriculum implementation and management, DHs ought to know what the DBE expects them to do, so that the envisaged curriculum is implemented. The participants pointed out a number of expectations, which include ensuring that all teachers have the annual teaching plan (ATP) and adhere to it, with monitoring of their completion of topics on a daily/ weekly basis. The DHs avowed that they use the ATP as a self-monitoring tool and to check their teachers' usage of the monitoring tool for curriculum coverage. Apart from the ATP, the DHs indicated that the DBE also expects them to engage in extensive assessment moderation of all tasks that are administered in their subject area. Whereas DHs are aware of the ATP monitoring tool, the document analysis revealed that not all of them monitor curriculum coverage. and the same was also observed in their files. This suggests that while the DHs know what is expected of them, it is not carried out in practice.

Similarly, the study conducted by Mkhwanazi et al. (2018) found that even when documents are signed by the DH, there is no alignment between what is signed for and what is covered in the class, suggesting that management of curriculum coverage is donge on paper but not in reality – in other words, merely for compliance purposes. In this study, the lack of monitoring of curriculum coverage was evident because the ATPs were not signed, which suggests that the DHs' practices of adhering to monitoring are done for compliance with the DBE's expectations.

The ATP guides teachers on the time that is allocated for each topic, and they have to plan their lessons accordingly to meet this expectation. For Technical Mathematics the weekly instructional time is 4.5 hours for Grades 10–12 (DBE, 2016a). An early study by Moodley (2013, p. 92) on implementation of CAPS in South Africa revealed that "Although the specification in CAPS of content, pace, sequencing and assessment, has been welcomed by educators they would prefer it to be less prescriptive with reference to time frames". Recently, Ojo and Mathabathe's (2021, p. 26) study that investigated the effectiveness of CAPS pointed out that "the challenge with implementing the subject (mathematics) is that students who find it hard to understand the contents of the subject do not have enough time to learn the concepts". This suggests that completion of the prescribed content to be covered as specified in the ATP could be impossible for teachers, especially in a new subject like Technical Mathematics, where teachers need to spend a reasonable amount of time dissecting the content for learners.

When participants were asked about the DBE's expectations of DHs regarding curriculum implementation, monitoring, and management, they had the following to say:

> **Mr Alpha:** *The expectations are quite high. How we monitor is that we have a programme that is called an ATP that we need to check and complete on a daily basis. That is in terms of expectations by the DBE, we need to complete that… The monitoring is that we continuously have CASS [continuous assessment] moderation where we have to take our portfolios together with our ATP. Our portfolios in this right here* [showing his file], *where we have to do all assessment tasks that are related to SBA. So that's how the monitoring from the DBE is done with the subject advisors together with coordinators that have been appointed to see us.*

The DH (Mr Alpha) raises the issue of high expectation of the DBE concerning curriculum monitoring. He points out that the tool that DHs have at their disposal to monitor curriculum implementation is the ATP. In trying to explain how they use the ATP to monitor the curriculum, he mentioned that it is used to continuously check if the intended curriculum is covered on a daily basis. This is also part of the moderation, where teaching needs to be aligned with assessment. What is noted is that when he speaks of curriculum monitoring, Mr Alpha is referring to monitoring curriculum coverage, not implementation. Before monitoring curriculum coverage, it is critical to monitor implementation, that is, the actual process of teaching and learning. Based on Mr Alpha's response, the findings showed that little or nothing is done to monitor implementation of the curriculum at a school level.

Similarly, Mr Gamma mentioned that managing Technical Mathematics means ensuring completion of the specified content spelled out in the ATP. He ensures thar tasks are moderated in compliance with the CAPS document:

> **Mr Gamma:** *Managing means checking that the ATP is followed, CAPS curriculum is followed or confirmed to see that assessments are done on time, and moderation of assessments are done in keeping with the CAPS document.*

DHs as curriculum and instructional leaders liaise with the subject teachers in their department (internal) and with their subject advisors to comply with the moderation expectations of Umalusi, which is an external accreditation body that oversees quality control of assessments and results. DHs as senior staff members are prescribed and held responsible by Umalusi for moderation of assessments that are administered at school level. Umalusi (2020, p. 8) defines moderation as "a process that ensures that assessment of the outcomes described in the National Qualifications Framework standards, or qualifications, is fair, valid and reliable". Also, the CAPS (DBE, 2014a, p. 51) states that "Moderation refers to the process which ensures that the assessment tasks are fair, valid and reliable".

Performing internal and external moderation is one of the forms of monitoring the curriculum that the DBE expects. The moderation, as spelled out in *Government Gazette* no. 41082 of (DBE, 2022b, p. 13) indicates that assessment tasks should be done following these evaluation criteria:

- the assessment tasks are aligned to the CAPS;
- assessments tasks and tools are valid, fair, and practicable;
- the instructions relating to the assessment tasks are clearly stated;
- the content must be in keeping with what the learner has been exposed to;
- the assessment task must be free of any bias;
- the language of the assessment task is in keeping with the language level of the learners for which it is designed; and
- the cognitive levels at which the assessment tasks are pitched are consistent with the requirements as stipulated in the CAPS.

Consequently, Technical Mathematics DHs have the obligation to ensure the practicality of the criteria using the moderation tools afforded by the DBE. The DHs' responsibility in this regard is to ensure that moderation is carried out at the school level prior to and after the administration of all formal assessments, at every level. This includes, but is not limited to, checking of teachers' files, learners' files, recording of marks, and that the marks are captured correctly in the South African School Administration and Management System (SA-SAMS). The DHs participating in this study indicated that they were following the moderation expectations guided by the evaluation criteria from the DBE and Umalusi.

Mrs Beta, DH from School B, indicated that she complies with the DBE expectations when managing Technical Mathematics, and mentions the following in terms of moderation:

Mrs Beta: *The Department is expecting reports on the subject, like when we go for moderations our work is checked on a regular basis. The DBE expects learners to do well in the subject so they can get access to tertiary institutions, specifically in Universities of Technology and Technikons.*

Mr Gamma, DH from School C, raised that moderation is done regularly to ensure that the subject is monitored and moderated at all grade levels. He added that workshops are held by the DBE to ensure that they know what is expected of them as DHs:

Mr Gamma: *I think we have regular or bi-annual or twice a year we have workshops that are running in terms of curriculum coverage and so forth and implementing of it. Monitoring and management is also done on a term-wise basis, when educators go for moderation from Grade 10, 11 and 12. Moderation of past exam papers or if any assessments are done; together with content workshops that are done on a regular basis for the subject teachers.*

The DHs' responses again showed that they are aware of the DBE's expectations, and they are getting assistance from the Department to implement said expectations. The DHs also indicated that they are working with subject advisors to ensure that school moderation meets the expectations of Umalusi, especially in Grade 12 where the expectations are high.

7.2 Departmental Heads' implementation of Technical Mathematics

Technical Mathematics implementation came at point where DHs and teachers were getting used to the two mathematics streams of Pure Mathematics and Mathematical Literacy under CAPS. Technical Mathematics was then implemented in schools in 2016, when teachers were somewhat used to the existing curriculum. The new subject then impinged, and the DHs had to reimagine and redefine their roles and identities in the new subject. This called for urgent capacitation of principals, DHs (implementation at school level) and teachers (implementation in the classroom).

Under this theme the researcher now describes the roles of DHs in ensuring implementation and sustainability of the Technical Mathematics curriculum in their schools, and the contextual forces and institutional forces, to explore how they carried out their roles. The DHs' agency in curriculum implementation was examined, when exposed to different factors imposed by the DBE and their school context. Schools had to meet certain criteria so that Technical Mathematics and other technical subjects are populated in their schools. The DBE set out norms and standards that were aimed at uniform implementation of Technical Mathematics across all technical schools in South Africa.

In ascertaining DHs' views on the changes in their roles brought about by the introduction of Technical Mathematics, the following conversation ensued between the researcher and DH participant Mrs Beta in response to the question 'Since the introduction of Curriculum 2005, Revised National Curriculum and CAPS leading to introduction of Technical Mathematics, how have these changes affected you?':

> **Mrs Beta:** *With regards to Mathematics and Science the changes are not dramatic, they are changes that one is able to handle. Specifically for Mathematics, the content is still the same, the changes that are there are the documentation, the types of documents that we use to record, and some of the things that are required by the SASMS* [South Africa School Administration and Management System]. *Generally, the changes are not that dramatic.*

In this DH's view, Technical Mathematics curriculum changes are minimal as the DBE introduced topics that were previously removed and brought back into the mathematics curriculum. In light of her experiences in undergoing several curriculum changes, she concluded that the Technical Mathematics curriculum is manageable and can be implemented in the same way. Having SMT support, DBE support, resources in place, teachers, workshops and the learners were identified as the main enabling factors that promoted effective implementation of Technical Mathematics.

7.3 Departmental Heads' management of human resources – teachers

One of the DHs' roles includes identifying teachers who are capable to teach Technical Mathematics, and the selection criteria are detailed in the interim guidelines for the implementation of Technology and Technical subjects, (DBE, 2016b, p.7), where Section 8.1.1 states: "The current status quo for Norms and Standards with regards to Mathematics and Physical Sciences also apply to Technical Mathematics and Technical Sciences".

In two schools the DHs stated that for Technical Mathematics they only used seasoned Mathematics teachers. They indicated that most of the teachers have experienced most of the previous curriculum changes, including C2005, RNCS and CAPS. These teachers have taught most of the sections that were previously phased in and out of the Mathematics curriculum and also reintroduced in the Technical Mathematics curriculum. They indicated their fear of allocating new teachers to teach Technical Mathematics:

> **Mr Alpha:** *To be honest with you, the implementation of this has been such where they brought sections back that was taught previously. It is only the newer educators who are joining the system that would find a challenge. It is unfortunate for those DHs in those schools where teachers lack experience of the previous curriculum implementation. But fortunately for me, the educators that we have on the system have either been trained with those sections or they have done those sections as learners. Like if you take an era back where learners were doing Mathematics at school, they didn't do geometry. So now with the introduction of geometry back into the syllabus, they will find it challenging. But if you take a teacher who did Mathematics and did geometry, they will manage. However, we have lots of workshops that take place on an ongoing basis for Mathematics. As I explained regarding the Technical Math, we have quite a bit of support.*

Mr Alpha's views are that the implementation of Technical Mathematics resembles what happened in the past era when certain sections were brought in and out of the Mathematics curriculum. His worry was that new teachers might be overwhelmed, especially if they had not previously been exposed to the content that they are supposed to teach in Technical Mathematics. He affirms that a number of workshops are in place which aim to capacitate teachers with content and pedagogy of teaching Technical Mathematics. He was confident in his implementation of Technical Mathematics in his school, and only worried about other schools where teachers lack expertise of teaching the new subject. His assumption was that having experienced Pure Mathematics, teachers teaching Technical Mathematics enables him and the teachers to implement the subject.

Of the same view, the DH from School C, Mr Gamma, indicated that in his implementation of Technical Mathematics he only uses experienced Mathematics teachers to teach the subject:

> **Mr Gamma:** *I manage it* [Technical Mathematics] *by making sure that I've got the expert teachers to teach Technical Math. If the teacher is qualified to teach Mathematical Literacy, he or she won't be teaching Technical Math. Okay! So, one of the ways I manage is to ensure that I've got the right teachers who are teaching the subject.*

Drawn from the above extracts, there is evidence that while DHs believe that holding a teaching degree in Mathematics is a necessity to teach Technical Mathematics, what they value more when allocating workload to teachers is Mathematics teachers with experience in teaching across the curriculum, regarding them as better suited to teach Technical Mathematics. Thus, one of the ways in which they manage implementation of the curriculum is to be selective as to who teaches the subject. The DHs' view is that teachers who are qualified to teach Mathematics but have no experience are not the preferred choice to teach Technical Mathematics. As a result, they have to take the role of teaching Technical Mathematics upon themselves in their respective schools.

During the lesson observations, it was noted that in some schools they have one DH post for Science, Mathematics, and Technical subjects (School B), whereas in others one DH is responsible for all technical subjects (Schools A and C) and they have another DH post for Science and Mathematics subjects. The dynamics of the DH post in different school contexts affords or limits DHs in terms of time to manage all the subjects in their department while executing their role of teaching Technical Mathematics. What is noteworthy is that two DHs, Mr Alpha and Mr Gamma, have similar beliefs about what constitutes management of the implementation of Technical Mathematics; that is, experience in teaching is more valued than qualification. What transpired in this study is that the DHs who are Mathematics specialists rely mostly on Mathematics teachers, and those who are inclined to the technology subjects would prefer artisan teachers to teach Technical Mathematics (as in the case of Mrs Beta).

Technical Mathematics embodies both artisan skills and professional qualification. As stipulated in DBE (2016b), Section 8.2: The requirements for the employment of Artisans as Teachers stipulates that:

> The PAM document makes provision for employment of critical skills and those provisions should remain; however, the following should be added on the requirements for the

> employment of Artisans: The Artisan should have a Matric (Grade 12) or equivalent qualification; The Artisan should have completed his/her Trade Test; and The Artisan should have two (2) years relevant working experience. (p. 8).

The DBE (2016b) Section 8.8 puts emphasis on the professionalisation of the artisan teacher:

> The Provincial Education Departments should encourage Artisans to acquire a teacher qualification in line with the provisions of the Strategy for Teacher Qualifications. (p. 9)

Contrary to the views of Mr Alpha and Mr Gamma, who prioritise experience as the key factor in managing the teaching of Technical Mathematics, Mrs Beta prioritises teachers with artisan skills. However, whereas Mrs Beta believes that artisan teachers are those most suited to teach Technical Mathematics, she contradicted herself by saying that during her observation the pedagogy is demonstrated to her satisfactorily. She had this to say concerning management of the implementation of Technical Mathematics in relation to human resources:

> **Mrs Beta:** *The teachers often pair their knowledge of Mathematics and the Technical Mathematics CAPS documents. The reason why one of the teachers often struggles is that the teacher did an Engineering course and thereafter one year ACE programme, which qualified him to be a teacher. The teacher then has to get to the level best of learners' understanding, which is not always demonstrated.*

This extract shows that she does not prioritise artisan skills, because she is blaming the teacher with such skills for not being able to teach. This suggests that her beliefs about allocating the teaching load are based on the artisan teachers' background, but there is also a challenge of knowing how to teach (pedagogy) among the artisan teachers.

Noting that the participants had different experiences concerning management of the implementation of Technical Mathematics when it comes to employment provision of Technical Mathematics teachers, they did all however value the support of ongoing workshops that aimed to capacitate teachers. The support is also valuable for them as DHs, as they are also teaching the subjects. With continuous changes in the education system in South Africa, DHs are a crucial component in managing and implementing the developments regarding curricular changes (Tapala, 2019). Tapala (2019, p. 73) argues that "The issue is that the DHs like all educators are not trained on the new curriculum developments, rendering them helpless when it comes to training and developing their own staff'. For this reason, it is not surprising to find that DHs in this study seem reluctant to allocate new teachers in implementation of the new curriculum.

What can be drawn from this study is that teachers of Mathematics are expected to teach either Mathematics and/or Mathematical Literacy, and/or Technical Mathematics. The following comments from the three DHs suggest that experienced Mathematics teachers are trusted more to teach Technical Mathematics:

> **Mr Gamma:** *I've got two seasoned educators that teach Technical Mathematics.*
>
> **Mr Alpha:** *Most of the educators in this department right now are seasoned educators, who taught Mathematics.*
>
> **Mrs Beta:** *The teachers that are experienced in teaching Mathematics fit in very quickly, only teachers that struggle a bit are teachers that are teaching for the first time.*

This expectation disregards the fact that they were not trained to teach either Mathematical Literacy or Technical Mathematics. The assumption that a few days of workshops will equip them to teach a subject they were not fully trained to teach may result in limiting learners' attainment of knowledge. To succeed, DHs must learn while teaching simultaneously, as they have to learn while teaching at the same time. This neglects the fact that learning does not automatically equal understanding. Thus, teachers who struggle to conceptualise some technical concepts might pass the misconceptions on to their learners.

Machaba and Du Plooy (2019, p. 2) argue that Mathematics and Mathematical Literacy "are dialectically linked and viewing these seemingly contradictory mathematical pathways from multiple perspectives suggests that they are, in fact, completely reconcilable", and they insist that the two subjects "are not only complementary but that any dichotomy between the two subjects cannot be justified". With the addition of Technical Mathematics in the curriculum, the roles of Mathematics DHs and teachers need to be redefined, and I argue that it cannot be presumed that they fit into all three Mathematics streams.

7.4 Selection of learners for Technical Mathematics course

The other component in curriculum implementation, especially for the Mathematics curriculum is selection of learners with mathematics capabilities who can cope with the subject merits. Ideally these are learners who show interest in the subject and whose careers are inclined towards Technical Mathematics. The National Development Plan set a target in 2013 to produce 30 000 artisans by 2030 (National Planning Commission, 2013), and the Technical Mathematics stream is in line with exposing learners to the trade industry (DBE, 2015a). Ogunkunle and George (2015, p. 389) specify envisioned artisan learners' skills, positing that:

> For one to become an artisan, one will need a strong background in basic Mathematics such as quantification, relations, geometrical shapes and measurements. Artisans need basic mathematical knowledge to develop the artisan creative skills. This basic mathematical knowledge is to be taught in the classroom with respect to application and practice.

The DHs' roles in the FET phase then encompass identifying and selecting learners who meet the requirements set by the SMT. The DHs participating in this study shared how they recruit learners and select them to do Technical Mathematics. The researcher asked participants: What informs learners' choice of Technical Mathematics, and how do they (DHs) decide which learners to select? The DHs had the following to say:

> **Mr Gamma:** *We have a course selection process and it's a robust process where learners are spoken to about the technical subjects, including Technical Math and the clear choices that they have. So, we tend to have like a career day where parents are spoken to and given information about what are the clear options out there, and what are the subjects that we offer. This helps them to have an idea that Technical Mathematics also has a PAT component which makes it easier for learners to pass Technical Math; therefore they make the choices based on the importance of the subject in learners' career.*

Mr Gamma's role in course selection includes guiding learners in terms of different courses that are offered in his school, so that they can make informed choices. He stated that during career guidance day, parents are invited to help their learners make informed choices based on their career interests and capabilities. In the context of Technical Mathematics, learners are informed about the nature of the subject and the assessment that is encompassed in the subject. This DH indicated that Technical Mathematics has a PAT component, which makes it easier for learners to gain a pass compared to Pure Mathematics and Mathematical Literacy.

Similarly, Mrs Beta, the DH from School B, shared that together with her SMT they go beyond to monitor the mathematical knowledge of learners from Grades 8 and 9, and the learners who are consistently getting good marks are advised to choose between two streams of mathematics, that is Pure Mathematics and Technical Mathematics. This is reflected in her comment:

> **Mrs Beta:** *We use a simple strategy, we monitor learners from Grade 8 and 9 and those that are doing well in Mathematics in Grade 8 and 9, we advise them to either choose Pure Mathematics or Technical Mathematics in Grade 10. Technical Mathematics is specifically for learners that are doing technical subjects. If a learner chose to do technical subjects and is doing well in GET* [General Education & Training (Grades R - 9)] *Mathematics, they can do Technical Mathematics or Pure Mathematics. But most learners are choosing Technical Mathematics rather than Pure Mathematics, because they have a perception that it is easier, which is wrong.*

The three DHs seemed to have the same pattern of learner selection for Technical Mathematics. Mr Alpha states that as the SMT, they set a benchmark of a 50% Grade 9 mark in Mathematics. Learners that score 50% and above are then given preference to take the subject. He attests that this is not always the case, as the majority of learners who end up opting for Technical Mathematics are not ideal candidates, as their pass mark is usually below 50% for their Grade 9 Mathematics mark:

> **Mr Alpha:** *That is a very simple process. We take learners who have the aptitude for Mathematics to do Mathematics, because you would appreciate that Mathematics is a little bit more challenging compared to Technical Math. We benchmark a cutoff point in terms of a learner who wants to do Mathematics. Having said that, sometimes with the learners' results that are the poor, we go for economic class sizes; let's say for argument's sake, you cannot now say you want to take over 50% of those learners. And if you go by that, you're only going to end up with 10 learners in your Math class. So, we are a little bit flexible in terms of that. So, we want our economic class units to be a minimum of 25. So, we take 25 learners who got the highest Math mark from Grade 9, but we predominantly look for that.*

What transpired from the DHs' course selection process is that it is informed by learners' capabilities, learners' career choices, parental guidance and school subject combinations that are offered in respective schools. Whereas the first preference is for learners who meet the minimum requirements, Technical Mathematics also competes with Mathematics; thus learners who are rejected from the Pure Mathematics course end up choosing Technical Mathematics. The DH mentioned that Technical Mathematics classes are overcrowded by learners who have no interest in the subject. Whereas DHs hold a mandate to place learners in the subject of their choice, they also need to be sensitive of the social issues that affect learners.

It also transpired from the DHs' comments that poor Mathematics results in Grade 9, with learners struggling to get 50%, dictated that the DHs had to lower the prospect of quality over quantity, and admit these learners to do Technical Mathematics. A similar finding is drawn from Magwaza's (2021) study on the influence of the pass mark in determining the subjects to be taken by Grade 10 learners. That study was conducted in four schools in Limpopo, South Africa, and the findings revealed that low marks achieved by learners in Grade 9 influenced them to reject subjects such as Mathematics in subsequent grades, due to a fear of failing. As evident from the DHs' comments, although they might prefer learners with good grades to enrol in Technical Mathematics, they have to consider other factors – for example, the enrolment target to implement the subject.

7.5 Departmental Heads' management of teaching and learning resources

Management of teaching and learning resources is one of the critical aspects in implementation of the new subject. The DH liaises with the SMT, especially the principal, to cater for the needs of the subject in the school budget. The DH needs to know at least the resources needed by teachers and learners for effective teaching and learning. This requires principals to be familiar with the subject needs, so they can support the DHs where they fall short. In the context of Technical Mathematics, learners need to be exposed to trade industry tools that teaching them mastery of critical skills needed for artisan jobs, and these tools should be linked to solving practical, real-life problems. DHs plays a significant role in ensuring that materials that aid the learning process are readily available at teachers' and learners' disposal. The PAM document stipulates that one of the DH's roles includes being responsible for distributing resources for all subjects in their department. The DBE (2016, p. 29) stipulates core duties and responsibilities of the DH, stating that they should be aware of "The latest ideas on, and approaches to the subject, method, techniques, evaluation and materials/resources in their field and effectively communicating these with the staff members concerned". Part of this includes ensuring that learners are adequately provided with textbooks and all necessary equipment required for the subject.

Attakumah's (2020, p. 105) study on textbook use and academic achievement affirms that "Standardized textbooks are very important resources that are used in teaching and learning to facilitate learning and learning outcomes in schools". He argues that textbooks help with illustration of unfamiliar ideas for learners' understanding. It is therefore imperative for teachers to use more than one textbook, to supplement those that the learners use in the classroom. Oakes and Saunders (2002) affirm that textbooks are fundamental and primary tools that give learners an idea of what they are required to learn. Hence, the inadequate provision and shortages of textbooks block learners' independent learning, with learners primarily depending on the teacher to provide notes and learning materials during the lesson, or share a textbook with other learners.

In managing implementation of the curriculum, DHs need to ensure that all learners are provided with this basic need for their subject. To ascertain the DHs' practices in managing and implementing Technical Mathematics in terms of teaching resources, they were asked about resources put in place for Technical Mathematics.

Mrs Beta indicated that in most lessons she uses a textbook as the teaching resource, as most learners in other grades have their own copy, with exception of Grade 10 where some learners have to share one copy:

> **Mrs Beta:** *The Department of Education provides us with textbooks, although the Grade 10 textbooks are little bit sketchy. All learners have textbooks, except for the Grade 10s where not all learners have textbooks.*

Mrs Beta's response indicated that the provision of Grade 11–12 textbooks was adequate, whereas Grade 10 learners had limited textbooks. It became evident that the retrieval policy was poorly managed and that the replacement of textbooks was dubious, even if this DH did not want to discuss the causes behind the textbook shortage or what she meant by being "sketchy". One would expect that in the entry level of Grade 10 there would be adequate resources, as the subject was newly introduced in schools.

In contrast, Mr Gamma indicated that at his school he had enough teaching and learning resources to teach Technical Mathematics, and he also uses support materials provided by the DBE to supplement textbooks in his teaching While he as a teacher has enough resources, like Mrs Beta, he alluded to a shortage of resources for the learners:

> **Mr Gamma:** *We've got enough resources. We've got textbooks, we've got resource booklets and so forth. We wish we could get resource booklets for every learner, but the Department gives us a few resource booklets of which we have to make copies for ourselves to give to learners. But textbooks, resources, teachers, we do have, but in terms of resources for every learner, we don't have enough.*

Mr Gamma reflected that in his school they depend on usage of textbooks and support material from the DBE for each grade level. The DH alluded to different measures in place to aid teaching of Technical Mathematics, saying that when teachers go for workshops they always come back with resources that supplement the textbooks.

During lesson observation, Mr Alpha pleaded with learners to consult ex-Grade 12 learners to return their learner support documents, as they are in short supply for the current Grade 12s:

> **Mr Alpha:** *Just a humble appeal, for the learners who were doing Grade 12 last year, if you can reach to them if they want to donate it back to the school, they can. What I can do with it, I can give it to you for you to use, and again we can recycle again for next year's matrics, or if we get a new lot of books, then we can use those with more recent papers in it.*

Mr Gamma proposes that learners should donate the learner support document, as the school is running short of these learning materials. In my conversation with the DH, he highlighted that the DBE should prepare materials for all learners, as the support documents are detailed and have lots of pages; this requires a sophisticated printing facility, which is not at their disposal. Asking learners to donate was one of the means that the DH undertook to enhance learning for the current learners.

Echoing the same sentiment as Mr Gamma, Mr Alpha mooted that he has adequate textbooks and also made use of the teaching and learning materials provided by the DoE for extended support. The DH states that he uses LTSM in his teaching, as it provides support where the textbooks fall short. His preference was based on the fact that the subject advisors and other learned personnel develop the booklet by aligning it to the ATP. He commends that it dissects the learning content into lessons according to the ATP and following exam guidelines, which is sometimes lacking in ordinary textbooks. He also argues that these lessons are unrealistic in terms of the content that needs to be covered in each day:

Mr Alpha: *The Department of Education provides us with teaching and learning material. I'm just taking a copy right now of learning material. Okay, take this booklet. It's a 2022 booklet. Where it provides learning support, and this is provided by the Department. Okay. This year is done by subject advisors, other learned personnel also break it down into different lessons as they're going through this thing right now. Each lesson. So what it does for educators and learners, it provides support. Yeah! So, you will notice that they teach it like this for one lesson. Can you see? I see … It's going to take me another day, two days, two hours. But then you are only given two weeks to complete one lesson. You have to be honest about the fact that our learners can't comprehend this in one lesson.*

Furthermore, Mr Alpha highlighted that the common textbooks, that is, Sasol Inzalo textbooks for Technical Mathematics Grades 10–12, are equally distributed in schools.

4. **Retention of textbooks**

   4.1. **<u>In the last week of the third school term</u>** learners must be instructed to bring all their textbooks to school to be checked by class teachers.
   4.2. If books are missing, parents must be informed and asked to replace them, or pay their replacement value.
   4.3. Parents are sent an account for a missing book and are reminded regularly if payment is not forthcoming.
   4.4. The school purchases new copies of the missing book(s) from the supplier and issues the new book(s) to the learner.

Figure 7.1 *School A textbook retention policy.*

It transpired from document analysis that Mr Alpha keeps track of what is assigned to each learner and they have the obligation to look after their textbooks. His management of teaching and learning resources, mainly the textbooks, was based firmly on a management and retrieval policy that they designed with teachers (see Figure 7.1). As a result of this policy, there are sufficient textbooks for all learners in Grades 10–12. He maintained that learners need to be continuously reminded to return textbooks, especially towards the end of the school year.

It became evident that the DHs' management of resources varies and is influenced by different factors. The shortage of textbooks does impinge on effective teaching and curriculum delivery. A retrieval policy was not evident in the case of Mr Gamma and Mrs Beta, which illustrates that for some DHs the management of learner resources is prioritised in the management and implementation of Technical Mathematics, while for others it is not and they shift the blame to the DBE for not providing adequate resources.

7.6 What does the Technical Mathematics classroom look like?

In School A, the Technical Mathematics classroom is an ordinary classroom where the teacher uses 'chalk and talk'. There is no provision for a learner-centred approach. The classroom is big, and accommodates about 30 learners doing Technical Mathematics, so they are not overcrowded. The DH prefers to use physical objects for demonstrating, and hardly ever uses technology support to supplement his teaching. The DH mentioned that the school provided them with laptops which they use for running school software and setting examination papers. While the DBE provides teacher support and learner support materials for teaching and learning in the classroom, there are still subject demands that require classroom facilities to support practical work in Technical Mathematics. Figures 7.2 and 7.3 show the Technical Mathematics classroom in School A.

Figure 7.2. *View of the Technical Mathematics classroom in School A.*

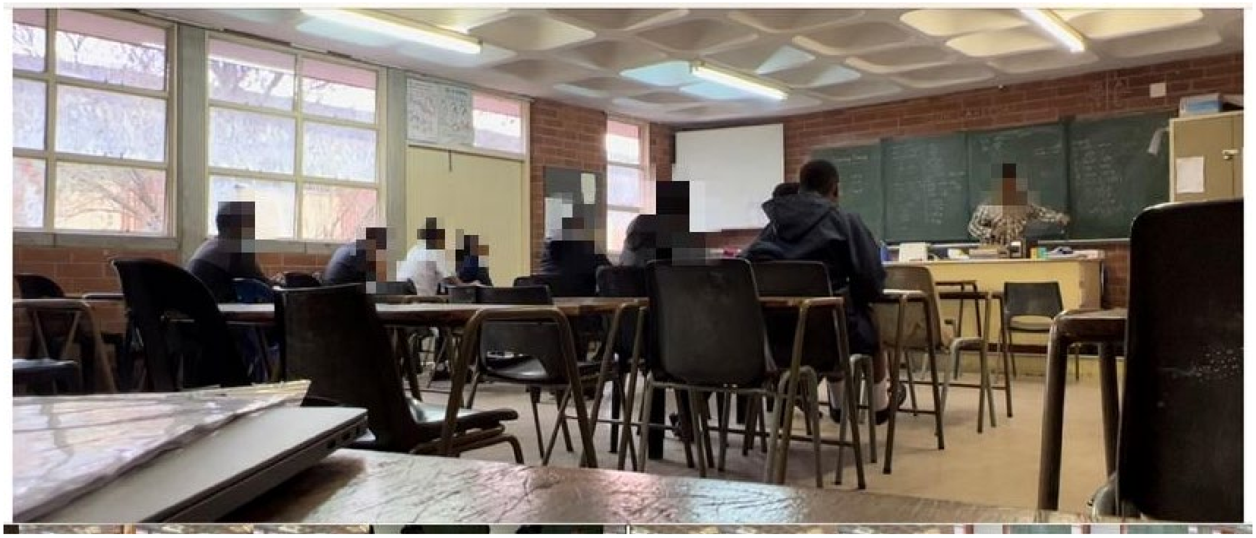


Figure 7.3. *Technical Mathematics classroom in School A.*

In School B, I observed a lesson in the laboratory where the DH routinely conducts her lessons. This class was 'just a science laboratory', there was nothing there that related to the Technical Mathematics curriculum, even on the walls. Nevertheless, the Technical Mathematics classroom seems to support the use of technology. She pointed out that she brings some teaching aids, like a data projector, as needed for the lesson. She prepares visual images and videos to gives learners a sense of the contextual background of the problem presented and the experience in the technical field that most learners are not aware of. The DH mentioned that in her department, Technical Mathematics teachers have access to school laptops and they share the data projector as needed:

> **Mrs Beta:** *We have materials that we use; teaching and learning support materials (*LTSM*). We have an overhead projector, whiteboards and laptops.*

The use of LTSM seemed to be on par in terms of its management, as the DH ensures that all teachers have equal access to the resources to enhance their teaching of the subject. What was noted is that physical resources to support the teaching of Technical Mathematics were lacking. The DH chose to use the laboratory because it is the only classroom with an overhead projector. Figures 7.4 and 7.5 show the Technical Mathematics classroom (laboratory) in School B.

Figure 7.4. *Technical Mathematics classroom (laboratory) in School B.*

Figure 7.5. *The Technical Mathematics classroom (laboratory) in use in School B.*

Whereas using technology might be advantageous to the teaching of Technical Mathematics, learners need to have a conducive environment where they are all seated and facing in one direction during instruction. The DH then to manage classroom resources by limiting the intake or adding another unit/class in the grade level.

In School B the laboratory that the DH uses for teaching Technical Mathematics is quite small, and does not cater for a large group of learners. Since the class has large number of learners, they must share their space. Writing PAT and any test means that some learners have to use the teacher's table, and some would stand for the duration of assessment since no tables were available. The DH pointed out that many learners are choosing Technical Mathematics, and their numbers are quite high compared to the Mathematics intake, and that affects the seating arrangement in her class.

In School C, teaching and learning takes place in an ordinary classroom setting. There is no or minimal use of technology to supplement the DH's teaching of Technical Mathematics. While the DH has a laptop, it is for administration work mostly rather than teaching. The overhead projector needs to be booked and is shared by more than 40 staff members in the school. Now and again the DH avoids the administrative task of booking for this teaching resource. Moreover, the classroom does not have a whiteboard for data projection, so a change of venue is needed whenever the DH decides to use technology in his classroom.

Figures 7.6 and 7.7 show the Technical Mathematics classroom in School C.

Figure 7.6. *Technical Mathematics classroom in use in School C.*

Figure 7.7. *View of the Technical Mathematics classroom in use at School C.*

The DHs in the selected schools in this study asserted that the classrooms accommodate not more than 30 learners per class. This helps with easing classroom management and learners' attainment of knowledge. The classroom environment is significant in allowing teachers to reach all learners during the lesson – which is not the case in overcrowded classrooms. Whereas learners are allowed to enrol in the subject of Technical Mathematics, the DHs set their cut-off points by looking at the classroom sizes, which can accommodate only a certain number of learners.

7.7 What influences Departmental Heads to enact their roles in the way they do?

The third research question aims to understand the underpinning reasons for the DHs enacting their roles in the way that they do. This was explored in their responses to the questions posed by the researcher. The findings of this study suggest that DHs use different management styles when enacting their roles, which are influenced by the school contexts that the DHs operate in. The staff support and expectations from the school principals, subject advisors and the DoE inform the management style they adopt in their schools. The DHs' personal biographies also determine the way they enact their roles. Smith and Andrews (1989, p. 15) use various terms to describe instructional leadership, referring to shared instructional leadership by stating that such managers are “Running a tight ship”. In essence, the DHs were found to be using a top-down management style, and shared instructional leadership (distributive leadership management), finding the balance between the two leadership styles with different forces pushing and pulling them in different directions.

7.7.1 Case 1: Instructional leadership (top-down management) style

Baffour-Awuah and Agyei's (2020) study on leadership styles describes instructional leadership as a type of management where the leader transmits instructions from top management to the staff at the bottom level to implement. The researchers assert that “the instructional leader combines management decisions and normal school routines with reference to educational goals to exercise professional duty” (p. 38). From the findings of this study, it was concluded that Mr Alpha, the DH from School A, uses a top-down management style. Rudhumbu (2015, p. 106) in Botswana attests that “Traditionally, the role of the academic middle manager has been viewed as transmitters of top management views to the lower echelons of the organization”. This leadership style prevails as the DH lacks autonomy in his role; he defines his role as an interpreter of information from higher authorities, the SMT and subject advisors to post level 1 teachers. He is expected by the school to follow the mandate from the DBE to implement the curriculum.

The DH’s management duties relied on checking that teachers are doing what they are supposed to do in class, adhering strictly to the ATP. He ensures that teachers have and implement preplanned lesson plans to implement the curriculum firmly. The DH ensures that teachers are assigning assignments, PATs, common tests, and provincial examinations on the stipulated dates. After the administration of assessments, the DH ensures that teachers complete their marking of scripts and tasks following the SMT assessment plan. The next step is moderation of tasks, where teachers submit their 10% of learners’ assessment tasks. Although the DH has senior teachers among his staff, all of the moderation is done by him as the subject is still new. The DH also teaches Grade 11 and 12 Technical Mathematics, which means that he knows all the curriculum needs and changes that take place. He is overworked, as the expectations from the principal are high and he needs to achieve results in the subject, and this is transferred to the teachers as well. This is reflected in the following statement:

Mr Alpha: *I'm also teaching the Grade 11 and 12. So, I'm monitoring Grade 10 and that is the only area that I was teaching, which I'm not teaching right now, that was due my loading. So therefore, I have to find myself knowing and being hands-on in terms of checking what they are doing. I did the analysis for terms one and two, so I know the results, but that doesn't necessarily speak to their content in terms of the syllabus.*

The influence of the considerable pressure brought by the CAPS policy makers, school context and expected roles of the DH were found to be forces that inevitably shaped Mr Alpha's enactment of an instructional leadership style. He argues that management of Technical Mathematics is not that challenging – what is challenging is to ensure that learners are doing well in the subject:

Mr Alpha: *Managing it is not challenging, but what is challenging is to get interventions with educators for learners to pass.*

Mr Alpha maintains that part of his management role is to ensure that learners' behaviour is corrected, especially in a school where learners' keenness to learn is significantly low. These contextual forces exert pressure on the DH to get learners to be attentive, do their homework and prepare adequately for their assessments. This is reflected in the conversation that he had with the learners at the beginning of the lesson:

Mr Alpha: *I think you are all aware that tomorrow is a parents' meeting. I will see every single parent, I want to inform them of your position in terms of passing the grade. I don't want to frighten you, but I want to tell them, so that they have at least another half of the year to correct your attitude. Remember, I told you that there is nothing wrong with you, I keep on saying this to you. The fact that you are here, it means that you have potential. What is the problem? You don't do your work.*

He works with all stakeholders – parents, SMT, teachers and subject advisors – to ensure that learners' behaviour is corrected, especially those who are not doing their work, to reach the goal of getting good end results. This was also evident during Mr Alpha's lesson when the Deputy Principal was walking around the school and found learners who did not do their homework standing outside the classroom. The DH put the disciplinary measures in place, and the Deputy Principal supported the DH by talking to the learners and encouraging them to do their homework. The DH involves parents by calling parents' meeting to discuss learners' behaviour and their performance in Technical Mathematics.

7.7.2 Case 2: Shared instructional leadership style

Conley and Goldman (1994, cited in Baffour-Awuah & Agyei, 2020, p. 34) state that "One major characteristic of shared instructional leadership is that leaders maintain coherence, agreement and consonance of educational programmes through investment in teachers' instructional resources and support". This was evident in the case of Mrs Beta, the DH from School B. What is significant is that teachers are included in the decision-making process, and they are active participants in the management of the subjects in their department. Notably, the DH's role is overwhelming, especially in schools where Mathematics, Science, Technology, and technical subjects are managed by one departmental head.

Mrs Beta's leadership style resembles the shared instructional leadership style. She ensures that teachers are capacitated in executing leadership roles, by assigning some of her roles and responsibilities to post level 1 teachers. She affirms that distributing her management role eases her own role and makes the teachers understand the expectations from the school and the demands of the curriculum. Both teachers and the DH work towards the common goal of meeting standards while narrowing their focus on learners' attainment of the learning goals. The DH posits that she shares responsibilities with other teachers, and felt that this is helpful in the implementation of Technical Mathematics in her school. Her shared instructional leadership management style is reflected in the following comment:

> **Mrs Beta:** *In our department, Science, Mathematics, and Technology, we have what we call subject specialists or subject heads. So, I do not take care of all the needs for all the subjects in my department. We have subject heads for Mathematics, Physical Sciences, Life Sciences and so on. So, my job as the DH becomes easier because I have people that are supporting me in running of my roles, I don't just do it on my own.*

Whereas there are ever-rising expectations imposed on the DHs by the school and by the DBE, the DH created an atmosphere in her department where all teachers are assigned with duties that make the department more efficient. The DH affirms that subject heads are helpful, as they know their subjects' specifics, they are communicating with their respective subject advisors, and communicate with other subject teachers in their department. Since the DH is a Mathematics specialist, it is impossible for her to moderate learners' work as she does not have knowledge of different subjects in her department. She only oversees the subject monitoring, using her management plan in which specific management tasks are stipulated, and the teachers must complete them in due time. The DH asserts that the effective use of staff members mostly makes teachers feel valued, and they have a significant contribution to make in the management of individual subjects and the department needs. Glickman (1989, p. 6) refers to this leadership as "leader of instructional leaders", which ultimately means that teachers are seen as equals rather than subordinates. The DH views them as equals capable of managing their subject areas.

In the context of Technical Mathematics instructional leadership, the DH has the role of managing the subject's needs. It was found that whereas the workload is eased by distributing management roles, the DH still finds it difficult to enact moderation in due time. There was no evidence of proactive management noted, and the DH was too relaxed and relied on other teachers for enacting her primary roles. The autonomy of teachers in this leadership style prevails, but they don't have not much to do other than ensure an improvement in their practice and in learners' performance.

7.7.3 Case 3: Top-down management style

The management style of Mr Gamma, the DH from School C, consisted of both the instructional leadership and shared instructional leadership styles. His management style did not fit into existing management styles, as he was found to be directive and also exercised a little bit of flexibility in terms of the extent to which teachers can execute roles in his department. He prefers to take ownership of his DH role, executing most of the management role and leaving out the roles that have no major or significant impact in the implementation of Technical Mathematics.

The DH manages the subject on his own, but does allow other teachers to intervene when it comes to mentoring new teachers or practising pre-service teachers. Mr Gamma manages technical subjects and teaches Technical Mathematics and Technical Science. He shares different experiences with the implementation of both subjects that were introduced in the same year, when he started to teach both subjects. He asserts that there are many challenges with managing Technical Mathematics, especially during exam times, but he works closely with the Science and Mathematics DH, and the Technical Mathematics team to ensure smooth running of his department. Moreover, the DH states that he receives lot of support from the SMT, especially the principal together with the subject advisor, who continuously check their implementation and managing of Technical Mathematics:

Mr Gamma: *The other thing is that it's quite tricky to manage in terms of exams and so forth, but we are able to work together as a team to ensure that the subject is manageable.*

This DH assigns master teachers with the responsibility of mentoring new teachers and helps them with classroom management strategies. The reason why the DH enact his roles in this way was based on his overwhelming duties. The DHs are not just teachers, they are also managers of the teachers with different professional needs. Mr Gamma has an open-door policy, and teachers and learners are able to discuss shortcomings, and experiences. This DH uses this to deal with challenges as they arise, and does not wait for formal staff meetings. Having open lines of communication – especially via the WhatsApp group that was introduced by the DH – means that teachers are able to share their challenges, ranging from reporting poor learner behaviour for immediate support, to curriculum needs where they share circulars, assessments/marking guidelines, upcoming workshops and important moderation dates. Figure 7.8 shows a conversation where the DH engages with the teachers through the Technical Mathematics WhatsApp group.

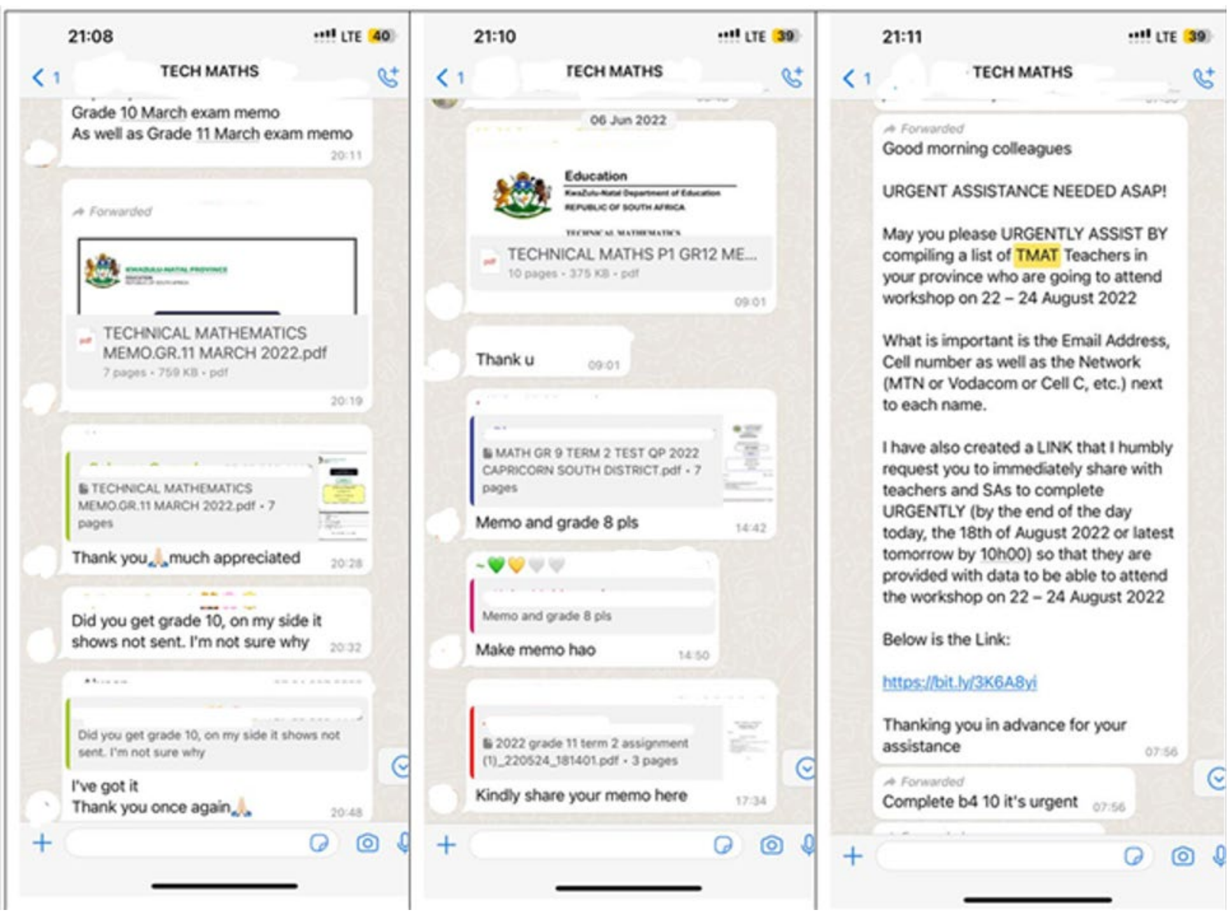


Figure 7.8. *DH's WhatsApp conversation with teachers.*

7.8 Conclusion

Chapter 7 discussed findings concerning DHs' enactment of their roles and responsibilities of implementing and managing Technical Mathematics. The DHs participating in this study shared their management strategies in the implementation and management of Technical Mathematics. They showed strong adherence in following the CAPS, ATP and POA. The DHs' implementation of Technical Mathematics was based on selecting their preferred teachers to teach the subject on the basis of their knowledge of mathematics and teaching experience. Part of their management was a robust process of recruiting and placement of learners in the Technical Mathematics course in Grade 10, which also had an impact on their results, when the sifting-out process of learners achieving 60% in Grade 9 Mathematics is compromised. Distribution and management of LTSM varied in different schools, and availability of resources continues to be a challenge, especially in Technical Mathematics as a new subject. It was shown how the curriculum is implemented in different contexts. Lastly, DHs' leadership styles were revealed, and they were found to be influenced by the school context they operate in.

The next Chapter will discuss the challenges and enabling factors encountered by the DHs when implementing and managing Technical Mathematics.

Chapter 8

Enabling and challenging factors in Departmental Heads' implementation, management and teaching of Technical Mathematics

The previous chapter focused on DHs' enactment of their roles and responsibilities to implement and manage Technical Mathematics. The aim of this chapter is to examine challenges and enabling factors encountered by the DHs when implementing and managing Technical Mathematics. The researcher used semi-structured interviews, a focus group, lesson observation and document analysis to understand the factors that contribute to the successes and challenges of implementing Technical Mathematics in three different schools. Samuel's (2008) professional forces – biographical, programmatic, contextual and institutional – were examined in terms of whether they enabled or constrained the DHs' implementation, management, and teaching of Technical Mathematics in their respective schools. Like all other curriculums that have been implemented, Technical Mathematics was also found to have its own challenges and successes that the DHs experienced. The prevailing themes emerging from the data in respect of the study framework are listed in Table 8.1.

Table 8.1: Prevailing themes from the data with respect to enabling and challenging factors in DHs' implementation, management and teaching of Technical Mathematics

Enabling factors	Challenging factors
Suitable teachers to teach the curriculum	Delayed inclusion of PAT in Technical Mathematics curriculum
Continuous evaluation and support	Lack of professional development workshop for management roles
Inclusion of the PAT component in Technical Mathematics	Too much content to cover
Professional development workshops for teaching Technical Mathematics	Learner attitudes towards the subject
Collaborative practices	

8.1 Enabling factors contributing to implementation and management of Technical Mathematics

Analysis of the data revealed that the DHs identified several factors that they consider helpful for the implementation and management of the Technical Mathematics curriculum, which are discussed in the sections below.

8.1.1 Suitable teachers teaching Technical Mathematics.

One of the common enabling factors in the implementation of Technical Mathematics that all three DHs attest to was getting the right teachers to teach the subject. The DHs affirmed that assigning experienced Mathematics teachers to teach Technical Mathematics was a major step that they had to take. Teachers were identified in each school and assigned with the teaching load, and the DHs participating in this study were proactive in teaching and managing the new subject and had the assistance of senior teachers. When the DHs were asked about the main enabler when implementing Technical Mathematics, Mr Gamma had the following to say:

> **Mr Gamma:** *Obviously getting the right teacher to teach, that one. Another thing is ensuring that we have all the resources available to us, whether it's the textbook, whether it's mathematical equipment, whether it is additional resources provided by the government, whether it's stuff from the Just in Time Programme, ensuring that our educators are workshopped about changes in the curriculum, changes in the topic, or new topics introduced.*

Mr Gamma considered getting the right teachers to teach as the main enabler of the implementation of Technical Mathematics. He argues that teachers need to be exposed to content and pedagogy workshops to be aligned with curriculum needs. Ball (2003, p. 4) articulated that “No curriculum can teach itself”. Significantly, the DHs’ enabling factor shows the value placed on teachers and practical means of supporting them to teach. Ball (2003, p. 1) insisted that “We cannot afford to keep re-learning that improvement of students’ learning depends on skillful teaching, and that skillful teaching depends on capable teachers and what they know and can do”. It is noteworthy that teachers were the most important factor, and they also needed capacitation to meet the curriculum needs for learners to gain subject knowledge. Resources could be in place, but without a craftsperson who knows how to handle their tools, the educational goals would not be accomplished.

Mr Alpha, the DH from School A, shared a similar experience regarding enablers of technical curriculum implementation in his, school adding that the challenge is with getting results from learners:

> **Mr Alpha:** *Educators who are teaching it right now, have been teaching for years, and they have learned the techniques and know the techniques and know what to do. So, the challenge right now is in terms of results, enhancing results, but not necessarily the methodology. Because that has been accomplished. And many of them who are teaching Mathematics are seasoned Mathematics teachers. Unlike certain schools where they have their educators who are teaching the skills (artisan teachers) are teaching for them. That's a bit of a challenge.*

This DH alluded to the fact that his enabler was getting seasoned teachers to teach. He attests that the teachers he manages have adequate pedagogy that they draw from their experience. His assumption was that having seasoned teachers eased his role as DH as they are more capable of tacking challenges that could hinder the effective implementation of Technical Mathematics in their classrooms. Rice (2010, 2013) affirms that experience enables teachers to perform far better than novice teachers. A similar view is shared in the early literature by Becker (1964, as cited in Podolsky, Kini & Darling-Hammond, 2019, p. 2), who argue that "more experienced workers are more effective employees because they acquire more knowledge about how to perform their work effectively over the course of their careers". In essence, the belief that experienced teachers are more effective comes as a result of close monitoring over years that they are continuously producing quality results and meet the desired expectations in the subjects they teach.

I argue that exposing teachers – whether experienced or novice – to continuous learning might increase their gains and relevance in their teaching. Podolsky et al. (2019, p. 9) reviewed a number of studies on the effectiveness of experienced teachers for learners' gains, which revealed a positive relationship between experience and learners' gains and state "We reviewed 30 studies examining the effects of teaching experience on student achievement, as measured by standardized test scores. Of these 30 studies, 28 found that teaching experience is positively and significantly associated with teacher effectiveness". Also, Hightower et al. (2011) note a substantial improvement in learners' work when they are taught by experienced teachers. In contrast, Rice (2010, p. 1) argues that "Teachers show the greatest productivity gains during their first few years on the job, after which their performance tends to level off". For Rice (2013), the teachers' effectiveness is weakened by their lack of enthusiasm. This raise the need for DHs to monitor seasoned teachers regarding their work, for professional growth and not as a fault-finding mission. They also need to ensure that the teachers are motivated to work in their given contextual conditions.

Mrs Beta, the DH from School B, stated that her main enablers in curriculum implementation included the teachers and other stakeholders that are hands-on in this area. While she acknowledges the prominent role that teachers play in the implementation of Technical Mathematics, she mentions that without the other structures it would be impossible to effectively execute her role of curriculum implementation, management and teaching in her school:

> **Mrs Beta:** *Teachers, subject advisors and the Department of Education are people that are hands-on in the implementation and teaching of Technical Mathematics. Technical Mathematics has provincial and national subject coordinators, those are people who are helping us a lot in the implementation of the subject or curriculum as such.*

While the DH acknowledges the importance of teachers, they were not seen as the only factor that drives curriculum implementation. Nevertheless, the whole structure working together for a common goal allowed the implementation to be a success. The DH did not have any attachment with seasoned teachers, as in her school the Technical Mathematics teachers are mostly new teachers. While all of the DHs are of the view that suitable teachers are an enabler for the implementation of Technical Mathematics, not all agree on the criteria of what makes a teacher suitable. For example, Mr Gamma and Mr Alpha emphasise experience, as they believe seasoned teachers have the required knowledge and pedagogies, while Mrs Beta emphasises commitment. What is not explicitly articulated by the DHs is how experience and commitment translate into being a specialist in the subject, since Technical Mathematics is a new subject and the seasoned teachers are not specialists in Technical Mathematics but are specialists in Pure Mathematics.

Since the one-on-one interviews revealed that the DHs were reluctant to use the new teachers, they were asked in a focus group about the guidance they can give to a newly appointed teacher to ensure that they unpack the Technical Mathematics curriculum correctly. They had the following to say:

Mr Alpha: *Eish! It is a bit of a challenging question. I'm going to be honest with you and tell you that if the teacher hasn't taught Technical Mathematics, he will be able to teach half the syllabus, but the challenging sections – we will have to workshop him on it. I'm saying 'we' – I don't think it will be possible for me to be tasked for all the days of the workshop. There are other senior and seasoned Technical Mathematics educators who will also share that. If you are a Mathematics teacher you would have covered most of the sections in Mathematics, it the areas that are not taught in Mathematics that we will cover with him, and I'm saying for those we will share the responsibility as the department to cover them. In fact, it's very simple, I can say to you, listen these are the four sections, which one so you want to do? And go to the next educator and ask them which sections they want to do, and I will then cover the balance. For example, complex numbers, if you want to do complex numbers, you will do it. I will definitely oversee what kind of content is relevant to you. I don't want you to go to a lesson and 10 minutes later you don't know what to do. That is awkward. You have to teach according to the CAPS document.*

The DHs' focus group interview revealed that the DHs are reluctant to use new teachers to teach Technical Mathematics as they feel that they are not fit to withstand the demands of the subject. Mr Alpha suggested that inducting a new teacher in Technical Mathematics includes evaluating the mathematical content that they are capable of teaching. The DH argues that Mathematics teachers should have covered most of the sections in Mathematics preparatory courses. Nevertheless, new Mathematics teachers can only teach half of the syllabus and they need continuous workshops that will enhance their knowledge in terms of the challenging sections in the Technical Mathematics syllabus.

Mr Gamma, the DH from school C had the following to say:

Mr Gamma: *The first step is to provide the teacher with the CAPS document, annual teaching plan, programme of assessment, and all resources available. My next step will be to set up a mentoring programme with a senior Technical Mathematics teacher from the school or another school. Thirdly, invite the subject advisor in to advise, guide and mentor the teacher. Provide opportunities for the teacher to attend workshops on the subject. Fourthly, on a weekly basis the teacher must meet with me as a Departmental Head, so I can manage the teacher's files, forecast, lesson plans, marking and assessments.*

Mr Gamma suggests that the teacher needs to be provided with the CAPS document, so that they understand the curriculum before they can teach. The DH maintains that new teachers need to be mentored by pairing them with senior Technical Mathematics teachers so they can learn more about the teaching and administration of the subject. Their induction process extends to providing opportunities to attend DBE workshops that help teachers to reskill and reduce knowledge gaps that might exist.

Mrs Beta, the DH from School B, had the following to say:

> **Mrs Beta:** *Firstly, I would suggest that the teacher gets the CAPS document. Secondly, the teacher must get textbooks for all grade levels, Grade 10–12. Teacher guidelines for the respective grades, ATP, POA, so they will see the subject expectations. Details of the subject advisor, as they are in a better position to unpack the subject and curriculum.*

Mrs Beta suggested that getting used to the CAPS document is the first important step for teachers to understand the subject. Providing mentoring with the help of senior Technical Mathematics teachers, getting the subject advisor in to advise and offering multiple opportunities for the teacher to attend workshops on the subject are important induction steps that equip teachers for readiness to teach the new subject. In fact, Podolsky et al. (2019, p. 20) concluded that "not all experience is educative", suggesting that some seasoned teachers are ineffective and that "some novice teachers are dynamic and effective".

8.1.2 Continuous evaluation and support

The DHs mention that the use of the QMS helps them to identify teachers' knowledge of the subject and of teaching. Raikwar and Soni (2021, p. 28) describe QMS as "a method of organizing and logically systemizing sequence of activities & processes such that their quality can be observed, measured, validated and improved". The QMS is important but relies on the DHs to oversee that teachers adhere to the requirements by personalising the improvement plan and are encouraged to see the value of improving their practice. DHs use the QMS for teachers' appraisal, with the aim of ensuring that teachers are effective and accountable when executing their teaching roles (Myende, 2014). In this study, DHs were asked 'In what ways does the QMS assist the you in identifying teachers' needs or support, or does teachers' continuous improvement facilitate accountability?'. The DHs shared their practices on how they communicate with teachers and execute their managerial role in the QMS.

Mr Gamma asserts that he uses the QMS as a platform to understand his teachers' knowledge of the subject and how they deliver their instructions. The DH alludes to the fact that the QMS also provides an opportunity for him to understand learners' capabilities in the subject, noting their areas of strengths and of concern at which interventions should be targeted. He views the QMS as a window to the curriculum, where he gets to understand what transpired in the teaching and learning of Technical Mathematics in different classrooms. The DHs emphasised that teachers should not see it as hindrance but as a tool that aims to improve their professional practices:

> **Mr Gamma:** *Obviously, the QMS observation sheet allows us to gauge teachers' subject knowledge, gauge pupils' learning abilities, and basically look at the teaching and learning that takes place. And obviously, if you have high-quality teaching, you will expect high-quality learning.*

Mr Gamma argues that the QMS is used to measure teachers' knowledge of the subject while noting their strengths, which he says he can use to make suggestions to other teachers who are teaching the same subject. The DH argues that the QMS allows him to have an idea of how learning takes place in the classroom, and that having teachers who are exceptional makes the teaching and learning easier to manage.

Mrs Beta, the DH from School B, had the following to say:

> **Mrs Beta:** *QMS helps a lot in terms of having hands-on experience with a teacher who is teaching the subject, you get feedback and teachers get feedback from your observation. We also have one-on-one meeting with the educators, not just the QMS, whereby we sit down and discuss the challenges and pave the way forward in terms of how to help the teachers where they have issues.*

Mrs Beta mentions that the QMS helps her to have a professional conversation with the teachers, where she gives feedback on the lesson and suggestions on how it could be improved. Teachers also voice their opinions on how the subject could be improved by the DH for learners' maximum gain. The DH also uses one-on-one meetings with the subject teachers to discuss the shortfalls and successes in the subject, while devising a feasible improvement plan for the teachers' implementation. What seems to be lacking regarding what DHs put emphasis on is encouraging peer visits and self-assessment among teachers who are teaching Technical Mathematics which allows for reflection. Ngakane (2021, p. 29) posits that "During self-assessment an educator is expected to reflect critically on his/her own performance and to set own targets and time frames for improvement".

I argue that teachers also need to schedule peer classroom visits, so they understand what other teachers are doing in terms of pedagogy, content and classroom environment, and so on.

The need for DHs to formulate a subject improvement plan cannot be overemphasised, as it forms the foundation for teachers to align their growth plan in the subject to. DHs are then to monitor and support teachers to ensure that a subject improvement plan is envisaged for learners' attainment of knowledge.

Mr Alpha voiced that his monitoring and evaluation is eased by the fact that he is working with seasoned teachers who understand the curriculum implementation challenges. Teachers have been setting their personal goals while aligning them with the subject improvement plan and whole school improvement plan, which is also attainable as they take part in developing a Technical Mathematics subject policy in their department. This DH attests to the continuous informal interaction with the teachers, that helps him to understand the challenges they face every day. He did not seem to rely on the QMS for formal observations and professional conversations, as he enforces a culture of communication with his teachers. For this DH, teachers' areas of development are spoken about and easily dealt with before the formal meetings.

> **Mr Alpha:** *Most of the educators in this department right now are seasoned educators, who taught Mathematics. However, we still have this continuous interaction on a daily basis. When we see each other, it's the 'corridor chat' as I consider it; where we say what do you do? How are you doing it? Where are you in the syllabus? But we also have meetings set aside for where educators come with the issues, what the challenges are. And they also explain where they are in terms of the syllabus, but it's also monitored on an ongoing basis, or on a continuous basis, where educators bring their record books for me to evaluate and check. But what helps me is the interaction that I have with them and me going into those classes. Not with the intention of critiquing them, but just to provide support.*

Mr Alpha views his monitoring and support as an ongoing process, where he interacts with teachers, understanding their issues around the curriculum implementation in their classroom. The informal meetings with teachers is a way of finding out how best teachers could be assisted, while noting their concerns about the subject and learners. Teachers get to voice their frustrations emanating from their classroom management, their results, and their enablers in Technical Mathematics. These professional conversations thus help the DH to establish an action plan to curb the challenges that teachers face when executing their roles.

In the same way, De Clercq and Shalem's (2019, p. 46) findings revealed that professional conversation among the DHs and teachers "doubled-up on the integrated quality management system (IQMS) exercise, and that teachers' reflections were used to advance a development plan for the school". Also, continuous evaluation of learners' exercise books was one of the ways in which the DH got to know what transpires in the classroom, whether teachers are aligned with the curriculum, and if learners are doing and understanding their work. The DH also uses the QMS for appraisal, and he argues that its purpose is in providing necessary support for subject implementation to be effective. He cast aside the idea of crushing and criticising teachers, and asserts that this does not help the teacher to develop professionally – and thus providing support is his paramount goal in the classroom visits. The conducive school culture that the DH creates promoted teachers' autonomy within the department, as they are free to express their shortcomings while also having input on the subject improvement plan.

8.1.3 Inclusion of practical assessment task in the Technical Mathematics curriculum

Practical investigation and practical application constitute the PAT in Technical Mathematics. The PAT thus includes practical aspects of the Technical Mathematics field. The DBE guidelines for the PAT posits that Technical Mathematics is now among 18 other CAPS subjects that have a PAT component (previously, only 17 technology subjects had a practical component). In essence, it is the only Mathematics stream which integrates the practical work in the assessment task in the FET phase. The year 2021 marked the first year of implementation of the PAT in Technical Mathematics after implementation of the Technical Mathematics curriculum in 2016. The DBE took 6 years to implement the practical component in the Technical Mathematics curriculum. In the Guidelines for Practical Assessment Task document, the DBE (2022a, p. 3) states that:

> A practical assessment task (PAT) mark is a compulsory component of the final promotion mark for all candidates offering subjects that have a practical component and counts 25% (100 marks) of the examination mark at the end of the year. The practical assessment task for Technical Mathematics Grade 12 consists of three tasks (one task per term) which should be completed by end of Term 3. The tasks are COMPULSORY for ALL candidates offering Technical Mathematics in Grade 12.

The DHs' role in the implementation of the PAT in Technical Mathematics encompasses both administration and moderation of the PAT. DHs are to ensure that they and the teachers administer the PAT as part of the requirements of the subject.

The DHs in this study revealed that the inclusion of the PAT has assisted toward learners' improvement in the subject compared to five years back when Technical Mathematics was introduced. Mrs Beta argued that as from the year 2021, after the inclusion of PAT, learner performance has improved as teachers are now implementing the curriculum in its full spectrum:

> **Mrs Beta:** *The PAT component was only introduced in 2021. That is when we started to see significant change in learners' results, before that our results were dwelling between 1% - 29%; where the highest possible mark is 40% - 50%. Learners who were achieving more than 30% were those who were high performing in Grade 9 and learners who generally attended extra tuition.*

Similarly, Mr Gamma voiced that learners were not performing well initially, but now with the PAT component their results have improved. He attests that practical application has also helped learners to understand Technical Mathematics better:

> **Mr Gamma:** *The performance was initially not great, but when the PAT component was introduced, there has been improvement in results… So now there's a PAT component that helps to boost their marks in order for them to have a better understanding and better marks for this subject.*

Views in the same vein are shared by Mr Alpha, that through PAT learners are now getting a minimum pass mark in Technical Mathematics, but it is still not the best of results. He argues that the calibre of learners enrolling for the Technical Mathematics course do not have strong mathematics abilities:

Mr Alpha: *Let me explain to you, as of last year, as the introduction of the PAT component, it has helped us in terms of increasing our pass rate. But that's only as far as of last year 2021, It has definitely helped us in terms of implementing and loosening up the results. But as I said, with the introduction of PAT from last year, it has assisted a lot of learners in passing the subject. What must be borne in mind is the weaker learners are doing Technical Math, and it is not the easiest of syllabus and it's very challenging for learners to get good results. But as a result, with the PAT right now, it has helped learners to pass. Even* [though] *the pass which learners are obtaining is not the best of passes. They are mainly scraping the barrel to just get a pass.*

All three DHs participating in this study agreed that the PAT component has helped learners to improve their performance. Mr Alpha alludes to the fact that the PAT increased learners' pass rate, although they are still struggling with the abstract content. Nigerian scholar Afolabi (2017) in his study on a 'Practical approach to teaching and assessment in Mathematics' suggests that practical teaching and testing must be included in the Mathematics curriculum to instill a positive attitude to learners, reduce cognitive load and introduce learners to different assessments. He states that advantages of practical teaching and assessment are that "It makes the students to be exposed to varieties of assessment form, so that if he falls short in one, he can gain in the other. It will improve overall performance in mathematics and the anxiety will be reduced" (Afolabi, 2017, p. 11). The inclusion of the PAT was a major step in better attainment of results and enhancing practical skills that Technical Mathematics' learners enjoy doing, since it is relevant to their field of study. The DHs regards PAT as one of the enabling factors in the implementation of Technical Mathematics.

8.1.4 Professional development workshops for teaching Technical Mathematics

One of the enabling factors that help DHs to implement Technical Mathematics effectively in different schools was continuous workshops organised by the DBE. The DHs participating in this study had differing reactions to the how the workshops were conducted at the initiation of the subject and thereafter. Whereas the DHs felt that the workshops were not mainly for managing the subject and guiding them in implementation, they perceive them to be helpful in preparing teachers to teach the subject. The DHs in this study were asked 'Are there measures in place that help you to capacitate teachers or how often are teachers attending content workshops and how effective are those workshops?'.

Mr Alpha indicated that there were workshops that ran for about 3 weeks, where Technical Mathematics teachers were invited. These workshops were ongoing and aimed at introducing DHs and teachers to the Technical Mathematics content and pedagogy:

> **Mr Alpha:** *From the initiation of the subject, the workshop ran for, I think, two weeks or three weeks on a continuous basis, ... they kept bringing us to workshops and then supplement that with other additional workshops.*

Mr Alpha argues that there were many workshops in the initiation phase of the implementation of Technical Mathematics, when the teachers were still trying to understand the subject. and after that few workshops were conducted.

Mr Gamma shared a similar view on the occurrence of workshops. He states that the DBE has set up a number of workshops and invited teachers to attend. He asserts that these workshops are effective, and teachers get to share ideas on how they approach different Technical Mathematics content. Teachers who possess strong PCK and content knowledge demonstrate it in these workshops:

> **Mr Gamma:** *Every year there are workshops that take place, other workshops are scheduled over the entire weekend, Friday, Saturday, Sunday. Teachers do attend these workshops and they are very effective, because not only do teachers get to collaborate with other Technical Math educators, but they also acquire a lot of resources which are then used to effectively teach the subject.*

Mr Gamma perceived the frequency of workshops to be satisfactory, and that they were effective in the sense that it gave teachers a platform to share their knowledge and practices when implementing the curriculum. He asserts that it did not only capacitate with knowledge but also allowed them to acquire resources for teaching the content. Teachers were given lesson plans and they discussed how to deliver the content while noting the shortfalls in the lessons. Mr Gamma commends collaborating with teachers from different schools, stating that it was helpful as they get to share their problems, even when they were in their schools, through the professional learning communities they formed.

Mrs Beta had contrasting view. While in agreement that the workshops provided were helpful, she also pointed out that those conducted at the initiation of the subject were not sufficient to address all of the demands that came with Technical Mathematics, especially for a subject with such an intense curriculum:

> **Mrs Beta:** *The Department of Education set a number of workshops that teachers are required to attend; there are also webinars that teachers attend online. There are a number of documents that are provided by the Department of Education, like the recent one called the 'Step Ahead' document that helps teachers with the content. Its implementation was in the absence of proper training in terms of the methodology. Secondly, when the subject was rolled out the DBE did not have intense training for teachers who were to teach the subject. The 5 days' workshop that was conducted by the DBE was not enough for such an intense curriculum.*

Mrs Beta argues that as a DH, she received minimal support from the DBE to prepare her to implement Technical Mathematics effectively. The DH attests to the fact that some of the Technical Mathematics content was not adequately addressed in workshops, since there is such an intense curriculum, saying that its scope is beyond that of learners and not much attention was paid to this. Teachers had to learn the content while teaching it, as these workshops included weekends. According to Mrs Beta, teachers had not enough time to grasp the content. She argues that for some teachers, some of the content was new, while others were rusty since they last encountered it during their undergraduate Mathematics course. Drawing from comments from Mrs Beta, it could be argued that while the DH finds the professional workshops useful towards equipping them to teach the curriculum, these workshops did not address all their needs.

8.1.5 Collaboration within and across subjects and schools

Professional learning communities (PLCs) are platforms that teachers use to share their experiences and best practices. DHs' need for collaborating on ideas around implementation, teaching and managing Technical Mathematics makes them aware of potential problems and how best to avoid or resolve similar ones. Participating DHs collaborate with their teachers to discuss teaching of the curriculum, at the same time monitoring curriculum coverage. One DH, Mr Alpha, stated that teaching Grade 11 and 12 Technical Mathematics assisted him to understand challenges of teachers who are teaching in the FET phase. The DH mentions that discussions are taking place even during ‘corridor chats’, where they discuss subject-related matters informally:

> **Mr Alpha:** *I'm continuously knowing where they are. But the good thing about this is that we teach across the board. So, I'm teaching Grade 12. Like I know where I am on my syllabus, and the educator that's teaching Grade 12 should be more or less in line with me, or even sometimes maybe above me, but it shouldn't be where one educator is far behind the other.*

In the same way, Mrs Beta stated that their PLC extends from school to cluster and provincial platforms, where teachers collaborate to share pedagogical knowledge, and help each other to solve Technical Mathematics problems:

> **Mrs Beta:** *Pure Mathematics and Technical Mathematics teachers work together to identify problem areas and capacitate each other. They share their knowledge and experiences of the subject matter. We are using social media platform (WhatsApp group) to effectively communicate at provincial, district, and cluster level. These groups have helped a lot to effectively communicate, especially during the COVID-19 pandemic when physical workshops were not permitted. It is through these collaborations that teachers share their subject-related matters. Organisations like SASOL Inzalo also help to organise workshops and give teaching and learning materials.*

Mrs Beta emphasised that working with Mathematics teachers in her school helps to share resources and content, especially where the content is similar. In the Technical Mathematics sections that are not related to Pure Mathematics, they collaborate with neighbouring schools and use social media platforms like WhatsApp to engage with other teachers and subject advisors.

Mr Gamma indicated that he uses departmental meetings and workshops organised by the DBE as platforms for teachers to share their challenges and successes in the subject. Teachers who find challenges in their grade level liaise and collaborate with their mentor teachers and teachers from neighbouring schools.

In the focus group, DHs were asked what they do to support the teacher and at the same time help the learners when one of their teachers raises that they are not familiar with a certain topic in Technical Mathematics, and had the following to say:

Mr Gamma: *If the teacher is not familiar with a certain topic, he/she must refer to the CAPS document and to all resources given. It is their responsibility to liaise with the mentor, teachers from other schools and the subject advisor. As a Departmental Head I will provide opportunities for the teacher to attend workshops on the subject. I will also recommend that the teacher should meet with me to help draw up lesson plans and create resources that will help in easing the teaching of the topics in question.*

Mrs Beta also raised the practice of liaising with teachers, neighbouring schools, cluster and district levels:

Mrs Beta: *We liaise with our team and neighbouring schools that offer Technical Mathematics; if they are facing the same challenge, we move to the cluster, district, and notify the subject advisor, who then assesses and decides on what best they can do as the Department to help the teachers and learners. But it all starts within our school and neighbouring schools, to ask the teacher to come and teach or explain how best the content could be taught for learners to understand.*

Mr Alpha raised that he is proactive in helping teachers with challenges, and if he is unavailable to help he asks other senior teachers to offer support to the teachers in need. In Mr Alpha's view of teachers who are experiencing difficulties in content mastery of Technical Mathematics, it seemed doubtful that teachers could learn and teach at the same time. His experience of working with experienced teachers led to him having no faith in new teachers with challenges in content mastery. While he has strategies to help teachers with challenges, he thinks that more time is needed to offer support. His view is that presently many universities are not offering Technical Mathematics, and are not training new teachers to teach the subject:

Mr Alpha: *By the same token, if a new teacher is appointed, I will not use him in the Technical Mathematics, unless I am forced to do so. I will keep him in the school, and it will be his responsibility right now to come to me and ask for assistance in unpacking the curriculum. So, on a week-by-week basis, I can do one or two sections with him, so that within that year he graduates to know the syllabus. It cannot be done while he is teaching, he must make sacrifices to come to me and say these are these sections that I am uncomfortable to teach, when can you unpack it to me? I will make time available. If I am not available, as I pointed out to you, there are other senior teachers who will help him.*

Mr Alpha holds strong views on new teachers' need for professional development. He asserts that although there are no established PLCs in his department, capacitation of teachers could be done by him and other experienced teachers. He argues that new teachers are the ones who need capacitation, and unpacking the subject for them means that they gradually have to learn the content under his supervision, until they master Technical Mathematics. He argues that learning the Technical Mathematics content could not be done while the teacher is teaching.

In essence, the DHs had different approaches that allowed teachers to be supported in their schools. What transpired is that DHs do not have established collaborative practices, rather the support given is based on issues that arise at a particular time. Hence there are no solid support structures. These findings resonate with Malinga's (2016), which posit that DHs do not have established structures where they share their professional practices, especially having the demanding role of both managing and teaching. She argues that "While principals and teachers have associations, communities of practice or professional learning communities (PLCs), where they have opportunities to share their views and experiences on matters pertaining to their practice, HODs do not" (Malinga, 2016, p. 18).

I argue that there is a need for established collaborative practices among DHs, where they can share their knowledge and experiences of how they enact their leadership role, and how it could be improved for effective management of their teachers, learners and resources. The double role that DHs find themselves in calls for continuous capacitation.

Hairon et al. (2017) argue that strong leadership support from the DHs in PLCs and at school level could help to improve capacity for teaching. The findings in this study revealed that DHs enact their agency differently, by choosing to build informal structures of communication within their departments, and rely on external support for structures which are established by the DBE. While the DHs consider the sharing of knowledge to be an enabling factor and encourage it for teachers in their respective departments, the same cannot be said about DHs since they do not collaborate with other Technical Mathematics DHs from other schools.

8.2 Factors impeding the implementation and management of Technical Mathematics

While DHs highlighted the enabling factors that assist them with the Technical Mathematics curriculum implementation and management, they also noted some challenges that hinder them from implementing and managing the curriculum.

8.2.1 Delaying inclusion of PAT in the Technical Mathematics curriculum

One of the factors highlighted by DHs was the delay by the DBE in including PAT in the curriculum. As alluded to above, PAT was only introduced in 2021, meaning that for the six years since introduction of the curriculum, certain components were not taught nor examined for the benefit of the learners. This delayed PAT implementation disadvantaged the cohort of learners who had opted to take the subject during this time. Mrs Beta argued that the DBE's delay in implementing the PAT component was a huge failure that negatively affected many Technical Mathematics learners' lives. Many failed or passed with unimpressive marks in Grade 12. She had the following to say:

> **Mrs Beta:** *It took the Department about 6 years before they introduced the PAT component in 2020. Our subjects in technical-related subjects, we have 25% practical (where learners do the actual physical work) and 75% theory components. Now, all these 6 years there was no PAT component and learners were only writing theory in Technical Mathematics until 2021, when the DBE introduced the PAT component.*

Mrs Beta attests that the failure of the DBE to develop and implement the PAT component led to poor performance in Technical Mathematics in her school. The poor results demotivated learners from choosing the subject in their FET phase, although their interest was in subjects in the technical field. In essence, Technical Mathematics became a subject that kept learners away from doing technical subjects. In addition, Mrs Beta said the following:

> **Mrs Beta:** *The DBE did not do any justice by not including the PAT component from the get-go. It was long in discussion and that delayed its implementation for a six-year span. The DBE failed the implementation of Technical Mathematics! It failed learners! What happened to the learners who have failed their Grade 12 because of Technical Mathematics, if the PAT was ever going to be introduced? This is like the implementation of OBE* [outcomes-based

education], *that was introduced and some of our learners suffered the consequences. It is wrong that they took so long (more than 5 years) engaging, whereas learners were failing in the subject. As a result, very few learners choose to do Technical Mathematics and they feel that that it is difficult. In actual fact, technical subjects' curriculum allows a learner to pass by doing the practical component of the work. However, the way the DBE structures the curriculum, it is now the same as the gateway subject (Pure Mathematics and Mathematical Literacy), which makes it inaccessible for learners.*

Mrs Beta holds strong views on the DBE rushing to implement the curriculum in its immature stage, disadvantaging the first cohort of learners, who became 'lab rats' for testing what was working or not working. The same views were raised by Mr Gamma and Mr Alpha:

Mr Alpha: *As a result of Technical Mathematics per se, I want to share and be honest with you, it has closed a lot of doors for learners. Because our learners in this school who do the training would like to go to some technikons or some technical colleges to improve, and this [curriculum] has not allowed them to have that flexibility.*

Mr Alpha's views are that the delay of the PAT implementation not only failed the learners in Grade 12, but also close doors for them to get access to higher education institutions. He argues that learners were not only disadvantaged in terms of the practical aspect of the curriculum, but were also denied opportunities to gain access to higher education institutions, especially universities. Weaker learners found it relatively hard to achieve a pass mark, whereas the PAT would have allowed them to demonstrate their application of the content being assessed in a practical way.

8.2.2 Lack of professional development for DHs in management and implementation

All three DHs participating in this study indicated that there was no training specifically for DHs to implement and manage the Technical Mathematics curriculum. Lack of professional development training for DHs suggests that they were ill-prepared to execute their management roles. The DHs were mainly using their experiences of implementing other subjects, and not anything specifically tailored for Technical Mathematics. The changes envisaged in Technical Mathematics could be assumed to be haphazardly applied, where DHs were using skills that might not speak to the subject aims. What also made it difficult for DHs to be knowledgeable was the lack of personal professional development plans for themselves; the fact that they only have a teaching degree means they do not aspire to grow as subject managers. Their reliance on the DBE's professional development workshops – which are non-existent – suggests that they need to use their experiences and learning gained from their principals, who also do not have knowledge of Technical Mathematics. The lack of self-improvement makes it difficult for them to construe policies for their teachers and learners.

Although voiced in different ways, all three DHs argue that the implementation of Technical Mathematics happened in the absence of any training for their management roles. They were expected to meet standards which were not explained to them. The DBE's assumption that DHs would figure things out on their own resulted in the DHs not knowing what to tell the teachers if they had questions about the curriculum expectations. This is reflected in the following comment:

> **Mrs Beta:** *There is no specific training catering only for only Departmental Heads; all teachers (level 1, DHs and Principals) were called in for the same content workshop. We all received the same training, as long as you teach the subject – there was no specific workshop that catered for managing and monitoring the subject. Maybe if the Department can have specific workshops for Departmental Heads in how to monitor and manage the curriculum, there could be a difference.*

The grouping of all structures teaching the subject meant that workshops were for teaching purposes, not curriculum management. As alluded to by DHs, professional development workshops were about content and pedagogy, not about their roles in curriculum implementation and management. DHs raised the need for the DBE to capacitate them for their management and implementation roles, in order for the envisaged curriculum to be fully implemented.

The DHs posit that the overwhelming and unrealistic expectations contradict the lack support via management and implementation training. Based on their shared experiences, the DHs seem to have no support from the principals and SMTs in terms of the subject matter. The support that the DHs receive is based on allocating finances for the subject. There is no input in capacitating the DHs with the knowledge required to implement Technical Mathematics. While the DHs possess knowledge of Technical Mathematics content and pedagogy, their management and implementation are challenged by the DBE's lack of support for leadership expertise.

8.2.3 Content to be taught is too packed and complex

The DBE encourages DHs and technical schools to promote and implement Technical Mathematics despite the challenges that exist in schools. The DBE (2016b, p. 10) stipulates that "School Management Teams (SMT) should promote technical subjects for careers in Engineering, Technology, Technicians and Artisans". The DHs criticised the vastness and complexity of the subject content in Technical Mathematics for Grade 10–12 learners. Examiners are also adding fuel to the fire, with inconsistency regarding examination guidelines and the CAPS document, asking questions beyond the scope suggested in the examination guidelines.

The DHs' observation was that learners pass the PAT and SBA, and perform very badly in their final examinations. The DHs' challenges are evident in the following comments:

> **Mrs Beta:** *The major challenge was the low pass rate, we had to come with strategies that helped to overcome the challenge. The content that needed to be covered was quite a lot and we had to come with an intervention that allowed learners to spend time with the teacher – through extra classes that includes morning classes, afternoon classes, Saturday classes. We sent our learners for winter classes and so on.*

Similarly, Mr Gamma shared that there is a lot of Pure Mathematics in the Technical Mathematics content, and Technical Mathematics learners need more time to understand and constantly recap the content:

> **Mr Gamma:** *Technical Mathematics has lots of Pure Mathematics content and therefore learners need to ensure that they are revising for exams, they are doing their homework, they are doing their classwork, so they are gaining access to what other type of questions will actually come up in the exams ... Some of the challenges that still exist is that we have a large amount of content to cover. Okay. And obviously we have intervention classes, weekend classes, holiday classes, afternoon classes, that help to overcome that.*

Mr Gamma stresses that for learners to be fully prepared for examinations, they ought to thoroughly engage with all assessments, whether formative or summative. He argues that there is a great deal of content that needs to be covered in all grade levels, and limited time to teach it. Similarly, Mr Alpha noted that content coverage was affecting learners' performance in Technical

Mathematics. The DHs and Technical Mathematics teachers started extra classes to cover the content and meet examination expectations, to enable even the weaker learners to pass. These findings resonate with those of Pournara (2020), who argued that the cause of learning backlogs in South Africa is an overly packed curriculum.

Thus, the teaching and learning of Technical Mathematics come with its challenges, one of which is the content that needs to be covered before common assessments. DHs are forced to ask teachers and learners to work during weekends to cover the syllabus. They also need to issue indemnity letters to parents every week, requesting learners to come to school on a non-school day. The DHs voiced that this takes quality time with their families away from both the teachers and the DHs, without receiving incentives to do so. To further explore DHs' concerns about the overly packed curriculum, they were asked about topics learners found to be challenging. The DHs had the following to say:

> **Mrs Beta:** *Euclidian geometry, integral calculus, complex numbers, and logarithms. It is not all topics. It is the topics that were taught in Pure Mathematics … In a class of 36 learners, only 6 understand integration, and those are learners who are getting private extra tuition.*

Mr Alpha also argues that Technical Mathematics learners often find Pure Mathematics-related topics to be difficult. He asserts that the calibre of learners is not fit for such an extensive curriculum which does not give them sufficient time for drilling and revision. The curriculum is densely packed in such a way that it does not cater for weaker learners to catch up when they lack understanding:

> **Mr Alpha:** *I am going to say almost every topic is challenging for the learners, because my previous statement to you is that we're not receiving the calibre of learners for this particular content. These learners are mostly suited to the Mathematical Literacy or the national course, the N1, N2 syllabus, that kind of syllabus. And the syllabus right now is too extensive, where it doesn't allow us to do too much revision. I don't know if you understand what I am saying, by too much revision? Yes! For example, I must teach this one and I must move on to the next section. Move on! Because if you see this* [learning booklet], *it's a day-to-day routine that was provided by the Department.*

Mr Alpha's views are that Technical Mathematics topics are challenging, and teaching learners who choose the subject in order to gain an easy pass are challenged, as they discover that topics similar to those taught in Pure Mathematics are also taught in Technical Mathematics. The DH argues that the extensive nature of Technical Mathematics then requires him and his teachers to go over and beyond working hours, to ensure that learners get extra support to cope with the provincial and national examinations.

8.2.4 Learners' attitude towards Technical Mathematics

Learner absenteeism is one of the challenges that ultimately affects teaching and learning in the Technical Mathematics classroom. The DHs and teachers find themselves having to fill in the gaps in their teaching, as learners miss lessons. They sometimes have to repeat lessons taught on previous days so that learners can get to grip with next lesson. The content normally builds from prior knowledge. When learners are not pro-active in finding out what was taught in their absence, it becomes difficult to fill in the gaps for each individual. The DHs commented that they do not experience teacher absenteeism as much as they do absenteeism among the learners:

> **Mr Alpha:** *The attendance is another factor that contributes to learners. I've got learners who come in one day, two days, three days a week. For this particular learning area, you have got to be there every single day, because if you miss out two days of work – for example, you missed out today's work – you can't follow this up for the next few days. So, this is the challenge right now. When they are absent, they are not finding out how and what work was done and how they can get assistance… So that is a big challenge to them right now when they miss out one day's work, and Mathematics is a follow-on process. In tomorrow's lesson, they are now going to be in the deep end, and to get to the shallow end right now is going to be a big, big challenge.*

Mrs Alpha alluded to absenteeism, where learners are unable to attend for numerous reasons, as one of the major challenges that drag the curriculum coverage. He argues that learners miss important lessons, and end up failing or not achieving their desired marks. Teachers become responsible for filling in the gaps caused by absenteeism, as learners do not approach the teachers to find out what was done in their absence. Since the content is structured such that topics are prerequisites for those that follow, learners end up lacking a foundation for the topics they are learning. The Technical Mathematics curriculum is challenging, and thus learners need to be actively involved in their learning.

Mr Gamma mentioned that learners' apathy to work and attitude to the teachers and the subject contribute to their performance. He mentioned that they frequently have to contact parents and make them aware of the learners' shortfalls:

> **Mr Gamma:** *I think the attitude of the learners is also something that is a challenge. But we work closely with parents to ensure, and we work together, and we are on the same page, in ensuring that learners 'come to the party'.*

Mr Alpha voices that Technical Mathematics learners' attitude to their schoolwork is generally poor, and they are not taking their work seriously. He has tried a number of interventions to bring learners to order and make them do their work, but these seem to have had no significant effect in improving learners' attitude to their work:

> **Mr Alpha:** *I spoke to you about attitude of work. We tried different things, we call parents. We have put some measures in place, preparing them and calling higher authorities in the school, like the deputy principal, and he intervened (with learners who have not done their homework). The principal intervenes on an ongoing basis. So those are mechanisms that we use to enhance our results.*

The DH commented that one of the reasons underpinning learners' attitude and poor results in Technical Mathematics is primarily the DBE's progression policy. Learners take advantage of the fact that they are only allowed to fail once in the FET phase (Grades 10–12). The majority of these learners are progressed in Grades 9 and 10, and they opt for Technical Mathematics with the assumption that they will pass the subject easily by using the PAT and SBA. They do not put in much of the effort that is required in attaining the necessary skills to cope with tests and examinations:

> **Mr Alpha:** *But this is the biggest challenge, it is the learners who are not putting a shoulder to the wheel… And what has contributed to this? It is the passing requirements. Because they are not allowed to fail more than one year in a phase, inevitably they are going through, that*

is what has this resulted in, and this must be pointed out. It's the Department which makes these polices, do you understand? Learners are saying 'We can waste one year', at the end of the day, they will make it to Grade 12.

Mr Alpha alluded to the fact that the learning content of Technical Mathematics is as demanding as that of Pure Mathematics. Learners have a propensity to assume that its content is easy, and they don't put the required effort in.

8.3 Conclusion

This chapter examined the challenges and enabling factors encountered by the DHs when implementing and managing Technical Mathematics. The main enablers for Technical Mathematics curriculum implementation in the three schools were assigning teaching roles to more suitable teachers according to the DHs' criteria, providing continuous evaluation and support to their teachers using various monitoring tools (that is, ATP, POA and QMS), the inclusion of PATs that promoted practical skills in the teaching of Technical Mathematics, also improving learners; pass rate, continuous personal development workshops in content and pedagogy, and collaborative practices among Technical Mathematics teachers. Factors that hindered the implementation of Technical Mathematics were the delayed inclusion of PAT in the curriculum, lack of personal development workshops on DHs' management roles, too much content to cover, and learner attitudes towards the subject.

The next and final chapter presents a detailed summary of the study findings, conclusions, recommendations for further research, proposed framework for effective Technical Mathematics curriculum implementation, study limitations, the contribution of the study and concluding remarks.

Chapter 9

Summary of findings, conclusions, and recommendations

9.1 Introduction

The study aimed to gain an in-depth understanding of DHs' knowledge and practices of implementing Technical Mathematics in three schools in Pinetown District. After interrogating the data that was collected it was analysed and presented in the findings. Chapters 6, 7, and 8 outline the findings emanating from the cases of the three Departmental Heads (DHs) participating in this study. This chapter provides an overview of the chapters, a detailed summary of the study findings, conclusions, recommendations for further research, the limitations of the study, and contribution of the study to the Technical Mathematics field, as well as concluding remarks. This final chapter aims to synthesise the findings from the themes that emanated from the data, and to answer the key research questions.

9.1.1 Overview of the chapters

Chapter 1 presented an introduction to the study, a statement of the problem, the purpose and rationale, the research objectives, and critical questions. It also highlighted some underlying reasons why Mathematics DHs' knowledge and practices in implementing Technical Mathematics were deemed essential for research.

Chapter 2 accounted for a review of the literature related to the study phenomenon. I explored the literature on curriculum implementation and management issues and discussed enabling and challenging factors in curriculum implementation and management. The chapter also reviewed the literature on the roles of DHs in curriculum implementation and management. It then explored the relationship between mathematical knowledge for teaching and curriculum implementation, and factors that sustain implementation of new subjects within an existing curriculum. Chapter 2 concluded by summarising studies carried out on curriculum implementation and management.

Chapter 3 discussed the theoretical and conceptual framework that guides this research. The study was underpinned by Samuel's (2008) Force Field Model of teacher development, and its applicability to the study phenomenon is discussed. The conceptual framework, which substantiated DHs' knowledge needed for teaching (PCK) and knowledge for teaching technical mathematics (MKT), was also detailed. I then explored knowledge of curriculum management and implementation, which are prominent for DHs as they have dual roles in teaching and managing curriculum implementation. Furthermore, Chapter 3 discussed and justified the use of theoretical and conceptual triangulation in this study.

Chapter 4 detailed the methodology used in this study. It provided an in-depth account of the research design, methodology, methods, and sampling used to generate data for the study. The focus was on the chosen research paradigm, research style, data collection methods, and data analysis while considering ethical issues and the trustworthiness of the research. The chapter detailed the sampling method and the selection criteria used, and then addressed how ethical, validity, and reliability issues were safeguarded.

Chapter 5 provided an account of the comprehensive, in-depth data analysis process from the one-on-one interviews, focus group interviews, classroom observations, and document analysis. Data generated from this study using one-on-one interviews are reported verbatim, to ensure that the experiences that participants' shared captured their feelings about the phenomenon. This chapter presented a comprehensive thematic analysis of the data from the interviews that were audiotaped, transcribed, and coded using NVivo.

Chapter 6 discussed the study's findings, highlighting DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics. It outlined how DHs understand their roles in managing Technical Mathematics and challenges they face in this regard. This chapter provided valuable insights into the practices and knowledge of DHs in managing, implementing, and teaching Technical Mathematics. As a theoretical framework, Samuel's (2008) Force Field Model provided a clear lens through which to view the programmatic forces that influence DHs' teaching, learning, and curriculum management.

Chapter 7 discussed findings concerning DHs' enactment of their roles and responsibilities of implementing and managing Technical Mathematics. The stems of Samuel's (2008) Force Field Model that were used are the contextual forces (macro-social, political, historical context) and institutional forces (micro-contextual) that influence DHs' implementation and management of the Technical Mathematics curriculum in their schools. The chapter also explored the DHs' role as a mediator of institutional and contextual forces within their schools, and how they use their agency to decide which forces are relevant, what to adapt, and what to ignore.

Chapter 8 examined challenges and enabling factors encountered by the DHs when implementing and managing Technical Mathematics. The researcher used semi-structured interviews, focus groups, lesson observations, and document analysis to understand the factors contributing to the successes and challenges of implementing Technical Mathematics in the different schools under investigation.

Chapter 9 presents a summary and general conclusion based on the study's findings. It provides a comprehensive overview of the research questions, research methods, theoretical frameworks, and study findings. This chapter outlines the study's key findings, including challenges and factors that facilitate DHs in managing and implementing Technical Mathematics. After briefly summarising the study's main contributions to the field, the chapter provides recommendations for future research and the implications of the results.

9.2 Summary of the findings

This study set out to answer the following research questions:

1. What are the DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics?
2. How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics?
3. Why do DHs enact their roles in the way they do?
4. What are the contributing factors that enable DHs to implement, manage, and teach Technical Mathematics, and the challenges, if any, that hinder the implementation, managing, and teaching of Technical Mathematics?

9.2.1 DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics

To answer research question 1, I narrowed my focus to the knowledge of their roles in the implementation and management of Technical Mathematics, and their practices in the implementation and management of Technical Mathematics. I answer the question based on the themes that emerged from the findings of this study.

9.2.1.1 Knowledge and expertise

The findings of this study showed that in theory, DHs have the knowledge of what needs to be done; however, this is not translated into practice in their classrooms in the implementation and management of the subject. DHs in this study considered themselves to possess in-depth content knowledge, suggesting that they have great expertise in the subjects they manage. Roberts-Hull, Jensen and Cooper (2015) reported that high-performing education systems emphasise content knowledge and subject-specific expertise. Nevertheless, while DHs are expected to be seasoned Mathematics teachers, possessing in-depth subject matter knowledge, the critical findings showed that the teaching approach is embedded in developing abstract ideas, which contradicts the core aim of Technical Mathematics, which is application. None of the DHs demonstrated application-based teaching in their lesson, which compromised the effective implementation of the subject. In addition, in the conception of critical aspects needed in implementing the subject, the DHs emphasise curriculum coverage, and are not exposing learners to industry-based teaching or modeling industry-based learning.

Therefore, the findings of this study suggest a need for DH to be capacitated in their endeavor as they grapple with finding a balance between their dual roles of implementing and managing the implementation of Technical Mathematics for effective implementation of the Technical Mathematics curriculum. The DBE should provide support and capacitation to enhance the DHs' understanding of curriculum management while also focusing on reskilling teachers and ensuring DHs have expertise in the subjects they manage.

9.2.1.2 Role ambiguity

The study revealed that DHs were not entirely in control of curriculum management in their schools; their role was inhabited by the overly prescribed curriculum, where they needed to meet deadlines prescribed by the DBE in the CAPS, POA, and ATP. It remains unclear how they execute their management role, as they appear to be more inclined to teach; their management is by overseeing the implementation, while not being actively involved in the process. These findings agree with those of Seobi and Wood (2016), who considered DHs as final checkers of teacher reports. The DHs struggle to understand what they must do and translate these prescriptions into coherent, sustainable teaching and learning support, leading to role ambiguity. The DHs' roles are clearly defined in the DBE (2016) PAM document, so there should not be any role ambiguity; therefore, the DBE and DHs should work together towards implementing and managing Technical

Mathematics. The DHs working at Grade 12 level often find themselves overly occupied with classroom teaching, and since their main priority is to improve results, they have limited time to devote to their roles (Bush, 2013).

9.2.1.3 Mathematical knowledge for teaching Technical Mathematics

The study findings revealed that DHs participating in this study possess knowledge of Technical Mathematics through previous engagement with the content brought in and out of the previous Mathematics curriculum before the implementation of CAPS. Whereas this is true, in some sections of the Technical Mathematics curriculum, DHs and teachers have managed to grasp those concepts through DBE content workshops. In the light of Shulman's (1986) pedagogical content knowledge (PCK) and MKT advocated by Ball et al. (2008), DHs in this study possess the knowledge needed to teach Technical Mathematics to some degree. Nevertheless, capacity building is lacking at the school level; DHs are not assigning their teachers to teach senior Technical Mathematics classes as they lack content and pedagogy knowledge, and the DHs have no tangible measures to improve teachers' knowledge of the subject, suggesting a lack of knowledge of the curriculum on the part of the DHs. This study revealed that while DHs know that new teachers are challenged by the Grade 12 content, they have no measures in place to capacitate them, thus calling into question their competency when it comes to knowledge of teaching. Makhananesa and Sepeng's (2022) study endorsed this finding of DHs who do not give support to novice teachers. The DHs are challenged by contextualising the application of Technical Mathematical problems and demonstrating their relevance to the learner's real-life context. Based on the classroom observation, it was evident that DHs' classroom implementation of Technical Mathematics was exam-driven and based on covering the content, where learners were drilled on answering exam questions and not on conceptual understanding, on which Technical Mathematics is grounded.

Moreover, the study findings revealed that implementing the Technical Mathematics curriculum remains challenging, as DHs' obsession with rote teaching and learning was dominant in the Technical Mathematics classrooms. DHs most frequently used rote learning as their primary instructional approach, emphasising rote memorisation of abstract mathematical concepts and preparing learners for tests. However, the literature suggests that this teaching method often fails to promote a deeper, more meaningful understanding of mathematics among students. Skemp (1978) articulated the importance of fostering rational understanding, where learners not only understand ‘what to do’ but also comprehend ‘why’ they are doing it. The findings suggest that instrumental understanding was prevalent in the Technical Mathematics classrooms, and Skemp (1978) argues that it does not facilitate the development of a deeper understanding of mathematical concepts. Exemplary mathematics teaching is found in Mudaly and Naidoo's (2015) study, where master teachers used visuals and tangible objects to enhance deeper understanding of the subject, replacing chalk and talk. Based on what Ball et al. (2008) discuss as efficient mathematics teaching, this study’s findings contradict what they state is required – high levels of mathematical knowledge.

9.2.1.4 Overly prescriptive curriculum

The findings from the DHs participating in the study suggest that they find the Technical Mathematics curriculum restrictive and directive, while acknowledging the essence of having a structure to follow. This study highlighted that as much as CAPS may seem prescriptive, it aids in all aspects of curriculum management and implementation tools, that is, the ATP, POA, lesson planning, examination guidelines, and summative assessments. This study concludes that the prescriptive nature of Technical Mathematics gives an insight into the CAPS curriculum, which is beneficial in easing the management duties of DHs, as curriculum- monitoring tools are readily available and at the DHs’ disposal. Nevertheless, the overly prescriptive nature of CAPS compromises teachers’ autonomy as they conform to the prescribed curriculum (Msibi & Mchunu, 2013), leaving behind the learners as recipients of the curriculum (Naidoo, 2019). Moodley (2013) affirms that teachers find the intense pace as depriving learners of learning opportunities. Due to the lack of flexibility in Technical Mathematics, DHs and teachers are not teaching for understanding, they are teaching to meet the focus of the DBE exam system. Hence the use of past examination question papers informs their instruction. As a result of losing the ability to conduct school-based assessments (SBA) in schools, teachers cannot assess learners' understanding of the material they have taught. A lack of real-life applications and the integration of a technical field worldview may hinder learners' preparation for technical careers.

9.2.2 DHs' enactment of their roles and responsibilities to implement and manage Technical Mathematics

To answer research question 2, I narrowed my focus to DHs' enactment of their roles and responsibilities in the implementation and management of Technical Mathematics as their primary roles. The findings indicate that DHs have different perspectives and approaches when managing and implementing the Technical Mathematics curriculum.

9.2.2.1 Curriculum monitoring

When it comes to managing the implementation, the findings show this was non-existent, as even the curriculum coverage – which they seem to be foregrounding when talking about implementation – was not managed. The study findings revealed that one DH did not constantly monitor teachers' curriculum coverage using the ATP (see Figure 7.2). In contrast, other DHs seemed to complete the ATP for compliance purposes, and it was not a true reflection of what transpired in their schools (Figure 7.1). Such an absence of oversight can lead to several consequences, with far-reaching implications. It was further noted during observation and document analysis that teachers' reports on curriculum coverage and the exercises completed by learners in their exercise books do not match. This is regardless of the fact that reports have been endorsed by the DHs as a reflection of what has been covered, indicating that they are primarily concerned with meeting the reporting compliance of DBE external moderation rather than professional standards. Therefore, I argue that in this study, the DHs' monitoring practices are carried out solely for compliance – 'behavioural compliance' rather than displaying professional accountability (Metcalfe, 2018; Mkhwanazi et al., 2018). Similar findings were echoed by Mkhwanazi et al. (2018) in their study of curriculum monitoring, that DHs were not completing curriculum monitoring tools efficiently but rather were doing it for compliance purposes.

Drawing from the findings, the inconsistencies in curriculum management have the potential to threaten the quality of education provided to learners, with some teachers lacking critical information or skills for conducting instructional activities. It is therefore a cause for concern that six years after the introduction of Technical Mathematics, DHs as curriculum managers are still struggling to display effective implementation and management practices for the subject.

9.2.2.2 Managing human resources to ensure curriculum implementation

The study findings indicated that DHs have a prominent role in managing human resources and assisting their principals in recruiting and assigning suitable Technical Mathematics teachers. It was revealed that while DHs recruited experienced teachers, they assigned themselves the teaching role for Grades 11–12, suggesting that while they believe that experienced teachers are capable of implementing the curriculum. they do not have faith in them to implement it in the senior classes. DHs participating in this study believed that teachers who have taught Pure Mathematics are better equipped to teach Technical Mathematics. However, they had conflicting views concerning the suitability of teachers to teach Technical Mathematics. DHs argue that seasoned Pure Mathematics teachers quickly adapt to the subject's demands, while trade teachers are considered to have a concrete background in the trade industry. The challenge with both teachers is twofold: trade teachers lack pedagogical knowledge, and cannot teach effectively, while seasoned Mathematics teachers lack the trade skills that Technical Mathematics requires, and hence cannot expose learners to real-life technical problems. Thus, as evident in the findings, DHs are unable to assist teachers to develop expertise, as both abstract Mathematics and trade industry knowledge is critical in Technical Mathematics. Based on these findings, I concluded that DHs themselves need capacitation when it comes to monitoring the curriculum and managing the implementers, that is, the teachers.

9.2.2.3 Management of learners

The study revealed that DHs play a significant role in recruiting envisioned learners to the Technical Mathematics course through robust curriculum guidance, where parents are invited and clear choices are given to learners to make informed decisions on their career paths. The study findings indicated that DHs work more closely with the SMT and teachers in the Senior Phase to streamline learners based on their capabilities and to advise them on career paths. Importantly, DHs use Grade 8 and 9 Mathematics results to inform their selection of learners for Technical Mathematics, where learners obtaining more than 60% are given first preference. The study findings further revealed that learners who are good at maths choose Pure Mathematics, and those not meeting the requirements and not interested in Mathematical Literacy choose Technical Mathematics.

The study concludes that the lack of keenness to do the subject weighs in with more challenges experienced by DHs in their schools. Moreover, the study findings revealed that, since the practical assessment task (PAT) was introduced recently, most learners are taking the subject with the assumption that they will get an easy pass, since the PAT contributes 25% to learners' promotion marks, attracting learners who are apathetic about doing the subject.

9.2.2.4 Teaching and learning support materials management

The study findings revealed that textbooks are still considered essential teaching materials, that remain underdeveloped. The availability of textbooks in schools in this study was subject to the DHs' retrieval policy; where there was no clear policy, learners did not bring the books back and there was therefore a shortfall of textbooks, especially in Grade 10. To curb the crisis, subject advisors and the other learned personnel developed a teaching and learning booklet called 'Step Ahead' to provide support by aligning the content with examination-type questions and the ATP, with many past examination questions. The shortage of LTSM compromised the quality of teaching and learning provided in the schools, and priority should be given to essential resources for teaching and learning. The DHs in this study worked with the SMT to advise on the resources needed for the subject. A challenge remains in selecting the trade industry tools that are essential to teach the needed skills to artisan learners that reinforce applications and practical work. The use of technology to supplement teaching and learning is evident in one school, whereas the other schools mainly use textbooks. The lack of laboratories to give learners practical experience contributes to their disengagement from the subject, as they cannot relate to abstract things which they have never seen.

This study concludes that while procurement of resources is essential for subjects in the technical field, practical examples need to be embedded in the curriculum and make sense to learners with no first-hand technical experience. DHs as curriculum managers lack the expertise to carry out this responsibility, and thus need capacitation from the DBE. Moreover, the lack of technical field-related resources yields an instructional practice riddled with abstract ideas as opposed to application.

9.2.3 Reasons DHs enact the roles in the way they do

The study revealed that DHs are influenced by multifaceted factors that inform their practices. The study's theoretical framework provided lenses for understanding and interpreting findings related to professional forces, such as context and biography, which influence which leadership styles

DHs adopt or neglect in their schools. The DHs set a tone within their departments, then teachers follow their management style. The DHs alluded to the support of their Technical Mathematics staff and expectations from the school principals, subject advisors, and the DBE as critical elements that inform the management style they adopt in their schools.

In School A, where the DH uses a top-down management style, he enacts his roles by following up and checking teachers' work, as prescribed by the ATP, POA, and QMS. Overseeing a new subject, the DH wanted to be knowledgeable in all aspects, which resulted in him doing all the management duties by himself, including moderation of all tasks. He sees himself as an authoritative figure, so he emphasises strict adherence to the curriculum monitoring tools (the ATP), with less attention given to capacitating teachers. To manage learners, the DH works with parents to ensure both parties maintain learner discipline and academic performance. He meets with the teachers every month for formal meetings. This study concludes that although there is a hierarchical divide between the DH and teachers, data from document analysis revealed learners' poor performance in Technical Mathematics, and thus one may argue that the authoritative approach is driven by the enormous pressure DHs find themselves under in trying to improve results.

The DH from School B understands his staff's strengths and where they fall short; she therefore assigns duties accordingly. The school's contextual factors include an overwhelming workload of managing the Science and Mathematics departments and technical subjects. This leaves the DH with no choice but to delegate their management duties to master teachers. Whereas some senior teachers help in the department, they are not compensated as master teachers. The study revealed that when teachers are assigned managerial tasks, they feel valued in their respective departments. However, the DHs are sceptical about delegating managerial roles, fearing that teachers would think that they are incompetent to carry out their duties. They therefore sometimes hold on to roles even though there are other teachers with better expertise. It was evident in the study that all of the DHs are Pure Mathematics teachers, and they lack knowledge when it comes to the industry-based part of Technical Mathematics. However, there was limited delegation to teachers with such expertise to manage those aspects when it comes to curriculum management and implementation. Even the DH in School B, who works collaboratively with teachers, does not delegate the responsibility of managing the industry- based part to teachers in the school who have such expertise.

In School C, the DH adopted both instructional and shared instructional leadership, which was both directive and accommodative. The contextual and DH biography forces played a significant role in shaping the type of leadership adopted by this DH. Although the DH assigned certain duties to the senior teachers, the aspect of monitoring the curriculum was also not delegated. Mthethwa (2011) posits that leaders must understand their followers' strengths and weaknesses before applying appropriate leadership methods.

While the DHs in this study have some knowledge of the teachers' expertise, even those who believe in shared responsibility hold on to the role of curriculum management, even when challenged by it themselves.

9.2.4 Contributing factors that enable/hinder DHs to implement, manage, and teach Technical Mathematics

To answer research question 4, I focus on two main aspects of themes, the enabling and challenging factors in DHs curriculum implementation, management and teaching of Technical Mathematics, thereby discuss each with respect to the study findings.

9.2.4.1 Enablers

The study revealed that the main enabling factor was getting the right teachers to teach Technical Mathematics. The DHs' perception of the 'right teachers' is based on experience, knowledge of Pure Mathematics, and pedagogy. According to the DHs, teachers who have taught Pure Mathematics are crucial for the implementation and management of Technical Mathematics, as they are familiar with the intricacies or complexities of teaching. This is as opposed to an inexperienced teacher, who might focus only on teaching skills rather than a holistic curriculum, since he or she is still developing. Furthermore, according to the DHs, experienced teachers have been exposed to different content workshops during the subject's inception, so they understand what needs to be done and are not relying only on the DH. During the implementation of the subject, DHs find it challenging to assign any role to novice teachers, as they will require intensive training that they are not capacitated to offer at a school level.

While the DHs are of the view that experienced teachers are better equipped to teach Technical Mathematics, the data from document analysis presented a contradictory view, as in all three schools the learner performance was not good and work done by learners displayed inconsistency with curriculum coverage. Based on the findings, it could be argued that being a seasoned teacher does not necessarily translate into effective implementation of the curriculum in the classroom, and thus DHs should not shy away from capacitating novice teachers to teach Technical Mathematics.

The second listed enabler that promoted effective implementation from the perspective of the DHs was the continuous evaluation of teachers and learners, and the whole school evaluation. They emphasised the importance of the QMS for appraisal, which embeds self-evaluation, peer evaluation, and DH evaluation of teachers' work, including learners' work. The DHs raised that since the subject is still new, subject advisors are also working hand in hand with the DHs and teachers to ensure effective implementation.

Thirdly, the inclusion of a PAT in the Technical Mathematics curriculum was seen as the most critical enabler in improving results and instilling the practical skills needed in the technical field that learners are being prepared for. The study found that the PAT played an essential role in encouraging learners' interest in Technical Mathematics, reducing cognitive load, and introducing them to different types of assessments. The DHs are of the view that learners with different capabilities can now demonstrate their practical mathematics skills and have better chances of attaining a pass mark, as the PAT contributes 25% of their final mark.

Fourthly, the study revealed that professional development workshops served as a tool to capacitate teachers on the content knowledge and methodology needed for teaching Technical Mathematics. The DHs attested that workshops were carried out during the initiation of the subject and were continued at the cluster level. However, DHs had no guidance regarding the expectations of their management role, as the focus was merely on content and pedagogy. The DHs indicated that they would have preferred to have facilitators who have knowledge and expertise of the subject, and are not challenged by some of the questions that they expect teachers to teach and learners to understand. The DHs argue that their seasoned teachers are reluctant to attend workshops as they do not benefit from them, whereas new teachers find workshops useful.

Lastly, regular meetings – either formal or informal – help to quickly identify areas that need attention and thus assist with implementation and management. In addition, the support from subject advisers in terms of offering content workshops was considered an enabler by the DHs.

9.2.4.2 Challenges

The first challenge that hindered Technical Mathematics implementation, management, and teaching was the delay in including PAT in Technical Mathematics schools. This is perceived as a failure in implementing the subject. The study revealed that it took the DBE six years before implementing the PAT component, which disadvantaged the first cohort of learners, who could have benefitted from the skills and knowledge afforded by it. The study's findings indicate that the DBE's failure to develop and implement the PAT in due time led to poor performance in the schools; there was no room for the practical application of theory as envisaged in the CAPS document. According to the DHs, the DBE rushed the introduction of Technical Mathematics before all of its components were ready for implementation, resulting in animosity towards the subject. Learners were struggling with the abstract nature of Technical Mathematics and thus failing Grade 12, which they perceive as a gatekeeper to the HEI and trade work field they were prepared for. It became DHs' responsibility as implementers and managers of Technical Mathematics to account for their learners' poor performance to their parents, SMTs, and DBE.

Secondly, the findings indicate a lack of professional development training for DHs to execute their management roles, suggesting they were ill-prepared to assist their teachers in implementing their teaching roles. The study revealed that DHs use their personal experiences from implementing previous curricula, which are not explicitly tailored for Technical Mathematics, and principals' knowledge of past curriculum implementation, the latter also lacking subject knowledge and expertise of Mathematics. As a result, the changes envisaged in Technical Mathematics could be assumed to be enacted haphazardly, where DHs were using skills that might not speak to the aims of the subject. Whereas the DHs are challenged by the non-existent training from the DBE, they also lack a self-improvement professional development plan, making it difficult for them to construe policies for their teachers and learners. The study revealed that the DHs possess the knowledge of Technical Mathematics content and pedagogy, but their management and implementation practices are challenged by the lack of support afforded by the DBE. Participants in this study stressed the importance of the DBE equipping them with the competencies they need for managing and implementing the proposed curriculum. Several studies also confirm that DHs as immediate curriculum managers in the school are the critical people that need to be capacitated (De Clercq et al., 2015; Mthiyane et al., 2015; Tapala, 2019).

Thirdly, the study findings concerning the Technical Mathematics content revealed that DHs perceived the curriculum as too packed, vast, and complex throughout Grades 10–12. The DHs affirm that despite the interventions and strategies in place to cover the content (for example, extra classes conducted weekly and over weekends and holidays), obtaining a reasonable pass rate remains a challenge. The DHs perceive the curriculum as having too much to be covered, and learners have no background in some of the topics since it is a new subject. Moreover, the DHs felt that the Technical Mathematics curriculum has too much Pure Mathematics in it, which is considered to be abstract, and learners need more time to understand it. The findings suggest that the calibre of learners enrolled in Technical Mathematics courses is challenged by the abstract nature embedded in the subject. The study also revealed that the overly packed nature of Technical Mathematics hinders effective implementation and management; teachers rush the curriculum and concentrate on examination questions to expedite completion of the syllabus and improve learners' results. The DHs argue that what adds to the existing challenges with the content is that examiners were inconsistent by not following examination guidelines and the CAPS document; their questions were beyond the scope of the learners and examination guidelines.

Lastly, the study revealed that learner factors – that include absenteeism, late-coming, attitude to their schoolwork, and progression policy – compromise the implementation of Technical Mathematics in schools. The DHs alluded to the fact that learners who are frequently absent and come to school late do not follow up on the work done, which indicates a lack of discipline and work apathy. The DHs shared that learners are now taking Technical Mathematics in Grade 10 with the assumption of an easy pass, as they think the subject is a watered-down version of Pure Mathematics, later finding the content to be challenging. Moreover, when learners discover that they cannot change the course during the year, they misuse the progression policy by waiting to fail one year and then being progressed to Grades 11 and 12 to exit the schooling system. The other challenge is that the PAT making up 25% of the mark attracts learners, as they assume it is already granted to them without doing any work, whereas they still need to fulfil the PAT requirements.

While some of the factors are not necessarily specific to the subject but rather are related to the systems problem and school culture, they hinder the effective implementation and management of the Technical Mathematics curriculum, as indicated by the DHs.

9.3 Recommendations drawn from the findings of the study

Considering the study findings, the following recommendations are proposed to improve the implementation of Technical Mathematics in technical schools:

- This study recommends that the DBE capacitate DHs on their managerial roles and responsibilities; DHs need ongoing structured professional development.

- The formation of professional learning communities (PLCs) should be a common practice in neighbouring schools, where DHs and teachers share teaching and learning resources; DHs need to work together to share effective managerial practices in implementing Technical Mathematics.

- DHs need to ensure continuous monitoring, evaluation, and support in their departments; curriculum monitoring must be done regularly to ensure syllabus coverage, intensive supervision of teachers' and learners' work, and that teachers are supported as teachers, and not just for compliance purposes.

- DHs must be provided with adequate LTSM required for the implementation of the subject in the classroom. Shortages of resources, especially in a new subject, is a clear indication of poor implementation. DHs need to establish ways of conserving their LTSM in their departments.

- Parents should be encouraged to work with the DHs and SMTs and teachers to curb the ongoing lack of apathy, late-coming, and absenteeism that DHs alluded to as challenges in their schools.

9.4 Implications of the findings of the study

The findings of the study show that DHs may need additional support and training on curriculum management skills. The implication is that the DBE should make provision for professional development to enhance DHs' abilities to manage the Technical Mathematics curriculum effectively. Furthermore, the findings highlight the importance of continuous professional

development for DHs and teachers; this study suggests that the DBE policymakers should invest in ongoing professional development to get teachers up to speed with best practices on content and pedagogy, especially the application and contextualisation of Technical Mathematics problems in the technical field.
The study has highlighted the need for flexibility within the Technical Mathematics curriculum, that will also allow for DHs' autonomy in developing assessments that test the skills they have taught. DBE policymakers should consider revising the curriculum to allow for adaptation to the unique needs and levels of understanding of different groups of learners. According to this study, one-size-fits-all assessments do not accurately reflect students' understanding; mainly, the SBA should demonstrate learners' understanding of the content taught. The DBE must intensify its teacher development programmes to develop teachers' capacity to design quality assessment tasks.

9.5 Limitations of the study and recommendations for further research

The study is the first of its nature to gain an understanding of DHs' knowledge and practices of implementing Technical Mathematics, as this is still a new subject in the South African curriculum. The study has argued for understanding the phenomenon and not generalising findings; nevertheless, it is essential that future studies investigate the implementation of Technical Mathematics further as the DBE populates the subject across South African technical schools. Based on the empirical evidence presented in this study, it is the first time the knowledge and practices of Technical Mathematics DHs are investigated in secondary schools in South Africa, since the subject was first implemented in 2016.

The study sample of three DHs in three schools in one district is considered small; hence the study results cannot be generalised to all South African schools in different contexts. However, the findings provide insight into DHs' knowledge of implementing the new curriculum, while exposing their understanding and practices. This study was also limited to DHs teaching Technical Mathematics and possessing knowledge and subject expertise; however, we know that in South Africa DHs manage a lot of subjects, and some are Physics specialists or Computer specialists. Therefore it is recommended that further studies focusing on DHs who are not teaching Technical Mathematics – but are expected to manage and implement it – should be conducted. It would also be interesting to understand all stakeholders' perceptions of curriculum implementation, by including the principals, subject advisors, teachers, and learners, so we can deeply understand how they perceive implementation of the subject.

9.6 Contributions of the study

Theoretically, this study contributes to the knowledge of the implementation of Technical Mathematics as a new stream of Mathematics. DHs' roles and responsibilities in curriculum management and implementation are critical, as they are the immediate managers and curriculum instructors. The study sought to understand DHs' management practices and implementation of the subject in the classroom setting. As DHs take on multiple roles and employ multiple strategies, the study revealed that there were enabling factors that facilitated curriculum implementation and challenges that hindered it, which are exposed in this study. To the best of the researcher's knowledge, no study yet speaks to the implementation of Technical Mathematics in technical secondary schools in South Africa. The study findings raise the need for pre-service teacher education programmes to be tailored to align with school curriculum changes in order to be effective.

9.6.1 Suggested framework for teaching, managing, and implementing Technical Mathematics

The knowledge for teaching Mathematics stems from Shulman (1986), that is, the pedagogical content knowledge (PCK) needed for teaching different subjects. It also extends to Ball et al.'s (2008) mathematical knowledge for teaching (MKT), that emphasises the knowledge needed for teaching Mathematics. The researcher included Mathematics curriculum implementation and monitoring constructs to anchor discussions around the research phenomenon. This study argues that specific knowledge and expertise are needed to manage the Mathematics curriculum implementation, and this knowledge is essential for DHs to execute their roles. The two constructs, PCK and MKT, have focused more on Mathematics curriculum implementation (MCI) at a classroom level. This study argues for the importance of knowledge of Mathematics curriculum monitoring, which is necessary for DHs to understand how the curriculum could be improved on a continuous basis. In this study, I refer to this construct as knowledge of Technical Mathematics curriculum monitoring (KMCM), which aims to understand the knowledge, strategies, and tools that DHs use to evaluate the curriculum, self-evaluate, and evaluate the teachers they manage. Figure 9.1 presents the framework designed.

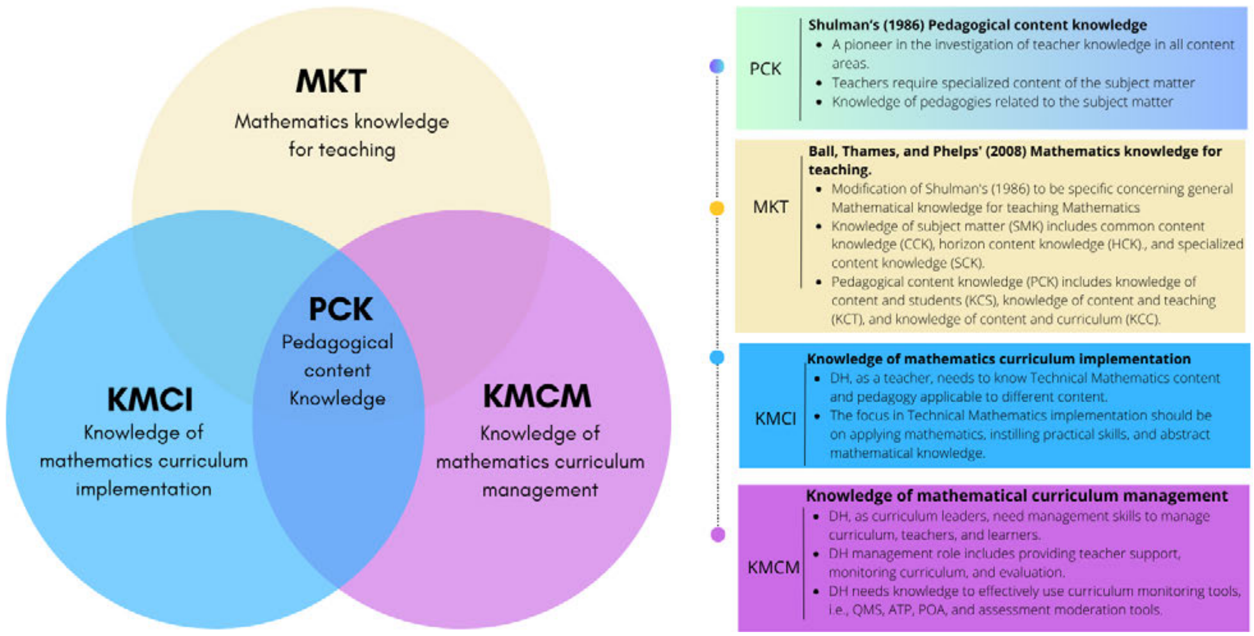


Figure 9.1. *Modification of Ball et al. (2008) applied to Departmental Heads' mathematical knowledge for implementing, teaching, and managing Technical Mathematics.*

These constructs give a holistic view of DHs' enactment of their roles and responsibilities to ensure effective curriculum implementation, management, and teaching of Technical Mathematics. The constructs strengthen systems relating to curriculum implementation, management, and teaching of Technical Mathematics.

9.7 Conclusion

The introduction of Technical Mathematics in 2016 was one of the fundamental curriculum differentiations in the Mathematics curriculum since the introduction of Mathematical Literacy in 2006 (Mthethwa, 2019). This study acknowledges the importance of Technical Mathematics, particularly for learners who are interested in applying mathematics to develop their artisan skills needed in the field of industry. As immediate instructional managers and teachers of Technical Mathematics, the knowledge and practices of DHs became a focal point for understanding the implementation of the subject in technical secondary schools. Hence, my conclusion to this chapter focuses on the objectives that this study sought to achieve.

Firstly, the research explores DHs' knowledge and practices of implementing and teaching Technical Mathematics in secondary schools. The study revealed that DHs are knowledgeable about Technical Mathematics in terms of content and pedagogical approaches developed through DBE workshops. Nevertheless, instrumental understanding prevailed in the DHs' practices, as their teaching was based on meeting examination standards and, in rare cases, they were teaching for relational understanding. Furthermore, their enactment of managerial roles in helping teachers to interpret the curriculum correctly was lacking. Some reasons for failing to enact their roles were a lack of training for their managerial roles and responsibilities, the curriculum being too prescriptive and thus compromising their autonomy, and their inability to relate the subject matter to learners' contexts as they lack technical field experience.

The second research objective was to examine Mathematics DHs' roles and responsibilities in implementing and teaching Technical Mathematics. The study findings revealed that DHs focused more on compliance rather than thoroughly monitoring the curriculum; they were more inclined to teach than to carry out their managerial role. DHs were not always aware of the extent to which the curriculum was covered, due to a lack of oversight and poor usage of curriculum monitoring tools like the ATP, which they were not consistently checking. This compromises the implementation of Technical Mathematics. The study revealed that the DHs are essential in recruiting and selecting suitable teachers to teach Technical Mathematics. However, they are conflicted, since there is a lack of artisan skills in seasoned Mathematics teachers, and trade teachers lack pedagogical knowledge. DHs did not provide capacity building to the teachers on the skills they lacked, due to their limited knowledge of the subject. The literature has frequently emphasised the need for DHs to have knowledge and expertise in the subject they manage, so that they know more than their teachers. Moreover, DHs' leadership styles had a strong bearing on their school's contextual and biographical forces; where teachers were supportive, DHs shared their managerial roles, and the converse was also true.

Lastly, the study examined challenges and enabling factors encountered by the DHs when implementing Technical Mathematics. The study revealed that institutional forces that hindered effective implementation included a shortage of teaching and learning resources, lack of capacity development for DHs' managerial duties, and DBE facilitators lacking subject knowledge and expertise as they are challenged by the content they present to teachers, rendering content workshops ineffective. Some CAPS programmatic forces inhibiting curriculum implementation include the vast and complex content, overly prescriptive curriculum, and delays in implementing

PAT. Contextual factors were Technical Mathematics' learner apathy, poor discipline, and poor management of LTSM.

One of the essential enabling factors raised by DHs was getting suitable teachers to teach, and these are seasoned Mathematics teachers who have been exposed to different curricular changes, having taught when certain sections were brought in and out. The study revealed that they possess adequate content knowledge and pedagogy, and over the years they have learned techniques for implementing the new curricula; however, they still need support. The inclusion of PAT in the curriculum enhanced learners' practical skills and improved results.

Collaborative practices through professional learning communities among DHs and teachers within their schools and neighbouring schools improved understanding of the subject expectations. Essentially, DHs' open-door policy and corridor chats encouraged teachers to share their challenges in curriculum implementation. More importantly, WhatsApp communiques was one of the efficient ways of sharing e-teaching and learning resources, supporting communication and connecting Technical Mathematics DHs, teachers and subject advisors.

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Appendices

Appendix A	Permission letter from HOD KZN Department of Education
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Appendix A: Permission letter from HOD KZN Department of Education

KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 392 1063

Email: Phindile.duma@kzndoe.gov.za

Enquiries: Phindile Duma

Ref.:2/4/8/1729

Mr MM Khoza
Flat 9 BlueGrass
3 Kings Road
PINETOWN
3610

Dear Mr Khoza

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"MATHEMATICS HEADS OF DEPARTMENT EXPERIENCES OF THE IMPLEMENTATION OF TECHNICAL MATHEMATICS: A CASE STUDY OF THREE TECHNICAL SCHOOLS IN PINETOWN DISTRICT"**, in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 26 April 2021 to 31 August 2023.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

PINETOWN DISTRICT

[redacted]

[redacted] **Dr. EV Nzama**
Head of Department: Education
Date: 28 April 2021

GROWING KWAZULU-NATAL TOGETHER

Appendix B: Ethical clearance certificate from UKZN

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

14 November 2021

Mfundo Mondli Khoza (209536877)
School Of Education
Edgewood Campus

Dear MM Khoza,

Protocol reference number: HSSREC/00003217/2021
Project title: Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District.
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 11 August 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 14 November 2022.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Appendix C: Principal consent letter and declaration

Flat 9 Bluegrass
Kings Road
Pinetown,
3600

Dear Principal

RE: Request for permission to conduct research at your school.

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*".

The research aims to explore DHs' experiences of implementing Technical Mathematics. The researcher aims to understand DHs' experiences of implementing the new subject in your school. The study will understand how DHs enact their roles and responsibilities of implementing and teaching Technical Mathematics. The challenges and enabling factors encountered by the DHs' during implementation.

I hereby request to conduct my research with Technical Mathematics DH at your school. I would like to collect data from the DHs' using multiple methods of data collection (interview, focus group and observations). The DH is expected to spend at least 60-180 minutes to reflecting on their experience/s for a period of 3 days. There will be semi-structured interviews which will help in getting insight into what DHs will be reflecting about.

This study is purely for academic purposes and there will be no financial gain involved. You are assured that the findings of this research will not be used for any other purpose other than the PhD dissertation. In this regard, no harm will be caused to the school and the Dh participating in this project. This study will ensure that anonymity of both school and the Dh is ensured by using pseudonyms to protect your school and learners.

The decision to participate in this study is entirely voluntary and you may withdraw your permission for the research without any negative consequences. If you have any further questions about the study, at any time feel free to contact me. Should you have any other concerns about your rights as research participant, you may contact my supervisor Dr. Zanele Ngcobo, contact details: ngcoboA2@ukzn.ac.za, [redacted].

Thank You
Yours faithfully
Mfundo Mondli Khoza
Student number: 209536877
Contact number:: [redacted]
Email: 209536877@stu.ukzn.ac.za / mfundo.khoza@gmail.com

You may also contact the Research Office through:
Email: HSSREC@ukzn.ac.za

Thank you for your contribution to this research.

Acknowledgement by the principal

I ………………………………………...……………, the Principal of …………………..……………………..…

grant/ not grant permission to Mfundo Mondli Khoza to conduct his research in the above-mentioned school.

……………………………………… ………………………………..…

PRINCIPAL SIGNATURE DATE

School Stamp

Acknowledgement by the principal

I ...[redacted]..., the Principal of [redacted] School

grant/ ~~not grant~~ permission to Mfundo Mondli Khoza to conduct his research in the above-mentioned school.

[redacted]

PRINCIPAL SIGNATURE

02/08/2022

DATE

School Stamp

[redacted]VE
HIGH SCHOOL
02 -09- 2022
BOX 2[redacted]
TELEFAX : 031 [redacted]

Acknowledgement by the principal

I..........[redacted]................, the Principal of [redacted] grant/ ~~not grant~~ permission to Mfundo Mondli Khoza to conduct his research in the above-mentioned school.

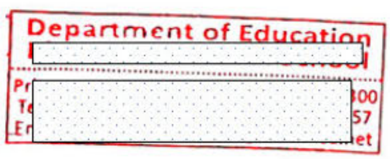
[redacted]

PRINCIPAL SIGNATURE

23 JUN 2022

DATE

School Stamp



Acknowledgement by the principal

I, [redacted] Principal of G[redacted] School

grant/ ~~not grant~~ permission to Mfundo Mondli Khoza to conduct his research in the above-mentioned school.

[redacted]

PRINCIPAL SIGNATURE

29-07/22.

DATE

School Stamp

KWAZULU-NATAL DEPT. OF EDUCATION

[redacted]

E[redacted]

Appendix D: Departmental Head consent letter and declaration

Flat 9 Bluegrass
Kings Road
Pinetown
3600

INFORMED CONSENT LETTER

Dear Participant

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*". I would like to gather the information by asking you questions related to the subject implementation in your department.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The interview may last for about 45 minutes to 1 hour.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

Equipment	Willing	Not willing
Audio equipment		
Photographic equipment		
Video equipment		

Yours faithfully
Mfundo Mondli Khoza
I can be contacted at: Email: mfundo.khoza@gmail.com or 209536877@stu.ukzn.ac.za Cell: [redacted]

My supervisor is Dr Zanele Ngcobo who is located at the School of Education, Edgewood campus, University of KwaZulu-Natal (UKZN).
Contact details: Room CU 150, Main Tutorial Building, Edgewood Campus, UKZN.
Email: NgcoboA2@ukzn.ac.za Phone number: 031 2603784
Any queries should be addressed to: Email: HSSREC@ukzn.ac.za
Thank you for your contribution to this research.

DECLARATION

I…………………………………………………………………………… (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

……………………………………… …………………

SIGNATURE OF PARTICIPANT DATE

Flat 9 Bluegrass
Kings Road
Pinetown
3600

INFORMED CONSENT LETTER

Dear Participant

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, *"Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District"*. I would like to gather the information by asking you questions related to the subject implementation in your department.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The interview may last for about 45 minutes to 1 hour.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

Equipment	Willing	Not willing
Audio equipment	✓	
Photographic equipment	✓	
Video equipment	✓	

Yours faithfully
Mfundo Mondli Khoza
I can be contacted at: Email: mfundo.khoza@gmail.com or 209536877@stu.ukzn.ac.za Cell: [redacted]

My supervisor is Dr Zanele Ngcobo who is located at the School of Education, Edgewood campus, University of KwaZulu-Natal (UKZN).
Contact details: Room CU 150, Main Tutorial Building, Edgewood Campus, UKZN.
Email: NgcoboA2@ukzn.ac.za Phone number: 031 2603784
Any queries should be addressed to: Email: HSSREC@ukzn.ac.za
Thank you for your contribution to this research.

DECLARATION

I ....[redacted]........................ (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

[redacted]

SIGNATURE OF PARTICIPANT

28 - 07 - 2022.
....

DATE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Flat 9 Bluegrass
Kings Road
Pinetown
3600

INFORMED CONSENT LETTER

Dear Participant

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*". I would like to gather the information by asking you questions related to the subject implementation in your department.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The interview may last for about 45 minutes to 1 hour.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

Equipment	Willing	Not willing
Audio equipment	X	
Photographic equipment	X	
Video equipment	X	

Yours faithfully
Mfundo Mondli Khoza
I can be contacted at: Email: mfundo.khoza@gmail.com or 209536877@stu.ukzn.ac.za Cell: [redacted]

My supervisor is Dr Zanele Ngcobo who is located at the School of Education, Edgewood campus, University of KwaZulu-Natal (UKZN).
Contact details: Room CU 150, Main Tutorial Building, Edgewood Campus, UKZN.
Email: NgcoboA2@ukzn.ac.za Phone number: 031 2603784
Any queries should be addressed to: Email: HSSREC@ukzn.ac.za
Thank you for your contribution to this research.

DECLARATION

I..[redacted]..................... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

[redacted]

SIGNATURE OF PARTICIPANT

02/08/2022

DATE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Flat 9 Bluegrass
Kings Road
Pinetown
3600

INFORMED CONSENT LETTER

Dear Participant

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*". I would like to gather the information by asking you questions related to the subject implementation in your department.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The interview may last for about 45 minutes to 1 hour.
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

Equipment	Willing	Not willing
Audio equipment	/	
Photographic equipment	/	
Video equipment	/	

Yours faithfully
Mfundo Mondli Khoza
I can be contacted at: Email: mfundo.khoza@gmail.com or 209536877@stu.ukzn.ac.za Cell: [redacted]

My supervisor is Dr Zanele Ngcobo who is located at the School of Education, Edgewood campus, University of KwaZulu-Natal (UKZN).
Contact details: Room CU 150, Main Tutorial Building, Edgewood Campus, UKZN.
Email: NgcoboA2@ukzn.ac.za Phone number: 031 2603784
Any queries should be addressed to: Email: HSSREC@ukzn.ac.za
Thank you for your contribution to this research.

DECLARATION

I........[redacted]......................... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

[redacted]

SIGNATURE OF PARTICIPANT

23/6/2022

DATE

Appendix E: Learner consent letter and declaration

Flat 9 Bluegrass
3 Kings Road
Pinetown
3600

INFORMED CONSENT LETTER

Dear Participant

My name is Mfundo Khoza, I am a Doctor of Philosophy (PhD) student at the University of KwaZulu-Natal Edgewood campus. I am currently engaged in a research project entitled, "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*". I would like to observe your Technical Mathematics classroom.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person but reported only as a population member opinion.
- The observation may last for about 45 minutes to 1 hour.
- Any information obtained from your classroom cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the observation to be recorded by the following equipment:

Equipment	Willing	Not willing
Audio equipment		
Photographic equipment		
Video equipment		

I can be contacted at:
Email: mfundo.khoza@gmail.com or 209536877@stu.ukzn.ac.za Cell: [redacted]
My supervisor is Dr Zanele Ngcobo who is located at the School of Education, Edgewood campus, University of KwaZulu-Natal (UKZN).

Contact details: Room CU 150, Main Tutorial Building, Edgewood Campus, UKZN.
email: NgcoboA2@ukzn.ac.za Phone number: 031 2603784

I certify that I have explained the study to the participant/s and consider that she/he understands what is involved and freely consents to participation.

Researcher's name: Mfundo Mondli Khoza
Researcher's signature………………………………….. **Date………………………………………**

I, the participant whose signature appears below, have read a transcript of my participation and agree to its use by the researcher as explained.

Participant's signature…………………………………… **Date…………………………………………**

Appendix F: Parent/ Guardian consent form for child participation in research

Flat 9 Bluegrass
3 Kings Road
Pinetown,
3600

PARENTAL CONSENT FORM FOR CHILD PARTICIPATION IN RESEARCH

I …... hereby consent to my child ....
*Parent/Guardian's Name (*please print*) *Child Participant Name (*please print*)

Participating, as requested, in the school for the research project on "*Mathematics Heads of Department experiences of the implementation of Technical Mathematics: a case study of three Technical schools in Pinetown District*".

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I agree to my child's involvement in the research and that my child's information may be used.
4. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
5. I understand that:

Phone number: 031 2603784

I certify that I have explained the study to the participant/s and consider that she/he understands what is involved and freely consents to participation.

Researcher's name: Mfundo Mondli Khoza

Researcher's signature………………………………….... **Date………………………………………**

7. I, the participant whose signature appears below, have read a transcript of my participation and agree to its use by the researcher as explained.

Participant's signature…………………………………… **Date……………………………………………...**

Appendix G: Lesson Observation schedule

Flat 9 Bluegrass
Kings Road
Pinetown
3600

Mathematics Departmental Heads' Lesson Observation

School Pseudo name:	
DH Pseudo name:	
Grade:	
Lesson theme:	
Purpose of the lesson:	
Classroom setup:	
No. of learners	

1. How was the lesson started?

2. Does the lesson link up with a previous theme, or is it mainly independent?

3. Resources used by the DH in the development of the learning content

4. How did the DH supplement the learning content?

5. In what way did the learners contribute to the learning content?

6. Which teaching media were used by the teacher? (E.g., overhead projector, blackboard, posters, video, textbooks, pictures, etc.)

2. How did the teacher involve the learners in lesson activities?

Activities of teacher	*Activities of learners*

3. How was learning assessed?

4. What are the challenges that the DH faces when teaching the lesson?

5. How did the Departmental Head overcome the mentioned challenges?

6. What are the enabling factors that promoted DH to teach the lesson?

7. How did the Departmental Head apply the mentioned enabling factors to promote the teaching of the lesson?

Appendix H: Semi-structured interview schedule

UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI

Flat 9 Bluegrass
Kings Road
Pinetown,
3600

Semi-structured interview schedule

I am a researcher in the field of Mathematics education, and I will be asking you various questions that will help me understand your experiences with implementing Technical Mathematics as a new subject. I will be voice-recording your responses, and this will help me to transcribe the data correctly without missing important information. There are no correct or wrong answers in this interview; thus, please feel free to respond in the manner you want. Thank you for agreeing to participate in this study and to be interviewed.

Main Question: What are the DHs' practices and knowledge of managing, implementing, and teaching Technical Mathematics?

1. What is your understanding of managing and implementing the Technical Mathematics curriculum?
2. What are the expectations from the DBE on the curriculum implementation, monitoring, and management?
3. What is your understanding of PCK and MKT in Technical Mathematics?

3.1 In your classroom observation (QMS), explain the extent to which teachers demonstrate MKT.

3.2 To what extent does the QMS help to identify teachers' needs, support continuous growth, promote accountability, and help you evaluate teachers?

3.3 Are there measures in place to capacitate teachers? How often do teachers attend content workshops, and how effective are the workshops?

4. What do you think about your PCK & MKT of teaching Technical Mathematics?
5. What do you do to ensure that your teachers are capacitated with PCK and MKT?
6. To what extent do teachers share their knowledge (PLC - professional learning community) about content and pedagogy in Technical Mathematics?
7. In what ways is the Department of Basic Education preparing you as the DH to implement Technical Mathematics in your school effectively?

7.1 To what extent would you say you receive support from the school principal and subject advisors to ensure effective implementation of Technical Mathematics in your school? Why?

8. What have been your successes in implementing Technical Mathematics in your school?

8.1 How did you ensure the success? Why is that?

9. What challenges do you encounter with executing your roles?

9.1 How do you meet those challenges? Why do you do that?

10. Which Technical Mathematics topics challenge learners and which topics do learners find relatively easy to understand?

10.1 What are common misconceptions that learners have in Technical Mathematics? How do you address them? Why do you do that?

11. Using CAPS document, to what extent do you and your teachers have to conform to the syllabus, or how much flexibility do you have over what you teach & assess?

Main Question 2: How do DHs enact their roles and responsibilities to implement and manage Technical Mathematics? and Question 3: Why do DHs enact their roles in the way they do?

12. As the DH, you have double roles of implementing the new subject, Technical Mathematics, and managing it; what has been your experience thus far?
13. How do you carry your DHs' roles? Why do you do that?
14. Explain how the recent mathematics curricular changes from the introduction of C2005, RNCS, CAPS, Mathematical Literacy, and Technical Mathematics affect you as DH to execute your roles.
15. What informs learners' choice of Technical Mathematics? How do you select learners from grade 9 to grade 10 to either choose Technical Mathematics, pure mathematics, or mathematical literacy?
16. How are your learners performing in Technical Mathematics? What are the underpinning reasons, and how do you ensure they improve their performance?

Main Question 4: What are the contributing factors that enable DHs to implement, manage, and teach Technical Mathematics and the challenges, if any, that hinder the implementation, managing, and teaching of Technical Mathematics?

17. What do you consider to be the main enablers of implementing Technical Mathematics thus far?
18. How do you monitor Technical Mathematics curriculum implementation? What are your enabling factors and challenges? How do you address the challenges?
19. What tools do you use to ensure curriculum coverage and that teachers are professionally supported?
20. What resources do you have in place for teaching Technical Mathematics? Are there enough resources at your disposal to effectively teach? What resources are missing, that could improve teaching and learning at your school?
21. What measures are in place to develop teachers' skills and offer support to enhance their skills to teach Technical Mathematics successfully?

Appendix I: Focus Group interview schedule

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Focus Group interview schedule

I am a researcher, and I will be asking you various questions that will help me understand your experiences of implementing Technical Mathematics as a new subject. I will be voice-recording your responses, and this will help me to transcribe the data correctly without missing important information. There are no correct or wrong answers in this interview; thus, please feel free to respond in the manner you want. Thank you for agreeing to participate in this study and to be interviewed.

School pseudo name	Mr. Alpha	Mrs. Beta	Mr. Gamma
DH Pseudo name			
Grades teaching:			
Number of teachers DH manages.			
Number of learners DH manages			

1.

A new mathematics teacher has been appointed to your school to teach technical mathematics. The teacher has never been exposed to technical mathematics before. What guidance can you give to ensure that they unpack the Technical Mathematics curriculum correctly?

2.

One of your teachers has raised that they are not familiar with a particular topic in technical mathematics. What do you do as a DH to support the teacher and help learners at the same time?

3.

You are in a parents' meeting, and you are asked to explain about tech math. What advice would you give to parents who want their children to do Technical Mathematics?

4.

The Department of Education calls you to raise your concern about implementation, managing, and teaching Technical Mathematics. What are the key things that will help DHs in other schools to ensure the successful implementation of the subject?

5.

What are your biggest challenges of having double roles, teaching and managing the subject at the same time, since Technical Mathematics has been recently implemented in your school?

Appendix J: Document Analysis

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Document Analysis

I am a researcher, and I will be analysing documents that you use when teaching, monitoring, and implementing a Technical Mathematics curriculum. This will help me to understand how you implement, teach, and monitor technical mathematics as a new subject. Thank you for agreeing to participate in this study.

Documents	**Analysis**
Departmental Head's files	
Curriculum monitoring tool used by the Departmental Head	
Minutes of the meetings and agenda of meetings	
Learners' files	
Programme of assessment (POA)	
Teachers' files	

Appendix K: Turnitin similarity report

Turnitin Originality Report

Processed on: 09-Nov-2023 9:27 PM
CAT
ID: 2223088657
Word Count: 83692
Submitted: 1

DH_knowledge_and_practices.docx By Mfundo khoza

Similarity Index	Similarity by Source	
3%	Internet Sources:	N/A
	Publications:	3%
	Student Papers:	N/A

< 1% match ("Research Advances in the Mathematical Education of Pre-service Elementary Teachers", Springer Science and Business Media LLC, 2018)
"Research Advances in the Mathematical Education of Pre-service Elementary Teachers", Springer Science and Business Media LLC, 2018

< 1% match (Tshepo T. Tapala, M. P van Niekerk, Kobus Mentz. "Curriculum leadership barriers experienced by heads of department: a look at South African secondary schools", International Journal of Leadership in Education, 2020)
Tshepo T. Tapala, M. P van Niekerk, Kobus Mentz. "Curriculum leadership barriers experienced by heads of department: a look at South African secondary schools", International Journal of Leadership in Education, 2020

< 1% match ("Encyclopedia of Mathematics Education", Springer Science and Business Media LLC, 2020)
"Encyclopedia of Mathematics Education", Springer Science and Business Media LLC, 2020

Appendix L: Letter from editor

Leverne Gething, M.Phil., *cum laude*
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e-mail: leverne@eject.co.za

3 November 2023

Declaration of Editing of a PhD thesis:

Mathematics Heads of Department experiences of the implementation of Technical Mathematics: case study of three Technical schools in Pinetown District

I hereby declare that I carried out language editing of the above thesis on behalf of Mfundo Mondli Khoza

I am a professional writer and editor with many years of experience (e.g. 5 years on the *South African Medical Journal*, 10 years heading the corporate communication division at the SA Medical Research Council), who specialises in Science and Technology editing – but am adept at editing in many different subject areas. I have previously edited many academic papers and theses for various higher education institutions and journals.

I am a full member of the South African Freelancers' Association as well as of the Professional Editors' Association.

Yours sincerely

[redacted]

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