Mathematics teachers' diagnostic assessment practices in the implementation of Lesson Study

by

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Declaration

I declare that the dissertation, which I hereby submit for the degree in Magister Educationis at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Andrea Vetter

September 2022

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Ethics Statement

The author, whose name appears on the title page of this dissertation, has obtained, for research described in this work, the applicable research ethics approval.

The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for Researchers and the Policy guidelines for responsible research.

Signature:

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Dedication

I dedicate this research to my parents Roann and Clinton Vetter for their continuous motivation, support and guidance. Thank you for always encouraging me to continue working with excellence until I reach my goals and to never give up on something I am passionate about. Your endless support will never go unnoticed. I love you both so much and I promise to continue making you proud.

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Abstract

Lesson Study (LS) is a teacher-led and practice-situated professional development (PD) model that teachers use to improve their teaching and to foster learners' mathematical thinking. There are different variants of LS globally. The unique feature of South Africa's LS variant is at the diagnostic assessment/analysis stage. Diagnostic assessment/analysis is credited for assisting teachers to gain an in-depth understanding of learners' misconceptions about a particular topic or concept. The purpose of this qualitative case study, based on interpretive paradigm, was to examine mathematics teachers' diagnostic assessment practices when implementing LS. I addressed the following main research question: *How do mathematics teachers use the LS cycle to identify learners' misconceptions in mathematics?* Data was collected through observations and interviews from *a* team of mathematics teachers participating in in-school LS. I used two theoretical lenses: the *situated learning theory (SLT)* in which LS is rooted, and the taxonomy of *diagnostic competences* (Fischer, Kollar, Ufer, Sodian, Hussmann, Pekrun, R. & Eberle, 2014).

Four key findings were revealed: firstly, teachers conducted a comprehensive diagnostic analysis to identify the problem and generating possible causes of the problem; secondly, in their attempt to create artefacts (instructional activities) teachers did not collaboratively interrogate them to ensure that they were purposeful; thirdly, although the process of generating evidence through lesson presentation was done appropriately, teachers were restricted by the activities and questions that were not purposeful; and lastly, instead of focusing mainly on evaluating evidence against their assumptions during the reflection session, teachers focused on the challenges and the affordances of LS. Essentially, there is a need for policy makers and teacher development institutions to empower teachers on diagnostic assessment, thereby institutionalising it as a mathematics classroom culture.

Key words: Lesson Study, diagnostic assessment, diagnostic analysis, diagnostic competences, mathematics misconceptions

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PROOFREADING AND EDITING CERTIFICATE

Busy Bee Editing have completed the proofreading, editing, layout, syntax, reference checking, spelling and grammar checking to the best of their ability on a 35,396-word Master's Thesis for Andrea Vetter, titled **MATHEMATICS TEACHERS' DIAGNOSTIC ASSESSMENT PRACTICES IN THE IMPLEMENTATION OF LESSON STUDY**, submitted in partial fulfilment of the requirements for the degree **MAGISTER EDUCATIONIS**, in the Faculty of Education at the **UNIVERSITY OF PRETORIA**.

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List of Abbreviations

CAPS	Curriculum and Assessment Policy Statement
CPD	Continuous Professional Development
DBE	Department of Basic Education
ELS	Early Learning School
JICA	Japan International Cooperation Agency
LS	Lesson Study
MSSI	Mpumalanga Secondary Science Initiative
NCTM	National Council of Teachers of Mathematics
PD	Professional Development
SA	South Africa
SLT	Situated Learning Theory
TIMSS	Trends in International Mathematics and Science Study
TPD	Teacher Professional Development

Description of Key Terms

Academic achievement

Academic achievement can be defined as learned proficiency in basic skills and content knowledge (Moore, 2019).

Learner

While other countries globally use the term pupils or students, according to the South African Schools Act (84 of 1996) the term *learner* is used instead of pupils or students to denote a person receiving or obliged to receive education in the schooling sector

Research lesson

In the context of LS, Takahashi and McDougal (2016: p. 515) define a research lesson as: "A lesson taught by a teacher in the planning team while the other team members and other educators who are not on the planning team observe". Since a research lesson is collaboratively planned, I have used the terms collaborative lesson plan and research lesson interchangeably.

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CHAPTER 1: OVERVIEW OF THE STUDY

1.1 Introduction

South Africa (SA) is underperforming substantially in education, particularly in mathematics teaching and learning (McCarthy & Oliphant, 2013). However, although the 2019 trends in International Mathematics and Science Study (TIMSS) revealed that South African learners have made significant progress, learners are still falling behind their international counterparts (Bhengu, 2020). The TIMSS results showed that only 40 percent of Grade 9 learners in SA demonstrated basic mathematics knowledge (Bhengu, 2020). It is well known that SA faces many challenges that hinder quality education being given to learners (Arends, Winnaar & Mosimege, 2017). One of these challenges has been shown to be teacher professionalism (Arends et al., 2017).

Jojo (2019) accentuates that the teaching of mathematics is an art that requires continuous professional development (CPD) that will equip teachers to teach all concepts of mathematics to the learners in a better way. Teachers' professional development (TPD) is the foundation of quality education because it is an ongoing process that focuses on the whole spectrum of expertise, skills, and attitudes needed to successfully educate learners (Bernadine, 2019). Steyn (2011) argues that teachers' skills and knowledge can decline over time, therefore there is a need for teachers to be regularly involved in quality TPD programs. TPD programs have become a major focal point of school improvement initiatives (Steyn, 2011).

LS is a popular and effective approach for teachers' professional development in Japan (Elipane, 2017). LS entails a small group of teachers collaboratively planning a series of research lessons for learners based on a common learning objective, with one teacher teaching the collaboratively developed lesson and their colleagues observing learners learning during the lesson (Elipane, 2017). Takahashi and McDougal (2016) observed that LS is an effective PD model for teachers because it is highly structured and teachers learn from each other. Experts in the field, commonly referred to as knowledgeable others, are usually involved and contribute to the insights given during post-lesson discussions and planning. Countries around the globe, including SA, have adapted the Japanese LS to suit their contexts. The LS cycle in SA consists of a unique first step, diagnostic assessment/analysis (Sekao & Engelbrecht, 2021). The main purpose of diagnostic assessment/analysis in the South African LS cycle is to diagnose learners' difficulties in mathematics concepts or topics and to guide lesson planning. According to the prescripts of LS, the results of diagnostic analysis will inform pedagogic and content considerations of the collaborative lesson planning to follow.

1.2 Problem Statement

Diagnostic assessment is one of the assessment types advocated in the Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education, 2012) as "a tool for teachers to assess the strengths and weaknesses of learners and to design teaching and learning strategies that will address the individual needs of a learner." (p. 154). Diagnostic competence is a critical aspect of diagnostic assessment that can have a significant impact on learners' learning processes and performance (Beck & Zlatkin-Troitschanskaia, 2013). Despite its widespread acceptance and inclusion in the curriculum, research reveals that teachers frequently lack the ability to accurately assess their learners' performance, ability, commitment, and heterogeneity (Beck & Zlatkin-Troitschanskaia, 2013).

In South African schools, over a decade ago, Kanjee (2009) noticed that teachers interpreted the implementation of classroom assessments as merely serving the purpose for the accumulation of marks rather than for the use in improving teaching and learning. It is in the researchers experience that, despite diagnostic assessment being a requirement for mathematics teachers' practice, it is not fully applied in the teaching and learning process. In instances where they identify learners' errors and misconceptions through diagnostic assessment /analysis, they do so hypothetically and do not test their hypotheses to either confirm or dispel them, thereby risking applying inappropriate interventions. However, the problem regarding diagnostic assessment seems not to be prevalent and unique. Research in Nigeria revealed that of the 50 participants, 66 percent believe that diagnostic assessment is too time-consuming, 80 percent only plan for summative assessments at the end of each topic, while 70 percent believe that diagnostic assessment is not as important as formative and summative assessments (Jimola & Ofodu, 2019).

1.3 Purpose and Rationale

The purpose of this research is to examine mathematics teachers' diagnostic assessment practices when implementing LS. I realized that teachers do not pay attention to diagnostic analysis, or it is done out of compliance, albeit superficially as a mathematics teacher. The responses of learners are seldomly analysed or used to improve the teaching and learning of the assessed topic. This study was important to undertake because diagnostic assessment/analysis is known to assist teachers to gain an understanding of learner's current knowledge and misconceptions about a topic. It also helps teachers to determine the appropriate resources that can be used to improve the overall teaching and learning of the topic (William, 2011).

By teachers not taking time to conduct diagnostic assessment/analysis they stand a risk of not being able to determine the factors that might impede learners' progress in mathematics. They also risk not being knowledgeable about where the learners are in their acquisition of mathematics knowledge and skills. The teachers may also be unable to build on the knowledge that has been taught. Given the issues mentioned above, there was a need to explore mathematics teachers' diagnostic assessment practices within a South African LS context. The contribution of this study is that it will provide an in-depth understanding of diagnostic process as used in the LS cycle, thereby, testing the assumptions about perceived learners' misconceptions in mathematics.

1.4 Research Questions

The primary research question to be explored in study is: *How do mathematics teachers use the LS cycle to identify learners' misconceptions in mathematics?* The following secondary research questions, whose focus I have briefly clarified underneath each, were explored to address the primary research question:

a) *How do teachers conduct diagnostic analysis to identify learners' problematic areas in mathematics concepts?* According to stage 1 of the LS cycle identifying the goal of the research lesson starts by identifying learners' problematic areas in a particular concept in mathematics. My interest, therefore, is to understand the process teachers follow to identify learners' misconceptions (and types thereof).

This should culminate in teachers making assumptions about what they perceive to be the misconceptions.

b) *How do teachers construct artefacts to test their assumptions about learners' problematic areas in mathematics concepts?* As proposed by Fischer et al. (2014) the artefacts could include the mathematics tasks/activities designed to test their (the teachers') perceived learners' misconceptions. These activities and how they will be executed feature in stage 2 of the LS cycle, i.e. collaborative lesson planning.

c) *How do teachers generate evidence when testing their assumptions about learners' problematic areas in mathematics concepts?* This question involves the testing of their assumptions through the use of the artefacts (mathematic tasks/activities) in order to generate evidence. Generating evidence takes place when one teacher teaches the lesson while others observe and document how learners respond to the activities as espoused by stage 3 of the LS cycle.

d) *How do teachers evaluate evidence generated from testing their assumptions?* Evaluating evidence takes place during the post-lesson reflection (stage 4 of the LS cycle). During reflection, teachers ought to confirm or refute their assumptions regarding their perceived misconceptions.

1.5 Literature Review

As mentioned previously the general aim of this study was to examine how mathematics teachers' use the LS cycle to identify learners' misconceptions. I examined literature focusing on definitions of LS, the PD of teachers, the use of diagnostic assessments and the South African version of the LS cycle. Although I have presented a detailed review of the literature in Chapter 2, in this section I present an abridged version of the literature review.

Darling-Hammond, Hyler, Gardener and Espinoza (2017, p. 2) described TPD as a: "structured professional learning that results in changes in teacher practices and improvements in students learning outcomes". Throughout Japan, LS is used as a vehicle for sustainable TPD (Hunter & Back, 2011). The LS model was designed with the teacher's continuous CPD as the base but with the learners learning as the core focus (Hunter & Back, 2011). Workshops, seminars and conferences are commonly used as PD models in SA. These methods are criticized for not providing enough time, activities and content for teachers to increase their knowledge and abilities (Steyn, 2008; Darling-Hammond et al., 2017). Like many other countries, SA has adapted the Japanese LS cycle to suit the needs of our current education system. The significance about the South African version of the LS cycle is that teachers identify a problem or a goal for the LS during the diagnostic analysis/ assessment stage. The National Council of Teachers of Mathematics (NCTM) (2014) describes diagnostic assessment as a means of highlighting potential misconceptions and gaps in students' knowledge within the specific problematic area. Teachers use the information generated from diagnostic analysis to learn more about the students' recurring misconceptions in the targeted domain (Ketterlin-Geller, 2009). The result of the diagnostic analysis assists in guiding the LS process. Fischer et al. (2014, p. 6) suggests eight steps in the diagnostic process, namely, "problem identification, questioning, generating hypothesis, constructing artefacts, generating evidence, evaluating evidence, drawing to conclusions, and communication of the results". This approach promotes PD and reflective teaching (Elipane, 2017). It focuses both on improving the planning before a lesson and building strategies for better instruction to improve learning.

Two theoretical lenses to explore the study, namely the *Situated learning theory (SLT)* in which LS is rooted and the *diagnostic competences* by Fischer et al. (2014). SLT is central to this research as teachers are required to collaborate during the LS cycle, they do that by bringing their prior subject knowledge as well as work in a particular context. In this study it would be a classroom environment where they will be diagnosing the difficulties learners experience in a specific mathematics concepts or topic. Fischer et al's. (2014) diagnostic competences are quite critical in informing the crafting of the research questions and development of the data collection instruments in this study. The link between the framework, research questions, instruments and the relevant stages of the LS are presented in Table 2.

1.6 Research Methodology

Saunders, Lewis and Thornhill (2019) proposed a research onion framework that illustrates the different aspects of the research methodology. I used the research onion to guide the structure and flow of my research methodology.

My study is underpinned by *interpretivism paradigm* through which I explored a deeper understanding of the phenomenon and its complexity in its unique context instead of generalizing the base of understanding to the whole population (Creswell, 2014). I chose this paradigm as my study was conducted in the natural setting, the classroom, which gave the ability to gather in-depth data about the research topic.

I primarily chose the *inductive research approach* because it involved the search for patterns from observations and the development of explanations for those patterns (Bernard, 2011) as teachers grapple with diagnostic analysis of learner responses. One of the main aims of inductive research is to gather and to interpret rich and in-depth data about the studied phenomenon which is what I wanted to achieve in answering my four secondary research questions. However, since I had knowledge about how diagnostic analysis ought to be conducted within the LS context, deductive approach played a secondary role.

My study followed a *qualitative research approach*. In line with the interpretivist paradigm, qualitative research allowed to gather in-depth contextual information by observing human interactions, thoughts and reasoning holistically in a social context (Daniel, 2016). I chose qualitative research as my methodological approach because I was interested in exploring the meanings teachers assign to their own experiences in relation to diagnostic analysis of learners' responses. I used a case study research design whose attributes are in line with the attributes of the interpretivist tradition. As Yin (2009) observed, a case study can be used to explain, describe, or explore events in their natural context they occur.

A *cross sectional time frame*, which Saunders at al. (2019) refer to as a "snapshot" was selected for this study as it enabled to look at data from a sample at one specific point in time (Cherry, 2019). Qualitative cross-sectional study is observational and descriptive in nature (Cherry, 2019); therefore, it is in line with the attributes of a case study design I have adopted. I used two non-probability sampling methods, namely *purposeful sampling* and *convenient sampling* methods. Purposeful sampling can be defined as the researcher selecting a specific group of people to gain detailed knowledge about the specific phenomenon and not make a generalization (McCombes, 2021). The sample in this study is a small group of five primary school mathematics teachers who are familiar with LS. Convenience sampling technique is used to recruit participants who are easily accessible to the researcher in terms of their geographical location and willingness to participate in the study (Eitkan, 2016). In line with this view, I selected five teachers from the school which I am currently employed in, it is also in close proximity for easy access for data to be collected.

I used multiple *data collection techniques* in line with the prescripts of an interpretivist paradigm and qualitative studies. I collected data through observations and unstructured interviews. The main aim of observations is to develop a holistic understanding of the phenomenon (Musante & DeWalt, 2010), which in the context of my study is teachers' diagnostic practices. Unstructured interviews can be defined as a type of interview where the questions nor answer categories are not pre-determined (Wildemuth, 2017). My main intention for using unstructured interviews was to be exposed to unanticipated themes to help corroborate and/or clarify the information gathered through observation.

1.7 Quality Criteria

I ensured trustworthiness in study by creating member checks where the participants got an opportunity to read over the data collected thereby giving them a chance to correct any wrong interpretations. Methodological triangulation was my second way to ensure trustworthiness of my data by making sure that data gathered was by means of different data collection methods (Korstjens & Moser, 2018) i.e., unstructured interviews and observations. I have presented a detailed explanation of quality criteria in Chapter 3.

1.8 Ethical Consideration

I adhered to all the guidelines of ethical behaviour as stipulated by the Ethics Committee of the Faculty of Education at the University of Pretoria. I obtained approval from the Ethics Committee at the University of Pretoria (Annexure B) to collect data, after which I obtained an Ethical Clearance Certificate. Permission to conduct research in the school was granted by the principal (Annexure D) along with permission to conduct research by the teachers (Annexure E). Consent forms for the principal (Annexure C) and teachers (Annexure F) were given once the study was explained in detail them. The consent forms ensured the teachers of anonymity and ensured that they understood it was voluntary to participate and that the data would be kept confidential. I adhered to the prescripts of the Protection of Personal Information (POPI) Act.

1.9 Chapter Outline

To assure a well-structured research report in which the content flows in a logical order and in which the research aims, and questions are addressed, the chapters are outlined below.

Chapter 1: Overview of the Study

This chapter presents an overview of the whole study which includes, inter alia, the background, problem statement, purpose and rationale, research questions, truncated literature review and methodological issues. It is worth mentioning that Chapter 1 captures the summary of the main parts of the study for which details are presented in the subsequent chapters.

Chapter 2: Literature Review and Theoretical Framework

Discussed the theoretical framework in detail, and I reviewed and synthesised relevant literature for the study.

Chapter 3: Research Methodology

I examined the methodological issues pertaining to the study guided by the research onion advocated by Saunders et al. (2017). These include the philosophical perspective, methodological approach, research design, sampling, data collection and analysis strategies.

Chapter 4: Presentation of the Research Findings

I present the findings of the data collected through observations and unstructured interviews in line with the research questions and the findings according to Fischer et al. (2014).

Chapter 5: Discussion of Findings, Recommendations and Conclusions

I discuss the findings including their implications for mathematics classroom practice. In addition, I reflected on how the two lenses that framed the study assisted in the collection of data and in answering my research questions. I made recommendations for future studies and concluded the study by bringing it to a logical end.

CHAPTER 2: THE LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

The main aim of the current study was to examine mathematics teachers' diagnostic assessment practices in the context of LS. In this chapter I reviewed literature associated with LS and diagnostic assessment/analysis. Essentially, I organised Chapter 2 according to two main sections namely, the review of literature covering the LS and its instantiations; and the theoretical framework covering the two lenses which frames the study, i.e. SLT and the competencies of Fischer et al.'s (2014) diagnostic process.

2.2 Origin and Global Interest of LS

The word 'Lesson Study' is derived from the Japanese word *jugyou Kenkyuu* and refers to a lesson that teachers collaboratively plan, observe and discuss (Lewis, 2000; Takahashi & McDougal, 2016).

Collaboration, which portrays the attributes of LS, is often confused with cooperation. Pantcheva (n.d) defines collaboration as working together with someone or with a group of people in order to achieve a single shared goal while cooperation in contrast is working with people by achieving one's own goals as part of a common goal and therefore the two constructs need to be demystified.

LS is a PD model that has gained popularity in many countries since it was first introduced in Japan over a century ago. Throughout research, there are various definitions on what LS actually is. LS, according to Ono and Ferreira (2010), is a type of PD activity that takes place in the classroom and is characterised by being classroom-based, context-based, learner-cantered, improvement-oriented, and teacher-led. In addition to this definition, Mokhele (2013) adds that LS is a PD model that was designed to guide teachers in developing good quality lessons and to assist them to gain a better understanding of the way in which their learners learn best.

Throughout Japan, LS is seen as an engrained PD model for teachers. Lewis, Perry and Hurd (2008) assert that LS differs from other PD models because learners are at the heart or at the centrepiece of this model, whereas other PD models focus exclusively on the teachers. LS often follows a cyclic pattern where a group of teachers collaboratively plan a lesson based on a topic that teachers have difficulty teaching or that students find difficult to learn. Once the lesson is planned one teacher will teach it while the rest of the teachers observe. After the lesson is taught the teachers gather again and discuss details about how the lesson went and what could be improved. This cycle can go on for as many times as required.

LS was brought to light by the research of Stigler, Gonzales, Kawanka, Knoll, & Serrano (1999). Stigler et al. (1999) collected data on how teachers in Germany, Japan and the United States teach mathematics. This was done through TIMSS videotape classroom study and the findings on how Japan teachers teach mathematics were what brought LS to the attention of other countries. Many countries have taken the concept of the Japanese LS cycle and adapted it to suit the needs of their educational systems, SA being one of them (Sekao, 2019).

2.2.1 South African LS cycle

LS was introduced in SA in 1999 (Sekao & Engelbrecht, 2021). The first LS project in SA was in the Mpumalanga province. The project was called the Mpumalanga Secondary Science Initiative (MSSI). This project was a joined project between the Mpumalanga Department of Education, the Japan International Cooperation Agency (JICA) and the University of Pretoria (Ono & Ferreira, 2010). LS was introduced in SA to improve the teaching and learning of mathematics (Ono & Ferreira, 2010). In the year 2006, LS was placed in a lengthy hiatus due to challenges such as curriculum reform processes experienced in the education system in SA (Sekao & Engelbrecht, 2021). The DBE and the JICA revived the LS model for TPD in the year 2011.

The recommencement of LS in SA resulted in a more structured approach to use LS as a method to develop mathematics teachers in their teaching and learning (Sekao & Engelbrecht, 2021). Currently, many schools in SA use the 5-stage LS model for TPD as illustrated in Figure 1 (Sekao & Engelbrecht, 2021), followed by the explication of each stage.

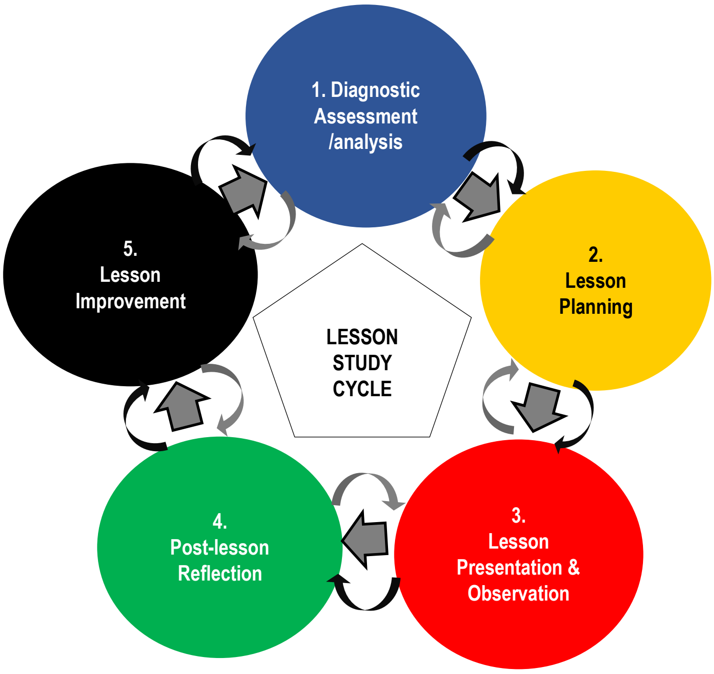


Figure 1: LS cycle (Source: Sekao & Engelbrecht, 2021)

2.2.1.1 Diagnostic assessment/analysis

The stage of diagnostic assessment/analysis makes the South African version of LS unique as it gives a clear indication of how problematic topics or concepts in mathematics are identified whereas other variants of the LS cycle do not display that clearly (Sekao, 2019). Diagnostic analysis is a familiar phenomenon among teachers in South Africa since it has been used to generate diagnostic reports from the national assessments in mathematics to determine the nature of conceptual and procedural knowledge deficiencies that learners had (Sekao, 2019). However, during the diagnostic assessment/analysis of the Lesson Study cycle teachers use assessments such as classwork, tests or examinations to identify common misconceptions that learners have in a specific topic.

A good diagnostic test provides evidence of common misunderstandings that are held by the student, which could prevent progression in developing the required level of mathematical understanding. The emerged misconceptions will then be the focus of the research lesson. The reason why the words diagnostic assessment and diagnostic analysis are used in the SA's version of the LS cycle is because the type of diagnosis depends on whether a specific diagnostic assessment is developed, administered, marked and then the responses analysed, or whether summative assessment responses are analysed diagnostically (Sekao & Engelbrecht, 2021).

2.2.1.2 Collaborative lesson planning

According to literature, collaboration is an effective form of PD (Gutierez, 2021). Teachers are required to engage in PD practices which are situated in a community of practice. The community of practice is where teachers regularly collaborate and exchange ideas and insights to improve their teaching (Gutierez, 2021). During the collaborative lesson planning stage of the LS cycle, teachers share their knowledge of content and pedagogical practices to develop a lesson, often called a research lesson, to address the difficulties learners experience in mathematics (Sekao & Engelbrecht, 2021).

A collaborative lesson plan is dubbed a research lesson because it is a special lesson associated with LS where teachers gather information, study instructional materials (*kyouzai kenkyuu* in Japanese) including textbooks and develop a lesson to address specific mathematical concepts that learners struggle with. The study of curriculum materials (*kyouzai kenkyuu*) is a critical feature of LS and particularly significant during collaborative lesson planning because it empowers teachers to investigate the relevance of the activities for learning before they are used during teaching (Melville & Corey, 2022). In other words, copying activities from the textbooks and using them for teaching without prior interrogation for their fitness-for-purpose has a potential to inhibit the achievement of the learning objectives. The lesson is then tested in authentic contexts – the classroom in real time (Sekao & Engelbrecht, 2021). The quality of the lesson plan determines the quality of the learning opportunities that will be provided to the learners. Therefore, a considerable amount of time and effort should be put into the planning phase of the lesson (Gutierez, 2021).

Advantages of collaborative lesson planning is the provision for the continuous learning, the improvement in professional practices, and professional support (Gutierez, 2021). Research has shown that there are better results and benefits to students when teachers work together as a team in a collaborative manner (Al-Shareef & Al-Qarni, 2016). Overall, the main benefit of teacher collaboration is to create a safe and open platform for teachers to freely exchange their ideas, share useful teaching resources and to find ways to improve their teaching effectiveness (Yuan & Zhang, 2016). The benefits of working in a team and collaborating are increased collegiality, as it reduces teacher isolation, facilitating and sharing of resources and ideas, as well as emphasizes a teacher's individual and shared strength (Boles & Troen, 2010).

Lesson planning is an essential element of effective teaching. Some of the key activities of collaborative lesson planning is developing or identifying (from textbooks) purposeful teaching and learning activities, developing clear learning objectives and strategies to check students understanding (Al-Shareef & Al-Qarni, 2016). The purposefully created activities should foster learners' mathematical thinking (NCTM, 2014) and should test learners relational understanding, which is defined as learners knowing what to do, being able to explain why and knowing how to alter procedures in a new situation (Skemp, 1978).

Purposeful activities do not merely focus on instrumental understanding which is described as learners only knowing how to follow a rule or procedure accurately without understanding why these rules or procedures work (Skemp, 1978). In concurrence, Finkel (2016), as cited in Chubb (2018) describes mathematics activities as those that should encourage active thinking and reasoning (dynamic practice) and not only expect learners to memorize rules, formulas or follow procedures through repetition as this results in little to no thinking or reasoning for learners (rote practice). A rote-dynamic dichotomy which teachers should bear in mind when creating instructional activities for learners is succinctly presented in Table 1.

Table 1: The role of practice (Finkel, 2016, as cited in Chubb, 2018)

ROTE PRACTICE	DYNAMIC PRACTICE
Emphasis on memorising of rules, formulas, algorithms, etc.	Emphasis on understanding and applying rules, formulas, algorithms, etc.
Emphasis on following procedures, often with fidelity.	Emphasis on relationship between and making sense of concepts and procedures.
Passive learning that does not promote thinking.	Active learning that promotes mathematical thinking.

Often teachers in a typical mathematics classroom are dominated by activities that promote 'rote practice' and that to be successful in mathematics learners ought to practice it regularly. I consider it a false narrative because if relational understanding can be a common feature in mathematics classrooms, learning by drill and practice would not be a common feature. Lewis (2020) explains the dangers of drill and practice by stating that learners will only rely on remembering the procedures for the purpose of assessments but will not understand the concept properly. Lewis (2020) also asserts that memorizing causes problems in future when more complex tasks arise and require more mathematical thinking or problem solving, the learners will not know what to do. This concurs with what some scholars refer to as the *Einstellung effect* where learners apply ill-fitting solutions because they incorrectly identify problems as being familiar or similar to previously solved ones (Obispo & Rodrigo, 2017). Finkel (2016) as cited by Chubb (2018) demonstrates the effectiveness of dynamic practice as a 'way' for learners to gain a deeper understanding or make more connections between concepts which will enhance their mathematical thinking.

Lesson planning results in lessons running smoothly and efficiently as teachers are also expected to come up with questions that they will be posed during the lesson presentation that will engage and encourage mathematical thinking (NCTM, 1991). Questioning is an important tool in teaching mathematics as it assists teachers in measuring academic progress and learners' comprehension of the topic at hand (McCarthy, Sithole, McCarthy & Gyan, 2016). McCarthy et al. (2016) goes on to explain how teachers restrict learners' thinking by not asking questions across all the cognitive domains. Purposeful questions are listed as one of the eight practices that guide effective mathematics teaching (NCTM, 2014).

NCTM (2014, p.3) described the aim of purposeful questions as to "assess and advance students' reasoning and making sense about important mathematical ideas and relationships". They further explain how mathematical success lies in teachers questioning learners within these four groups, namely; gathering information (learners are required to recall facts, definitions and procedures), probing mathematical thinking (learners mastering the skill of explaining or clarifying their thinking), making mathematics visible (discussing structures and connections that exists) and encouraging reflection of justification (learners should reveal a deeper understanding and reasoning). Questioning within a mathematics classroom shifts limited thinking to the exploration of new solutions and repetition of procedures to the investigation of reasoning and connections (McCarthy et al., 2016). Kistian, Armanto and Sudrajat (2017) note the importance of self-discovery activities in a mathematics classroom. They assert that self-discovery promotes active learning and when done correctly the learners remember the work easier because they have played an active role through self- finding or self-investigation in the activities which ultimately would last longer in their memory (Kistian et al., 2017).

Effective lesson planning also provides insight into the way teachers are approaching their teaching process to help students make progress and provides a structured lesson route (Al-Shareef & Al-Qarni, 2016). During stage 2 of the LS cycle, teachers collaboratively plan the lesson, they discuss different methods to approach the topic, determine lesson objectives as well as the activities and questions that will be used for teaching and learning (Sekao, 2019). At the end of collaborative lesson planning, teachers are required to develop an observation tool in preparation for the next stage of the LS cycle.

2.2.1.3 Lesson presentation and observation

LS advocates for presenting and observing the lesson in authentic contexts (Sekao & Engelbrecht, 2021). The authentic contexts imply that the normal day-to-day running of the school should not be tampered with. Therefore, the school timetable should be followed as it is, and the teacher who volunteers to teach the research lesson while being observed should do so in his or her class.

Lesson presentation and teachers' knowledge of subject matter have been regarded as factors that contribute to learners' performances in mathematics (Danda & Abdian, 2012). According to Ntibi, Neji and Agube (2020) a good lesson presentation leads to the achievement of set objectives as well as sustaining the learners' attention. For classroom teaching to be effective, teachers must have sufficient subject knowledge. This refers to the level where teachers demonstrate a good grasp of knowledge of the subject being taught and the skills needed to teach that subject (Ntibi et al., 2020). Ntibi et al. (2020) noted that even when a teacher shows great subject knowledge the choice of method of presentation may reduce or enhance his or her effectiveness in imparting such knowledge to the learner. A study based on examining the influence of teachers' lesson presentation on students' academic achievement concluded that lesson presentation has a strong positive effect on students' achievements in algebraic processes (Ntibi et al., 2020).

In LS, a knowledgeable other or expert is invited to attend as an observer during the lesson observation. Takahashi (2014) suggests three major reasons why a knowledgeable other should be invited to observe the lesson and later participate in post-lesson reflection. In no particular order, a knowledgeable other will provide a different perspective on the LS work of the group, he or she will provide information about the subject matter content, new ideas or reforms and they will share the work of other LS groups.

During this stage, lesson presentation and observation take place simultaneously. The teachers who were involved in the collaboratively planned lesson (research lesson) are required to observe the lesson being taught by the teacher who volunteered to teach the lesson that they had all planned together. While observing, the teachers make use of an observations tool which they would have developed during the planning stage of the lesson to assist them by informing them exactly what they are looking for during the lesson without disrupting the lesson or the teacher who presents the lesson. After the lesson has been taught, the group of teachers will all meet and have a post-lesson reflection.

2.2.1.4 Post lesson-reflection

Dewey (1933, p. 9) originally defined reflection as “the active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and further conclusions to which it tends”. During the process of reflection, people recall, consider and assess their experiences usually with the goal of improving their practice and to extend their understanding of that experience (Cimer, Cimer, & Vekli, 2013). Critical reflection involves questioning the broader structures of society and challenging the status quo (Cimer et al., 2013). Critical reflection is a crucial part of TPD as it allows teachers to step back and see what they do from a wider perspective. This allows teachers to think of other ideas and actions to consider enhancing the learning process in their classrooms (Cimer et al., 2013). During this stage, the teachers are expected to discuss what they observed during the lesson as well as determine what went well and what did not go as planned in relation to the lesson objectives that were discussed in stage 2 of the LS cycle (Sekao, 2019). The teachers are also expected to discuss how the teaching and learning process can be improved.

The focus of the reflection is not the teacher who taught the lesson, but rather learners' mathematical thinking. The teacher who taught the lesson is a vessel through which the ideas of the group are tested in practice. Reflection requires teachers to consider the big picture of their teaching and to evaluate the effectiveness of a lesson or a series of lessons not just in terms of measurable outcomes like students' exam grades, but also in terms of exploring the nature of the teaching and learning process and evaluating what was learned, by whom, and how learning might become more effective in the future (Moore, 2000; Cimer et al., 2013).

Reflective practice is seen as a complex and intellectually challenging activity as its success depends on the skills of the reflective practitioner as well as the quality of the support provided by the learning environment. During the post-lesson reflection phase of LS, the entire group of teachers who collaboratively planned the lesson are required to reflect on that lesson. Each member of the group has to give their input of what they observed and what can be improved on as well as what went well and worked. Cimer et al. (2013) stress that teachers need to be supported by a skilled practitioner who can assist with the reflection and can reflect, analyse and dialogue their own practice. A knowledgeable other or expert in mathematics and LS is usually involved in the reflection process to assist teachers from an outside point of view. During the post-lesson reflection stage, the knowledgeable other will make final comments based on the whole process and give his or her views from an outside perspective (Takahashi, 2014).

Engaging in reflective practices has many benefits for teachers such as assisting them in dealing with uncertainties and unexpected situations in a classroom and general school environment because reflection encourages them to critically appraise themselves, their current beliefs, attitudes and relationships with the students and others in the school (Cimer et al., 2013). By teachers gaining a better understanding of their own individual teaching and practice through reflective practice, teachers can improve their effectiveness in teaching (Cimer et al., 2013). Generally, it is accepted that reflection leads to PD and growth in teachers.

Reflection can assist teachers in becoming lifelong learners by allowing them to generate and store personal knowledge on a constant basis. Teachers are at the centre of the learning process with reflective processes, and they are responsible for their own growth and learning. Widjaja, Vale, Groves and Doig (2017) noted that during this stage it is important for teachers to focus on reflecting on the entire process and most importantly learners learning rather than criticizing the teacher who taught the lesson. The teacher who taught the lesson, therefore, should not be subject to judgement as he or she would have just been a vessel of their (lesson study teams') collaborative ideas.

2.2.1.5 Lesson improvement

Lesson improvement is the last stage of the LS cycle. In this stage the teachers are required to incorporate the discussed changes, document them and share the report with each member of the group. A study conducted by Helmbold, Venketsamy and Heerden (2021) revealed several impacts of the PD on teachers through LS. The teachers who were involved in a LS project indicated that their content and pedagogical content knowledge improved. They also explained how LS made them raise the standard of their teaching as well as improve their self-confidence (Helmbold et al., 2021).

2.2.2 TPD through LS

Teaching is a profession that requires ongoing PD and learning. According to Steyn (2011) TPD is the process of keeping teachers' skills and knowledge updated so as to improve learner academic achievements. PD, according to Mizell (2010), is a practice that schools adopt to ensure that their teachers continue to improve their skills throughout their careers. However, Darling-Hammond et al. (2017, p. 2) defined TPD as a "structured professional learning that results in changes in teacher practices and improvements in students learning outcomes". The LS model was designed with the teacher's CPD as the base but with the teachers learning as the core focus (Hunter & Back, 2011). Rahim, Sulaiman and Tajularipin (2016) conducted a study in a Malaysian school where teachers implemented LS and explored their (teachers') learning experiences. After the study was concluded, teachers indicated that by participating in LS, they could identify their strengths in teaching as well as their weaknesses which helped them to know what they need to work on to become better teachers. Many of the teachers claimed that peer collaboration helped them tremendously in improving their professional and content knowledge. Overall, the teachers said that the LS process improved their instruction (Rahim et al., 2016).

Over a decade ago, Steyn (2008) explained how workshops, seminars, and conferences are seen as PD models in SA. These methods, which are presumably being practiced today, have been criticized for not providing enough time, activities, and content for teachers to increase their knowledge and abilities (Steyn, 2008; Darling-Hammond et al., 2017). Research has suggested that effective PD has the characteristics of being based on teacher prior experiences, it takes place over a long period of time, it must involve teachers planning, discussing and predicting, and then reflecting on what actually worked and what did not. It should enable teachers to plan collaboratively and involve an expert in the field to assist (Gutskey, 2003).

LS embodies effective TPD in numerous ways (Bae, Hayes, Seitz, Connor & DiStefano, 2016). Firstly, LS is an ongoing process in contrast to the short seminars and workshops that do not provide enough time for teachers to implement, test or critically reflect on the skills they have gained and to see if it will be used in their classrooms (Bae et al., 2016). Secondly, LS requires teachers to engage in a collaborative manner where every member gets an opportunity to present his or her ideas about the research lesson which in turn assists the rest of the teachers to learn and grow, whereas traditional PD methods are based on teachers being passive recipients of information (Bae et al., 2016). Thirdly, LS is embedded in teachers daily work and is situated in their classrooms which promotes improvements to meet the needs of the learners, whereas other PD models occur at conference venues or workshop centres.

Most importantly, LS focuses on in-depth discussions and observations of how learners learn which guides the teachers in their lesson planning and implementation. In this way, implementing LS in the classrooms enables teachers to collaboratively experiment and test different ways of teaching the research lesson while the learners are still at the forefront of their decisions (Bae et al., 2016). Although studies have shown numerous benefits for LS, Mon, Dali and Sam (2016) noted within LS, there are challenges that teachers face such as time constraints, keeping up with their workload, lack of teaching knowledge and the perception of teaching observations.

Effective PD programs should include elements of collaboration where there should be a space created for teachers to meet and share their ideas (Darling-Hammond et al., 2017). Darling-Hammond et al. (2017) stressed how teachers should use effective models for practice such as LS, however, in a South African context, there are very few studies done on the effectiveness of LS as a PD model.

2.3 Implications of Diagnostic Assessment for Mathematics Teaching and Learning

2.3.1 Diagnostic assessment

Diagnosis as a practice has its roots in the medical field and it was first used in around 300 BC (Berger, 1999). The term diagnosing is used frequently throughout the medical field and is associated with activities and processes of classifying causes and forms of phenomena (Heitzmaan, Seidel, Opitz, Hetmanek, Wecker, Fischer & Fischer, 2019) which, in the medical field, includes illnesses. Within the education and medical field, diagnosing activities are considered components of professional problem-solving. In education specifically, diagnosing is often regarded as a critical precondition and an element of adaptive teaching (Heitzmaan, et al., 2019). In essence, diagnoses are needed as decision points for action and for interventions targeted at addressing or mitigating a problem (Heitzmaan et al., 2019). Fischer et al. (2014) have identified eight diagnostic competences for scientific reasoning. Medical practitioners and the education sector have used those competences as steps to assist them in the diagnostic process (Heitzmaan, et al., 2019; Wildgans-lang, Scheuerer, Obersteiner & Fischer et al., 2020).

The National Council of Teachers of Mathematics (NCTM) (2015) describes diagnostic assessment as a means of highlighting potential misconceptions and gaps in students' knowledge within the specific problematic area. In fact, Fischer et al. (2014) suggested that teachers should demonstrate certain diagnostic competences, such as, identifying a problem, questioning and generating hypothesis to diagnose learners' misconceptions. Teachers use the information generated from diagnostic assessment/ analysis to learn more about the students' recurring misconceptions in the targeted domain (Ketterlin-Geller, 2009). Although NCTM (2015) asserts that diagnostic assessment/analysis should be done at the beginning of the year and at the start of each topic, opinion because diagnostic analysis/assessment is an integral part of teaching and learning.

Astute teachers pick up on misconceptions throughout the teaching and learning process. For instance, marking formative assessments or when learners respond orally during the presentation of the lesson, teachers often identify misconceptions among learners. Sheridan (2012) conducted a study on the effect of implementing diagnostic assessment in a mathematics classroom and found that by doing this assessment, it enhanced the students' performance in the assessed topic.

Geok-Shim, Haduzaifah and Azizan (2017) concur that there is a positive correlation between mathematics diagnostic assessment and the students' results. Evidently there seems to be a consensus that diagnostic assessments benefit the learners and guides teaching. The problem, however, is that there are very few studies done in SA on the impact diagnostic assessment might have on the learners' results. There is also very little evidence of teachers conducting diagnostic assessments in mathematics despite it being a requirement in the CAPS. This could mean that teachers plan and conduct lessons based on the assumption that all learners have the pre-knowledge needed to understand/master the topic.

A study conducted in Indonesia by Wijaya, Retnawati, Setyaningrum and Aoyama, (2019) examined teachers' use of diagnostic tests, analysis and assessments. The study showed that 53 percent of the teachers diagnosed their students during the lesson, 42 percent explained that they conducted the diagnosis after the completion of teaching that specific topic and the remaining 5 percent said they diagnose students' difficulties at the beginning of the semester. Based on these results it can be deduced that teachers who conduct diagnosis at the end of the semester are not conducting a diagnosis test, instead they are doing a diagnostic analysis of the results from the semester.

Wijaya et al. (2019) explains how doing a test at the beginning of a semester to examine students' prior knowledge about the topic is also not considered a diagnostic test as teachers are not yet aware of the misconceptions that learners might have. I hold a different view about this assertion as teachers conduct diagnostic tests to test a hypothesis of common misconceptions learners usually have on that particular topic.

The Indonesian study also showed different ways in which teachers administer student diagnosis. The most frequent way according to the study was through a test where 56 percent of the teachers made use of a test to diagnose students' difficulties. These teachers gave the students the test to write and analysed the results diagnostically to determine what they find difficult. Of the teacher's 28 percent said that they do diagnoses during the lesson by observing the students' gestures and kinds of questions asked and 17 percent of the teachers' conducted diagnoses through interviews or conversations with the students (Wijaya et al., 2019).

Wijaya et al. (2019) went on to examine what the teachers do once they have diagnosed the students. They found that 48 percent of teachers conducted a remedial, which was basically re-teaching the topic that the students found challenging; 31 percent reverted to drill and additional practices on the challenging topic; and only 17 percent used those results to develop new teaching strategies to overcome the students' difficulties. Lastly, 5 percent of the teachers used the results and developed teaching media. These teachers argued that the lack of teaching media could contribute to students' difficulties in mathematics. Overall, the results of this study conclude that teachers do not perform in-depth diagnosis of students' difficulties in learning mathematics. Teachers do not thoroughly identify students' thinking processes in relation to the mathematics concepts they are learning.

2.3.2 Teachers diagnostic competences

Throughout the recent years, teachers' diagnostic competences have become a crucial part in the teaching and learning process. "Teacher's diagnostic competence could be defined as teachers' ability to interpret students' thinking and reasoning process, to monitor students' progress and difficulties, and to provide appropriate responses to the results of the diagnosis" (Wijaya et al., 2019, p.359).

Larrain and Kaiser (2019) define diagnostic competence as teachers constantly identifying and analysing each individual student's work as well as the work of the entire class to understand their current level of understanding on the topic and use that as a starting point to plan further instructional activities aimed at promoting learning.

Diagnoses has been regarded as crucial because it allows teachers to understand the thinking process of students as well as planning based on their thinking pattern to promote learning (Larrain & Kaiser, 2019). Additionally, Larrain and Kaiser (2019) stated that diagnostic competence allows teachers to comprehend students' ways of reasoning and adapt their teaching strategies to promote learning. Although the word diagnosis is used more in the medical field, teachers use diagnostic activities in their everyday teaching (Larrain & Kaiser, 2019). The way in which teachers use it is by analysing students learning outcomes and processes in order to plan further teaching and learning.

Situation-based diagnostic competence refers to a teacher's ability to acquire information throughout class time about their students' mathematical knowledge, challenges, and misconceptions and to do ongoing analyses that allows them to deliver appropriate pedagogical solutions (Hoth, Döhrmann, Kaiser, Busse, König & Blömek, 2016). The goal of diagnostic competences should be for teachers to adapt their teaching and learning after identifying the students' errors in order to help the students overcome their misconceptions (Heinrichs & Kaiser, 2018).

2.3.3 Misconceptions

Misconceptions are a common phenomenon in life. No matter how well a lesson is presented, or how well a topic was taught, misconceptions can still occur (MacDonald, 2010). In fact, misconceptions are not only located in learners, but can stem from teachers too especially when their own subject knowledge is weak or their confidence in the material is low (Jarvis, Mckeon & Taylor, 2005; Mupa & Chinooneka, 2015).

Khalid and Embong (2020) stated that errors were found to stem from carelessness, poor basic knowledge or mixing up rules which is a result of surface understanding while misconceptions in contrast are caused by superficial understanding and learners trying to memorize the rules but apply them incorrectly. Error analysis assist teachers in pin-pointing students' errors which the teacher can then provide instruction targeted to the students' area of need. Identifying students' misconceptions or errors is the first step to providing remedial or corrective instruction (Heinrichs & Kaiser, 2018). Heinrichs and Kaiser (2018) developed a diagnostic process model where they identified three common steps in diagnostic process in error situations, namely, perceiving or identifying, understanding or interpreting and deciding how to proceed.

In the first step teachers are required to *analyse students work* in order to identify errors. In step two of the process, teachers are required to look for *possible reasons* for the students' error. During this stage teachers need to be able to interpret the errors in accordance with a particular learning situation. They also have to look at the type of error it is and make possible hypothesis about possible causes of that error. The last stage requires the teacher to *deal with the error*, taking into consideration their hypothesis about the cause of the error, the teachers need to plan a strategy aimed at helping the students overcome their error and promote further learning.

Wijaya et al., (2019) found that students difficulties in mastering concepts in mathematics occur because students struggle to link between the knowledge they are studying and the prior knowledge they have. The analysis of students' difficulties should be a preliminary step in the process of improving the students' performance as it clearly outlines the key aspects of students learning processes that need to be developed (Wijaya et al., 2019).

It is the teachers' responsibility to identify and help the student overcome difficulties in the teaching and learning process. Effective mathematics teaching requires teachers to understand what students know and need to learn (NCTM, 2022). Hence, it is crucial for teachers to be aware of their students' difficulties in learning mathematics in order to develop and perform learning activities effectively (Wijaya et al., 2019). There are two main types of misconceptions found in mathematics, namely, procedural and conceptual misconceptions (Nahdi & Jatisunda, 2020).

Procedural misconceptions include learners' incorrect understanding of the rules or routines that need to be followed to answer a specific question whereas conceptual misconceptions include learners' lack of understanding of mathematical relationships that need to be used when answering a specific question (Nahdi & Jatisunda, 2020).

Hurell (2021) argued that teachers who teach more procedural knowledge than conceptual knowledge leave learners with ineffectual mathematical reasoning and the learners tend to conduct incorrect or partially correct procedures. This statement adds to what some scholars refer to as the Einstellung effect, where learners apply ill-fitting solutions because they incorrectly identify problems as being familiar or similar to previously solved ones (Obispo & Rodrigo, 2017). Without pre-empting or anticipating what will emerge, in my study I will explore any type of misconception that learners will have.

2.4 Diagnostic Assessment as an Integral Component of the LS in the South African Context

Many countries around the world have adopted the LS model. For instance, according to Dudley (2019), the United Kingdom (UK) version of LS has added additional steps to the original LS established by the Japanese. The importance of the UK version is that they include interviews of the students to gain their feedback on what worked for them, what they thought they learned and how they think the lesson could be improved if it was taught to another class.

In Zambia, LS has eight steps which go through a “Plan, Do and See” process twice (Banda, Mudena, Tindi & Nakai, 2014). The South African LS model has five stages, namely: diagnostic assessment/analysis, collaborative lesson planning, lesson presentation and observation, post-lesson reflection and lesson improvement (Sekao & Engelbrecht, 2021).

It should be noted that although there could be other variations of LS in SA, referring to this model as a South African LS model is due to its wide-spread use in many public schools (Sekao, 2019). The significance about the South African version is that teachers identify a problem or a goal for the LS during the diagnostic analysis/assessment stage. The result of the diagnostic analysis assists in guiding the LS process. Globally, although identifying a goal or the focus for the LS cycle is stated as the first stage, the process of doing so is generally not pronounced.

Fischer et al. (2014, p. 6) suggests eight steps in the diagnostic process, namely, problem identification, questioning, generating a hypothesis, constructing artefacts, generating evidence, evaluating evidence, drawing conclusions, and communicating results. This approach promotes PD and reflective teaching (Elipane, 2017) and focuses both on improving the planning before a lesson and building strategies for better instruction to improve learners learning.

2.5 Theoretical Framework

I used two theoretical lenses to explore study, namely, the *SLT* in which LS is rooted, and the *diagnostic competences* proposed by Fischer et al. (2014). Each one of the two theoretical perspectives serve a specific purpose in my study: *SLT* provides a theoretical base for LS, while *diagnostic competences* guide diagnostic process or structure. Synergising the two theoretical lenses, therefore, assisted me to gain in-depth understanding of teachers' diagnostic practices during the implementation of LS. The link between the framework, research questions, instruments and the relevant stages of the LS are presented in Figure 2.

2.5.1 Situated learning theory

My study is underpinned by the SLT (Lave & Wegnar, 1991). Lave and Wegnar (1991) stress that learning occurs when individuals are members of a community. Within a community of practice, group members jointly share and develop practices, learn from their interactions and gain opportunities to develop personally, professionally or intellectually (Besar, 2018). Knowledge emerges as a result of individuals participating in a community (Besar, 2018).

Situated learning emphasizes the opportunity for learners to reveal their abilities and talents within a learning environment that mirrors the culture and tools that are cast in the same mould as those used in real life situations (Besar, 2018). The SLT is heavily reliant on collaboration (Kurt, 2021). Teachers are required to work together and discuss their thinking within the group. SLT is the core of this research as teachers are required to collaborate during the LS cycle, by bringing their prior subject knowledge as well as work in a particular context.

In this study it would be a classroom environment where they will diagnose the difficulties learners experience in a specific mathematics concepts or topic. SLT suggests that LS enables teachers to strengthen a professional community, and build the norms and tools needed for instructional improvement, as situated theories of learning proposes (Lewis, Perry & Hurd, 2009). From the view of interpretivism, the situated learning will allow to gain a deeper understanding of the phenomenon and its complexity because it stresses the importance of collaboration between the participants and the context of the current study which is the classroom.

2.5.2 Diagnostic competences

Fischer et al. (2014) stated that the diagnostic process, which also constitutes diagnostic competences, consists of eight steps namely: *problem identification, questioning, generating a hypothesis, constructing artifacts or activities, generating evidence, evaluating evidence, drawing conclusions, and communicating the results*. In the current study I used the diagnostic competences as a diagnostic process. Although study focused on the diagnostic analysis/assessment stage of the LS cycle, all the stages of the LS cycle were used to confirm or refute the perceived learners' misconceptions. In other words, I depart from the premise that there is a risk of misdiagnosing learners if the diagnostic process is limited to the analysis of written learner responses. The outcome of such analysis remains an assumption until somehow tested and verified.

In the current study, I use the LS cycle together with Fischer et al.'s (2014) diagnostic process innovatively to gain a deep understanding of learners' mathematical difficulties or misconceptions (see Figure 2). In the first step of Fisher et al.'s (2014) diagnostic process, *identifying a problem*, the teachers are expected to identify problematic areas learners face within the specified topic. This step will be conducted during the first stage (diagnostic analysis) of the LS cycle. Teachers will gather evidence from learners' examination scripts of what common misconceptions are that need to be addressed.

Questioning is where teachers will ask themselves what the possible causes of the misconceptions are that learners experience. This step will also be conducted during the diagnostic analysis stage as teachers will work collaboratively to determine the focus area of the research lesson. *Generating hypothesis* is where the teachers are expected to generate assumptions on what could be causing the problems (e.g. misconceptions in mathematics) that learners are experiencing.

This step will happen in the diagnostic analysis stage where teachers will discuss based on the learners' results what they think the problem or misconceptions are that learners have. In the fourth step, teachers are required to *construct artefacts/activities* to use in the lesson planning that will help them test their assumptions and confirm or refute their diagnosed problem.

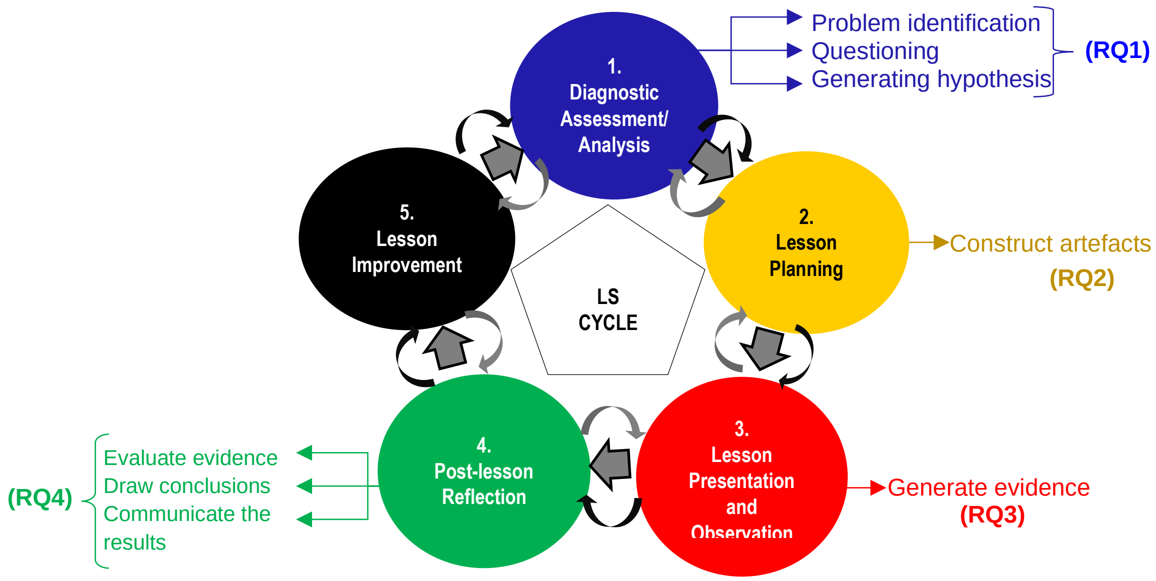


Figure 2: Integrated diagnostic process into the LS cycle

This step will be conducted in stage 2 of the LS cycle i.e. collaborative lesson planning. Teachers are required to work collaboratively to develop lesson objectives as well as purposeful activities that will be used in the research lesson. Step 3 is to *generate evidence*, during this step one teacher will be teaching the collaboratively planned lesson while the others observe the lesson. The teachers who are observing the lesson will be taking notes on the way learners respond to questions, how learners respond to the activities etc. By doing this, they will generate evidence that will either confirm or dispute their hypothesis. Step 4 will take place in the fourth stage of the LS cycle i.e., post-lesson reflection. This is where the teachers will meet after the lesson has been taught and *evaluate the evidence* that was gathered during the lesson presentation and observation stage. The group of teachers will also *draw conclusions* and *communicate the results* of the lesson as well as determine if their objectives were met and to confirm or dispute their hypothesis. Although there are five stages for the LS cycle, one can argue that during post lesson reflection, teachers will communicate ways to improve the lesson for future reference. For the purpose of this study post lesson reflection and lesson improvement happened simultaneously. Although Fischer et al. (2014) seemed to imply that the diagnostic competences are applied linearly, these competences can be applied in a cyclic format, each step can be addressed iteratively where one can always go back to the previous question when required i.e., evaluating evidence, drawing conclusions, and communicating the results

2.6 Conclusion

In this chapter I examined literature that looked at the origin of LS and how it attracted global interest. A detailed explanation of the South African LS cycle was presented. In addition, I examined literature on diagnostic assessment which is the integral construct in my study. The two theoretical lenses, which undergird my study, were also explained in detail, namely SLT and the diagnostic competences proposed by Fischer et al. (2014). Both of these theoretical lenses are appropriate to my study in two unique but complementary manner: SLT undergirds the LS approach, while diagnostic competences provides structure and detail of the diagnostic process. The next chapter provides a detailed description of the methodology used in this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In this chapter I describe the methodological issues utilized to assist in examining mathematics teachers' diagnostic assessment practices in LS. Saunders et al. (2019) proposed a research onion framework that illustrates the different aspects of the research methodology. I used the research onion to guide the structure and flow of my research methodology. For Saunders et al. (2019) the sequence of the aspects covered in the methodology include: research philosophy, research approach, methodological choice, research strategy, time horizon, and data collection and analysis. These aspects are dealt with in the next sections. In addition, I have articulated the issues of trustworthiness (quality measures) as well as ethical considerations.

3.2 Research Philosophy

Interpretivism assumes the view that there is not one but many realities (Maree, 2016). Rehman and Alhatri (2016) concur by stating that there is not one chosen or preferred reality about a phenomenon, but the existence of multiple pieces of knowledge is accepted with the acknowledgment that researchers bring different perspectives to the issue. Interpretivism is a type of ideographic research that examines individual cases or experiences and has the ability to comprehend other people's voices, meanings, and actions. In this perspective, the source of knowledge is the meaning of various events (Rahman, 2017).

My study is situated in the interpretivist paradigm because I wanted to examine mathematics teachers' diagnostic assessment practices in LS. I agreed with Creswell and Poth's (2016) view that the interpretivist perspective enables researchers to gain a deeper understanding of the phenomenon and its complexity in its unique context instead of generalizing the base of understanding to the whole population. The unique context resonates with the theoretical framework. I chose, SLT, which foregrounds the context – the classroom. The main goal of interpretivism is to understand the interpretation of individuals about the social phenomena they interact with (Rashid, Rashid, Warraich, Sabir & Waseem, 2019).

Alharahsheh and Pius (2020) describe two qualities of interpretivism. First, they explained that the research would focus on the whole experience rather than considering certain parts. Therefore, in this study I am focusing on how mathematics teachers use the LS cycle to identify learners' misconceptions. Second, interpretivism enables the researcher to explore a further depth of individual experiences through informal discussions and interviews. I collected data through unstructured interviews which helped to understand in-depth the experiences of the teachers related to the title of the study and the research questions throughout the LS cycle.

Ontology can be defined as the 'nature of reality' (Alharahsheh & Pius, 2020). Saunders et al. (2012) asserted that relativist ontology means you believe that the issues under consideration have various realities, each of which can be explored and given significant meaning. This research showed the diagnostic assessment practices of mathematics teachers in LS. From the ontological perspective of interpretivism, when researchers conduct qualitative research, they are embracing the idea of multiple realities (Creswell & Poth, 2016). I used multiple data collection methods such as observations and unstructured interviews to cater for the multiple realities that are emphasised in interpretive research (Creswell & Poth, 2016).

From the epistemological perspective, interpretivism involved the researcher immersing herself or himself in the natural setting of where the study is taking place, which in this case is a classroom environment where teachers are collaborating on the research lesson (Alharahsheh & Pius, 2020). This is in line with my theoretical framework which shows collaboration as the core focus of the SLT as well as one of the main elements of the LS.

One of the characteristics of interpretivism is that the researcher tends to be subjective and therefore tends to be bias. To mitigate against possible bias, I used the unstructured interviews to clarify and corroborate any information that was gathered. In fact, the findings could not be generalised, instead they were only meant to gain in-depth knowledge and understanding of the phenomena under investigation – teachers' diagnostic practices. I chose this paradigm as I conducted the study in its natural setting of a classroom which gave me the ability to gather in-depth data about my researched topic. In order to understand the phenomenon of diagnostic assessment/analysis, focused on teachers' views, experiences and interpretations within their natural setting, i.e., implementing the LS approach in their school environment as part of their practice.

3.3 Research Approach

I have primarily chosen an inductive research approach as it involved the search for patterns from observations and the development of explanations for those patterns (Bernard, 2011) as teachers grappled with the diagnostic analysis of learner responses. In line with the interpretivist paradigm, interpretivists place more emphasis on an inductive rather than a deductive method because they believe theory emerges from data collection rather than being the driving force behind data (Rehman & Alharthi, 2016).

One of the main aims of inductive research is to gather and interpret rich and in-depth data about the studied phenomenon which is what I wanted to achieve in answering my four secondary research questions. However, since I will have knowledge about how diagnostic analysis ought to be conducted within the LS context and being informed by Fischer et al.'s (2014) diagnostic process, deductive approach played a secondary role. Inductive and deductive approaches can be employed together for a more complete understanding of the topic that the research is studying (DeCarlo, 2015), in this case diagnostic analysis.

3.4 Methodological Choice

Qualitative, quantitative and mixed methods are the three common methodological choices in research (Creswell, 2013; Saunders et al., 2019). In line with the interpretivist paradigm, I used a qualitative approach in my research by using a case study design in which participants were studied in their natural setting.

According to Denzin and Lincoln (2011), qualitative research is a set of complex interpretive practices, it is an interdisciplinary field that incorporates a larger range of epistemological viewpoints, research methods and interpretative tools for comprehending human experiences. In line with the interpretivist paradigm, qualitative research allows researchers to gather in-depth contextual information to observe human interactions, thoughts and reasoning holistically in a social context (Daniel, 2016).

Nassaji (2020, p. 430) suggested that even though qualitative research is "naturalistic and interpretive, it is also systematic and involves a careful process of identifying a problem, collecting, analysing, explaining, evaluating and interpreting data. According to Creswell (2013) the qualitative approach is used when there is little or no knowledge about a particular phenomenon or concept. There is relatively little empirical knowledge on mathematics teachers' diagnostic assessment practices in SA. Interestingly, more than two decades ago Lubisi (2000) lamented a dearth of research focused on assessment practices in schools in SA. This, therefore, justifies the adoption of the qualitative approach as it brings new insight into the LS cycle, more specifically the diagnostic assessment stage. Rather than explaining and manipulating variables, qualitative research seeks to understand and explore them by getting a better understanding of human behaviour and experiences (Nassaji, 2020). In addition, through a qualitative research approach I was interested in exploring the meanings teachers assign to their own experiences in relation to diagnostic analysis of learners' responses.

Qualitative researchers feel that the action of the participants can better be understood when it is observed in the setting it occurs in, which resonates with the character of SLT, LS, as well as the epistemological perspective of interpretivist tradition. Through observations, I immersed myself in the classroom environment so as to better understand the teachers' experiences when engaging in the diagnostic process within the LS cycle. Qualitative approaches are employed to achieve deeper insights (probe) into the researched topic (Rahman, 2017; Queiros, Faria & Almeida, 2017). Probing gave me the opportunity to explore the depth, richness and complexity inherent in the teachers' experiences of their diagnostic assessment practices in LS. Their experiences were explained verbally rather than numerically as espoused by a qualitative research approach.

In qualitative research studies, the researcher becomes part of the research because he or she interacted with the participants through the collection of the data. As a result, the researchers preconceived bias or assumptions may influence the data collection. This is one of the main critiques for making use of qualitative research (Tufford & Newman, 2010). To mitigate this concern, Tufford and Newman (2010) suggested that the researcher makes use of bracketing to ensure that his or her biases do not interfere with the research. As described by Chan, Fung and Chien (2013, p. 1) “bracketing is a methodological device of phenomenological inquiry that requires deliberate putting aside of one’s own beliefs about the phenomenon under investigation or what one already knows about the subject prior to and throughout the phenomenological investigation”.

Bracketing is a qualitative research approach for reducing the negative impacts of assumptions that may taint the research process (Tufford & Newman, 2010). One way in which I used bracketing was by keeping notes during the data collection and analysis stages to examine and reflect on the engagement with the data. Tufford and Newman (2010) suggested that the researcher keeps a reflexive journal from the beginning of the data collection stage to the end. Before I started collecting data, in my journal, I indicated reasons for conducting this study and any assumptions I had on the research were explained.

A case study design was utilized in this study to examine how mathematics teachers use the LS cycle to identify learners’ misconceptions in mathematics. A case study is a research strategy that hones into a specific phenomenon to gather in-depth data on the researched topic within a specific context (Rashid et al., 2019). Yin (2009) stated that a case study can be used to explain, describe, or explore events in every context they occur. Case studies, according to Yin (2003), are useful when a researcher wants to answer the "how" or "why" questions, when he or she has minimal influence over events, and when the focus is on current phenomena in a real-world setting. These assertions are in line with the prescripts of both the interpretivist philosophy and the qualitative research approach as discussed earlier.

Instead of relying solely on teachers self-reporting, this study was viewed through an in-depth examination of the entire LS cycle, which included direct classroom observations to study the teachers' diagnostic assessment practices in their natural setting. Again, the thread that links SLT, interpretivist paradigm, qualitative approach and case study design is quite evident. The case study design afforded a unique opportunity to explore and gain a deep understanding of how mathematics teachers conduct diagnostic assessment/analysis to identify learners problematic areas in mathematics concepts (research question 1), how teachers construct artefacts to test their assumptions about learners problematic areas (research question 2), how teachers generate evidence when testing their assumptions about learners problematic areas (research question 3) and how teachers evaluate evidence generated from testing their assumptions (research question 4).

Creswell (2013, p. 97) further defined a case study as a “bounded system” which is contained in a setting, which may include a specified time period, events or processes. This study is bounded within a single setting, which was an independent school in Gauteng where an in-school LS was implemented.

The study was bounded by a time frame as well which was during the third term in the year 2022. This study was not only bounded within a single setting and within a time frame, but the study was also bounded by events, namely the LS PD model. Furthermore, Creswell (2013) emphasized the significance of obtaining numerous sources of data throughout the course of a case study investigation.

Triangulation was used in this study by collecting data from two different sources: unstructured interviews and observations which were audio-visually recorded. Triangulation not only improved the research study's trustworthiness, but it also revealed numerous viewpoints on the PD model, allowing to better comprehend the participants' experiences. Case studies are usually criticized on the grounds that their results and findings cannot be generalized (Gomm, Hammersley & Forster, 2017; Yin, 2012). This was not seen as a limitation for this study as the purpose was not to get a generalization of the findings of the researched topic, but to gather in-depth information on the diagnostic assessment practices of mathematics teachers.

3.5 Sampling

I used two non-probability sampling methods to draw a sample that constituted the case, namely purposeful sampling and convenient sampling methods. Purposeful sampling is defined by selecting a specific group of people to gain detailed knowledge about the specific phenomenon and not to generalize (McCombes, 2021). The sample in this study is a small group of five primary school mathematics teachers whose school constitutes the LS project. Convenience sampling technique is used to recruit participants who are easily accessible to the researcher in terms of their geographical location and willingness to participate in the study (Eitkan, 2016). In line with this view, I selected the school where currently I am employed at which allowed for easy data collection.

Table 2: Inclusion and exclusion criteria for study

	Inclusion Criteria	Exclusion Criteria
Schools	- Gauteng school - Practicing LS internally.	- Schools that aren't practicing LS. - Schools in other provinces.
Teachers	- Primary and high school mathematics teachers who are familiar with LS.	- Teachers who are not familiar with LS. - Teachers of other subjects.

The authentic context advocated by the LS implied that the normal day-to-day running of the school should not be tempered with. Given this view, I selected the school and teachers to participate in my study (see Table 2); however, the teachers selected the grade and the topic and concept deemed problematic in line with the prescripts of LS. Again, in line with the prescripts of LS, the teacher who taught the lesson volunteered to do so by virtue of the grade they have chosen. The lesson was taught as it appears in the timetable and the teacher who taught the lesson was the teacher who normally teaches that class during that period.

The main disadvantage of purposeful sampling is that the results cannot be generalised (Etikan, Abubakar & Alkassim, 2016). This, however, is not considered a disadvantage for my study as I was doing an in-depth analysis of a specific case and the results would be applicable to that case and not the entire population. Researcher bias is also a major disadvantage in both convenience and purposeful sampling (Etikan et al., 2016). To mitigate this, I provided the teachers with my field notes to see if I had collected the correct information and not made my own interpretations of what they said. I also used unstructured interviews to confirm certain unclear findings that I did not understand.

3.6 Time Horizon

A cross-sectional time frame, which Saunders et al. (2019) referred to as a "snapshot" was selected for this study as it enabled me to look at data from a sample at one specific point (Cherry, 2019). A qualitative cross-sectional study is observational and descriptive in nature (Cherry, 2019), therefore it is in line with the attributes of a case study design adopted. Cross-sectional studies examine a specific issue at a single point where the environment of the participants remain the same (Wang & Cheng, 2020) and researcher can record the data as is which agreed with the attributes of the SLT and LS.

In contrast to its counterpart, longitudinal studies are conducted over a long period of time, the data is observed for the same group of participants, however, their environment can change (Wang & Cheng, 2020). Cross-sectional time frames allow the researcher to analyse multiple variables or characteristics at once (Wang & Cheng, 2020) which in the case of my study was teachers' diagnostic competences, the way they plan and teach a lesson and how they reflect on their teaching practice.

Many findings can be used to create an in-depth research study (Wang & Cheng, 2020) which was in line with the prescripts of an interpretivist case study research design. Again, a disadvantage of not being able to make generalisations of the results is evident for cross-sectional studies (Wang & Cheng, 2020) however, I did not see this as a disadvantage as the aim was not to make generalisations rather to do an in-depth analysis.

3.7 Data Collection

In the interpretivist paradigm and the case study research design, it is necessary to have multiple perspectives of the phenomenon and to triangulate the data. One way of acquiring multiple perspectives and triangulating data is to use different data collection methods (Creswell, 2014). Creswell (2014) suggested that there are several methods of data collection that can be used in a qualitative study such as interviews, observations, artefacts and various documents.

I used multiple data collection techniques in line with the prescripts of an interpretivist paradigm and qualitative studies. I used observations and unstructured interviews simultaneously which will be discussed in detail in the next paragraphs. However, the link between the data collection instruments and the research questions is shown in Table 3.

Table 3: Overview of the study

<table>
<tr><th rowspan="2">RESEARCH QUESTIONS</th><th rowspan="2">LESSON STUDY STAGE</th><th colspan="2">FRAMEWORK</th><th rowspan="2">DATA COLLECTION STRATEGY</th></tr>
<tr><th>Fischer et al.'s (2014) diagnostic steps</th><th>Situated Learning Theory</th></tr>
<tr><td>How do teachers conduct diagnostic analysis to identify learners' problematic areas in specific mathematics concepts?</td><td>Diagnostic assessment/ analysis</td><td>• Problem Identification
• Questioning
• Generate hypotheses</td><td rowspan="4">Teacher collaboration in the school and classroom context</td><td>• Observation
• Unstructured Interviews</td></tr>
<tr><td>How do teachers construct artefacts to test their assumptions about learners' problematic areas in mathematics concepts?</td><td>Collaborative lesson planning</td><td>Construct artefacts/ activities</td><td>• Observation
• Unstructured interviews</td></tr>
<tr><td>How do teachers generate evidence when testing their assumptions about learners' problematic areas in mathematics concepts?</td><td>Lesson presentation & observation</td><td>Generate evidence</td><td>Observation</td></tr>
<tr><td>How do teachers evaluate evidence generated from testing their assumptions?</td><td>Post-lesson reflection</td><td>• Evaluate evidence
• Draw conclusions
• Communicate the results</td><td>• Observation
• Unstructured Interviews</td></tr>
</table>

3.7.1 Observations

The main aim of observations in research is to develop a holistic understanding of the phenomenon (Musante & DeWalt, 2010) which in the context of my study was mathematics teachers' diagnostic practices in the context of LS. Observations is a means of collecting data where the researcher has to immerse themselves in the natural setting of the participants while taking notes and/or recordings, in this case it was a classroom environment (Wegner, Kawulich & Garner, 2012). In my study, I used the 'observer as a participant' method to collect data. According to Wagner et al. (2012) an observer as a participant is a researcher who participates in a social setting under study but is an observer only, not a group member. The teachers were aware of presence in the classroom; however, did not interact or engage with the teachers in anyway during the process where they were meant to be observed. I engaged with the teachers through conversational interviews when required. By physically being there, I was able to gather data that helped to better understand the experiences teachers had. How they conducted diagnostic analysis to identify the learners' problematic areas in the specific mathematical concept (research question 1), as well as how teachers constructed artefacts to test their assumptions about learners' problematic areas in mathematics concepts (research question 2). I also observed how teachers generated evidence when testing their assumptions of learners' problematic areas in mathematics (research question 3). Last, I observed how teachers evaluate evidence generated from tested assumptions (research question 4).

Although my study focused on observing teachers' diagnostic processes, learners' mathematical thinking, which is one of the key focus areas of LS, was also of interest to me. However, since thinking is a cognitive process that may not be observable, I observed learners' (oral and written) responses to gain insights into their thinking. Vignettes (snapshots) of learners' written responses and teachers' instructional activities were used to illustrate what I observed.

During observations I took (field) notes on everything that was relevant to my study as per the observation protocol (Annexure B). An observation protocol helps researchers to focus on the information they need to observe (Wegner et al., 2012). Filed notes are used to assist the researcher to observe the participants behaviour, non-verbal communication as well as the conversations they have together (Wegner et al., 2012). During observations, I recorded all the information observed using an audio-visual recorder. Audio-visual recordings can be effective for research that is conducted in one room since the recording device can be set up in one position, specifically focusing on the interactions the researcher wishes to observe (Asan & Montague, 2014). In this case, the data was collected in the setting of a classroom where all the teachers who sat around the table were seen and could be heard. I used this method to gather correct and accurate data on the participants feelings, views, experiences and non-verbal actions.

I chose audio-visual recording as a data collection method as it accurately records events in their natural setting, it allowed me to verify the data I collected via my field notes which gave me insight into the consistency between what I observed and what I could have missed (Asan & Montague, 2014). Observations which were audio-visually recorded provided me with enough data to answer my research questions which were explained above. Before the data could be collected, the participants (teachers) were given consent forms to sign. They were informed about the audio-visual recordings.

3.7.2 Unstructured interview

Interviews are common data collection techniques that researchers use to gain access to people's experiences as well as their inner thoughts, attitudes and feelings about a certain phenomenon (Wildemuth, 2017). Wildemuth (2017) adds that there are three main types of interviews used in research: structured interviews, semi-structured interviews and unstructured interviews. I chose the latter for my study. Saks and Allsop (2007) define unstructured interviews as in-depth, open-ended conversations. Unstructured interviews can also be defined as a type of interview where the questions nor answers are not pre-determined (Wildemuth, 2017).

Corbin and Morse (2003) have suggested that one of the advantages of unstructured interviews is its flexibility. They further explain how the flexibility aspect of unstructured interviews allows the researcher to follow the lead of the interviewees into how they construct meaning and identify different themes which results in gaining insight into in-depth information about phenomenon investigations. My main intention for using unstructured interviews was to be exposed to unanticipated themes which helped me develop a better understanding of the interviewees' social reality from their perspective (Wildemuth, 2017).

Researchers who use unstructured interviews believe that they must make sense of the participants world in their natural setting. The only way to get accurate and in-depth information is for the researcher to approach it through the participants own perspectives, which goes hand in hand with the interpretivist paradigm (Wildemuth, 2017). In my study I used unstructured interviews from stage 1 to stage 4 of the LS cycle. I also audio-visually recorded these interviews (except for stage 3, as there were minors in the class) so I could go back to them when clarification was needed on what was said and observed. Through unstructured interviews, I could clarify and corroborate on certain aspects that were picked up while teachers conducted diagnostic analysis, planned and taught the lesson during the reflection stage as well as during observations.

During unstructured interviews, I conducted what some scholars might refer to as conversational interviews (Mockcovak, 2016; Adhabi & Anozie, 2017) which is defined as an interviewing method that encourages open conversations. While conducting unstructured interviews, researchers become a part of what they are studying. Doing so enables them to observe and informally ask the participants questions while observing and taking notes (Adhabi & Anozie, 2017). These types of interviews are known to assist the researcher to dig deeper into exploiting a particular phenomenon and gaining clarity (Mockcovak, 2016; Adhabi & Anozie, 2017). Therefore, the conversational interviews were integrated into all stages of the LS cycle where applicable to assist me gain clarity when one of the teachers mentioned something that was not understood.

I gained clarity by asking questions immediately after a statement was uttered by a teacher to gain more information. By conducting unstructured conversational interviews, I was able to gather in-depth data about my research questions. The only place unstructured interviews did not happen was during lesson presentation and observations as it is against what LS stands for, to interject in the lesson while the teacher is teaching.

3.8 Data Analysis

In research, data is collected in order to answer the research questions of the study. Graue (2015) explains that data has to be analysed and interpreted in order to derive meaning from it. Data analysis is the breaking down of complex research material into its fundamental and simplified state (Jena, 2012). Flick (2014, p. 5) refers to qualitative data analysis as “the classification and interpretation of linguistic (or visual) material to make statements about implicit and explicit dimensions and structures of meaning in the material and what is represented in it.” According to Graue (2015, p. 12), qualitative data analysis is “a process of the description, classification and interconnection of phenomena with the researchers’ concepts”.

According to Graue (2015) data collection, data reduction, data displays and conclusion drawing, or verification are the four key aspects in data analysis. Since the unstructured interviews were included in the audio-visual recordings, I listened to the recordings without writing anything down, then I listened to it again and started transcribing. Once the data was transcribed, I familiarised myself with the data (Graue, 2015) by reading and re-reading the transcripts while also checking to see if anything significant had not been missed collected from both the field notes and the transcribed notes. All these helped me make sense of the data. I then proceeded to organize the transcribed data and the data from my field notes according to Fischer et al.'s (2014) diagnostic competences as they constituted the themes for my analysis and the attributes for my research questions as depicted in Figure 2.

3.9 Quality Criteria

Qualitative researchers seek trustworthiness in their studies. Trustworthiness simply poses the question, can the findings or the results be trusted? (Korstjens & Moser, 2018). To answer the question and achieve trustworthiness in a qualitative study, the researcher has to ensure creditability, confirmability, transferability and dependability (Korstjens & Moser, 2018).

3.9.1 Credibility

Creditability established whether the research findings present plausible information drawn from the participants original data and is a correct interpretation of the participants original views (Korstjens & Moser, 2018). I invested time with the participants (prolonged interaction) and became familiar with their setting and environment which helped to build trust and in turn gather rich in-depth data. I constantly observed and noted down the characteristics and elements which were most important and relevant for my study, as this helped me focus on the information that needed to be gathered.

Triangulation refers to using more than one data collection approach when doing research in order to gather rich data and to help confirm the results of the study (Wilson, 2014). Triangulation helps the researcher to reduce bias as it double checks the results obtained from the research (Anney, 2014). I used observations and unstructured interviews to gather data from different viewpoints. Member checks was the last method used to ensure trustworthiness in my study. By creating member checks, the participants had the opportunity to read over the data collected through my field notes, unstructured interviews and transcripts from the recordings. This gave the participants the opportunity to correct any wrong interpretations made (Anney, 2014).

3.9.2 Confirmability

Confirmability is another method used to ensure trustworthiness in a qualitative study. Confirmability is concerned with demonstrating that the researchers' findings and interpretation was derived from the data collected and not his or her personal inputs. It also requires the researcher to clearly demonstrate how they got to their conclusions (Nowell, Norris, White & Moules, 2017). To ensure confirmability, the data collected was checked by the participants. This ensured that the data was correct and accurate and not based on my own particular viewpoints (Korstjens & Moser, 2018).

3.9.3 Transferability

Transferability refers to the degree in which results can be transferred to another context (Anney, 2014) of a similar nature as the current study, e.g., similar sample, phenomenon. To ensure transferability I produced thick descriptions of the entire process from the research site, data collection processes as well as how the data was analysed. Thick descriptions in the context of research was first coined by Gilbert Ryle in 1949 (Ponterotto, 2006). Ponterotto (2006) asserts that thick description is more than collecting data on what a person is doing, instead, it presents context, emotion and establishes significance of experiences. Thick descriptions, in contrast to thin descriptions, builds a clear picture of individuals in the context of the setting by letting their voices, feelings and actions of meanings be heard. This characteristic of thick descriptions agrees with the prescripts of SLT and LS which analyses individuals in the context of their setting in order to gain accurate results. By doing this, findings can be replicated to other studies similar to mine (Anney, 2014).

3.9.4 Dependability

To achieve dependability in a study, researchers are required to ensure that their process is logical, traceable and clearly documented (Nowell et al., 2017). The strategy needed to ensure dependability in a study is an 'audit trail' (Korstjens & Moser, 2018). An audit trail is a complete set of notes on decisions made during the research process, research team meetings, reflective thoughts, sampling and the findings that the researcher has made and kept throughout the entire study (Korstjens & Moser, 2018). Keeping the raw data, filed notes and the transcripts helped me cross reference the data and create a clearer audit trial (Nowell et al., 2017). I also ensured dependability by triangulation where two data collection methods were used throughout the study to corroborate the findings.

3.10 Ethical Considerations

Ethical considerations are put in place to protect participants in the research study (Arifin, 2018). Research cannot be undertaken unless ethics has been taken into consideration. During the study, I adhered to the following ethical considerations as mentioned below

Permission was obtained from the Ethics Committee at the University of Pretoria and the principal of the school as well as the participants of the study i.e. primary school mathematics teachers. The learners were minors so permission to use their scripts was obtained from the principal of the independent school who is authorised to do so on behalf of the parents. While obtaining consent from the various parties, I informed them about the purpose of the study, and clearly explained their roles as participants as well as my role as the researcher. After successfully defending my research proposal, an application to conduct research was submitted and approved. My ethics proposal was approved in October 2021 which meant that data could only be collected in 2022. Before collecting the data, I explained the entire process to the participants and the informed consent letters were given out. Participants had the opportunity to ask any questions on uncertainties they had at the time.

Voluntary: After introducing myself and explaining the purpose, aims and benefits of the study, I informed the participants that their participation in the study was completely voluntary and that they were free not to participate or to opt out anytime with no consequences. One of the participants opted to withdraw after being involved in the collaborative lesson planning stage, all her contributions were not considered during the presentation and discussion of the findings.

Anonymity: The participants and the school were informed that they would remain anonymous throughout the study and that no information revealing their identities will be shared. Fictitious names were given to the participates and all the research data was kept confidential.

Privacy: Participants were informed that all the data recorded would remain private and only myself and my supervisor would have access to the audio-video recordings. This ensured that all participants remained anonymous and protected their identity. The data remained the property of the University of Pretoria and was handed over for safe keeping.

No harm or risk to participants: The participants were assured that there was no risk associated with the study, therefore physical or mental discomfort to the participants was not anticipated.

Confidence: I ensured that there was trust between the participants and myself by creating an environment they felt comfortable in. In fact, collegial support in the form of teachers observing each other's lessons is an institutionalised practice in the school, therefore it was not expected that teachers and learners would feel uncomfortable during the lesson observation. However, I constantly assured the participants that everything was kept confidential.

3.11 Conclusion

In this interpretivist qualitative case study, which was guided by the research onion, I outlined applicable methodological issues that included philosophical perspectives, research approaches, methodological choices, sampling, time horizon, data collections, and data analysis. Where applicable, I presented their merits supported by literature that justified their relevance for my study, and the limitations. I further articulated the issues pertaining to trustworthiness in qualitative studies which include credibility, confirmability, transferability and dependability. In each case I explained how they were applied in my study. I concluded the chapter by outlining the ethical considerations that were adhered to throughout the study.

CHAPTER 4: PRESENTATION OF RESEARCH FINDINGS

4.1 Introduction

In this section I present the findings of the analysed data collected from observations, and unstructured interviews. This chapter presents the findings of the research focusing on the demographics of the school and what emerged from each stage of the LS cycle, i.e. stage 1 to 5. I used Fischer's et al.'s (2014) diagnostic competences that emerged under each stage of the LS cycle as the themes to organise the presentation of the findings. The presentation of the findings will be displayed according to Figure 2.

4.2 Demographics of the School

The school where the study was conducted is an independent school in Gauteng province in SA. The school accommodates learners from the Early Learning School (ELS) (from three months to six years old) to Grade 12 (eighteen years old). As this is a fairly new school, the total number of learners is approximately five hundred. The whole school is on one campus however the ELS, primary school and college (high school) are in their own buildings. When the LS program was introduced to the staff, all mathematics teachers from Grade 4 to Grade 12 were interested in participating. As this was a new and unheard-of approach to all the teachers, a workshop was arranged prior to the actual implementation of the LS cycle.

As the day for the workshop drew closer, one of the mathematics teachers who taught Grade 8 to 10 had to excuse himself due to personal matters that he had to attend to. The workshop was on what LS is and its impact on teaching and learning of mathematics was explained to the teachers as well as how it can be implemented in a school. The various LS cycles implemented in different countries were presented but most of the time was spent on the South African version on the LS in detail. Before the study ensued, another teacher opted not to participate in the study and only six teachers continued to participate. One of the teachers who took part in the workshop and in the collaborative lesson planning decided to withdraw their consent before the lesson was taught. As per the ethical procedures, none of the contributions made by this teacher were used in the data collection nor the findings. Therefore, the total number of teachers who participated from beginning to end were five primary school mathematics teachers. The study ensued at an opportune time when the learners had just written the mid-year examinations which were marked by their relevant teachers and while marking, Grades 5, 6 and 7 the teachers picked up that the question on fractions was poorly answered across the grades. Therefore, a partial diagnostic analysis of learner responses was conducted by the teachers on the mid-year examination papers. All teachers' names mentioned below are fictitious.

4.3 Findings of data collected during diagnostic assessment/ analysis (Stage 1) of the LS cycle

4.3.1 Problem identification

The Grade 6 learners mid-year examination scripts were split equally amongst the teachers and all teachers turned to question 4 which was related to fractions. Alice in particular took up the "leader" role and gave everyone instructions on what to do. Her instruction to the teachers was to look at how learners answered the question and try to find common errors or mistakes that the learners have made in this question. Upon going through a few papers' Emily noted that one question in particular was the worst answered in the sense that learners were all getting it wrong and very few had gotten full marks for this question.

The question read: *Calculate* $\frac{2}{5}\ of\ 45$

Some of the learners' responses regarding this question are presented in Figure 5. Since the responses belong to different learners, I labelled them A and B for ease of reference.

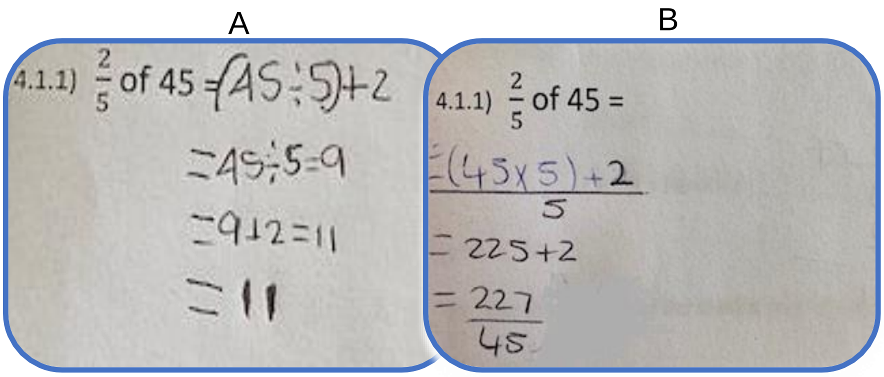


Figure 3: Learners' response to question

All the teachers tried to figure out what the possible issues were with this question.

4.3.2 Questioning

In an attempt to gain insights into the learners' responses to the aforementioned question regarding fractions, teachers engaged in conversations which were dominated by some key questions such as:

Emily: *"Did we teach this concept enough?"*

Alice answered by explaining that: "you could explain a concept millions of times but if you don't find out what exactly is confusing them or what they do not understand about the question, you won't be getting through to them."

Alice: "*What examples did you use in your class to explain questions such as these?"*

Betty answered this question by saying, "I think, looking back, I actually did not pay attention to the examples given as I used the textbook as my main source of reference, so I can't remember the exact examples."

Thandi: "*Were learners just taught a method on how to solve fractions or was there an in-depth explanation given to them?"*

Alice looked at the way learners responded and noticed that most of their answers were written in the form of a fraction, more specifically a mixed fraction or an improper fraction.

After raising this to the rest of the teachers Emily commented by saying, *"I've picked it up many times in class as well when I teach that my Grade 6's think that all questions that include fractions should have a fraction as the answer and not a whole number."*

Based on further analysis the teachers picked up two misconceptions that have been recurring amongst the group of Grade 6 learners. Referring to the learners' responses in Figure 5B, this learner had mistaken this question as a mixed fraction and did the method of multiplying the 45 by 5 and adding 2 then putting it all over the denominator of 5 and that would be their answers. While Figure 5A shows the correct first step, however instead of multiplying the numerator by the 9, the learner added it. Thandi commented that the learners did not look at the whole number 45 as a fraction $\frac{45}{1}$ because if they did, they would know they could multiply across.

4.3.3 Hypothesis for possible sources of the problem

The findings presented in this section come from the assumptions that teachers had as possible sources of the errors or misconceptions revealed from the learners' responses. At this point, I referred to them as assumptions because they were based on teachers' subjective analyses of learners' responses.

Alice explained how she picked up during teaching that learners struggled with identifying a fraction as a whole. Thandi added to this by describing how she teaches this concept in the class: "I always tell my kids that the denominator means how many parts of a whole there is therefore $\frac{45}{1}$ means that there is 1 part of 45 but in class the learners ask why it is not $\frac{45}{45}$ since that also gives 1?"

Emily added that the learners were taught the method of converting mixed numbers into improper fractions in the class, but they haven't perfected it, so they applied the concept but they do not remember why they are doing the steps.

Stemming from Alice's and Emily's statements which seem to suggest that they somewhat contributed to incorrect learner responses, I probed further by asking this question: "During your teaching, what do you think you as a teacher contributed to not making learners understand these types of questions?"

Thandi responded: "Based on the workshop, I think the examples we use in class to teach these methods is what confuses them, for example convert $5\,\frac{3}{5}$ to an improper fraction. The steps would be to multiply 5 by 5 and add 3 then put it over the denominator of 5 but because there is two 5's learners might not know which one we are referring to if they do not understand what a denominator or numerator is."

Emily raised the importance of allowing learners to do practical investigations so that they themselves can figure out how to get to the answer. In that way they will understand it better than just using arrows or saying, "*this divided by those times this which is just a method, and they don't understand why we are doing it."*

A misconception picked up by the teachers was that learners do not understand that simplifying a fraction can result in a whole number. Every time learners see fractions, they think that their answer has to be in a fraction format even if they worked it out correctly as a whole, they would still put the whole number over the denominator.

Alice explained how she once used an example in class saying, "I've got 15 cakes, how much is $\frac{3}{5}$ of this cake? The learners got the answer of 9 but some still put it over the denominator of 5 because they think that all questions related to a fraction should have a fraction as the answer."

In an attempt to consolidate teachers' assumptions about the possible causes of learners' errors or misconceptions regarding fractions, I asked the following question: "What are your hypotheses for learners' errors?"

The teachers discussed this question and came up with the following assumptions:

1) Learners confuse questions such as calculate $\frac{1}{4}\ of\ 20$ with a mixed fraction.
2) Learners do not understand the mathematical method taught to them but have some knowledge on something that needs to divide and something that needs to add. Hence, they apply it but incorrectly.
3) Learners placed in group one will always leave their answer as a fraction as they do not understand that it can work out to a whole number.
4) Learners will find the solutions easier if they have physical objects to use to assist them such as the blocks.

Thabo added that these assumptions mainly cater for learners in groups one and two which as previously stated are for the weaker learners getting below a 50 percent average and not the other groups. The teachers agreed that the focus of the lesson would be to try get the weaker learners to the level they are meant to be on while trying to extend or enrich the stronger learners.

4.3.4 Possible solutions

The teachers started to discuss possible solutions on how to approach fixing this issue. Suggestions from Thabo, such as teaching percentages before fractions, would be beneficial since learners would have approached the question as 70 percent of 90 which basically means the same as $\frac{7}{10}$ of 90. Thandi suggested teaching decimals before fractions, so the learners actually get that $\frac{1}{2}$ is the same as 0.5.

Emily said something interesting by suggesting: *“What happens if we teach fractions from the beginning of long division because long division is actually wrong, you don’t get a remainder, yet in Grade 4 that’s what we say to the learners.’’*

Alice added that she picked up the same problem with Grade 7’s when they divide $\frac{5}{6}$ and they change it to decimal, they write the remainder of 3. *“I tell them you cannot get remainders because there is no such thing as a remainder.”*

Alice said:

> *The problem is that year in and year out we tell our kids to forget what they studied the previous year, and we teach them something new based on that concept which is what confuses them. We keep trying to undo what was previously taught instead of teaching it correctly from the beginning.*

Thandi said:

> *That’s why we should teach decimals first because we teach Grade 7’s to add zeros to their ‘remainders’ and keep diving, and that way their answer will be something point something then we introduce fractions by showing that they are the same thing.*

Emily said:

> *But how do we teach that to Grade 4’s since fractions start there and build on from Grades 4 to 6? We should start at long division. Instead of teaching them that it’s a remainder we should teach them that it’s a fraction, then from long division we go onto the process of fractions and that way they will conceptualize it.*

Alice said:

> *Our problem is we are teaching learning methods and not explaining why we do certain things. For example, we teach them in Grade 5 to convert $\frac{5}{10}$ to a decimal its 0.5 then $\frac{12}{10}$ is 0.12. Then we move on to the next, Grade 6 where we get $\frac{1}{2}$ and we tell them in order to change it to a decimal, it has to be over 10,100 or 1,000 or else you can't do it. Then they learn to multiply the denominator and the numerator to get it over a denominator of 10, 100 or 1,000. But the issue comes is now you get to Grade 7, and you get $\frac{5}{6}$ now they cannot do that method anymore. So, we actually need to show them how to change it to a decimal from when we work with a half and not say we cannot change it of its not over 10, 100 or 1000. There should be one method taught from Grade 4 throughout. Learners show no understanding of the actual concept rather they are trying to remember all these different methods.*

4.4 Findings of Data Collected During Collaborative Lesson Planning (Stage 2) of the LS Cycle

Once the teachers had identified their issues and moved on to the next stage of the LS cycle, they started by again posing questions to themselves and others first on how to approach teaching this lesson. Alice said*, "now that we know what the problem is, how do we rectify that in a lesson."*

The teachers decided to teach a lesson using physical objects, drawings and what they called "abstracts" which was basically a formula given to the learners (Figure 10). The teachers spoke about how revising all three concepts will force the learners to go back to basics using all three methods.

Sarah posed an important question on what happens with the learners who have already mastered these types of questions since they might get bored using cubes and drawings to answer simple questions. The teachers grappled with the idea of how to accommodate all the learners in the classroom since there were a few who got the question correct and understand clearly how to answer those type of questions. The teachers came up with the solution of working in what they referred to as stations where the learners will be divided into groups based on their abilities according to the diagnostic analysis results. The teachers decided to have five stations that would have activities in which the level of difficulty would increase from station 1 to station 5; however, each group of learners would only get through to 3 stations. Their reasoning behind this was to start the weaker learners off at station 1 with basic fractions and start the stronger group off at station 3 with more difficult fractions-related questions.

I posed the question to the teachers on how this whole lesson will be managed regarding the time for each station. Thandi responded by saying each group will have 15 minutes per station and every member of the group will have two questions to demonstrate to the rest of the group to show their understanding of it whether through a drawing or with a physical object or through calculations.

My question to the teachers was: “Why are you not mixing learners of different abilities in one group?” Emily responded by saying the reason for the split in groups from weakest to strongest was so the stronger learners do not take over and just freely give answers to the weaker learners and for the stronger learners to go up to station 5 where there will be a problem-solving activity that will require them to extend their knowledge, in that way they also benefit from the lesson. The teachers further went on to discuss what the objective of the lesson would be and what the activities would be. The activities are discussed per station below.

4.4.1 Creating artefacts/activities

For the introduction of the lesson, teachers brainstormed ideas on how they could introduce this lesson to the learners and what activities they would use. Thandi suggested cutting apples in quarters or bringing pizzas and cutting them equally. An interesting suggestion came from Alice to give learners a piece of paper and ask them to divide it into $\frac{1}{8}$ by folding it. Emily disagreed by explaining where the issue comes in with the examples we use in class because she interpreted that instruction as a fraction of a whole because if you divide that piece of paper into 8, it will be 16 pieces and the learners will see it as a piece and not a fraction as a whole. Which was exactly the problem we saw with the question of calculate $\frac{2}{5}\ of\ 45$. It’s like saying you have 45 apples as the whole number not 45 pieces of apples.

This brought the teachers to discussing where they would select activities from. Resources such as a variety of textbooks, previous examination papers and worksheets were selected as their bases for creating activities. The teachers discussed what would take place at each station. There are 26 learners in the class, they will be split into groups of five based on their abilities. Each station will test the teacher's assumptions based on their assumptions listed earlier. Station 1 is the easiest where learners were given a question that they could solve using a physical resource which in this case was Lego blocks, in station 2 they were required to use a drawing to help them answer the questions, in station 3 an abstract (which was basically a formula given by the teacher), in station 4 basic application of word problems, and in station 5 were complex word problems. The goal for this according to the teachers was for the weaker learners to only get up to station 3, that way they would have covered the basics for this topic which is to be able to use the formula given to do calculations with fractions and for the stronger learners to start at station 3 and work to station 5 so they can be challenged and not feel bored or left out of the lesson that way it accommodates both.

Thandi then asked what happens to the other three groups when group 1 starts at station 1 and group 5 starts at station 3, what would the rest of the learners be doing. The teachers discussed possible solutions and decided to make double the material per station in that way they could hand out station 1 material to both groups one and two and station 2 material would be handed out to group three, with station 3 material handed out to groups four and five. Group one and two were required to get from station 1 to station 3 while group three was required to go from station 2 to station 4 and groups four and five were meant to start at station 3 and end at station 5.

My question to the teachers: "How will the learners be assessed to see if your hypothesis was correct?" The teachers suggested that each learner has an individual answer sheet and two work cards per station. A work card will have two questions based on the station the learners are on, an example of a work card is seen in Figure 7.

Alice suggested how difficult it would be to mark this as it will take so much time considering that each learner is getting different questions. Once the teachers were happy with the lesson plan, they divided the work per station amongst themselves, so each teacher was responsible to create questions based on each station. The lesson was planned on Saturday and was taught the following week Thursday as the teachers required time to complete the topic they were dealing with currently in class and also, they needed time to prepare these activities.

4.5 Findings of Data Collected During Lesson Presentation and Observation (Stage 3) of the LS cycle

The lesson was presented after second break (13:00 p.m.) on a Thursday afternoon to a Grade 6 class of 26 learners. There are four Grade 6 classes in this school, this class was selected to do the research lesson because they performed the poorest in the mid-year examination and the other three classes have grasped the concept of fractions with Thandi saying they generally had an average of 70 percent and above every term. The teachers discussed possible reasons for the big difference in marks and concluded that this class has most of the new learners who come from different schools, and that they could be a contributing issue since they do not know how the learners were taught at those schools. To Justify this, Emily who is the mathematics teacher to this class explained how the learners who have been in the school since Grade 4 are the ones found to be getting marks of above 60 percent generally whereas the new learners tend to show tremendous gaps in their knowledge. She picked this up during teaching, when learners are given homework questions or when they write tests or assessments.

Before the learners entered, the teacher stood at the door and allocated them into groups. The groups were predetermined according to the learners' results from the mid-year examination. Group one had learners who scored between 20 to 30 percent, group two had learners who scored between 40 to 50 percent. Group three had learners who scored between 60 to 70 percent, group four learners scored between 70 to 80 percent while group five had learners who scored above 80 percent. Groups one to four had five learners per group while group five had six learners. As the learners walked in, they were excited to see all the materials at their allocated stations.

To start the lesson, Emily introduced myself and Thandi to the students and greeted the learners. Emily posed a question to the learners. At the front of the class, she had six apples, the question asked was: "*What type of number (whole or fraction) will you* *get if I ask you to calculate* $\frac{2}{3}\, of 6$*. So if I say to you, you are going to get* $\frac{2}{3}\ of\ these\ 6\ apples$*. What would your answer be?"*

Learners from groups four and five said a whole number while learners in groups one to two said a fraction. Learners in group three did not answer the question fast enough before Emily continued. Emily went on to explain the concept of calculations with fractions by saying to the learners that they are going to look at fractions again, *"we are going to start at the most basic questions and work our way up to the harder and more challenging questions."* Emily explained to the learners that: "*the denominator tells us what happens to the whole number and the numerator tells us how many of these groups we will have*." She drew a diagram (see Figure 4) on the board which was used to illustrate and explain this concept.

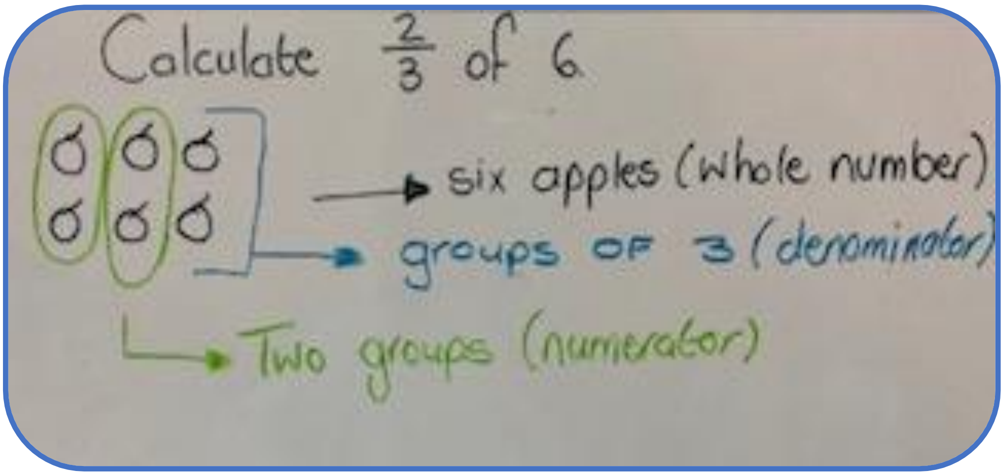


Figure 4: Teacher's explanation on the board

Emily explained how the six apples were divided into three groups and the numerator told us how many we will have totalling to four apples.

One learner in group five asked, *"Why can't we just use the method of dividing the whole number by the denominator and multiplying it by the numerator to get the answer".* Emily responded by saying, *"Yes, you can because that is another way we will look at when calculating fractions."* Emily gave the learners instructions on what will happen at each station. Station 1 had questions where the learners used the blocks given to help them answer the questions. Figure 5 shows an example of the question used in station 1 and the blocks each leaner was given.

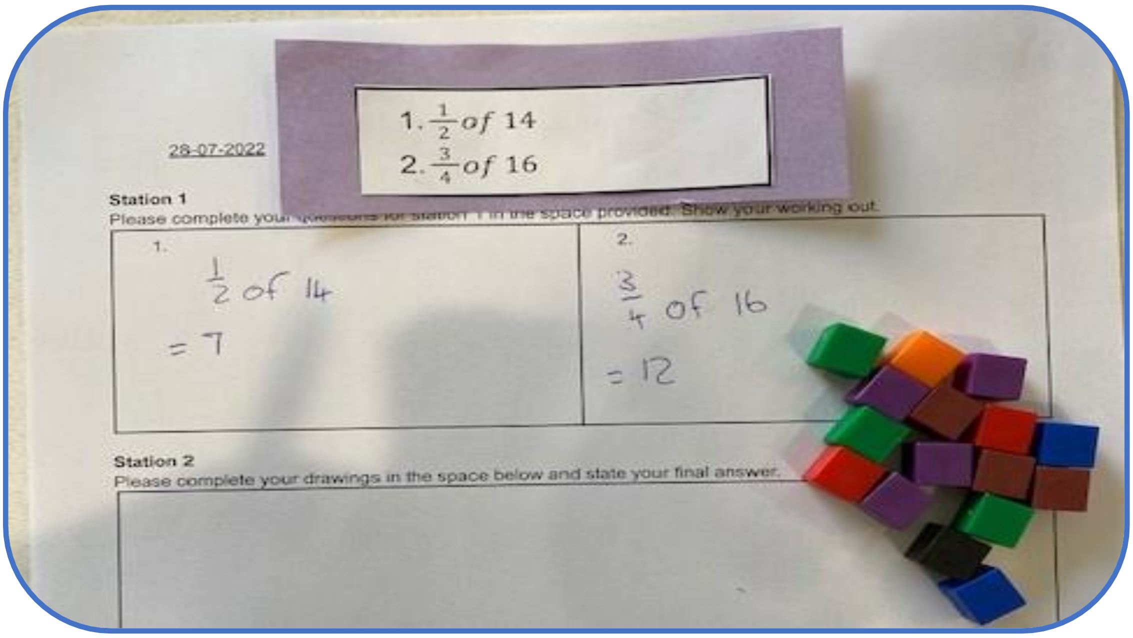


Figure 5: Station 1 example of a work card and the learners answer sheet

Station 1 was the physical station, where a learner took 14 blocks as the whole number and divided it into two groups as per the denominator and counted how many blocks were in one group as per the numerator and did the same with the second question.

Station 2 was the abstract station where learners had to draw a diagram that will assist them in answering the question. In Figure 6, there is a picture of learner A's work for station 2.

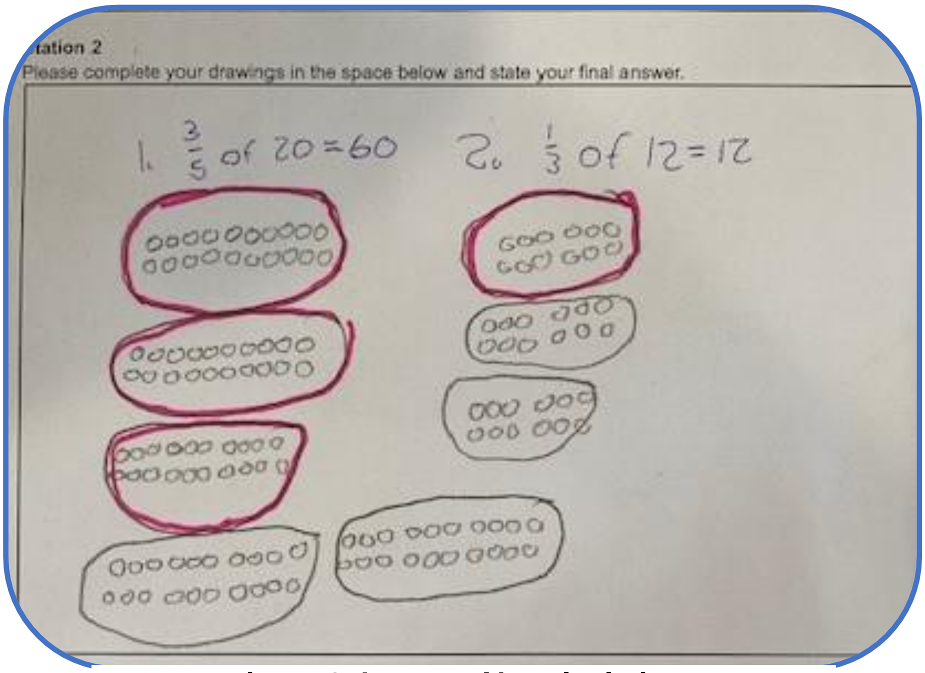


Figure 6: Learner A's calculations

When Emily asked the learner to explain how he got to the answer, the learner confidently said he made five groups of 20 and circled three which added up to 60. The same happened with question 2 where he was expected to calculate $\frac{1}{3}\ of\ 12$. The learner explained to Emily that he drew three groups of 12 and circled one group as per the numerator and that was how he got 12 as his answer.

The learners in group one struggled at station 2 with this activity. There was a question for the learners to calculate $\frac{4}{10}\ of\ 10$. This question confused two of the learners in group one because of the whole number and denominator being the same. The two learners struggled to put it into groups and instead worked out the answer to be 40 as seen in Figure 7.

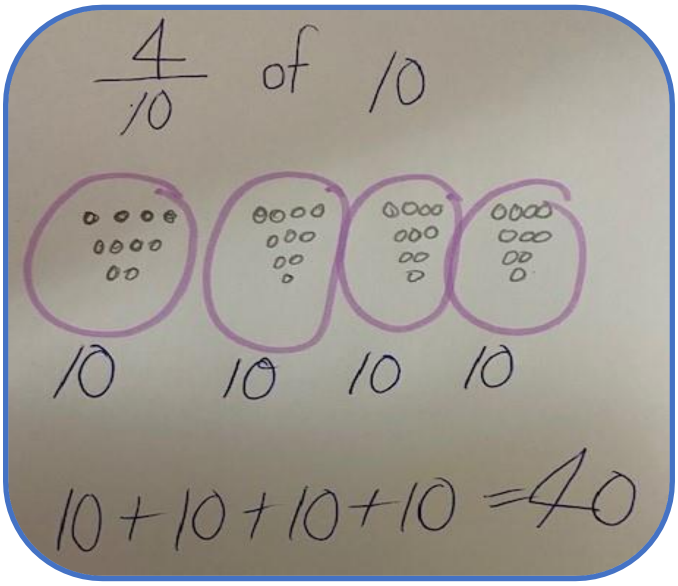


Figure 7: Learner B's calculations

Figure 7 showed learner B's calculations. When Emily asked her to explain how she got to that answer the learner said she drew four groups of apples with 10 apples in each group giving her 40 apples. Station 3 was a station where learners were meant to use the mathematical concept shown to them to assist them in answering the question. Figure 8 showed the example that was given to the learners before they started the activity for station 3 as well as the type of questions learners were expected to answer within this group.

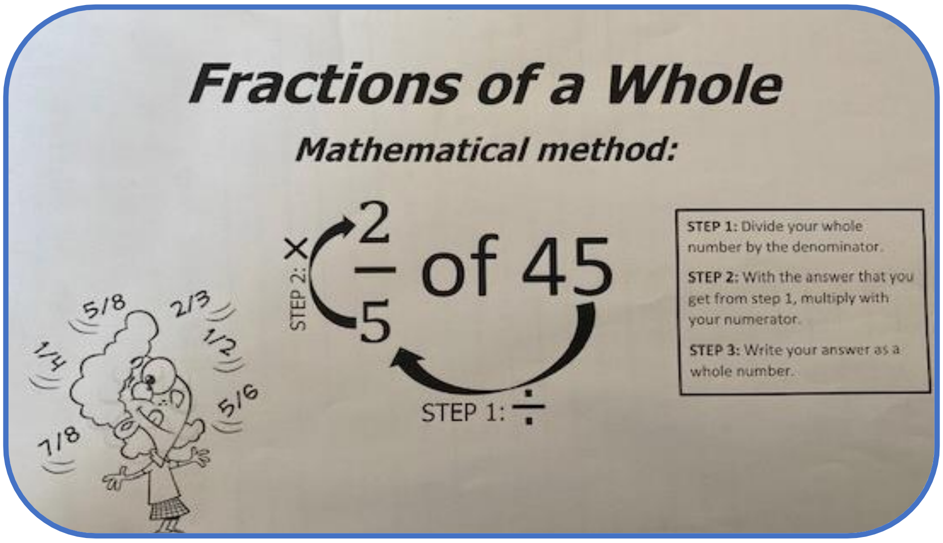


Figure 8: Method given to learners at station 3

This was the method that learners were expected to use to answer questions in Figure 9.

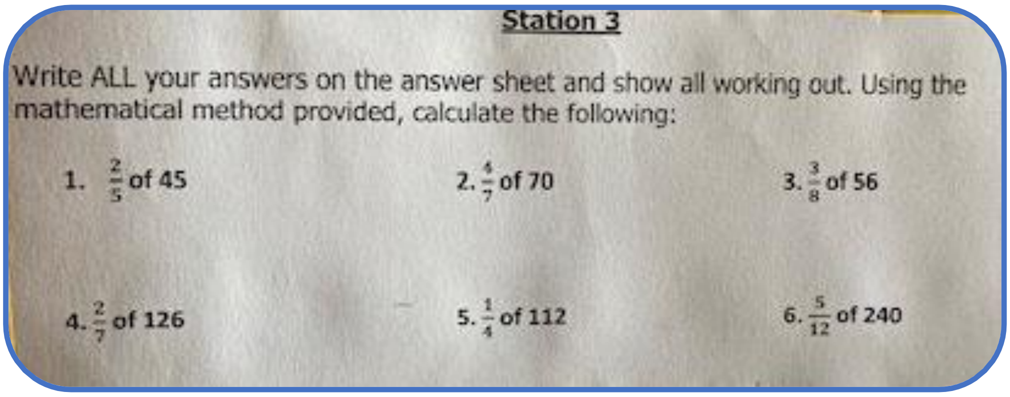


Figure 9: Typical questions from station 3

The questions in Figure 10 consisted much bigger numbers making it harder for learners to draw, for example $\frac{1}{4}$ of 112 it will take the learners long to first draw 112 'apples' then continue with the calculation. Emily explained how they should use the method of: "*divide your whole number by your denominator and multiply your answer by the numerator*." Emily placed emphasis on the fact that the answer to fraction related questions does not always mean that the answer cannot be a whole number, in this case she informed learners that their answers would be whole numbers. The learners approached this question better now with the method in front of them, many used long division to assist them in answering these questions. Minor calculation errors were picked at this station compared to the way they answered it in the mid-year examinations.

Station 4 was where learners from group five came to after completing station 3. This was the application station where learners had to apply their knowledge on fractions to basic word problems such as the ones in Figure 10.

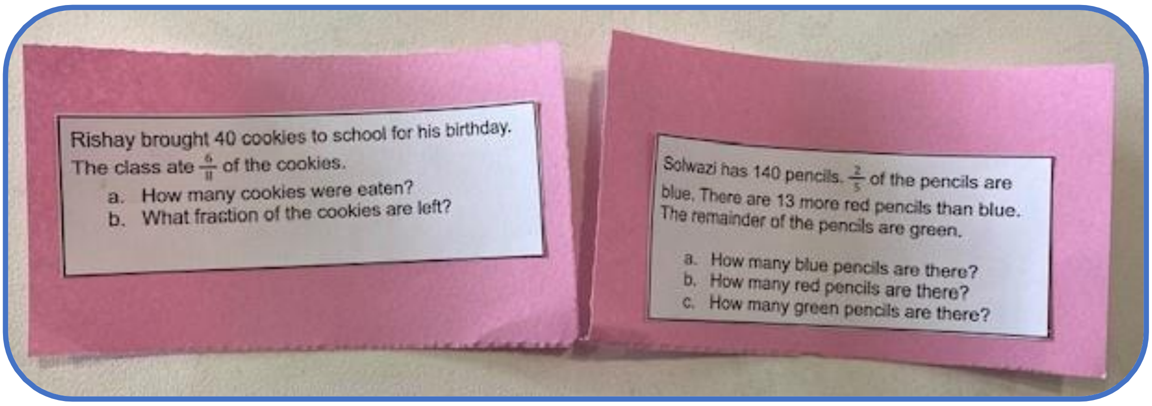
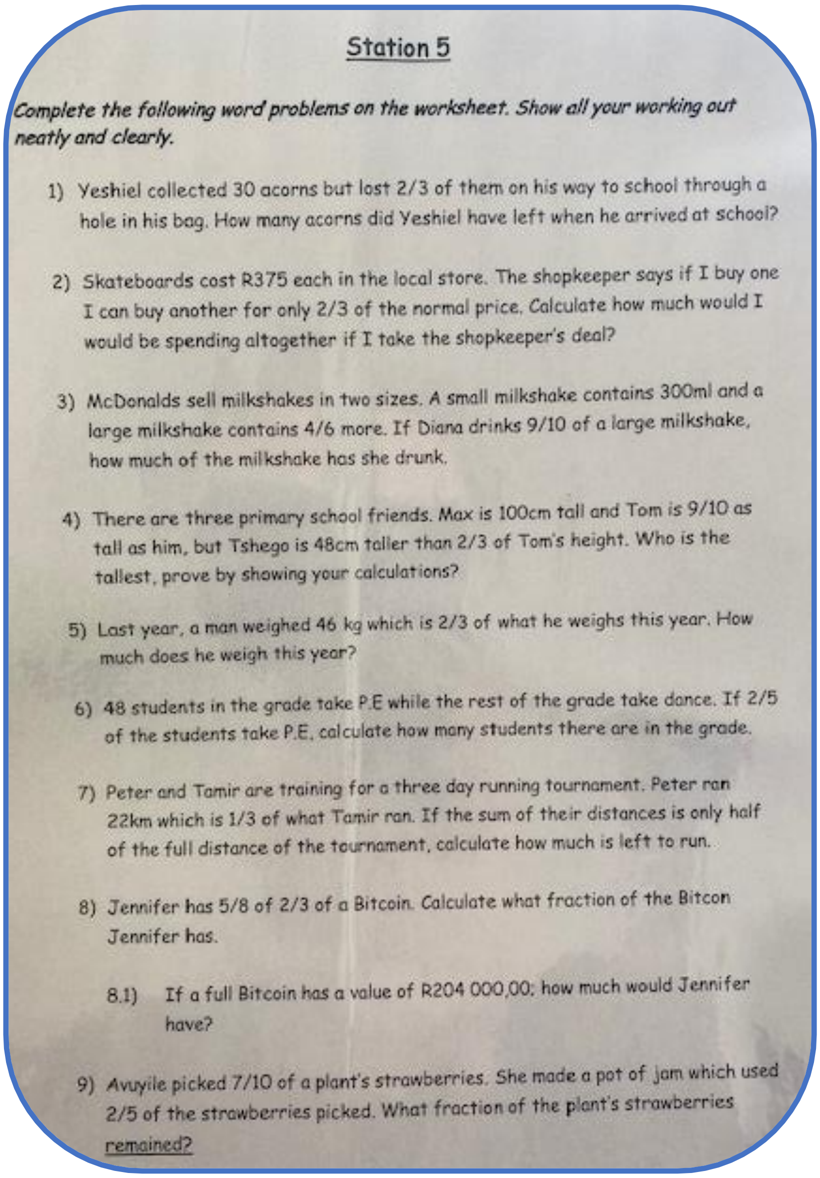


Figure 10: Questions from station 4

The learners in groups four and five managed to get through these questions without hesitation. Once the learners in group five got to station 4, they were competing who would answer their questions the fastest, however, once they got to station 5, they realized it would be better if they tackled each question together as a group. The learners collaborated well, and each of them contributed by giving reasons and explanations for each statement or solution that they suggested. The type of questions given to the learners at station 5 are presented in Figure 11.


Station 5

Complete the following word problems on the worksheet. Show all your working out neatly and clearly.

1) Yeshiel collected 30 acorns but lost 2/3 of them on his way to school through a hole in his bag. How many acorns did Yeshiel have left when he arrived at school?

2) Skateboards cost R375 each in the local store. The shopkeeper says if I buy one I can buy another for only 2/3 of the normal price. Calculate how much would I would be spending altogether if I take the shopkeeper's deal?

3) McDonalds sell milkshakes in two sizes. A small milkshake contains 300ml and a large milkshake contains 4/6 more. If Diana drinks 9/10 of a large milkshake, how much of the milkshake has she drunk.

4) There are three primary school friends. Max is 100cm tall and Tom is 9/10 as tall as him, but Tshego is 48cm taller than 2/3 of Tom's height. Who is the tallest, prove by showing your calculations?

5) Last year, a man weighed 46 kg which is 2/3 of what he weighs this year. How much does he weigh this year?

6) 48 students in the grade take P.E while the rest of the grade take dance. If 2/5 of the students take P.E. calculate how many students there are in the grade.

7) Peter and Tamir are training for a three day running tournament. Peter ran 22km which is 1/3 of what Tamir ran. If the sum of their distances is only half of the full distance of the tournament, calculate how much is left to run.

8) Jennifer has 5/8 of 2/3 of a Bitcoin. Calculate what fraction of the Bitcon Jennifer has.

8.1) If a full Bitcoin has a value of R204 000,00; how much would Jennifer have?

9) Avuyile picked 7/10 of a plant's strawberries. She made a pot of jam which used 2/5 of the strawberries picked. What fraction of the plant's strawberries remained?

Figure 11: Questions from station 5

The group had just started with station 5 and the lesson had come to an end. During the lesson, Emily walked around checking the learners work as they had completed each question and she would re-explain what they were meant to do if the learner did not understand the question. Emily made sure to ask a lot of “why” questions as well as asking learners to explain how they got to an answer. If a learner got something wrong, Emily reverted to using the Lego blocks to explain it again or she used pictures that she drew to explain it. The learners’ worksheets were collected at the end of the lesson which were meant to be marked by Emily and feedback will be given to learners.

4.6 Findings of Data Collected During Post-lesson Reflection and Lesson Improvement (Stages 4 & 5) of the LS Cycle

Post lesson reflection was meant to happen on the same day as the research lesson was presented however there were certain issues (not related to LS) within the school that needed to be dealt with meaning the teachers who participated in the research lesson were not be able to attend. The post lesson reflection happened on Monday morning before school officially started where four out of the five teachers who had originally planned the lesson came together to reflect on how it went, the challenges experienced and the overall experiences and recommendations. The teacher who did not attend (Thabo) was ill and was booked off for the day.

The reflection process was a little challenging to the teachers that were not able to attend as observers due to them having to teach at the same time. There was, therefore, essentially only two teachers (Emily and Thandi) who had an opportunity to observe and then to reflect on the lesson. However, the other two teachers Alice and Betty were able to present their views, however minimal, on the other stages of the LS cycle since post-lesson reflection included a reflection on the other stages too.

4.6.1 What succeeded and went well

Emily started the reflection process by explaining how she felt that the collaborative lesson planning went well as all the teachers experienced different challenges within their classrooms so getting an input from everyone to come up with one lesson was “amazing” to her. Emily also liked the fact that this process is not to blame for one another’s teaching styles or what happens in their classrooms but rather to come and change the misconceptions as they are picked up. Emily also added that it would be great to do a cycle on the topics teachers struggle to teach as this could be a contributing factor as to why learners do not understand a topic well and that could be from teachers not teaching it well enough because they themselves do not understand it well enough.

Betty liked the fact that LS has created a platform where it was okay for teachers to come together and ask for help when they required it, she also stated it was nice to know that the teachers she thought would know everything also had difficulties teaching some topics making it easier for her to ask for help. Alice explained how sad she was for not being able to observe the lesson; however, she had already started implementing the things learnt from the workshop in her teaching.

Alice said, "*The most important thing I have picked up from this process is that one, we as teachers need to start working together and two, on a more personal note I have come to realize the importance of selecting more purposeful activities and examples for my learners*."

Thandi agreed with the collaboration being the most helpful because she explained that as teachers, "*we start to form a routine and year in, and year out teach the same concepts in the same way and use the same methods, this way it will help us as teachers get out of our bubbles and work together to make mathematics more fun and understandable to the learners*." Thandi explained how she felt the teaching was more learner centred and fun making learners wanting to work and progress to the next station. Thandi also explained how she felt the lesson accommodated all the learners' abilities in the class which worked well.

Emily noted how interesting it was to actually look at the way learners are thinking instead of taking in the paper and just marking it for the sake of getting marks for the report. Emily said, *"This process taught me how important it is to conduct diagnostic assessments because now that I have physically seen how learners interpret and answer questions, I know it's probably the same mistakes others will make therefore I can pre-empt it and look for other ways to teach it, so my classes next year don't make the same mistakes."*

Betty added to that by saying she struggles to identify what exactly is the learners' issues or misconceptions so she would not know how to create a diagnostic assessment, but she has already started implementing diagnostic analysis as she marks their scripts.

4.6.2 What did not go according to plan

The first thing that did not go according to plan according to Emily was sticking to the time frame of 15 minutes per station. Emily explained how this did not take the weaker learners into consideration because group one and group two learners did not complete all the questions at station 1 yet they were moved to station 2 at the end of the 15 minutes. Thandi added that she observed the learners in group one and group two who could do the questions easier with the help of the blocks, but they struggled a lot when it came to using a drawing to help them answer the question. Group one and two were meant to reach station 3 by the end of the lesson but they only ended at station 2 due to the time it took them to complete the activities in each station. Station 3 where the example of how to answer the question that was given to them (Figure 9), the learners simply copied the method for each question, they always referred to the steps.

Emily noted that this could have been tested differently as she felt that it was too easy since the method was given to them and all they had to do was copy the method. Thandi observed that the learners in group one and two were not working together as a group as per the instructions. The learners were given different questions so they had to explain to their group members how they would get to their answer. Thandi noted that it could be because they are scared to give the wrong answers in case the rest of the group judges them or because they were not sitting with their friends, so the group members were almost like ‘strangers’ to them.

Alice raised the concern that although LS has all these benefits, she feels it is time consuming and as a small school its limiting in the sense that the teachers involved cannot leave their classes unattended to observe the research lesson as there is not enough teachers to watch the learners in the other classes while they observe. Alice went on to explain how it also took long to design the activities and to ensure all learners are catered for.

4.7 Recommendations

Emily suggested that at station 3 where the method was given to learners should have been a self-discovery station instead. At the time Emily couldn't think of a better way to ask it without giving the learners the method. She suggested giving them the question and not limiting them to any method but questioned how they will successfully teach the method since that was the goal of the lesson.

Alice agreed and explained that according to the CAPS, they do not necessarily test the method in which learners get to their answers but rather test that the way in which a learner got there in a mathematically correct way. She suggested that they should have given learners the question and not limit them to a specific method on how to answer it, that way they will use a method they are most comfortable with.

Thandi raised the question on what would happen if the whole number was 120, because if that's the case it will take learners long to draw 120 apples or to take out 120 blocks. This also might be time consuming especially during a test or an examination hence this is why they need to learn the method.

Betty questioned how then would we teach the learners this method without teaching only for the method but to teach for understanding? The teachers did not have an answer for this question. Emily noted that the questions that have the same denominator and whole number should rather be tested in station 3 or 4 since it confused the learners from group one and two as they did not know how to draw diagrams to assist them answering that question (Figure 7).

Questions like these required some level of knowledge regarding the roles of denominators, numerators and whole numbers and because of this it should be a higher-level question. My question to the teachers was how they decided which questions should be tested in each station. Thandi responded by saying they separated the workload and gave each teacher a station to do but she took questions based on previous experiences that learners struggled with. My question to Thandi was if she looked at the different cognitive levels or not? Her response was: *"well since it was station 3 that I designed the activities for, all the questions were on the same thinking level, as stations 1 and 2 were on separate levels as well."* Emily created the activities for station 1, she responded by saying she took questions from the textbook and Betty who created the activities for station 2 said she used the mid-year examination questions.

To eliminate the time, it takes to mark this work, Betty recommended that the activities should have been peer assessed since the learners were meant to be explaining to their friends how they got to their answers. However, Thandi said that would not work as some of the learners cannot confirm whether it is right or not as they themselves struggled with some of the questions.

The teachers continued to speak about possibilities of another cycle within the school, however they would prefer all the mathematics teachers from the ELS to be involved so the correct method can be taught from the beginning and in that way teachers won't have to say forget what you learnt last year or try to re-invent the wheel. The feedback session ended with me thanking them for taking part in my study and suggested to them that this should be a practice that continues within the school.

4.8 Conclusion

Based on the data that was collected, the emerging findings indicate that LS afforded teachers an opportunity to collaboratively identify learners' difficulties in mathematics – a critical skill in diagnostic process. Through LS, teachers were able to conduct diagnostic analysis by identifying a problem, brainstorming possible reasons from the problem through questioning and by generating hypothesis (assumptions) regarding the possible causes of misconceptions that learners have in specific mathematics topics or concepts.

Although deviating from the prescripts of LS by working cooperatively instead of collaboratively, teachers created artefacts to test their assumptions. Generally, the findings from lesson presentation indicated that the teachers' instruction leans more towards instrumental understanding rather than relational understanding and through post-lesson reflections, the teachers discussed different ways to improve the research lesson.

CHAPTER 5: DISCUSSION OF FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

The purpose of my study was to examine mathematics teachers' diagnostic assessment practices when implementing LS. This chapter aimed to respond to the four secondary research questions through a detailed discussion of the findings. Each section will be presented according to the conceptual framework developed from Fischer et al.'s (2014) diagnostic competences that emerged within each research question as per Figure 3. I concluded each subsection by answering the applicable research question. The chapter ends with recommendations, limitations and a conclusion.

5.2 Synopsis of the Research Study

The problem that was identified and that initiated my study was that despite diagnostic assessment being a requirement for mathematics teachers' practice, it is not fully applied in the teaching and learning process. In instances where teachers identify learners' errors and misconceptions through diagnostic assessment/analysis, they do so hypothetically and do not test their hypotheses to either confirm or refute them, thereby risking applying inappropriate interventions. This could mean that teachers plan and conduct lessons based on the assumption that all learners have met the pre-requisites of a topic. The SLT in which LS cycle is entrenched along with Fischer et al.'s (2014) diagnostic competences were used as a framework to assist in exploring teachers' diagnostic practices in the context of LS. Although SLT undergirds the LS as a teacher development model, Fischer et al.'s (2014) diagnostic competences provided a diagnostic process thereby guiding the conceptualisation of the research questions.

This qualitative research followed a case study research design (Chapter 3) which was considered appropriate because a case study design is well known to enable a researcher to gain concrete, contextual and in-depth knowledge about their studied case (Yin, 2009) and the qualitative research approach. In line with the interpretivist paradigm, it allowed me to gather in-depth contextual information by observing the teachers conduct diagnostic analysis, planning and teaching the lesson and reflecting on the lesson taught holistically.

My research aimed to examine mathematics teachers' diagnostic assessment practices in the implementation of LS. I was guided by my primary research question: **How do mathematics teachers use the LS cycle to identify learners' misconceptions in mathematics?**

The secondary research questions that assisted me to answer the primary research question included:

a) How do teachers conduct diagnostic analysis to identify learners' problematic areas in mathematics concepts?
b) How do teachers construct artefacts to test their assumptions about learners' problematic areas in mathematics concepts?
c) How do teachers generate evidence when testing their assumptions about learners' problematic areas in mathematics concepts?
d) How do teachers evaluate evidence generated from testing their assumptions?

To answer the secondary research questions, teachers were purposefully selected based on them being primary school mathematics teachers who were currently teaching mathematics in the selected school and were conveniently selected based on their geographical location which for this study was in the independent school nearer to my workplace.

Data was collected through observations and then unstructured interviews, which happened simultaneously throughout the LS cycle as explained in Chapter 3. I observed teachers conducting diagnostic analysis, collaboratively planning the lesson, presenting the lesson and reflecting on the lesson.

5.3 Discussions

In this section, I discuss the findings and their implications for mathematics teaching and learning. I have organised the discussions according to the sequence of the secondary research questions. In other words, each sub-heading is derived from the relevant secondary research question. Each sub-heading starts with the summary of the relevant findings and is followed by the discussions. After dealing with each sub-heading which focuses on a specific research question, I concluded each section by answering the research question.

5.3.1 Conducting diagnostic analysis to identify learners' problematic areas

As the sub-heading suggests, in this sub-section I discussed the findings related to research question one which states: *How do teachers conduct diagnostic assessment/analysis to identify learners' problematic areas in mathematics concepts?*

Through this research question, I wanted to understand the process teachers followed to identify learners' misconceptions (and types thereof).

In this study, teachers conducted diagnostic analysis on the learner's mid-year examination results. Although they were not aware of Fischer et al.'s (2014) diagnostic process, the discussions during stage one (diagnostic assessment/analysis) of the LS cycle reflected the attributes such as identify a problem, questioning and generating a hypothesis/assumption of what could be the possible causes thereof. Of these competences suggested by Fischer et al. (2014) during stage one of the LS cycle, the teachers firstly tried to *identify* what the *problem* was with the specific question through brainstorming by *questioning* each other's teaching methods and teaching material used during teaching. In other words, they seemed to suggest that their teaching methods could have been the cause of learners' misconceptions. They also critiqued their teaching activities (artefacts) and afterwards *generated hypothesis*/*assumptions* that they would put to the test during the lesson presentation.

What was interesting is, after teachers identified the problem which was calculations including fractions of a whole number through diagnostic analysis of the mid-year examination. They brainstormed ideas as to what the possible reasons could be for the misconceptions learners had by focusing on their teaching methods. This is a rare occurrence because often teachers would exclude themselves as possible contributors to the learners' misconceptions, and instead ascribe the misconceptions solely to the learners themselves. Teachers are known to also create misconceptions when their own subject knowledge is weak or their confidence in the material is low (Jarvis, Mckeon & Taylor, 2005; Mupa & Chinooneka, 2015). By questioning themselves, teachers were obliged to reflect on their practices by analysing the way in which they taught fractions and the artefacts they used in the classroom to teach this concept.

LS, by its design, is about teacher learning through collaboration and PD, therefore when the teachers worked together in a collaboratively manner, they learnt that their teaching methods could have been a possible cause for learners' misconceptions. It is generally very seldom that teachers are able to own up and admit that they could be at fault when learners are underperforming. Teachers never want to blame or see themselves as the reasons for learners' errors or misconceptions, through LS and with teachers working collaboratively, they owned up and admitted that they could be at fault, which is what we need in mathematics teaching and learning.

From the teachers admitting to being a possible cause of the learner's misconception, they knew exactly what needs to change for future teaching which would benefit the learners tremendously as they are aware of what contributions they made to aid in these misconceptions. LS therefore afforded the teachers to learn from and reflect on their own practice.

While trying to further explore the problem identified, an interesting discovery on the way teachers teach was revealed when Alice said she "tells" her learner what to do. Telling learners what to do and how to do it does not promote understanding as learners are just taught methods and no actual reasoning of why certain things are done. By teachers 'telling' learners what to do could be a contributing factor to the misconceptions that learners develop as they are not giving learners the freedom to actually understand the concept, rather the learners tend to memorize the procedures.

Through observations, there were many instances where I picked up that learners knew how to apply a method taught to them but they did so incorrectly. This confirms what some scholars refer to as the Einstellung effect where learners are stuck in their old way of thinking, therefore, they apply incorrect, ill-fitting solutions and methods to a question that seems familiar to previously solved ones (Obispo & Rodrigo, 2017).

By learners applying ill-fitting solutions to familiar questions proves that the teaching of mathematics in this case leaned more towards the emphasizing of methods or algorithms (instrumental understanding) instead of teaching for conceptual and relational understanding (Skemp, 1978). The implications for this is that learners are taught how to apply methods and formulas and are not taught to understand the concept or reasoning as to why certain things are done in a specific way resulting in them memorizing these methods and applying them to all familiar questions. I agreed with Lewis (2016) who asserted that learners who rely only on remembering steps to solve problems have issues when it comes to the more complex problems as they do not understand the mathematical concept. If the learners were taught through understanding of mathematics where relational understanding was taught, they would not be grappling with these problems.

Based on this, could see that from the teaching point of view when teachers communicated the possible assumptions in terms of what they think are causes of learner's errors and misconceptions, it was evident that some of the issues stem from the way learners were taught which was teaching them algorithmic ways (instrumental understanding) of mathematics instead of teaching for understanding (relational understanding). The whole process of diagnostic assessment/analysis seemed like a new process to the teachers and showed that it was not something done regularly as prescribed by CAPS.

Although the NCTM (2015) suggested that diagnostic assessments should be done at the beginning of the year, the participants of this study have explained how they pick up misconceptions throughout their teaching in the form of written or oral responses from learners and while marking formative assessments. However, there is very little evidence on what they do about these misconceptions once they have picked them up, which confirms the study conducted by Kanjee (2009) who found that teachers seldomly use the results of diagnostic assessments/analysis to improve the teaching and learning of mathematics. Through LS, the teachers felt as if it was a safe environment to speak about their challenges in the teaching of mathematics. This was evident during the reflection stage of the LS cycle when Betty added that she did not know how to create diagnostic assessments which could mean she didn't know how to diagnose learners' problematic areas. This is concerning because if teachers are not conducting diagnostic assessments/analysis, it could mean they plan lessons based on the assumption that all learners have met the pre-requisites of a topic. Or one can argue that teachers are not fully aware of the impact identifying and correcting a misconception might have on a learner, or even though CAPS who advocates for these types of assessments to be done. They are not done for the correct reasons which is ultimately to identify learners' misconceptions and use those results to improve teaching.

This adds on to research by Beck and Zlatkin-Trioitschanskaia (2013) who noticed that despite the widespread acceptance and inclusion in the curriculum, teachers frequently lack the ability to accurately assess their learners' performance and ability. By teachers not conducting diagnostic assessments or analysis they stand a risk of not being able to analyse learners' misconceptions or to use this as a base for teaching. Teachers generated hypothesis or assumptions through questioning themselves and the teaching artefacts that were used during the teaching of fractions in class.

To conclude this section, and to directly respond to the first research question: *How do teachers conduct diagnostic assessment/analysis to identify learners' problematic areas in mathematics concepts*, teachers used the mid-year examination paper as a starting point for diagnosis. Although they were unaware of the diagnostic competences by Fischer et al. (2014), view is that they conducted a diagnostic analysis on the learners' responses by identifying the problem, brainstorming possible reasons for the misconceptions in the form of questioning and generating assumptions regarding the possible causes of the learners' errors or misconceptions. In doing so, they did not only attribute the misconceptions to learners, but to their teaching practice as well.

5.3.2 Constructing artefacts to test assumptions about learners' problematic areas

This subsection will be discussing emerging issues from research question two which states: *How do teachers construct artefacts to test their assumptions about learners' problematic areas in mathematics concepts?*
As proposed by Fischer et al. (2014) the artefacts could include the mathematics tasks and activities designed to test the teachers' perceived learners' misconceptions. During collaborative lesson planning espoused in LS, teachers are required to construct artefacts (activities) and develop purposeful questions that will be used to facilitate learning during lesson presentation. While developing questions, teachers

are also meant to pre-empt possible questions that learners might ask and/or anticipate how they may respond to the questions posed by the teacher. Since LS is conceptually and practically characterised by collaboration, the development of the artefacts and questions should be a collaborative effort - created by the group of teachers together during the collaborative lesson planning stage.

Despite the teachers discussing where they will get ideas for activities from i.e.: textbooks, previous examination papers and internet sources, in my study, it was not entirely evident how the teachers' constructed artefacts. During the collaborative lesson planning stage, the teachers divided the activities that would feature at each station, and the tasks were created in their own time, not in the presence of any of the other teachers.

By the teachers dividing the work amongst each other implied a significant deviation from the prescripts of LS, i.e. from collaboration to cooperation. Pantcheva (n.d.) assists us to differentiate between these two constructs by providing two distinct portrayals thereof: cooperation involves working with people by achieving one's own goals as part of a common goal and collaboration involves working together with someone or a group of people in order to achieve a single shared goal. Evidently, collaboration goes against what LS stands for.

The implication for not working collaboratively to discuss these activities was that teachers were not able to assist each other in creating purposeful activities which were meant to foster learners' mathematics thinking and to test learners relational understanding (NCTM, 2014). In fact, there was a gross deviation from conducting *kyouzaikenkyuu* – a collaborative process of thoroughly interrogating the instructional activities before using them during teaching (Melville & Corey, 2022). It is through *kyouzaikenkyuu* that teachers share views on the creation of purposeful activities. The purpose of creating purposeful activities is to assist teachers to draw evidence about learners mathematical understanding after examining their responses (McCarthy et al., 2016).

By teachers creating the activities on their own, this could mean that they may have taken any question from textbooks or previous examination papers that were related to their 'station' without examining if that question would confirm or refute their hypothesis or if it would encourage learners to think critically. My view on this matter stems from observing the teachers plan and present the lesson. During the diagnostic assessment/analysis stage the teachers discussed how their examples used in class could contribute to learners not fully understanding a concept or contribute to learners' misconceptions (Jarvis et al., 2005; Mupa & Chinooneka, 2015). The example of using the same whole number and numerator in a question requiring learners to calculate a fraction of a whole was identified to be an issue during previous teaching instances, yet a similar question was asked at station 2 where the learners were expected to calculate four-tenths of ten. This gives an indication that the teachers might have not looked at the questions that they had selected for each station even after they discussed the importance of selecting purposeful questions to test the learners.

The prescripts of LS are firm about purposeful activities and questions being used to facilitate learning. While the teachers allocated work to each other based on how the activities would be done, there was no evidence of teachers discussing possible purposeful questions that they could use to facilitate learning during lesson presentation. Questioning within a mathematics classroom is a dynamic teacher instructional intervention as it has the ability to engage learners, encourage problem solving and critical thinking (McCarthy et al., 2016).

By teachers not thinking of purposeful questions to ask during the lesson, they stand a risk of not being able to understand learners thinking. If they do not develop their reasoning skills which in turn will not promote a deeper understanding of mathematics. Purposeful questions should feature through all cognitive domains or else learners will think it is restricted (McCarthy et al., 2016). This could mean that teachers who ask questions that require a yes or a no answer, straight recall of facts or formulas are only testing learners on a lower cognitive level, which is likely to deprive them (teachers) an opportunity to gain a deep understanding of learners underlying (mis)conceptions. This type of question was evident in the lesson presentation where the teacher asked the learners a question that required a one-word answer. This was also the only type of a question asked in the lesson. Although lower order questions are important in a mathematics classroom, they should not be the dominant questions asked as they do not promote reasoning, or encourage reflection as prescribed by NCTM (2014).

Teachers are required to come up with questions that encourage learners to think, create viable arguments, challenge their assumptions and encourage provoking thought (Babu & Mim, 2017).

Despite not working collaboratively, the idea of creating ‘stations’ was innovative as the teachers made sure that learners with all types of abilities (weaker and stronger learners) were catered for in the lesson as their respective levels of ability.

To conclude this section and directly respond to the second research question which states: *How do teachers construct artefacts to test their assumptions about learners' problematic areas in mathematics concepts?* The teachers did not develop the artefacts/activities in a collaborative manner as advocated by LS. It is, therefore, not evident how the teachers constructed these artefacts; however, they claimed to have taken questions from previous examination papers, textbooks and the internet to create the activities for each station. In addition, some of the developed artefacts (instructional activities) seemed not to be purposeful, especially against the backdrop that teachers did not engage in *kyouzaikenkyuu*. Given this scenario, confirming or refuting their assumptions about the assumed causes of the learners' misconceptions was bound to be illusive.

5.3.3 Generating evidence when testing assumptions through lesson presentation

In this sub-section, I discussed the findings of third research question which states: *How do teachers generate evidence when testing their assumptions about learners' problematic areas in mathematics concepts?* This question involves generating evidence when teachers test their assumptions through the use of the artefacts (mathematics tasks/activities). Assumptions in the context of this study were possible explanations or reasons for the misconception's learners have. Generating evidence takes place when one teacher teaches the lesson while others observe and document how learners respond to the activities as espoused by stage three of the LS cycle.

During the collaborative lesson planning stage, the teachers came up with assumptions/hypothesis that were based on the problem that was identified. Some of their assumptions/hypotheses regarding fractions included: *learners do not understand the mathematical method taught to them but have some knowledge on* *something that needs to be divided and something that needs to be added,* and *learners confuse calculations where there is a fraction and a whole with a mixed fraction and learners in group one (weaker learners) will leave all their answers in the form of a fraction.*

When I observed the learners answering the questions from station 3, they had six of the exact same mathematical problems with different numbers (Figure 9). In my opinion this activity was not actually testing the teachers' hypothesis/assumptions or the learners' ability to answer questions of that nature. First, they were given the formula or method that they were expected to use (Figure 8). Many of the learners just substituted the values into that formula to get their answers which in most times were correct. By the formula being given to them, the activity was not necessarily testing their understanding of fractions of a whole, rather it was testing their ability to substitute which was not the aim of the lesson. Through this observation I concluded that the activity at station 3 was simply what Finkel (2016) calls rote practice, it was repetitive activity consisting of six of the same questions with different numbers.

This goes against what Finkel (2016) suggests which is that mathematical activities should encourage active thinking and reasoning and not only require learners to memorize formulas or follow procedures through repetition, as this results in little to no thinking or reasoning to learners. In Skemp's (1978) view, this type of activity promotes instrumental understanding as it only relies on learners following a procedure. I concur with Lewis (2020) who explains how this type of 'drill' repetition does not encourage critical thinking in learners. The purpose of creating purposeful activities is to assist teachers to draw evidence about learners mathematical understanding after examining their responses (McCarthy et al., 2016). The activity found in Figure 6 also refuted the teacher's assumption which stated that learners confuse questions including calculating a fraction of a whole number with mixed fractions. Because the learners did not confuse it as a mixed fraction, one could argue that it was due to the teachers giving the learners the formula to use and not letting the learners figure it out on their own.

This shows another example of teachers who teach using instrumental understanding techniques as their main teaching method, leaving no room for learners to reason and create their own meaning to the question. This goes back to teachers enforcing teaching for methods or procedures rather than teaching for understanding.

If the teachers had taken the time to work, interrogate and create the instructional activity together, chances are they would have come up with a better way to test their hypothesis/assumptions in station 3 rather than giving the learners the formula and expecting them to simply substitute the numbers in. During observation, the learners made minor errors at station 3 compared to how they had answered questions of a similar nature in the mid-year examination. One could argue that this was due to prescribing a method and telling learners to apply it as is. This left no room for interpretation or critical thinking for learners. Through this practice, teachers deprive themselves of the opportunity to effectively test their assumptions about what could have been the core problem that resulted in learners' misconceptions. In fact, the evidence generated during teaching was misleading. Prescribing a formula for learners to use may give teachers an impression that learners have grasped the concept, while in fact, the original problem remains.

Another issue that was picked up during observation is the type of questions asked at station 2, such as the one in Figure 7 where the learners were required to calculate $\frac{4}{10}\ of\ 10$. This question was not well thought through as the teachers had discussed during the lesson planning stage of the LS cycle (stage two) how the weaker learners tend to struggle with questions that have the same denominator and whole number yet they asked this question at station 2. Since the learners did not understand the concept of calculating a fraction of a whole number through the teachers teaching of the formula, the teachers picked up that the learners actually did not understand the role of each value, i.e.; denominator or whole number, played in this type of calculations. The weaker learners may not have mastered the understanding of calculating a fraction of a whole number, now when there was two of the same number, i.e.: denominator and the whole number, the learners did not understand how to tackle that question. If the activities were planned together the teachers would have realized that this was one of those questions that are not meant to be asked for the weaker learners as they are still trying to understand the whole idea of calculating a fraction of a whole number. This question (Figure 7) also refuted teachers' assumptions/hypothesis which indicated that learners in group one (weaker learners) will leave their answers as fractions. The learners did not leave their answers in the form of a fraction, instead they did incorrect calculations that resulted in them having a larger number than the given whole number as an answer.

By the learners getting a larger number as an answer shows a lack of conceptual understanding for fractions. Conceptually, a fraction of an object or quantity ought to be smaller than the original object or quantity; therefore, the learners would have realised that obtaining an answer that is greater than the original number for which a fraction was to be calculated, was not plausibility. This also adds on to the research of Obispo and Rodrigo (2017) who asserted that learners tend to perform ill-fitting or incorrect methods to a question that seems familiar to previously solved ones which is known as the *Einstellung effect*. The learners are aware of how to do basic operations of adding, multiplying and dividing. Hence why they were able to divide the 10 into 4 groups and added them together to get 40. This, I suppose, is the influence of dealing with whole numbers. If teachers are only teaching and creating activities that foster instrumental understanding, learners will see mathematics as isolated pieces of knowledge whereas if they teach from a more relational understanding level, learners will make connections between concepts and not treat everything as separate (Obispo & Rodrigo, 2017). However, the Einstellung effect is compounded by teachers instructional activities that do not help learners demystify their misconceptions, thereby rendering the evidence stemming from these activities misleading.

During the collaborative lesson planning stage teachers did not come up with questions that would be used to stimulate critical thinking for the learners during the teaching process to gain in-depth understanding of their assumed misconceptions except the one question asked by Emily in the introduction of the lesson. The question posed to the learners was *“What type of number (fraction/whole) would you get if I asked you to calculate a fraction of a whole number?”* After the learners had responded, Emily did not elaborate or take time to further explain why it is wrong to have a fraction as an answer. In other words, she did not rectify the learner’s misconception immediately. She agreed with the learners in group five who stated it would be a whole number and moved on. The implication for Emily not rectifying the learners’ wrong answer immediately could leave the weaker learners feeling excluded and could result in carrying their misconceptions with them to higher grades as they do not understand why their answer was wrong and why the learners in group five's answer was correct. Emily missed an opportunity to understand the learners reasoning behind their answer which in turn prevented her from rectifying the learners' misconceptions. Identifying misconceptions is important in any mathematics classroom as it assists teachers to adapt their teaching styles and lessons to help mitigate learners' misconceptions. By not identifying the actual misconceptions, teachers stand a risk of not changing their teaching styles or methods to assist in rectifying these misconceptions.

According to the conventions of LS, the teachers are required to come up with questions that they would ask during lesson presentation to probe learners thinking and to discuss the anticipated learners' responses. In my study, the teachers did not attend to this critical aspect, i.e., think of any questions that will be posed to learners during lesson presentation and discussing the anticipated responses.

Questioning is an important tool in teaching mathematics as it assists teachers in measuring academic progress and learners' comprehension of the topic at hand (McCarthy et al., 2016). Questioning is also known to help teachers gather information about how learners are thinking and, in that way, make it easier for them (the teachers) to distinguish what learners' misconceptions are and by determining this, they can start with the process of rectifying them. Teachers could test their assumptions/hypothesis through written forms - in their workbooks or through oral forms - answering questions in class.

To conclude this section and directly respond to my third research question which states: *How do teachers generate evidence when testing their assumptions about learners' problematic areas in mathematics concepts?* Teachers came up with artefacts (activities) that they would use to confirm or refute their hypothesis. They generate evidence by giving the learners an answer sheet to answer the activities on and then they mark the learners' responses and in turn will confirm or refute their assumptions/hypothesis. Although the process of generating evidence is appropriate, the activities the teachers came up with did not help them generate evidence as different misconceptions were evident than the ones they (the teachers) had hypothesized or assumed. This could have been because these activities were not collaboratively planned or may have not been well thought of to test their assumptions

/hypothesis. The teachers also did not come up with questions that would assist them in generating evidence about their perceived assumptions/hypothesis which may have been another reason for them not being able to confirm their assumptions/hypothesis.

5.3.4 Evaluating evidence generated from teaching

In this sub-section I discuss the findings related to my fourth research question which states: *How do teachers evaluate evidence generated from testing their assumptions?* Evaluating evidence takes place during the post-lesson reflection (stage four of the LS cycle). It should be noted that during stage three of the LS cycle, i.e., collaborative lesson presentation and observation, teachers who observe the lesson document their observations and use them when reflecting on the lesson during stage four of the LS cycle (post-lesson reflection). It is, therefore, during post-lesson reflection that teachers ought to confirm or refute their assumptions regarding their supposed misconceptions – which is the core of the current research question.

Critical reflection is a crucial part of TPD as it allows teachers to step back and see what they do from a wider perspective. This allows teachers to think of other ideas and actions to consider enhancing the learning process in their classrooms (Cimer et al., 2013). During post-lesson reflection, teachers are afforded the opportunity to share their observations of how learners received the lesson and to evaluate if their collaboratively planned lesson met the objectives of the lesson (Sekao, 2022). The post-lesson reflection afforded teachers the opportunity to evaluate the assumptions they made based on what the possible misconceptions were in terms of a particular concept which in this case was fractions. Since the post-lesson reflection happened three days after the lesson was presented, the teachers had to recall what had happened in the lesson and the important things that had emerged (Cimer et al., 2013).

During this stage, the teachers did not necessarily directly discuss if the activities that they had created had confirmed or refuted their assumptions/hypothesis, rather they discussed what went well, what did not go well, and what they could improve on for future cycles while referring to the activities. However, I could use their reflection on what went well, what did not go well, and what could be improved, to determine whether they confirmed or refuted their assumed learners' misconceptions. Teachers confirmed their assumption that there were learner misconceptions within the topic of calculating a fraction of a whole number; however, their assumptions/hypothesis were refuted based on how they constructed their activities, which is highly as a result of cooperatively planning the activities and not collaboratively planning them.

During discussion, the teachers noted that the activity at station 3 (Figure 9) was not a good way to test the learner's knowledge on calculating fractions of a whole number as they (the teachers) had given them the formula (Figure 8) that they (the learners) were expected to use when answering the questions. Upon reflecting about the activity, the teachers thought it would have been better not to give the learners a formula but instead let them answer the question how they see fit or through self-discovery. This would have been a better way to approach this question as self-discovery is known to encourage learners to discover the answer without direct instruction from the teacher (Kistian et al., 2017).

The heart of self-discovery allows learners to work through logical thinking and deductions which in turn make it easier for them to remember as they created the answer on their own. Through self-discovery, the teacher's role is not to impart knowledge, the teacher's role changes to be a facilitator who assists learners to construct their own knowledge. This method promotes active learning and when done correctly, the learners remember the work easier as they played an active role through self-finding or self-investigation which ultimately would last longer in their memory (Kistian et al., 2017).

The importance of selecting purposeful activities collaboratively was highlighted by teachers admitting to not creating a fit-for-purpose instructional activity. They saw first-hand the impact it had on the learners. By teachers creating activities of this nature, they would be promoting learners thinking and problem-solving skills (relational understanding) (Skemp, 1978) and in turn move away from the traditional teaching and testing through instrumental understanding only.

Through LS, teachers are afforded a safe space to speak and question each other without making it seem as if they are trying to bring each other down. This is an important attribute in LS as teachers collaboratively planned the lesson making it all of their efforts and not one person's effort. That way even though the activities were given to one person per station, the teacher responsible for this station did not feel attacked as the focus of the reflection was not on her as the teacher, rather on the learners learning through the activity (Widjaja et al. 2017). Contrary to what teachers in Sekao and Engelbrecht (2021) perceived as a personal 'attack' or blame on them during post-lesson reflection, the teachers in this study seemed comfortable to participate in the reflection session to evaluate their evidence.

There was more than one instance during post-lesson reflection where teachers realized the importance of moving away from teaching through mostly instrumental understanding but moving more towards relational understanding. However, it is still evident that despite this awareness, teachers tend to revert to the teaching method that is well known to them (direct instruction). This was seen when the teachers reflected on the lesson taught to evaluate the evidence and added that they intend doing a cycle with the ELS teachers so that they can teach the method correctly, so the learners could proceed to the next grades with the correct method taught. This, yet again, emphasizes how teaches lean more towards teaching for method and procedure rather than for understanding. The implications for teachers not thinking of other ways to teach mathematics other than through instrumental understanding risks learners having a poor understanding of mathematics and may not promote mathematical reasoning skills in learners.

Although it was not the purpose of study to determine challenges in LS, there were a few challenges that emerged during discussions in the post-lesson reflection stage which could have direct implications on the entire study. For instance, the teachers discussed possible limitations for implementing LS in the school which included LS being time consuming in the sense that planning the lesson takes long. The challenge of time is evident in other studies such as Mon, Dali and Sam (2016) as well as Sekao and Engelbrecht (2021). A second challenge they found was that it is difficult to implement LS in smaller schools in the sense that teachers involved in the collaborative lesson planning cannot observe the lesson being taught as the learners in their classes cannot be left unattended. One could argue that the post-lesson reflection could have brought in more rich and in-depth data about the lesson presentation and observation stage if all the teachers who had planned the lesson were also observing the lesson. The teachers who collaboratively planned the lesson could not all observe the lesson due to not being able to leave their classes unattended.

To conclude this section and directly respond to my fourth research question which states: *How do teachers evaluate evidence generated from testing their assumptions?* The teachers created a worksheet that each learner was given which would be taken in and marked after the lesson, and in that way they would evaluate if their assumptions were correct or not based on each learners' response to the questions. These activities did however bring light to teachers by informing them of the learners' misconceptions and proved that their teaching style should also include relational understanding and not only instructional understanding. The process of evaluation stems from post-lesson reflection therefore teachers evaluated their evidence through discussions that took place in the post-lesson reflection stage. The main focus of reflection was on what went well, what did not go well, and what could be improved. Although it was not the purpose of this study to determine challenges within the LS cycle, it was inevitable that challenges would arise and they (challenges) featured prominently during post-lesson reflection. These challenges also negatively impacted the post-lesson reflection stage as some of the teachers who planned the lesson could not observe it which affected the possibility of rich interpretations from their observations that would have taken place.

5.4 Reflecting on the Utility of the Theoretical Framework

LS is a context that grounded my study, but this context needed to be understood from a theoretical point of view, therefore SLT was found to be useful as it had all the attributes of LS. In SLT and LS, teachers are required to work collaboratively and not cooperatively in the context of their natural working environment (in this case classrooms). However, the main driver for my research was Fischer et al's (2014) diagnostic competences. From the point of view of the literature review, Fischer et al.'s (2014) diagnostic competences helped me to logically arrange the literature according to the diagnostic competences found within each stage of the LS cycle (Figure 2). It further assisted me to gain a deeper understanding of learners' mathematical misconceptions by assisting me in crafting my research questions and linking them to the applicable stages of the LS cycle. From the methodology point of view, my study followed a qualitative interpretivist case study design which stresses the importance of context which is one of the main characteristics of SLT and LS.

My observation tool was informed by Fischer et al.'s (2014) diagnostic competences along with the data collection instruments and evidently the findings which were informed by my research questions were presented and packaged according to the diagnostic competences. Lastly, the limitations and recommendations were based on the findings that were informed by Fischer et al.'s (2014) diagnostic competences. Therefore, these two theoretical lenses worked well for my study as they were evident in all the chapters.

5.5 Limitations

In this study, the first limitation that I experienced was that the analysis of learners' responses was based on summative assessment. Although it is acceptable to analyse summative results diagnostically, phrasing of questions which has a potential to contribute to learners' misconceptions if not moderated, was not the unit of analysis nor the focus of my study. The assumption was that it was subject to thorough moderation, and that there were no ambiguities that would have influenced learners to respond to certain questions in a particular wrong way.

The second limitation was the availability of the teachers to attend the workshop as well as contribute to the research lesson. Originally the plan was to create two different research lessons: one for the primary school and one for the high school; however, the high school teachers were not able to attend on the day. This would have assisted me in gaining a deeper understanding of how Fischer et al.'s (2014) diagnostic competences feature within the LS cycle since two cycles would have been conducted at different levels of schooling – primary school level and secondary/high school level.

The third limitation was that teachers could not do the post-lesson reflection on the same day after teaching the lesson as there were other important matters not related to LS that teachers had to attend to in the afternoon. This hindered the post-lesson reflection as the teachers could have forgotten important aspects that could have been discussed immediately during post-lesson reflection. In fact, not conducting a post-lesson reflection immediately after the lesson is presented as a slight deviation from the recommended process of LS. This was, however, not a serious setback because the recommendation on conducting it immediately after the lesson presentation and observation is more about a precaution rather than a conceptual deviation. Precaution in the sense of safeguarding currency and what was observed was indicated earlier. In fact, whenever possible it is recommended that post-lesson reflection should happen after the lesson presentation and observation in the same class where the lesson was taught so that the chalkboard writings could be accessible to teachers during reflection.

The fourth limitation was that some teachers who assisted in planning the research lesson were not able to observe the lesson being taught as they had their own classes during that time since their learners could not be left unattended. This negatively impacted the study as there were only two teachers who participated in both stages of lesson observation and post-lesson reflection. Participating in both stages empowers teachers to engage in deep reflection because they have a benefit of both processes. In other words, there would have been a possibility that more information would have been shared regarding the evaluation of evidence collected during the lesson presentation and observation stage of the LS cycle. Notwithstanding this limitation, the post-lesson reflection is a holistic activity, not limited to one LS cycle but involves the entire LS cycle.

Last, the current qualitative case study was based on a small sample that was selected purposively and conveniently and whose results cannot be generalisable. Despite an attempt to mitigate against the limitations associated with the methodological and sampling issues in the current study, it is possible that a bigger sample and a different methodological approach could reveal generalisable findings. This calls for further study on a similar research topic.

5.6 Recommendations

Diagnoses originated from the medical field; however, it needs to be further explored within the context of education. Just as a doctor needs to diagnoses a problem before giving a patient any medication, a teacher needs to diagnose the learners' difficulties in order to structure teaching appropriately. Although the results of my study are not generalizable, I recommend that teachers should be given more training on how to conduct diagnostic analysis or how to set up a diagnostic assessment. This way it will help mathematics teachers accurately diagnose learners' misconceptions and look for alternative ways to address them.

A second recommendation is for the DBE to create an intentional need for diagnostic assessments/analysis to be conducted in schools as this will be required of teachers to look at what learners are doing wrong and work on correcting their misconceptions in mathematics or assisting them in changing their teaching material and styles to cater for these misconceptions. Fischer et al.'s (2014) diagnostic competences could translate into a diagnostic process which could inform policy makers in terms of unpacking diagnostic assessments/analysis in the curriculum.

Last, since this study was based on diagnostic analysis of the learners' responses of summative assessment, it is recommended that further studies be conducted in the development of diagnostic assessment in mathematics. In other words, further research is required to explore teachers' skills and knowledge of developing and administering diagnostic assessment in mathematics classes and then analysing the responses of learners.

5.7 Conclusion

This chapter concluded my study which explored mathematics teachers' diagnostic assessment practices in the implementation of LS. Given that this was a qualitative study through a case study design which was located within the interpretivist paradigm, it was conducted through studying the participants within the natural setting (their classrooms). My study was guided by two theoretical lenses i.e.: SLT which undergirds the LS and Fischer et al.'s (2014) diagnostic competences which guided the framing of the research questions.

The reason for my interest in exploring this topic was because, despite diagnostic assessment being a requirement for mathematics teachers' practice in SA, it is not fully applied in the teaching and learning process and in instances where learners' misconceptions were identified through diagnostic assessments/analysis, teachers did not apply the necessary interventions to correct those misconceptions. In the same way, the medical field have to diagnose a patient first before they can provide the correct treatment, teachers should also prioritize diagnoses as this will guide their lesson planning and overall benefit the learners tremendously. In fact, Fischer et al.'s

(2014) diagnostic competences were originally created as a diagnoses process in the medical field, through their interdisciplinary study involving both medical and educational fields, the diagnostic competences were found applicable in the education field too.

The whole concept of diagnosis should be an integral part of teaching and learning where teachers diagnose learners' difficulties which in turn guides their lesson planning. Teachers are meant to use the information generated from diagnostic assessment/analysis to learn more about learners' misconceptions. Diagnosis if done correctly could benefit the learners through teaching as the teachers will be aware of their misconceptions.

Through this study it was evident that mathematics teachers use the entire LS cycle to identify the misconception, plan the research lesson that will include activities that will confirm or refute their assumptions on the identified problem, teach the lesson and reflect on it. LS is credited for enabling teachers to collaborate and learn from each other as well as to assist them in preparing lessons that will encourage learners to become critical thinkers. My primary research question was: *How do mathematics teachers use the LS cycle to identify learners' misconceptions in mathematics?* and was explored through the four secondary research questions.

The results revealed that teachers leaned more towards teaching instrumental understanding rather than relational understanding which was a contributing factor to the learners' misconceptions as the teachers emphasized methods, formulas and algorithms instead of teaching through relational understanding. Through this research it was found that by teachers not taking the time to conduct diagnostic assessment/analysis that they stand a risk of not being able to determine the factors that might impede learners' progress in mathematics. Despite a small sample whose results cannot be generalised, it could benefit both teachers and learners if this type of assessment could be researched further and be scaled up in schools. Teachers should be trained on how to conduct these types of assessments and what to do with the results once they have analysed the learners' responses to improve on their teaching.

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ANNEXURES

ANNEXURE A: Observation Protocol

Issues to observe		Notes
Conducting diagnostic analysis – RQ1 (Stage 1 of LS cycle)	• **Problem Identification** - How teachers identify the problem topic/concept learners are experiencing. • **Questioning** - brainstorming ideas about the possible causes of learners' errors and/or misconceptions stemming from the identified problematic topic/concept. • **Generate hypotheses** – what assumptions do teachers make about the possible sources of errors and/or misconceptions stemming from the identified problematic topic/concept.	
RQ2 (Stage 2 of LS cycle)	• **Creating purposeful artefacts** – How teachers created artefacts (activities) to test their hypothesis. • **Purposeful questions**- what questions did teachers come up with that will facilitate learning.	
RQ3 (Stage 3 of LS cycle)	• **Generating evidence**- How did teachers test if their hypothesis/assumptions were confirmed or refuted.	
Teachers' confirmation of their perceived misconceptions (Stage 2, 3, 4) RQ4 (Stage 1 of LS cycle)	• How teachers factored in their hypotheses to inform collaborative lesson planning. • How well did the artefacts/ activities prove teachers' hypotheses? • How did teachers generate evidence that concluded their hypotheses? • How teachers evaluated their evidence.	

ANNEXURE B: Ethics Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Amendment

Ethics Committee
09 November 2021

Miss AD Vetter

Dear Miss AD Vetter

REFERENCE: UP 19 03 01 SEKAO 21-02

We received the proposed amendments to your existing project. Your amendment is thus **approved**. The decision covers the entire research process, until completion of the study report, and not only the days that data will be collected. The approval is valid for two years for a Masters and three for Doctorate.

The approval by the Ethics Committee is subject to the following conditions being met:

1. The research will be conducted as stipulated on the application form submitted to the Ethics Committee with the supporting documents.
2. Proof of how you adhered to the Department of Basic Education (DBE) policy for research must be submitted where relevant.
3. In the event that the research protocol changed for whatever reason the Ethics Committee must be notified thereof by submitting an amendment to the application (Section E), together with all the supporting documentation that will be used for data collection namely; questionnaires, interview schedules and observation schedules, for further approval before data can be collected. Non-compliance implies that the Committee's approval is null and void. The changes may include the following but are not limited to:
    - Change of investigator,
    - Research methods any other aspect therefore and,
    - Participants.

The Ethics Committee of the Faculty of Education does not accept any liability for research misconduct, of whatsoever nature, committed by the researcher(s) in the implementation of the approved protocol.

Upon completion of your research you will need to submit the following documentations to the Ethics Committee for your

Clearance Certificate:

- Integrated Declaration Form (Form D08),
- Initial Ethics Approval letter and,
- Approval of Title.

Please quote the reference number UP 19 03 01 SEKAO 21-02 in any communication with the Ethics Committee.

Best wishes

Prof Funke Omidire
Chair: Ethics Committee
Faculty of Education

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Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

ANNEXURE C: Letter to School Principal

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Enquiries: Ms Andrea Vetter
Midview Gardens Estate, Blue Hills
Midrand, 1682
Email: u16079397@tuks.co.za

The principal
Reddford House Blue Hills
Midrand

Dear Principal

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY

I am an MEd student at the University of Pretoria and I am conducting a research study titled: ***Mathematics teachers' diagnostic assessment practices in the implementation of Lesson Study***. The purpose of the study is to examine mathematics teachers' diagnostic assessment practices when implementing LS. This letter serves to request your permission to conduct the afore-mentioned research in your school where Senior Phase learners and mathematics teachers will be involved.

If permission is granted, the primary school mathematics teachers will be invited to participate in this study by:

a) Being observed and audio/video recorded during the Lesson Study cycle.
b) Being part of the collaborative lesson planning session that will be audio/video recorded.
c) Availing their collaboratively prepared lesson plan for analysis.

The learners will be invited to participate in this study by being observed during lesson presentation. In addition, note that *participation* of the teachers and learners is completely *voluntary* and if they agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* teachers' consent and learner's assent to participate will be based on their understanding of the purpose and process of the study as I would have explained to them.
- *Safety in participation:* the teachers and learners will not be exposed to any risk or harm of any form because they will not be required to deviate from their day-to-day teaching and learning process.
- *Privacy*: The names and the data provided by both teachers and learners will be kept confidential and anonymous.

- *Trust*: both teachers and learners will not be subjected to any act of deception or betrayal in the research process or its published findings.

I also would like to request your permission to use the data provided, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Andrea Vetter, at 0714805231 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

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Andrea Vetter Dr R.D. Sekao (Supervisor)

ANNEXURE D: Letter of Consent - School Principal

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Enquiries: Ms Andrea Vetter
Midview Gardens Estate, Blue Hills
Midrand, 1682
Email: u16079397@tuks.co.za

Dear Ms A. Vetter

LETTER OF CONSENT TO CONDUCT THE RESEARCH STUDY

I,…………………………………….., principal of ………………………………………., voluntarily and willingly permit Ms A. Vetter to conduct a research study titled: ***Mathematics teachers' diagnostic assessment practices in the implementation of Lesson Study.*** I understand that the participation of both learners and the primary school mathematics teachers in the afore-mentioned study to which I am consenting, will involve:

a) Teachers and learners being observed during the lesson presentation.
b) Teachers being part of the interview that will be audio/video recorded.
c) Teachers availing the collaboratively prepared lesson plan for analysis.

I declare that I understand the purpose of the study and that you (the researcher) will subscribe to the ethical research principles, including the informed consent, safety, privacy (confidentiality and anonymity) and trust.

In addition, I grant the University of Pretoria permission to use data provided for this study, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Given the above information, I grant you permission to conduct your study in our school.

____________________	____________	___________
(**Name** and **surname**)	Signature	Date

ANNEXURE E: Letter to Teachers

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Enquiries: Ms Andrea Vetter
Midview Gardens Estate, Blue Hills
Midrand, 1682
Email: u16079397@tuks.co.za

Dear Teacher

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY

I am an MEd student at the University of Pretoria and I am conducting a research study titled: ***Mathematics teachers' diagnostic assessment practices in the implementation of Lesson Study***. The purpose of the study is to examine mathematics teachers' diagnostic assessment practices in LS. This letter serves to request your permission to conduct the afore-mentioned research where you would be involved.

If permission is granted, you as the primary school mathematics teacher will be invited to participate in this study by:

a) Being observed and audio/video recorded during the Lesson Study cycle.
b) Being part of the collaborative lesson planning session that will be audio/video recorded.
c) Availing the collaboratively prepared lesson plan for analysis.

The learners will be invited to participate in this study by being observed during lesson presentation. In addition, note that *participation* of the teachers and learners is completely *voluntary* and if they agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* teachers' consent and learner's assent to participate will be based on their understanding of the purpose and process of the study as I would have explained to them.
- *Safety in participation:* the teachers and learners will not be exposed to any risk or harm of any form because they will not be required to deviate from their day-to-day teaching and learning process.
- *Privacy*: The names and the data provided by both teachers and learners will be kept confidential and anonymous.
- *Trust*: both teachers and learners will not be subjected to any act of deception or betrayal in the research process or its published findings.

I also would like to request your permission to use the data provided, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

For any additional information, you may contact me, Andrea Vetter, at 0714805231 or my supervisor, Dr RD Sekao at, 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

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Andrea Vetter Dr R.D. Sekao (Supervisor)

ANNEXURE F: Letter of Consent – Teacher as Participant

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Enquiries: Ms Andrea Vetter
Midview Gardens Estate, Blue Hills
Midrand, 1682
Email: u16079397@tuks.co.za

Dear Ms A. Vetter

LETTER OF CONSENT TO CONDUCT THE RESEARCH STUDY

I,…………………………………….., teacher at………………, voluntarily and willingly permit Ms A. Vetter to conduct a research study titled: ***Mathematics teachers' diagnostic assessment practices in the implementation of Lesson Study.*** I understand that the participation of both learners and I in the afore-mentioned study to which I am consenting, will involve:

a) Learners and I being observed during the lesson presentation.

b) Being part of the interview that will be audio/video recorded.
c) Availing the collaboratively prepared lesson plan for analysis.

I declare that I understand the purpose of the study and that you (the researcher) will subscribe to the ethical research principles, including the informed consent, safety, privacy (confidentiality and anonymity) and trust.

In addition, I grant the University of Pretoria permission to use data provided for this study, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Given the above information, I grant you permission to conduct your study in our school.

________________________	______________	____________
(**Name** and **surname**)	Signature	Date