Examining Grade 8 mathematics teachers' formative assessment practices within the Lesson Study cycle

by

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Declaration

I declare that “Examining Grade 8 mathematics teachers' formative assessment practices within the Lesson Study cycle” is my own work and that all sources used or quoted herein have been indicated and acknowledged by means of complete references. I further declare that this work or part of it has not been previously submitted for examination or other qualification at this or any other higher education institution.

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Lauren Neuhoff

31 August 2022

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- Compliance with approved research protocol,
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- Informed consent/assent,
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- Registered title, and
- Data storage requirements.

Ethics statement

The author, whose name appears on the title page of this dissertation, has obtained for the research described in this work the applicable research ethics approval. The author declares that she has observed the ethical research standards required in terms of the University of Pretoria's *Code of ethics for the researchers and the Policy Guidelines for responsible research.*

Dedication

I dedicate this research

to

my fiancé, Justin Dwyane Schmidt, who has shown me nothing but constant support, encouragement and love in all the goals I have set out to achieve.

and

my close friend, Dr Brittany-Leigh Mitchell, for inspiring me to take on this journey through example.

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To have achieved this milestone in my life, I would like to express my sincere gratitude to the following people:

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Abstract

Assessment is a continuous process of identifying, gathering and interpreting learners' performance. The Senior Phase Mathematics CAPS further stipulates that assessment should consist of both formal and informal assessments such as formative assessments. It is necessary to conduct a formative assessment within Mathematics Education, as it focuses on the continuous improvement of learners' conceptual understanding within the teaching and learning process through constant and immediate feedback. However, mathematics teachers tend to teach for summative assessment purposes and seldom develop learners' conceptual understanding of mathematics concepts. A teacher development practice that emphasises collaborative lesson planning among a group of teachers, known as Lesson Study (LS), can be used to shift the focus of Mathematics Education from teaching for summative assessment purposes to teaching for understanding. LS, therefore, provides a fertile context to study how mathematics teachers work collaboratively to plan and teach, with formative assessment, to improve learner understanding. Thus, this qualitative study aimed to examine Grade 8 mathematics teachers' formative assessment practices within the in-school LS cycle. Hence, the purpose of the study was to examine how mathematics teachers collaboratively planned for and used formative assessment practices within the context of LS, to facilitate mathematics learning. The sample of the study included three Grade 8 mathematics teachers who participated in two in-school LS cycles. Two theoretical lenses framed the study: The Formative Assessment framework proposed by Antoniou and James (2014) and the Situated Learning Theory. The study aimed to answer the primary research question: How do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 Mathematics class? Data for the study were collected through observation of two consecutive stages within the LS cycle (collaborative lesson planning, the presentation of the lesson) and unstructured interviews. Data were analysed by means of transcribing the audio and video recordings of the observations and interviews, thereafter deductive and inductive analysis was conducted. The study's findings revealed that formative assessment is not at the forefront of planning a lesson. However, it is abundantly evident within a classroom. It is envisaged that the study will share insights on how teachers can use formative assessment in

mathematics within the Lesson Study cycle, thereby developing their skills in assessment *for* learning.

Key words: Lesson Study, formative assessment, mathematics, conceptual understanding, teacher development

Language editor

To whom it may concern,

I hereby confirm that I undertook the language editing for the dissertation:

Examining Grade 8 mathematics teachers' formative assessment practices within the Lesson Study cycle

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The work was well written overall.

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Table of Contents

List of Annexures

List of Figures

List of tables

CHAPTER 1: INTRODUCTION AND CONTEXTUALISATION OF THE STUDY

1.1. Introduction

According to the Senior Phase Mathematics Curriculum and Assessment Policy Statement (CAPS), assessment is "a continuous planned process of identifying, gathering and interpreting information regarding the performance of learners" (Department of Basic Education, 2011, p. 154). Furthermore, the Senior Phase CAPS stipulates that assessment should consist of both formal and informal assessments. Informal assessment such as formative assessment, is used "to aid the teaching and learning process" (Department of Basic Education, 2011, p. 154).

At the forefront of formative assessment research, Bloom (1969, p. 48) argues that the primary purpose of formative assessment is "to provide feedback and correctives at each stage of the teaching-learning process". The Senior Phase Mathematics CAPS states that "the fundamental distinguishing characteristic of formative assessment is constant feedback to learners, particularly with regard to learners' learning processes" (Department of Basic Education, 2011, p. 154).

Formative assessment is necessary for Mathematics Education since it focuses on the continuous improvement of learner understanding through timely and effective feedback. "The information provided by formative assessment can also be used by teachers to inform their methods of teaching" (Department of Basic Education, 2011, p. 154). Formative assessment, therefore, provides mathematics teachers with a platform to plan future teaching and the appropriate use of learning and teaching support materials (LTSM) (Fisher & Frey, 2014).

In agreement, Wiliam and Leahy (2016) state that formative assessment is centred around learner engagement. Rushton (2005, p. 510) claim that feedback provided within formative assessment "is part of the interactive components of teaching and learning" and therefore, frequent feedback through formative assessment can improve the teaching and learning process. Rushton (2005, p. 509) further argues that any information gained through feedback is necessary "to close the gap" between learners' current and desired levels of understanding.

Lesson Study is an approach developed decades ago in Japan to strengthen professional development among in-service teachers to improve the quality of the

teaching and learning process (Norwich, Dudley, & Ylonen, 2014). Lesson Study is a well-renowned approach practised in various countries and is also implemented across various subjects. However, for my study, the subject of interest is mathematics. The practice of Lesson Study in South Africa is a fairly novel concept as “South Africa has only recently started using [Lesson Study] to improve the teaching and learning of mathematics” (Sekao & Engelbrecht, 2021). The Lesson Study practiced within South Africa and by the University of Pretoria has five consecutive and iterative stages (Sekao & Engelbrecht, 2021). The Lesson Study cycle begins with the teachers identifying a concept that poses difficulties for learners, followed by collaboratively planning a lesson on the said concept. Once the lesson has been fully planned, one teacher presents the lesson while the rest observe for learner engagement and understanding. The teachers then again gather to reflect upon the lesson, indicating what went well and what can be improved. After that, the teachers implement the improvements, so the cycle begins again. The primary aim of formative assessment, when implemented in the context of Lesson Study, is to shift focus to “improved understanding of learner needs rather than the improvement of teaching” (Norwich et al., 2014, p. 193).

Therefore, based on the above and the fact that Lesson Study is a fairly novel concept for South African teachers, this study aimed to shed light on the use of formative assessment in Grade 8 Mathematics classes in the South African context. The study took place within two consecutive stages of the Lesson Study Cycle, namely Stage 2: Collaborative lesson planning and Stage 3: Lesson presentation and observation.

1.2. Problem statement and purpose of the study

Reddy (2005) states that “Mathematics [is] a key area of knowledge and competence for the development of an individual and the social, economic development of South Africa.” However, the teaching and learning of Mathematics seem to be more of a challenge than other subjects, and learner performance and achievement are particularly low (Ngobese, 2013). The problem could, among other things, lie with teachers of Mathematics who are not well-equipped to develop learners’ conceptual understanding of mathematical content and instead teach for summative purposes. Moreover, there is a dichotomy in the purpose of formative assessment between what the Senior Phase Mathematics CAPS claims and what research and literature claims.

Essentially, the Department of Basic Education states that formative assessment aids teachers in improving the teaching and learning process, while research states that formative assessment is a great tool to improve learner understanding. Additionally, formative assessment has not been adequately explored in the context of Lesson Study.

For the reasons mentioned above, the primary purpose of this study was to examine mathematics teachers' use of formative assessment during the implementation of the Lesson Study cycle in a Grade 8 Mathematics class. Formative assessment practices were examined in two consecutive stages of the Lesson Study Cycle to achieve this, namely Stage 2: Collaborative lesson planning and Stage 3: Lesson presentation and observation. Regarding the former, I explored teachers' planning of formative assessment as part of collaborative lesson planning. Concerning the latter, my focus was on using formative assessment to facilitate mathematics learning and the provision of feedback to learners.

1.3. Rationale

In my experience as a mathematics teacher, I noticed that assessment in school mathematics is dominated by summative assessment and seldom by formative assessment. Moreover, I believe that poorly implemented formative assessment leads to a lack of learner engagement and interest and, therefore, conceptual understanding. This is despite the well-articulated general aims of the South African mathematics curriculum, emphasising developing skills such as critical thinking and problem solving, often referred to as 21st-century skills. According to the Department of Basic Education (2011, p. 4), learners should "acquire and apply knowledge and skills in ways that are meaningful to their own lives". Advancing the acquisition of these skills is afforded by formative assessment, which is part of everyday teaching and learning of mathematics, and instead of prioritising quantitative results of learners, it emphasises learners' mathematical learning (Black & Wiliam, 2010). Exploring mathematics teachers' formative assessment practices is, therefore, necessary to gain more insights into how it is used to facilitate mathematics learning.

1.4. Literature review

As previously mentioned, the study's main purpose was to examine mathematics teachers' formative assessment practices during the implementation of the Lesson Study cycle in a Grade 8 Mathematics class. For this reason, I examined literature focusing on the tenets of formative assessment, elicitation questioning techniques, and creating a learner-centred environment through formative and explication of the Lesson Study practised in South Africa to gain a deeper understanding of what the literature says. Although a comprehensive review of literature is covered in Chapter 2, I have presented a summary in the next paragraphs.

A salient feature of formative assessment discussed throughout the literature is that formative assessment is ever-present in a learning environment. It feeds the teaching and learning process and encourages teachers and learners to look beyond learners' results but rather focus on learners' mathematical learning (Black & Wiliam, 2010). Formative assessment is a means to gain insight into learner conceptual understanding and provide meaningful feedback to learners' responses as a measure to develop their mathematical thinking. Feedback must encourage socio-mathematical discourse within a lesson (Havnes, Smith, Dysthe, & Ludvigsen, 2012).

The practice of formative assessment must be done consistently throughout the mathematics teaching and learning process. Using elicitation questioning techniques, teachers can engage with learners and encourage them to explore their mathematical ideas (Gotwals & Birmingham, 2016). Additionally, the literature suggests using various elicitation questioning techniques to develop learners' mathematical learning (Evans, Zeun, & Stanier, 2013). However, teachers must be mindful of the questions they pose to learners. The questions and problems given to learners must be given with purpose and must provide a platform for learners to explore their own mathematical understanding and construct their own knowledge " (Nicol & Macfarlane-Dick, 2006).

According to the literature, the use of formative assessment promotes learner-centred environments. Formative assessment practices place the focus on learner understanding and active participation within a lesson (Van der Nest, Long, & Engelbrecht, 2018). From the information gained from formative assessment, teachers can learn from their learners and adapt teaching decisions based on the needs of their learners (Sadler, 1998).

As mentioned previously, the practice of Lesson Study in South Africa and by the University of Pretoria has five consecutive and iterative stages (Sekao & Engelbrecht, 2021). It is within Stages 2 and 3 of the Lesson Study cycle where formative assessment features most prominently. Within Stage 2: Collaborative lesson planning, the teachers, discuss and plan the effective ways to teach the learners. Essentially, the teachers plan the lesson's structure, including the questions they wish to pose to the learners to elicit mathematical thinking. The questions must be well planned and planned to develop learners' conceptual understanding (Fernandez, 2002). Within Stage 3: Lesson presentation and observation, the planned formative assessment techniques are to be implemented. These techniques enable teachers to actively engage the learners with the topic at hand and provide insight into any gaps or misconceptions that learners may have (Elliott, 2019, p. 179).

From the above, I used two theoretical lenses to explore teachers' formative assessment practices as stipulated earlier. The first theoretical underpinning of my study is the Situated Learning Theory (Lewis, Perry, & Hurd, 2009), which provides a firm basis for the context of my study, namely Lesson Study. With the Situated Learning Theory lens, teachers are encouraged to actively participate in their teaching community (Lewis et al., 2009). The second theoretical underpinning of my study is the Formative Assessment framework (Antoniou & James, 2014). This framework presents formative assessment as five sequential processes. I used the framework when responding to the research questions.

1.5. Research questions

To examine Mathematics teachers' use of formative assessment practices within the context of Lesson Study, the primary research question for this study was:

How do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 Mathematics class?

From this primary research question, I formulated the following secondary research questions, which guided the study:

1) How do mathematics teachers collaboratively plan formative during the Lesson Study cycle?
2) In what ways do mathematics teachers use formative assessment to facilitate mathematics learning?
3) How do mathematics teachers provide meaningful feedback to learners?

1.6. Concept clarification

Conceptual understanding

Going beyond understanding the step-by-step procedures. It is evident by a learner's ability to apply mathematical operations across a spectrum of concepts. Essentially, it is the learners' ability to explain mathematical knowledge in their own words (Konicek-Moran & Keeley, 2015).

Declarative questioning techniques

Questioning that seeks clarification and not a sense of curiosity for the concept at hand (Clark, Harbaugh, & Seider, 2021). Declarative questions consist of lower-order and closed ended questions.

Elicitation questioning techniques

Questioning that is exploratory by nature and encourages learners explore and discuss their ideas and conceptual understanding (Barton, 2015). Elicitation questions are higher-order, open ended questions to provoke learner engagement and responses.

Formal assessment

"Formal assessment comprises School-Based Assessment (SBA) and End of the Year Examination. Formal assessment tasks are marked and formally recorded by the teacher for promotion purposes" (Department of Basic Education, 2011, p. 155).

Informal assessment

"Informal assessment is a daily monitoring of learners' progress" (Department of Basic Education, 2011, p. 155).

Learner achievement and performance

Learner achievement and performance are "what learners are able to do or how they demonstrate their competence" (Ngobese, 2013, p. 6). Throughout this research proposal, the two terms are used interchangeably.

Learner engagement

"[Learner] engagement is more than involvement or participation – it requires feelings and sensemaking as well as activity" (Trowler, 2010, p. 5). Learner engagement consists of learners interacting with their teacher, peers, and work (Trowler, 2010).

Mathematical thinking

Mathematical thinking is a way of thinking outside the box and to use mathematical ideas, concepts and understanding to solve real-world problems (Stacey, 2006).

Socio-mathematical discourse

Learners "are involved in learning communities in which all participants have opportunities to engage in productive mathematical discourse" (Hunter, 2009, p. 249). Socio-mathematical discourse "promote[s] the centrality of teachers supporting student communication of mathematical ideas and reasoning" (Hunter, 2009, p. 249).

1.7. Methodological considerations

The metaphor that informed the methodological considerations for the study was that of the 'Research Onion' presented by Saunders, Lewis, and Thornhill (2019). The study aimed at examining Mathematics teachers' formative assessment practices within the context of Lesson Study, so focus was placed on subjective experiences. This is why the epistemological paradigm of interpretivism was used to ground my study. With the use of interpretivism, I was able to gain in-depth insight on the teachers' use of formative assessment concerning how the teachers are involved in the Lesson Study, collaboratively plan to use formative assessment within a lesson; how formative assessment is used to elicit learners' mathematical thinking and lastly; how insightful and timely feedback can be provided from formative assessment. However, subjectivity is a key factor when working with an interpretivism paradigm as the underpinning of a study (Thanh & Thanh, 2015). Therefore, I was mindful of bias and misinterpretation throughout my study and ensured that the research problem was clear when I interpreted the study's findings.

Qualitative research was chosen as the methodological choice for my study. Through qualitative research, a fertile platform was provided to explore and gather insight into the mathematics teachers' perceptions of formative assessment within the context of Lesson Study. My study examined mathematics teachers' formative assessment practices within a classroom setting. That is to say, through qualitative research, I collected data from the natural settings of a classroom and the activities done within the teaching and learning process (Athanasou et al., 2012). From this point of reference and under the lens of interpretivism, I could interpret and construct meaning from the research findings.

Since I collected data using observing teachers gather to plan a lesson collaboratively and after that teach it, I observed the subject of my study as it occurred in real life (Yin, 2011) and so, a single case study designed was best suited for the research strategy of the study. Additionally, a single case study research strategy was appropriate for the study since the study focused on "a single entity around which there are boundaries" (Yazan, 2015, p. 139), that is; mathematics teachers' use of formative assessment within the Lesson Study context in a Grade 8 Mathematics class. I was able to address the "how" and "why" questions with regard to formative assessment in

the context of Lesson Study (Yazan, 2015). Essentially, the single case study research design aided in creating a connection between the study's findings and the research questions (Yazan, 2015).

I used purposive and convenience sampling to select the participants of the study. From the six secondary schools that were selected to implement Lesson Study by the Gauteng Department of Education and the University of Pretoria, I selected one school to conduct my research. The three participants selected from the school were selected because they met the specific criteria needed for the study: involvement in Lesson Study and associated with Grade 8 mathematics. Convenience sampling was used because the three participants met the practical criteria (Etikan, Musa, & Alkassim, 2016) of close geographical proximity and easy accessibility.

The data collection procedure was repeated twice within two Lesson Study cycles, the first Lesson Study cycle dealt with equivalent fractions, and the second dealt with algebraic equations. I used direct observations and unstructured interviews to collect data. From the observations of each stage, I was able to generate narrative descriptions of the teachers' use of formative assessment in Lesson Study. I used observation sheets (Annexures A and B) to guide my observations and gather in-depth insight into how formative assessment is incorporated within the two consecutive Lesson Study stages being studied.

For stage two of each Lesson Study cycle, I observed what the teachers discussed while collaboratively planning a lesson. Essentially, I observed how the teachers formulated the lesson outcomes and how they planned on achieving those lesson outcomes. Additionally, I gained insight into whether or not the teachers planned for the formative assessment techniques to be implemented such as specific questions to be asked or specific concept diagrams to be drawn.

For stage three of each Lesson Study cycle, I observed the presentation of the planned lesson. I had the opportunity to observe how the teacher presented the lesson, communicated the predetermined lesson outcomes to the learners and, after that, achieved them. I observed how the teacher engaged the learners in critical and mathematical thinking. I also noted how the teacher provided timely and meaningful feedback to the learners' responses.

While observing each stage of each Lesson Study cycle, I drafted questions to formulate an interview schedule (Annexure C and Annexure D) to guide my unstructured interviews. These questions were not predetermined before I had observed each stage. In other words, the questions I asked were based entirely on what I had observed as a means to corroborate my observations and gain more insight into the teachers' perspectives of formative assessment. I essentially conducted the unstructured interviews as a platform to have a conversation to gain further insight and data for the research questions while remaining a listener (Brinkmann, 2014).

Due to the fast pace and nature of the stages observed, I could not write down everything that was important. For this reason, I asked for and received permission from the participants to video and audio record the collaborative lesson planning, the lesson presentation and observation and the unstructured interviews for both Lesson Study cycles. I decoded these recordings at a later stage when presenting my findings.

Considering the characteristics of the interpretivist paradigm and the nature of qualitative research, I analysed the data guided by the participants' individual and shared experiences and perceptions (Thanh & Thanh, 2015). The analysis and interpretation of the observations and interviews for each Lesson Study cycle were done separately. From this analysis, key categories were determined such as the practice of oral and written formative assessment.

From the observation sheets, deductive analysis was used to determine whether or not the generalisations, as stipulated in my framework, applied to the specific instance (Hyde, 2000) of a Grade 8 Mathematics lesson in the context of Lesson Study. Additionally, the data gathered from the unstructured interviews were analysed and interpreted through inductive data analysis as new categories that were not stipulated in my framework emerged from the narrative analysis.

Using deductive and inductive data analysis of the research instruments, I organised my study's findings to generate in-depth descriptions of how a teacher can use formative assessment practices during the implementation of Lesson Study in a Grade 8 Mathematics class.

In order to establish trustworthiness while conducting the study, I had to keep in mind the various aspects of quality criteria, namely credibility, transferability, dependability and confirmability (Nieuwenhuis, 2016). In order to enhance the credibility of my study, I frequently contacted my supervisors, experts in both fields of Lesson Study and Mathematics Education. I submitted all my field notes to the participants to ensure I accurately captured the information. To ensure that the results of my study were transferable, I carefully considered the participants of my study and provided thick descriptions of the "context, participants and research design" (Nieuwenhuis, 2016, p. 124). I accurately and precisely recorded each stage of the two Lesson Study cycles to demonstrate dependability. Lastly, to ensure that my study demonstrated confirmability, I was aware of my bias and inclinations. For this reason, I provided the raw data to my supervisor to judge whether or not bias was evident.

I obtained approval to conduct my research study and ethics declaration after the completion of my study from the Ethics Committee of the University of Pretoria (Annexure F and Annexure M). After that, I obtained permission to conduct the study from the Gauteng Department of Education (Annexure G). Once I had received permission and approval to conduct my study from the University of Pretoria and the Gauteng Department of Education, I obtained written informed consent from the District Director, the principal of the public secondary school and the three Grade 8 mathematics teachers involved in the Lesson Study (Annexure I, Annexure J and Annexure K). As an additional ethical consideration, I practised fairness, trust, confidentiality and accountability throughout the study.

1.8. Possible contributions of the study

My aspiration for my study was that it would make a small contribution to mathematics teachers and encourage them to teach with formative assessment to develop learners' mathematical learning instead of for summative assessment purposes. Additionally, I hoped my study would shed light on how beneficial the practice of Lesson Study is to enhance the teaching and learning of Mathematics.

1.9. Structure of dissertation

Chapter 1: Introduction and contextualisation of the study

This chapter presents an overview of the study as a whole and contextualises the study as summarised above.

Chapter 2: Literature review and conceptual framework

This chapter provides an extensive review of the literature on the subject of the study to gain in-depth insight into formative assessment practices within the context of Lesson Study. Additionally, this chapter presents the theoretical framework that underpins the study.

Chapter 3: Research Methodology

This chapter contains the methodological considerations of the study as well as the relevant ethical considerations.

Chapter 4: Presentation of research findings

This chapter details the research findings from the data collected through direct observations and unstructured interviews.

Chapter 5: Discussion of the findings, conclusions and recommendations

This chapter presents a discussion of the research findings as a means to respond to the research questions. A reflection on how the framework guided the study is presented. The chapter concludes with the study's limitations and possible recommendations for future research.

CHAPTER 2: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. Introduction

The Senior Phase Mathematics Curriculum and Assessment Policy Statement (CAPS), as presented by the Department of Basic Education (2011, p. 154), defines assessment as the "continuous planned process of identifying, gathering and interpreting information regarding the performance of learners". In support, Farrell and Rushby (2016, p. 107) state that "assessment is the process of identifying, collecting and interpreting information about learning". Essentially assessment is used as a tool by teachers and learners to support, develop and encourage learning (Black, Harrison, & Lee, 2003). Taras (2005) further defines assessment as a certain set of judgements teachers make on a learner's work based on predetermined criteria and learning outcomes. Thinwiangthong, Eddy, and Inprasitha (2020, p. 103) argue that "assessment is considered one of the essential components of education". Many researchers such as Farrell and Rushby (2016, p. 108), agree that the process of assessment forms "an integral part of education". Assessment is often used as a measure "to close the gap between what is and what should be developed" (Farrell & Rushby, 2016, p. 107) regarding learner understanding.

Furthermore, assessment can be described as teachers' daily practice to develop and gain insight into learners' understanding of any task and then make teaching decisions to improve the teaching and learning process. Black and Wiliam (2010, p. 81) state that "learning is driven by what teachers and [learners] do in classrooms". Thus, it can be argued that assessment fuels the teaching and learning process and the day-to-day activities within a classroom.

Moreover, when used in the teacher development practice of Lesson Study, formative assessment is a great aid to the teaching and learning process. Sekao and Engelbrecht (2021) put forward the idea that the practice of Lesson Study aims to develop learner thinking and understanding by teachers collaboratively working together.

Assessment can further be defined by the different types of assessment and the tenets thereof. All types of assessment play a significant role in aiding learners to attain predetermined learning outcomes. For assessment to indicate learning, diagnostic, formative and summative assessments must be implemented accordingly. Although these types of assessments are different in many respects, Taras (2005) notes all types of assessment are simply processes by which the learners' work is compared to specific and predetermined outcomes, standards and criteria. Boesen, Lithner, and Palm (2010) further state that using different types of assessment, different types of mathematical reasoning such as memorised and creative mathematically founded reasonings, are assessed.

The various assessment types each have distinct characteristics that benefit the teaching and learning process, as seen in Figure 1. Van der Nest et al. (2018, p. 2) claim that to ensure "quality Mathematics Education for all, there is a need to expand the assessment process". Teachers should implement various assessment types to create a conducive mathematics learning environment and not focus on only one.

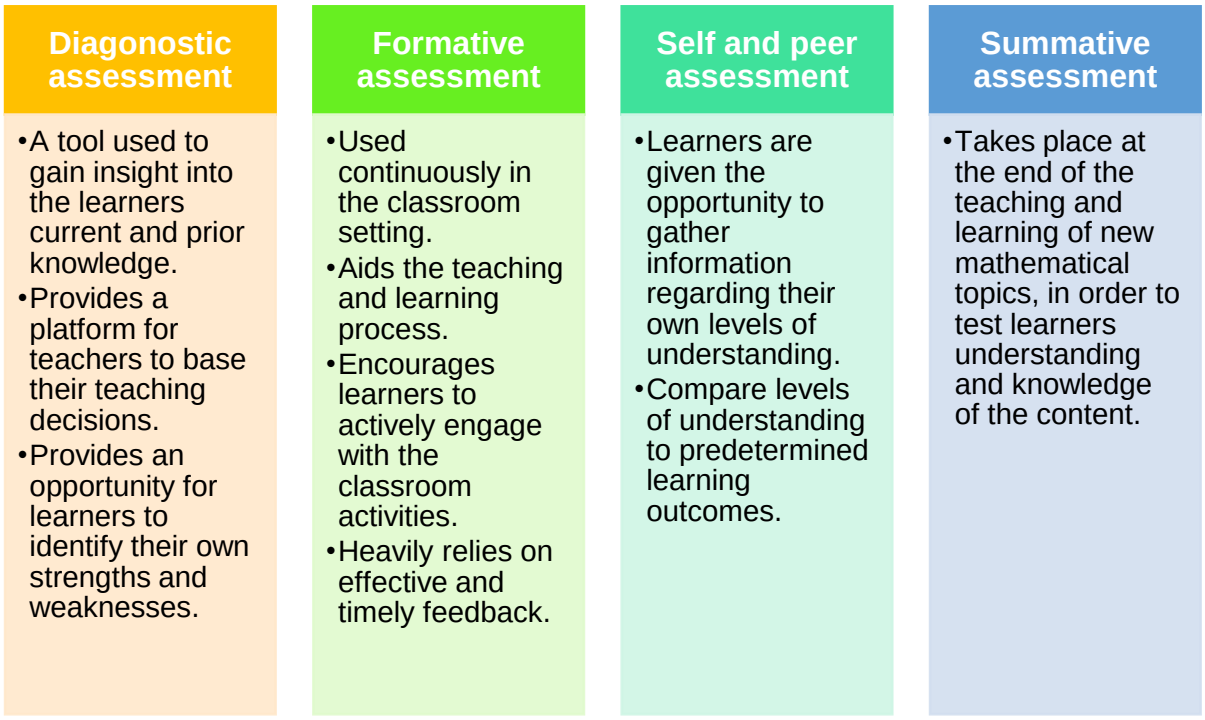

Figure 1: Types of assessment

Despite the affordances of each type of assessment aforementioned, for the purpose of this study, the focus is placed on formative assessment and, further, formative assessment in Mathematics education. The reason for this choice of assessment is that formative assessment proves to be the most appropriate assessment for gaining insight into learners' understanding, misconceptions and progress during the teaching and learning process. Unlike other types of assessment, formative assessment is characterised by constant and specific feedback in the process of teaching. Furthermore, when used in conjunction with all other types of assessment, formative assessment can boost learners' self-esteem and confidence regarding mathematical concepts.

In addition to the various types of assessment, assessment forms, tools and methods play a vital role in facilitating mathematics learning. Assessment forms consist of the different ways in which assessment can be presented to the learners. These include class quizzes, standardised tests, assignments, investigations or projects. Assessment tools is a marking guide used to examine the assessment form implemented, i.e., memorandums or rubrics. Assessment tools aid in determining whether or not a learner has attained the expected learning outcomes. Finally, assessment methods consist of the way in which the assessment tool is used to examine the assessment form. Assessment methods include teacher –, self –, peer – or group-assessments.

The context in which my study is situated is Lesson Study. As discussed by Sekao and Engelbrecht (2021), Lesson Study is a Japanese teacher development practice whereby teachers work together to enhance and develop learner understanding. Lesson Study compromises sequential and interrelated processes. According to Takahashi and McDougal (2016), a Lesson Study cycle begins with a group of teachers identifying a learning area to be focused on, followed by the group of teachers collaboratively planning a lesson based on the identified learning area. One of the teachers after that presents the lesson while the other teachers observe. This is followed by the group teachers once again gathering to reflect on the successes and areas for improvement of the lesson in order to improve upon future teaching decisions (Takahashi & McDougal, 2016).

2.2. Formative assessment

Although formative assessment has not been defined consistently throughout the literature (Antoniou & James, 2014), Black and Wiliam (2009) provide a well-defined perspective that encompasses the essence of formative assessment, thus:

> "…the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better" (p.7).

In addition to the above definition, Cornelius (2014, p. 112) defines formative assessment "as a classroom practice to monitor learner understanding and to adjust teaching to increase learning". Additionally, formative assessment techniques provide an ongoing source of information with regard to learner understanding and misconceptions (Dixson & Worrell, 2016). This information source allows teachers to adapt their teaching decisions to improve and maximise learner learning (Dixson & Worrell, 2016).

From these definitions, I broadly perceive formative assessment as all the activities done over the course of teaching as a measure to gain insight into the effectiveness or not of the teaching and learning process. Insight regarding learners' understanding consequently leads to mathematics teachers adjusting future means of teaching to meet their learners' needs (Thinwiangthong et al., 2020).

Through formative assessment practices, teachers are able to develop an "understanding [of] the nature of learning [which] is a fundamental step in making curricular instructional improvements" (Owen, 2016, p. 168). Leenknecht et al. (2021) state that formative assessment affects learners' learning, and learners' learning affects the type of formative assessment implemented within a lesson. Teachers can, therefore, use various formative assessment strategies in mathematics lessons to determine how learners "are progressing and where they are having trouble" (Boston, 2002, p. 1).

Teachers use the information from formative assessment to gain an understanding of the learners' individual conceptual understanding of mathematical concepts and areas of difficulties and plan future teaching to meet the needs of the learners (Black & Wiliam, 2010). As defined by Owen (2016, p. 169), conceptual understanding is "a

process which encompasses ongoing mental activity through the construction of relationships, the application of existing knowledge, the practice of self-reflection, an articulation of what has been learned and a sense of ownership that makes the learning process personally relevant". Further, Konicek-Moran and Keeley (2015) state that conceptual understanding is evidence that learners can think with the newly acquired mathematical knowledge, use it in other mathematical learning areas, describe and explain the knowledge in their own words and can compare the knowledge to other mathematical concepts. Additionally, Schoenfeld (2015) argues that a true representation of learners' conceptual understanding is seen in the learners' ability to approach new mathematical problems and strategically use the acquired knowledge in other contexts. Hence, simply described, conceptual understanding is when learners have fully grasped what is taught and can make it their own (Konicek-Moran & Keeley, 2015).

2.2.1. Formative assessment in practice

According to Black (2015, p. 171), formative assessment is ever-present in a learning environment as "teachers are continually faced with making instant decisions". In addition, Irons and Elkington (2021) state that there are ample opportunities for teachers to implement formative assessment practices throughout the mathematics lesson to develop learners' conceptual understanding of the topic at hand. Therefore, formative assessment is not considered a separate activity from the learning activities that take place within a classroom (Department of Basic Education, 2011). However, Antoniou and James (2014) argue that for classroom assessment to be considered formative, the teachers and the learners must use the information gained for formative purposes. In other words, information gained from formative assessment techniques must be used to develop learners' mathematics understanding.

It is important to note that the practice of formative assessment is seen as a process, not a test (Bennett, 2011). In agreement, Antoniou and James (2014) claim that the results of the process do not yield a product such as a grade but rather provide meaningful insight into learner understanding.

In mathematics lessons, ideas are not taught in isolation. Thus, when presenting a new mathematical concept, teachers are challenged with the task of interrelating all concepts. The task of interrelating concepts is achieved through a teacher's ability to

make teaching decisions as they see fit while teaching. For instance, when introducing the concept of equivalent common fractions to Grade 8 learners, the teacher may decide to introduce decimal fractions alongside it. Through various formative assessment techniques, this form of the interrelation of mathematical concepts will aid in developing learners' mathematical thinking. As Singh et al. (2018) discussed, mathematical thinking differs from simply “doing mathematics”. When teaching a mathematical concept to learners, teachers should aim to teach the learners to think mathematically about the concept. “The correlation between classroom learning and real life” (Singh et al., 2018, p. 299) must be made evident to the learners in order for them to be able to apply mathematical concepts to a variety of scenarios. Thus, as Singh et al. (2018) put forth, mathematical thinking is a process of learning mathematical concepts by breaking them down to their fundamentals to make sense of the concept as a whole.

However, it is important to note that formative assessment practices differ from one teacher to another, one class to another and one task to another. Thus, instant decisions made regarding teaching and which formative assessment techniques would work most effectively are uniquely dependent on the learning environment and outcomes (Leighton, 2019).

Formative assessment encourages teachers to look beyond the marks of a learner and to focus on “the talk, the writing and the actions through which [learners] develop and display the state of their understanding” (Black & Wiliam, 2010, p. 86). For these reasons, Black and Wiliam (2010, p. 82) argue that formative assessment is “at the heart of effective teaching”. Additionally, formative assessment practices should be used as a tool to engineer effective socio-mathematical discourse within the classroom and provide “learning tasks that elicit evidence of learning” (Wiliam & Leahy, 2016, p. 3).

Socio mathematical discourse is the act of engaging learners in an interactive dialogue with regard to mathematical concepts. The purpose of socio-mathematical discourse is to provide a platform for learners to gain a deeper conceptual understanding of the concepts at hand. It is important to note that Mathematics Education cannot be taught and learned effectively through teacher talk only. With socio-mathematical discourse, learners are given many opportunities to explore and develop their own arguments regarding the content. The learning of mathematics thus becomes learner-centred.

2.2.2. Timing of formative assessment

Black and Wiliam (2010) state that improving teachers' formative assessment practices lead to noteworthy learning gains. Shepard (2017), however, argues that formative assessment will not make the teaching and learning process effective overnight but instead needs to be practised frequently in the teaching and learning environment. Effective teaching can only be achieved by practising and improving formative assessment techniques continually and relatively slowly. A common confusion with regard to formative assessment is that it is treated as "early-warning summative [assessment]" (Shepard, 2017, p. 2) and not as an assessment to inform teachers and learners on the learning progress as it occurs. Shepard (2017) states that for formative assessment to be effective, the information gained must be used immediately to adjust teaching decisions and allow learners to take responsibility for their own learning.

Leighton (2019, p. 794) suggests that formative assessment strategies must be continually evolved and improved as "assessment knowledge is not static". Hence, Mathematics teachers need to continually develop formative assessment practices to meet the needs of the learners and encourage learners to engage in mathematical thinking and reasoning more than trying to remember.

2.2.3. The importance of feedback within formative assessment

Throughout the literature, it is clear that the term feedback goes hand in hand with the practice of formative assessment and vice versa. "Feedback is critical for learning any new skill" (Chan, Konrad, Gonzalez, Peters, & Ressa, 2014, p. 97). Furthermore, "there is considerable research evidence to shows that effective feedback leads to learning gains" (Nicol & Macfarlane-Dick, 2006, p. 204). Thus, feedback from formative assessment practices should encourage learners to think and develop their conceptual understanding (Irons & Elkington, 2021).

Leighton (2019) defines feedback as any dialogue that takes place between the teacher and the learners that are designed to guide learners in identifying the gap between the knowledge that they currently possess and the desired knowledge, all while improving the learner's ability to learn. Thus, assessment is transformed into learning through the use of feedback (Watling & Ginsburg, 2019). In addition, Chan et

al. (2014, p. 96) describe feedback as “a vehicle for integrating all other components of formative instructional practices”.

Additionally, Taras (2005) argues that for assessment to be formative, feedback is required. Formative assessment requires feedback that is purposefully designed “to be descriptive, specific, and actionable to inform and motivate [learners]” (Leighton, 2019, p. 803). Watling and Ginsburg (2019) argue that feedback provided through formative assessment acts as a means to correct errors and confirm learners’ correct responses, which in turn, has a powerful influence on how learners learn. Havnes et al. (2012) state that feedback needs to be provided to encourage active participation and engagement from the learners. Chan et al. (2014) state that feedback needs to be provided immediately to address specific misunderstandings and provide a platform for learners to respond and act to remediate their errors.

In agreement, Rakoczy et al. (2019, p. 2) state that feedback provides a platform for learners to identify “whether or not they correctly applied the mathematical operations needed to solve the tasks” and, after that, informs learners about the discrepancy between their understanding and the desired level of understanding. Through guided feedback, learners can answer three significant questions regarding their learning: “Where am I going? How am I going? Where to next?” (Rakoczy et al., 2019, p. 3).

2.2.4. Nature, contextualisation and timing of feedback

Although feedback is argued to be a central characteristic of formative assessment, Owen (2016) emphasises the quality and usefulness of the feedback. In agreement, Black and Wiliam (2010) state that the quality of learning from formative assessment depends on the quality of the feedback. Quality-rich feedback guides learners in identifying what is expected of them to achieve the desired lesson outcomes. In addition, quality feedback aids in developing a learner's ability to practise self-assessment and, thus, take responsibility for their own learning (Owen, 2016). An important facet of quality feedback, as identified by Sadler (1998, p. 79) in his early research on formative assessment, is the “nature, contextualisation [and] timing”.

With regard to the *nature of feedback*, the basic and inherent features of the feedback should be to develop learners' conceptual understanding before moving on to a new concept. For example, before introducing learners to algebraic equations, a teacher must ensure that learners can perform the necessary calculations with algebraic like

terms. One possible way that a teacher can ensure this understanding, or at the very least gain insight into the learner's understanding, is by providing the learners with a small quiz on algebraic like terms. The feedback on the quiz should be aimed at gaining insight into whether or not the learners have grasped the concept of an unknown variable.

The feedback's *contextualisation* must be stated so that learners can grasp meaning from it and use the feedback to integrate various concepts. For example, when teaching learners how to solve for unknown angles in geometry-related questions, learners may not understand the significance of providing a statement and a reason that explains the validity of the statement. Thus, a teacher will need to provide feedback to guide learners in understanding why one cannot assume something to be true in geometry without sound reasoning.

Lastly, the *timing of feedback* is essential to its effectiveness. It is no use for a teacher to provide feedback to learners on their progress and understanding of a certain concept once they have begun a new one. For example, if a teacher begins a lesson discussing geometry of 2D shapes, providing feedback on a test previously written months ago on ratios will distract the learners from the new work at hand. Moreover, the learners will have little, if any, recollection of the test and their answers. Therefore, the timing of the feedback concerning ratios must be given immediately. By providing instant feedback, teachers and learners will be able to identify any misconceptions and rectify them as soon as they occur. Additionally, since formative assessment encourages socio-mathematical discourse within a lesson, teachers and learners can respond to emerging issues promptly and timeously. McCarthy (2017) argues that high-quality and timely feedback needs to be regularly implemented to develop and maintain an efficient socio-mathematical discourse within the mathematics classroom.

2.2.5. Quality of feedback

Black and Wiliam (1998) further claim that the heart of pedagogy lies within the quality of the feedback used. Literature and research have proven that learning and achievement are enhanced through quality feedback (Andrade & Valtcheva, 2009). Thus, Watling and Ginsburg (2019, p. 3) call on teachers to use feedback with “great care to fulfil its potential”.

Additionally, Wiliam and Leahy (2016) argue that quality feedback provides a structure for learners to take responsibility for their learning and thus moves learning forward. With quality feedback, mathematics teachers can practise scaffolding within the lesson and develop learning (McCarthy, 2017). In addition, Owen (2016) emphasises that constant scaffolding through continuous feedback is important for effective teaching and learning. Teachers can develop learning by helping learners set smaller, more achievable goals to meet the desired learning outcome (Chan et al., 2014).

For instance, to teach Grade 8 learners the concept of equations, the learners need to clearly understand additive inverses. Thus, through scaffolding, a teacher can break down the steps of solving an equation using explaining how to identify the additive inverse of certain variables. The teacher can encourage the learner to master the concept of additive inverses before attempting to solve an equation. Thus, at each variable in the equation, the teacher must provide constant feedback to the learners so that they may understand what is expected of them and thus develop their conceptual understanding.

Watling and Ginsburg (2019, p. 4) state that quality feedback is “timely, specific, actionable and task-orientated”. For instance, with a formative assessment task on the addition and subtraction of common fractions, learners may find it helpful to receive individualised feedback on their misunderstandings such as not identifying the correct lowest common denominator before adding or subtracting or not simplifying their answers fully. “Feedback has shown to improve learning when it gives each [learner] specific guidance on strengths and weaknesses” (Black & Wiliam, 2010, p. 87). Thus, feedback that teachers provide to the learners needs to be catered for a specific mathematical task and the needs of each learner (Black & Wiliam, 2010).

Nicol and Macfarlane-Dick (2006) describe quality feedback as feedback that offers opportunities to bridge the gap between the learners’ current level of understanding and the desired level and feedback that provides teaching information to teachers so that they may adapt their methods of teaching to enhance the teaching and learning process.

It is important to note that feedback is rich in quality and is effective, if it used to address specific misunderstandings of a certain concept as it arises. As stipulated by Hattie and Timperley (2007, p. 86), “the main purpose of feedback is to reduce

discrepancies between current understandings and performance and a goal." Essentially, feedback given must aim to guide learners to attain the desired learning outcomes of the lesson. It is for this reason that productive levels of feedback need to be taken into consideration. If feedback is provided poorly, (for example, the teacher provides feedback that is not contextualised to the nature of the current lesson), learners may feel demotivated to actively engage within the lesson (Kluger & DeNisi, 1996). Productive levels of feedback include feedback that is appropriate for different learners, who have different levels of understanding. Further, productive levels of feedback provide an indication to the learner of what can be done "to modify his or her thinking or behaviour for the purpose of improving learning" (Shute, 2008, p. 154).

Thus, with the use of productive levels of feedback, teachers are able to ensure that learners remain engaged and continue to participate in the lesson. Productive levels of feedback allow teachers to guide learners to set specific, obtainable and realistic goals as a means to close any gaps between their current understanding levels and the desired levels of understanding (Hattie & Timperley, 2007).

2.2.6. Interpretation of feedback

Moreover, teachers cannot simply provide feedback to learners and assume their role in the teaching and learning process is completed. According to Rakoczy et al. (2019), a teacher cannot assume that a learner will automatically know what to do or how to implement the provided feedback. Thus, the teacher's role, according to Black and Wiliam (1998), is to serve as a mediator between the learner and the body of knowledge and skills. This is because teachers generally have superior knowledge concerning the mathematical content on hand than their learners (Sadler, 1998). In support, Box, Skoog, and Dabbs (2015, p. 3) argue that the teacher brings forth a certain "set of personal theories or constructs, based on beliefs, values, forms of knowledge, experiences, and goals that have a profound effect on what and how they teach".

In order to promote active participation and fully engage with learners in the teaching and learning process, mathematics teachers need to gather evidence indicating how learners interpret the feedback provided (Leighton, 2019). Therefore, teachers must guide learners to interpret feedback effectively (Sadler, 1998). Leighton (2019, p. 794)

broadly defines learner interpretation of feedback as “generating meaning from an activity in order to inform action”.

For example, it is useless to simply tell a learner to identify the lowest common denominator before adding or subtracting a fraction and assume that the learner understands. Instead, the teacher needs to describe in detail to the learner how to identify the lowest common denominator using finding the multiples for each denominator and then discussing the importance of selecting the lowest common multiple between the two denominators. After the teacher has described how to identify the lowest common denominator, the learner must interpret what has been discussed and put it into practice to demonstrate conceptual understanding.

Thus, interpreting feedback forms part of the formative assessment process: teachers provide feedback on a specific task, followed by learners interpreting the given feedback and implementing the intervention suggested by the teacher. If this interpretation, and thus the implementation of the feedback, is done correctly, the teacher can conclude that learning has taken place and new knowledge has been attained. However, if no change in performance occurs, the teacher needs to provide higher quality feedback for the learner to interpret (Leighton, 2019).

The feedback should be given in words that the learners are already familiar with. Students must be able to easily relate the feedback with the concept being taught. For example, when introducing learners to the mathematical topic of the Theorem of Pythagoras, a teacher cannot immediately start referring to jargon related to the concept such as the hypotenuse, without relating the new terminology to words that the learners are already familiar with such as the longest side of a right-angled triangle. It is the teacher's responsibility to ensure that learners can relate to and appropriately use mathematical terminology.

However, with all the above being stated, it is important to note that feedback may not always be helpful and can tend to be harmful. Teachers should “refrain from over-whelming [learners] with too much feedback” (Chan et al., 2014, p. 99). Teachers are therefore encouraged to limit their feedback to the desired learning outcomes that were made clear to the learners as a means to focus their attention on what they are doing well and where they can improve (Chan et al., 2014).

2.2.7. Formative assessment as assessment for learning.

Formative assessment is commonly used interchangeably with the term assessment *for* learning (Black & Wiliam, 2003). Assessment *for* learning indicates what the learners are expected to learn with regard to the predetermined specific mathematics learning outcomes, how far they are with regard to meeting those expectations and what methods of teaching are best to facilitate learner attainment of the specified learning outcomes. Similarly, formative assessment is used to convey and communicate the expectancies of the learners in mathematics classes (Antoniou & James, 2014). Thinwiangthong et al. (2020) argue that "any kind of assessment that is designed to promote [learners'] learning is consider assessment for learning".

Assessment *for* learning proves to be the most natural assessment as it forms part of everyday teaching and learning, "it is the most commonly used type of assessment because it can be used in different forms at any time during a mathematics lesson" (Department of Basic Education, 2011, p. 154). Assessment *for* learning pertains to "the whole classroom practice" and is not implemented as a separate activity from the day-to-day teaching and learning process (Andersson & Palm, 2017).

Furthermore, Black (2015) states that by using assessment *for* learning, a teacher can guide learners to learn how to learn. *Assessment for learning* places emphasis on learner involvement with their own learning. By involving learners in the various assessment activities and sharing the learning objectives with them, teachers can guide learners to improve their learning (Ninomiya, 2016).

Similar to formative assessment, assessment *for* learning encourages learners to learn for understanding, which in turn, "facilitates the likelihood of transfer [of knowledge] to new settings and contexts" (Owen, 2016, p. 169).

Baleni (2015) argues that the two terms may be used interchangeably because the assessment *for* learning and formative assessment takes place within the teaching and learning process, and both have the primary purpose of improving, developing and supporting learning. Formative assessment and assessment *for* learning are both types of assessment that promote thinking and learning (Keeley & Tobey, 2011). Additionally, Thinwiangthong et al. (2020, p. 105) state that both formative assessment and assessment *for* learning promote reflection on learner's learning and methods of

teaching while providing a platform for both teachers and learners “to see their learning paths in a positive way”.

However, Black and Wiliam (2003) argue that there is a slight distinction between the two terms. The difference lies in how to use the information gained from the assessment. “Assessment intended to promote learning only becomes formative when evidence is actually used to adapt teaching work to meet learning needs” (Antoniou & James, 2014, p. 155).

2.3. Elicitation questioning techniques during formative assessment

Because, formative assessment is primarily used as a means to gather information on learners' understanding of mathematical content (Department of Basic Education, 2011), various methods such as questioning techniques, have to be used by teachers to evoke engagement, critical thinking and responses from the learners. However, it is important to note that questioning techniques implemented by a teacher are used to prompt learner engagement and should contain more elicitation questioning techniques than declarative questioning techniques (Gotwals & Birmingham, 2016).

2.3.1. Elicitation questioning techniques

Elicitation questioning techniques are used to encourage learners to think and discuss their levels of understanding. For example, when teaching the concept of types of angles caused by a transversal cutting parallel lines in geometry, instead of simply performing the calculation on the board for the learners, a teacher may ask learners to discuss in groups all the possible methods to arrive at a solution and then ask the learners to demonstrate on the board at least two methods that will provide the correct solution. In contrast, declarative questioning techniques do not allow learners to explore their own reasoning but rather have either a right or wrong method to arrive at a solution.

According to Rakoczy et al. (2019), elicitation questioning techniques must meet certain criteria to obtain reliable and valid insight into learner learning. In addition, Singh et al. (2018) argue that to elicit learners' mathematical thinking and problem-solving skills, learners need to be exposed to various exercises, activities and problems that require an integration of mathematical concepts to arrive at a logical

solution. Evans et al. (2013, p. 6) claim that implementing a variety of formative assessment elicitation techniques in a learning environment is beneficial for learners as they do not “get overly used to just one type of assessment, and so that all [learners are] able to find an assessment that [is] useful in their learning”.

A variety of elicitation techniques are suggested throughout the literature. To mention a few, Boston (2002) suggests: inviting learners to participate in small group discussions over a concept; asking learners to vote on a correct answer among several provided; briefly testing learners' understanding before a new mathematical concept is taught and after; asking learners to summarise the main points of discussion that took place within the lesson and individually asking learners questions as they solve problems. The Department of Basic Education (2011) elaborates further by stating that simply pausing during a lesson to observe and discuss with learners how the learning is progressing serves as a beneficial elicitation technique.

Additionally, informal class tests and homework can be used as formative assessment forms (Boston, 2002). Homework and informal class tests are used to consolidate any new learning that has taken place within a lesson, and a teacher who analyses and points out specific individual errors in a learner’s work is a teacher who can guide learners on ways to improve their understanding. It is for this reason that frequent informal testing is encouraged. After each new mathematical concept is taught and learnt, teachers should take the time within lessons to conduct small informal class tests to gain insight into learner understanding. These informal class tests provide a sense of certainty for both the learners and the teachers (Martinez & Martinez, 1992).

2.3.2. Quality of questioning

Teachers must carefully consider the questions they wish to pose to their learners and decide on questions that lend themselves well to encouraging learners to use their critical thinking and problem-solving skills. Essentially, teachers must pose quality questions with a specific purpose. Thinwiangthong et al. (2020, p. 107) list three indicators of question quality: “open-ended questions, Bloom’s hierarchy of cognitive learning levels and prior knowledge”. Open needed questions are posed so that learners are encouraged to explore various correct or incorrect responses and develop their own arguments based on their problem-solving skills. Questions of Bloom’s hierarchy of cognitive learning levels include questions requiring learners to remember

facts, basic methodologies and calculations, understand how concepts work, apply various steps and calculations, analyse various possible methods to arrive at a correct solution and evaluate their solutions and problem-solving skills. Lastly, questions of quality for mathematics require learners to integrate their prior knowledge of concepts with the new work taught to arrive at a logical solution.

Additionally, quality questions should require the learner to use their prior knowledge to compose a logical solution. When addressing prior knowledge, learners can relate the old work with the new work, improving conceptual understanding and mathematical thinking, and leading to significant learning gains (Black & Wiliam, 1998). Evans et al. (2013) further state that when learners are required to create links from their prior knowledge to the desired knowledge, active participation is a necessity. When learners actively engage with the content, they can "construct their own knowledge and skills" (Nicol & Macfarlane-Dick, 2006, p. 200).

2.3.3. Interactive dialogue

Black (2015, p. 171) claims that through formative assessment strategies such as interactive dialogue, teachers can encourage learners to be "independent, responsible and effective learners". Moreover, for interactive dialogue to flourish, there needs to be active interaction between the teacher and the learners. Teachers should aim to guide learners with the questions and points for discussion as a means to steer them towards the intended learning outcomes. At the same time, learners provide an indication of their understanding with responses that are either expected or unexpected (Black, 2015). Teachers should be prepared to use these expected or unexpected responses to engage learners to actively participate in the dialogue and encourage learners to use mathematical reasoning and critical thinking to find a suitable solution.

Furthermore, the dialogue in a classroom should not be one-sided, whereby questions are only from teachers, learners should be encouraged to ask questions frequently on the topic (Garnett & Tobin, 1989), and thus, socio-mathematical discourse may take place effectively. Black (2015) argues that a learner's capacity to learn is deeply developed through interactive dialogue. Through interactive dialogue, learners become encouraged to act on the feedback provided while becoming more engaged

within the lesson and, therefore, take responsibility for their own learning (Wiliam & Leahy, 2016).

2.4. Creating a learner-centred learning environment through formative assessment

Wiliam and Leahy (2016) claim that the practice of formative assessment within a mathematics class is a profound change in Mathematics Education, as formative assessment provides a platform to shift Mathematics Education from teacher to learner-centred. Formative assessment promotes learners' "spirit of curiosity and love for Mathematics" (Department of Basic Education, 2011, p. 8). Formative assessment practices focus on classroom assessment, learner interaction and understanding, all of which "make a strong contribution to the improvement of learning" (Black & Wiliam, 1998, p. 7) and aims to develop learners' "deep conceptual understandings in order to make sense of Mathematics" (Department of Basic Education, 2011, p. 8). Additionally, Van der Nest et al. (2018) claim that formative assessment practices promote learner engagement and thus, a deeper insight can be gathered. In support, Thinwiangthong et al. (2020, p. 127) confidently claim that "formative assessment is able to improve the quality of education in the classroom".

Therefore, through formative assessment practices, teachers can learn from their learners. They are able to gain insight into how learners go about solving problems, "how they argue, evaluate, create, analyse and synthesise" (Sadler, 1998, p. 81). Moreover, van Halem, Goei, and Akkerman (2016) identify the first step to shifting focus to be learner-centred is through formative assessment practices whereby both the teacher and the learners can assess the current situation in terms of what knowledge the learners possess and what knowledge they are expected to acquire. An "analyses of [learners'] learning status are essential for" a learner-centred environment and for formative assessment practices to be effective (van Halem et al., 2016, p. 315)

Formative assessment, unlike other types of assessment, focuses on the continuous improvement and development of learner understanding. For this reason, Wiliam and Leahy (2016) state that formative assessment is centred around learner engagement and conceptual understanding. Moss and Brookhart (2019, p. 1) claim in support that effective implementation of formative assessment can "significantly raise [learner]

achievement and improve teacher effectiveness". One reason for this significant rise is that formative assessment practices encourage learners to continuously "reveal uncertainties in their understanding" (Andersson & Palm, 2017, p. 14).

2.4.1. The learner's role in formative assessment

The learners' role in formative assessment is an essential but frequently overlooked aspect. It is often hidden and taken for granted even though it plays a significant role (Black & Wiliam, 1998). Black and Wiliam (2010, p. 85) state that it is the learner who is "the ultimate user of [formative] assessment information that is elicited in order to improve learning". The role of the learner "distinguishes formative assessment from most other types of assessment" (Box et al., 2015, p. 3).

However, Tunstall and Gipps (1996) report that learners themselves do not see the potential helpfulness of formative assessment. The primary goal of formative assessment is centred on the learner; to improve learners' mathematical thinking and reasoning.

However, learners' ability to learn can only be developed through formative assessment practices if the learners can identify the areas that need improvement (Evans et al., 2013). According to Thinwiangthong et al. (2020, p. 107), mathematics teachers need to inform their learners of the desired learning outcomes, as a means to "get the [learners] to understand the direction of the learning".

One of the fundamental activities of formative assessment is to guide learners in establishing their level of understanding compared to the desired level. Evans et al. (2013) claim that learners need to be familiar with the desired lesson outcomes, informed about gaps in their knowledge and receive feedback to guide their learning through formative assessment.

Using formative assessment, learners are guided into taking remedial action and responsibility for their learning (Black & Wiliam, 1998). However, it is important to note that learners cannot always identify and close the gap in understanding single-handedly. The teacher must guide learners using identifying learners' specific errors and providing suggestions to correct said errors (Black & Wiliam, 1998).

2.4.2. Learners' attitudes towards formative assessment

Formative assessment is, therefore, "important as it allows learners to learn from, and reflect on their own performance" (Department of Basic Education, 2011, p. 155). Additionally, formative assessment serves as a means to motivate learners to learn (Evans et al., 2013). Learners can retain newly taught information if they are stimulated, motivated and entertained (Evans et al., 2013) while actively participating in the teaching and learning process. This, in turn, depends entirely on the attitude and motivation of the learners (Black & Wiliam, 1998).

Learners' attitudes and motivation depend on the nature of the classroom, the interaction and the learning process. When fun elements are incorporated into the teaching and learning process, a shift in learners' attitude and motivation occurs, where learners' feelings of stress and anxiety are reduced (Evans et al., 2013). Thus, it is of utmost importance that the teacher avoids negative and discouraging comments and feedback, which can often be seen and understood by the learner as "personal criticism" (Sadler, 1998, p. 84). In addition, Leighton (2019, p. 798) states that feedback in the form of formative assessment must be provided in such a manner that learners "understand, trust and are motivated to implement [it]".

The self-perception of a learner is a significant aspect to consider when creating a learner-centred environment. Learner-centred environments are created when the teachers believe that the learners can achieve (Black & Wiliam, 2010). Box et al. (2015) claim in support that when a teacher demonstrates clear support and encouragement in the learners' capabilities, learner-centred teaching and formative assessment techniques flourish. This is especially important to note when engaging with learners, as feedback provided through formative assessment must aim not to threaten the self-esteem of the learners (Watling & Ginsburg, 2019).

However, Blumenfeld (1992) notes in his review on *Classroom Learning and Motivation* that learners are reluctant to ask for help and tend to consider extra assistance to be indicative of their lack of understanding. For this reason, teachers must encourage learners to seek help when needed (Newman & Schwager, 1995) and participate actively in the teaching and learning process.

Competition and comparison between learners defeat the purpose of a learner-centred environment. Teachers must use formative assessment practices to shift the learners'

focus from competition of grades to personal improvement and development (Black & Wiliam, 2010). Wiliam and Leahy (2016, p. 9) argue that when implemented effectively, formative assessment shifts learner conversation from their grade levels to their "understanding about what they need to do specifically in terms of knowledge and/or skills".

Furthermore, any feedback provided by the teacher must not be ego-involved (Black & Wiliam, 1998). Despite their grade levels, all learners should be correctly praised and encouraged through formative assessment. The key word being 'correctly', teachers should not praise behaviour that is not linked to the desired goals of the lesson as this could lead to a derailment of the objectives of the teaching and learning process (Black & Wiliam, 1998).

2.4.3. Learners' responses to formative assessment

Creating a learner-centred environment through formative assessment often falls short, as teachers cannot fully carry out the formative assessment process. For instance, when engaging learners in socio-mathematical discourse, learners may respond with unexpected and incorrect answers, and how the teacher responds to these answers is critical to the development of the learner (Black & Wiliam, 2010). If the teacher simply moves past an incorrect answer and does not address the misunderstanding, the learner who offered a solution will be less likely to actively participate for the remainder of the lesson.

Academically weak learners are another challenge in creating a learner-centred environment through formative assessment. Academically weak learners tend to have insufficient motivation or desire to complete the required work, and thus, "it makes it hard to help them, because [the teacher does] not know how much they have understood" (Havnes et al., 2012, p. 25). These types of learners do not respond to the provided feedback and so do not take action to remediate their errors and improve their level of understanding.

However, Havnes et al. (2012) note in their study that sometimes academically weak learners do not follow up on the provided feedback because the teacher does not guide the learners to interpret the usefulness of the feedback and simply moves on to the next topic. Additionally, teachers "do not wait long enough for [learners] to think out their answers" (Black & Wiliam, 2010) and instead provide the answer a few

seconds after having posed the question. This type of behaviour leads learners to believe that their answers will inevitably be incorrect, and the teacher will move on to the next question. Thus, learners tend not to bother to fully think out a reasonable solution (Black & Wiliam, 2010). Black and Wiliam (2010) argue that any form of formative assessment that takes place within a lesson should be interactive, whereby thoughtful reflection by the learners is evoked and required.

2.4.4. Challenges of creating a learner-centred environment

The classroom experience for learners should be a fertile platform for them to develop and improve upon their own levels of conceptual understanding. A learner-centred environment should actively involve the learners in socio-mathematical discourse and demonstrate “real-world professional settings” (Baleni, 2015, p. 229).

However, implementing formative assessment practices effectively can be seen as challenging. Black and Wiliam (1998) note that teachers battle to find time to allow learners to discover and take responsibility for their own learning. This battle can be attributed to teachers not understanding the role of learners with formative assessment practices (Black & Wiliam, 1998) and the demanding pressure placed on a teacher to complete the curriculum in time for summative assessments. When teachers face time challenges, learning gains are minimal as learners do not participate in interactive dialogue and are thus not engaged in critical thinking.

2.5. Explication of the Lesson Study cycle

2.5.1. Origin and globalisation of Lesson Study

The teaching and learning process differs from one country to another, with each country’s education being shaped by its own “cultural scripts, beliefs and assumptions about how to engage [learners] with subject content” (Elliott, 2019, p. 177). An influential aspect of a country’s education is the form in which teacher development takes place. Lomibao (2016) states that the quality of the teaching and learning process depends on the teacher's quality, so improving teacher development practices is a key element in improving learner understanding.

One of the most widely acclaimed teacher development practices that were developed decades ago in Japan and have since gained international attention is known as

Lesson Study (Murata, 2011). Fernandez (2002, p. 294) states that The Japanese Lesson Study is a “systematic inquiry into teaching practice”. Furthermore, Norwich et al. (2014, p. 1) state that the Lesson Study cycle “examines and develops a series of lessons on a chosen [mathematical] topic as a form of professional development”. In agreement, Thinwiangthong et al. (2020) state that Lesson Study is used to improve teaching practice. Additionally, Van der Walt and de Beer (2016, p. 558) claim that through the practice of Lesson Study, teachers are able “to improve their lessons through critical reflection.”

According to Sekao and Engelbrecht (2021), this systematic inquiry consists of five consecutive and iterative stages. Namely diagnostic analysis, collaborative lesson planning, lesson presentation and observation, post-lesson reflection and lesson improvement. Throughout these stages, teachers are encouraged to learn from one another’s teaching experiences and improve on the general standard of the teaching and learning process (Fernandez, 2002).

In support, Elliott (2019) states that the Lesson Study cycle aims to shift educational focus from teachers in the classroom to the actual teaching and learning. Lewis, Perry, and Hurd (2004) claim that teachers’ knowledge of mathematical content, methods of teaching and ability to gain insight into learner thinking and reasoning is increased through the implementation of Lesson Study. Furthermore, Lesson Study is beneficial to pre-service teachers. The practice of Lesson Study can boost pre-service “teachers’ self-confidence, their pedagogical content knowledge and their understanding of the value of working collaboratively” (Van der Walt & de Beer, 2016, p. 562).

In agreement, Elliott (2019) states that for the implementation of Lesson Study to be fully successful, the teachers involved must aim to develop their own overall mathematical knowledge and not simply perfect one lesson. Lesson Study requires teachers to “think differently about teaching and learning”(Van der Walt & de Beer, 2016, p. 563). Therefore, it is important to note that the entire Lesson Study cycle cannot be completed in a matter of hours but should span over several weeks (Takahashi & McDougal, 2016). However, Lewis et al. (2004) state that through Lesson Study, readily available and high-quality lesson plans are produced.

2.5.2. The Lesson Study cycle in South Africa

According to Sekao and Engelbrecht (2021), implementing Lesson Study in South Africa is a relatively novice practice used to improve the teaching and learning process. However, due to the powerful impact of Lesson Study, many schools in South Africa have begun to implement it in a variety of subjects to create a learner-centred learning environment. Figure 2, as presented by Sekao and Engelbrecht (2021), depicts the process of the Lesson Study cycle practised in South Africa.

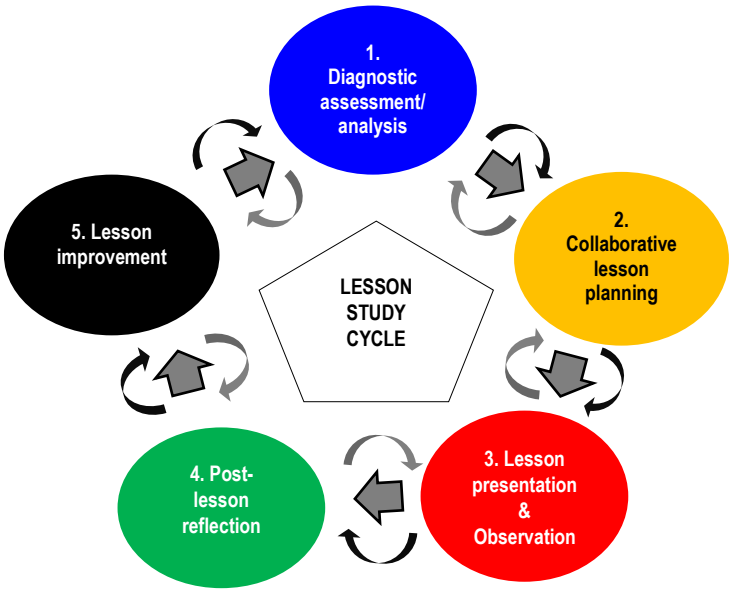

Figure 2: Lesson Study Cycle (Sekao & Engelbrecht, 2021)

The Lesson Study cycle begins with the crucial phase of Diagnostic Assessment/Analysis. In this stage, the teachers respond to a learning area that tends to present common learner misunderstandings (Sekao & Engelbrecht, 2021). These misunderstandings are identified from information received from a previous assessment. Teachers involved in the Lesson Study use the information gained to identify a specific learning outcome they want to achieve through some form of informed teaching. It is within this stage that teachers can identify what knowledge they want their learners to gain, and how they plan on developing learners' mathematical thinking and provide “insight into both subject matter and how [learners] think in relation to it” (Elliott, 2019, p. 184).

Once the teachers have identified what they want to plan a lesson around, they begin with Stage 2, Lesson Planning. Within this second stage, the teachers collaboratively

plan the various aspects of the lesson. Sekao and Engelbrecht (2021) suggest that teachers should collaboratively generate “different methods and strategies” for achieving the desired lesson outcomes. Stage 2 of the Lesson Study requires teachers to individually contribute to the lesson planning by adding their personal experiences on the identified topic (Sekao & Engelbrecht, 2021). Various perspectives on how to most effectively teach the topic are created by doing so.

After collaboratively planning the lesson, the lesson is conducted “by one of the [teachers] and [is] directly observed by the rest” (Norwich et al., 2014, p. 2) in Stage 3, Lesson Presentation and Observation. The planned lesson is taught at an agreed-upon time, place and date (Sekao & Engelbrecht, 2021). The teachers observing the lesson are provided with an observation sheet to document any key takeaways from the lesson (Sekao & Engelbrecht, 2021). Essentially, the observation sheet allows the observers to note what worked well in terms of learning thinking and engagement and what requires refining for future practices.

Once the lesson has been taught, the teachers involved once again gather for Stage 4 of the Lesson Study cycle, post-lesson reflection. During this stage, the teachers share their perspectives on the lesson (Sekao & Engelbrecht, 2021). The teachers reflect on whether or not the learning outcome identified in stage two was achieved. They discuss what aided in the achievement of the learning outcome and what could be improved upon for the next lesson (Sekao & Engelbrecht, 2021). Norwich et al. (2014) state that reviewing the lesson can provide insight into the learners’ perspective on the lesson.

In the last stage of the Lesson Study cycle, Stage 5 Lesson Improvement, the teachers use all the insight gained from the post-lesson reflection to improve the lesson (Sekao & Engelbrecht, 2021). At this point, the Lesson Study cycle repeats itself and begins at stage 1, with another identified learning area that needs attention.

2.5.3. Exploring formative assessment in Lesson Study

From the above mentioned, Stage 2 of the Lesson Study cycle: collaborative lesson planning provides a suitable platform for teachers to plan effective formative assessment that encourages learner engagement. Within this stage, the teachers meticulously plan every detail of the lesson to be taught (Fernandez, 2002).

Norwich et al. (2014, p. 2) argue that during the collaborative lesson planning stage of the Lesson Study cycle, “pedagogic questions are addressed”. The teachers involved in planning the Lesson Study ensure that the formative assessment to be used within the lesson will elicit learner responses indicating what has been understood and what needs to be retaught. Fernandez (2002) states that the teachers must ensure that questions they wish to pose to their learners must be purposeful and rich questions that aim to develop learners' conceptual understanding of the mathematical content at hand. Furthermore, teachers must plan for the type of feedback they will use to answer both expected and unexpected questions from the learners.

Takahashi and McDougal (2016, p. 514) argue that collaboratively planning a lesson and the formative assessment practices to take place thereof aids in “transforming traditional teacher-centred instructional practice to [learner]-centred instruction that focuses on mathematical thinking and problem solving”. Additionally, Verhoef, Tall, Coenders, and Van Smaalen (2014, p. 1) state that implementing formative assessment in the Lesson Study cycle results “in changes in the teachers’ educational goals and instructional strategies in relation to [learner] understanding”.

The formative assessment practices that the teachers purposefully designed to use within the lesson provide a platform for learners to actively participate and “engage with the content of the lesson by asking questions, expressing their points of view, proposing and testing solutions to problems posed by the content and reflecting about possible errors in their understanding” (Elliott, 2019, p. 179).

Thinwiangthong et al. (2020) conclude in their study on *Mathematics Teachers’ abilities in developing Formative Assessment* that mathematics teachers should use Lesson Study as a platform to develop and improve their formative assessment practices.

However, as previously discussed, since Lesson Study is a relatively novice teacher development practice in South Africa, Fernandez (2002, p. 398) points out “finding time and interest for Lesson Study” may be a challenge. Furthermore, Takahashi and McDougal (2016) state that even the teachers who attempt to implement Lesson Study cannot succeed due to the lack of exposure to it. Furthermore, Van der Nest et al. (2018) put forward the idea that teachers in South Africa do not receive sufficient

teacher-development training, especially regarding formative assessment and how to implement it effectively and promptly.

2.6. Theoretical framework

My study is based on the theoretical underpinnings of Situated Learning Theory, presented by Lewis et al. (2009) and the Formative Assessment framework presented by Antoniou and James (2014). Due to the ever-changing and fast-paced nature of the 21st Century, mathematics teachers need to be adaptable and willing to learn new ways of teaching (Goldsmith, Doerr, & Lewis, 2014). Lesson Study addresses this need for adaptiveness by encouraging teachers to work collaboratively in the school or classroom environment (embedded in practice) to improve the entirety of the teaching and learning process. Through the lens of Situated Learning Theory, teachers are encouraged to actively participate in their teaching community (Lewis et al., 2009). Through participation and collaborative work, teachers are exposed to other teachers' different perspectives, opinions and teaching pedagogies (Lewis et al., 2009). Fox (1997) argues that Situated Learning Theory shifts educational practices from the traditional notion of thinking about learning to be placed directly in the learning situation. In other words, authentic contexts provide a better platform for learning, and concerning teachers, job-embedded or situated teacher development programmes provide effective learning (Darling-Hammond, Hyler, & Gardner, 2017). Essentially, instead of simply informing teachers on what to do, both Lesson Study and Situated Learning Theory emphasise the significance of teachers being actively involved in the teacher development process. This involvement makes knowledge about different ideas and learners' mathematical thinking more visible to the teachers (Lewis et al., 2009). In addition to contributing to and developing one another's knowledge, skills and values, Lesson Study and Situated Learning Theory provide a fertile platform for teachers to improve upon future teaching decisions.

Therefore, to develop learners' mathematical thinking and conceptual understanding, teachers need to develop their own way of thinking and hence teach by collaboratively participating in teacher development practices whereby they are exposed to various new and different pedagogies and ideas. Within the collaborative participation, teachers are exposed to the significance of formative assessment practices and the

tenets thereof to ensure that learners are mastering the content taught to them while addressing any misunderstandings.

In addition to the Situated Learning Theory, the Formative Assessment framework (Antoniou & James, 2014) guided my study (Figure 3) in terms of answering the research questions. This framework consists of five sequential processes that play a significant role in the formative assessment process.

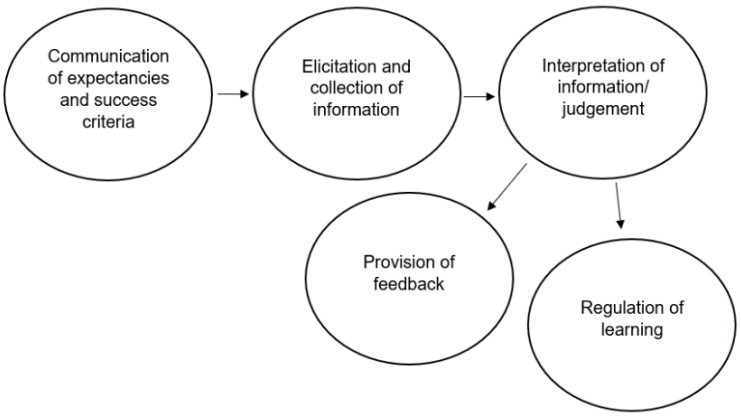

Figure 3: Formative assessment framework (Antoniou & James, 2014)

In agreement, Leenknecht et al. (2021) state that formative assessment can be viewed as a series of interrelated processes, namely teachers eliciting responses from learners, learners responding to teachers and teachers after that, using the information gathered from learners' responses, to enhance future teaching decisions and develop learner understanding. Thus, the different sequential processes of the Formative Assessment framework (Antoniou & James, 2014) all aim to inevitably lead to the development of learner thinking and understanding. Figure 4 provides an overview of how the processes stipulated within the Formative Assessment Framework (Antoniou & James, 2014) are implemented. Within the first process, teachers are expected to communicate the desired learning outcomes to the learners and provide a roadmap to attain them. The second process entails the teachers' eliciting responses from the learners and gathering insight on how the learners are progressing in terms of attaining the desired learning outcomes. The insight gathered assists teachers within the third process in interpreting the learners' conceptual understanding level and indicating what to do next. This question can be answered in one of two ways; either regulate learning or provide feedback, both of which constitute the fourth and fifth processes, respectively. The regulation of learning requires teachers to improve on future

teaching decisions to enhance the teaching and learning process while providing feedback. On the other hand, it constitutes the teacher providing specific, timely and meaningful feedback to the learners. My study follows the process of providing feedback to learners to deepen their levels of understanding.

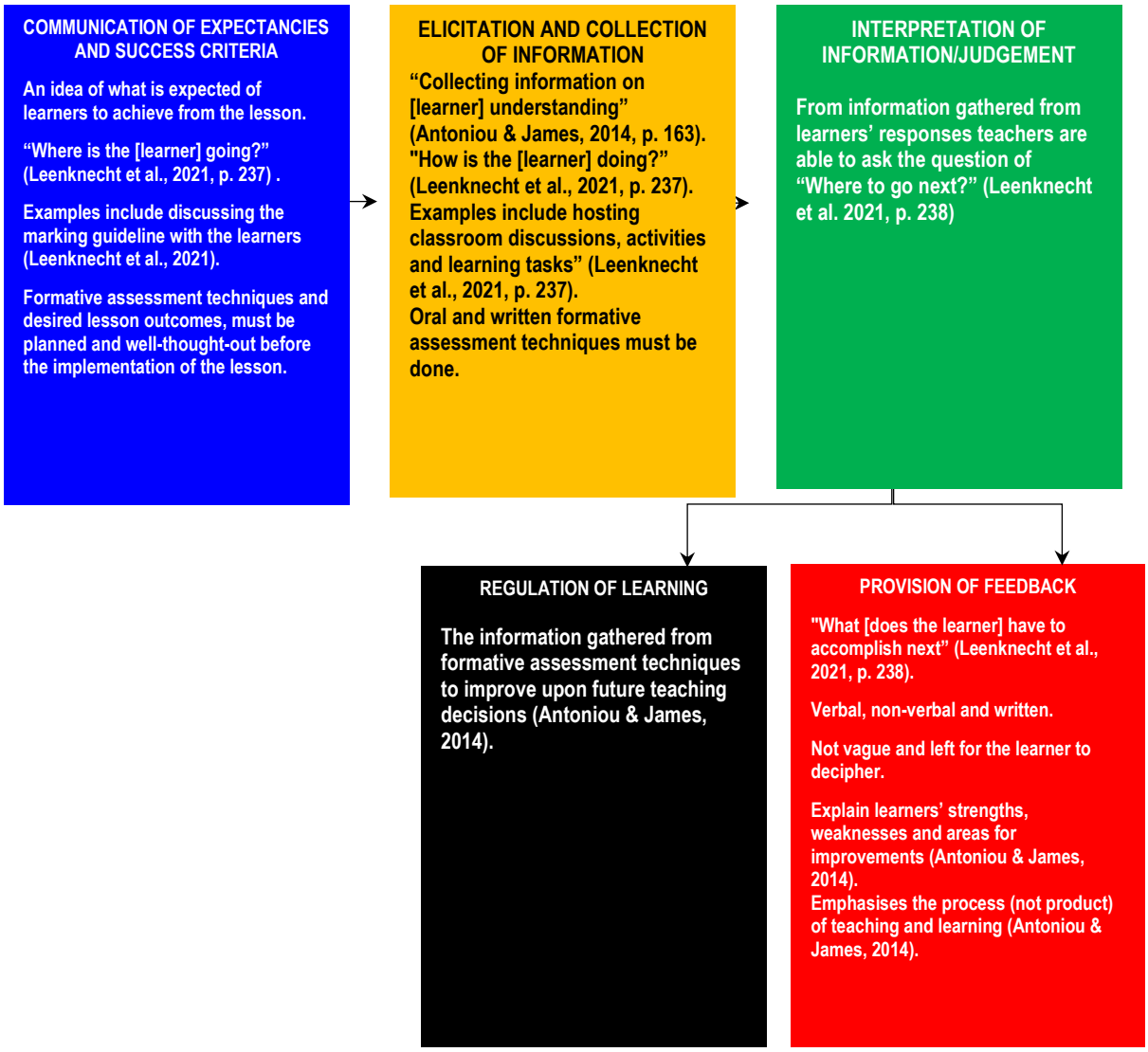

Figure 4: Key aspects of the formative assessment framework (adapted from Antoniou & James, 2014)

It should be noted that Lesson Study provides the context of my study, which is located within the Situated Learning Theory. Therefore, through Figure 5, I have demonstrated how the Formative Assessment framework (Antoniou & James, 2014) finds expression in the Lesson Study cycle and how each section is expected to assist me in responding to my research questions.

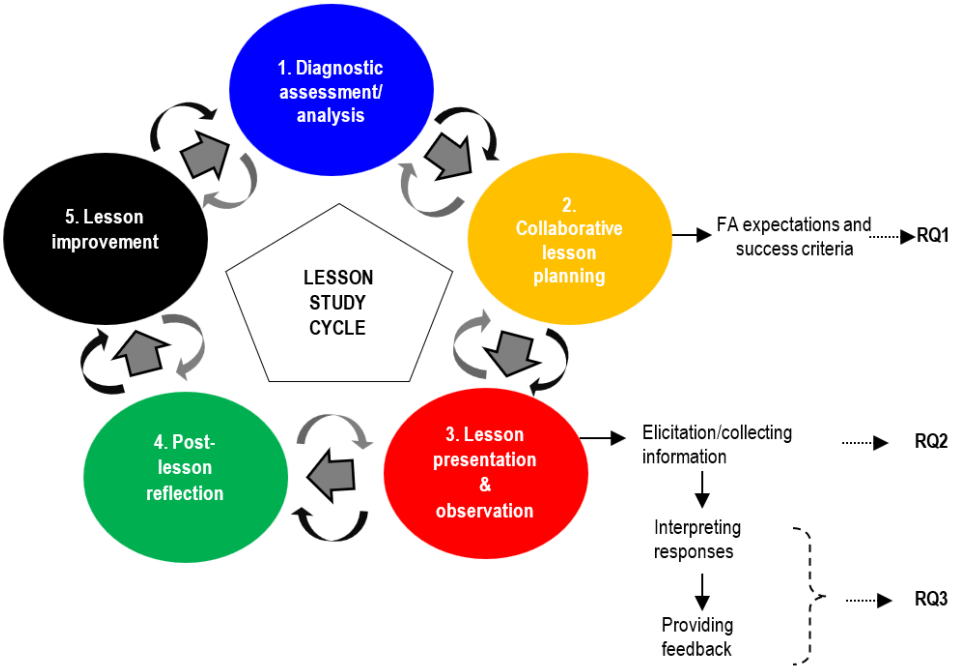

Figure 5: Embedding the Formative Assessment framework in the Lesson Study cycle

Although teachers followed the entire Lesson Study cycle, my interest was the *Collaborative lesson planning* stage and *Lesson presentation and observation* stage, in which formative assessment features eminently. Within these two stages, I gathered insight on how three Grade 8 Mathematics teachers planned to use formative assessment techniques, implemented formative assessment techniques, and used formative assessment to develop learner conceptual understanding through feedback.

Within Stage 2 of the Lesson Study cycle (Collaborative lesson planning), the first process of the Formative Assessment framework (Antoniou & James, 2014) guided my study in terms of answering the first secondary research question: *How do mathematics teachers collaboratively plan formative assessment during the Lesson Study cycle?* The first process of the Formative Assessment framework (Antoniou & James, 2014) describes the significance of communicating the expectancies and success criteria to the learners, as seen in Figure 4.

For learners' mathematical thinking and conceptual understanding to be developed, teachers need to ensure that they discuss what they expect the learners to achieve by the end of the lesson and plan the various forms of formative assessment techniques to gain insight into learners' understanding.

While all five processes of the Formative Assessment framework (Antoniou & James, 2014) guided my study, within Stage 3 of the Lesson Study Cycles (Lesson presentation and observation), I placed focus on only three steps from the Formative assessment framework to answer two of my secondary research questions. The second step of the framework, *Elicitation and collection of information*, guided me in answering my second secondary research question: *In what ways do mathematics teachers use formative assessment to facilitate mathematics learning?* With the guidance of the second step of the theoretical framework, I gathered insight into how the teacher presenting the lesson collected information on learner understanding and encouraged socio-mathematical discourse during teaching. Furthermore, I identified key takeaways of formative assessment practices such as oral and written formative assessment.

The third step of *Interpretation of information/judgement* and the fourth step of *Provision of feedback* assisted me in answering my third secondary research question: *How do teachers provide meaningful feedback to learners?* Within the third step, I gained insight into how teachers can identify gaps in the learners understanding from the information gathered from the various formative assessment techniques implemented. Following the third step, I gained insight guided by the fourth process, whereby teachers explain to the learners with regard to their strengths, weaknesses and areas of improvement.

It is from the context of Lesson Study, located within the Situated Learning Theory, and processes of the Formative Assessment framework (Antoniou & James, 2014) that I was able to answer my primary research question: *How do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 mathematics class*. Essentially, the framework assisted me in identifying key takeaways of the theoretical Formative Assessment framework (Antoniou & James, 2014) within the context of Lesson Study in a real-life setting.

2.7. Summary

Formative assessment has clearly received abundant attention over the years, and more is still to be researched and discussed. When implemented effectively, teachers can develop learners' problem-solving skills, mathematical thinking and conceptual understanding of mathematical content. Through the use of feedback, teachers are able to identify existing gaps in the learners' level of understanding and provide the necessary support to close said gaps. Learners also benefit from effective feedback, especially when they receive feedback that is specifically catered for them and for the task at hand. Further, formative assessment creates learner-centred learning environments and shifts the focus of Mathematics Education from teacher talk to engaging learners in socio-mathematical discourse. Finally, although Lesson Study is a relatively novice professional development practice in South Africa, it provides a fertile context for formative assessment to flourish within, for both teachers and learners.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

The metaphor informs the structure of this methodology chapter of the 'Research Onion' presented by Saunders et al. (2019). This metaphor presents six layers characterising the attributes of research methodology. The layers of the research onion peeled from outside to the centre include the research philosophy, research approach, methodological choice, research strategy, time horizon, and research techniques and procedures (Figure 6). I have explained and contextualised all these attributes for my study in the next section guided by Saunders et al.

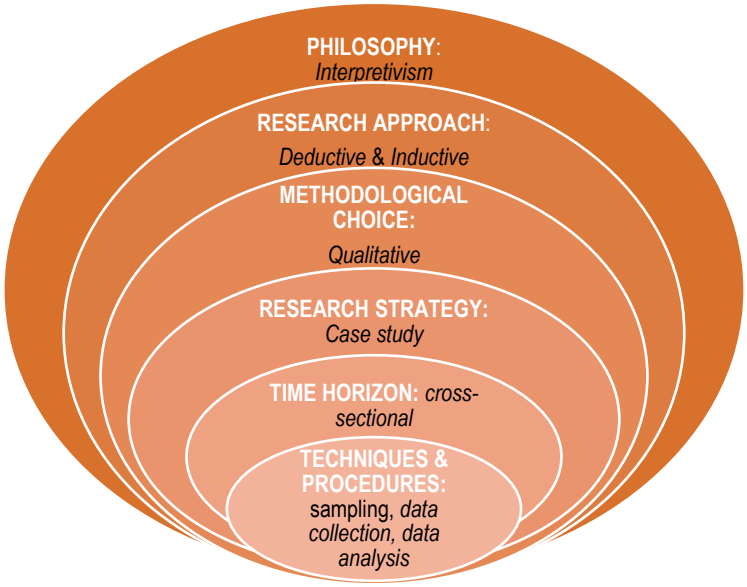

Figure 6: Research onion (Adapted from Saunders et al., 2019)

3.2. Research Philosophy

The epistemological paradigm that underpins my study is interpretivism. Ryan (2018) claims that truth and knowledge are subjective under the lens of interpretivism. In support, Maree (2016) states that interpretivism focuses on subjective experiences. Additionally, Maree (2016, p. 60) states that interpretivism "emphasises the ability of the individual to construct meaning". Therefore, the social world is constructed by how people interact, relate and share meanings (Maree, 2016). Because my study examined how three Grade 8 mathematics teachers used formative assessment within the context of Lesson Study to facilitate the teaching and learning process and to

develop learners' conceptual understanding, mathematical thinking and problem-solving skills, interpretivism provides a fertile platform to develop a richer understanding of the concept at hand.

From an interpretivist point of view, "knowledge and meaning are acts of interpretation" (Antwi & Hamza, 2015, p. 218). Therefore, I used interpretivism as a platform to explore how the teachers planned to use formative assessment; and how they implemented formative assessment and provided meaningful and timely feedback to learner responses. According to Antwi and Hamza (2015), interpretivism is underpinned by observing real-world events and interpreting the information gathered. Maree (2016, p. 61) states that "by observing people in their social contexts, there is greater opportunity to understand the perceptions they have" of formative assessment practices.

Thus, through interpretive research, my study focused on the participants' subjective experiences (Antwi & Hamza, 2015). Interpretivism provided a frame of reference for me to understand the participants' perspectives and practices in formative assessment (Thanh & Thanh, 2015). However, one aspect of the interpretivist tradition that I had to be mindful of was that multiple realities exist since dissimilar people perceive and interpret different phenomena differently. According to Maree (2016), under the lens of interpretivism, there are multiple explanations of a certain phenomenon. Therefore, in the Lesson Study context, I explored the shared meaning that the mathematics teachers attached to formative assessment.

3.3. Research approach

I made use of deductive and inductive analysis to analyse my data. Deductive analysis was used to determine whether or not the stipulations stated in my conceptual framework applied to the specific instance of Grade 8 mathematics teachers' formative assessment practices within the context of Lesson Study. After that, the findings of the data, which were not stipulated in my framework, were analysed inductively as a means to further build on my conceptual framework.

3.4. Methodological choice

Since the purpose of my study was to “create new, richer understandings and interpretations” (Saunders et al., 2019, p. 149) of teachers’ formative assessment practices in Grade 8 mathematics lessons, a qualitative method was chosen. According to Maree (2016), qualitative research provides a fertile platform to explore the perceptions of the participants and thus, generate knowledge. In addition, Athanasou et al. (2012) state that qualitative research is conducted in natural settings, such as the day-to-day activities within a classroom. Due to the nature of the participant's subjective and socially constructed perspectives as advocated by Lesson Study, which undergirds the interpretivist tradition, two qualitative data collection instruments/techniques were used to collect data: direct observations and unstructured interviews. The data collected from the observations were analysed deductively, and the data collected from the unstructured interviews were analysed inductively. Since more than one qualitative data collection technique was used, a multimethod qualitative design was employed.

Under the lens of interpretivism, the nature of reality is socially and subjectively constructed (Athanasou et al., 2012) and therefore, my study was grounded in qualitative research. This qualitative study intended to examine formative assessment practices of Grade 8 mathematics teachers within two consecutive stages of the Lesson Study cycle. From this, the aim of the study was not to influence the participants' behaviour. Rather, the aim was to observe and examine the planning events, implement formative assessment practices, and provide feedback as they naturally occur within the Lesson Study cycle and in the classroom.

Thanh and Thanh (2015, p. 25) state that a “qualitative approach often gives rich reports that are necessary for interpretivists to fully understand contexts”. Because the unstructured interviews for this study relied entirely on the direct observations conducted, the focus of the study was to provide rich descriptions of the teachers’ experiences and interpretations of those experiences with regard to formative assessment (Jackson, Drummond, & Camara, 2007).

3.5. Research Strategy

Due to the nature of my study and the attributes of interpretivism, a case study was an appropriate research design to be used. Yin (2011) states that case studies are often used as a means to analyse and document the process of implementation of an event, as it occurs in real life. In addition, Gustafsson (2017) states that case studies are intensive studies surrounding an individual or a group of people. With the use of a case study as my research strategy, I was able to gain insight into the phenomenon of Grade 8 teachers formative assessment practices within the context of Lesson Study.

Moreover, the case study research design aided in answering my research questions in a meaningful way. In other words, the case study research design guided me in answering my research questions by shedding light on the teachers' perspectives of formative assessment practices.

Yin (2011) divides case study research design into two categories, namely multiple-case study design and single-case study design. A multiple-case study design consists of several different groups of participants (Yin, 2011). I used a single-case study design with a selected group of participants for my study. The reason for using this design were to explore the single case of Grade 8 mathematics teachers' formative assessment practices in the context of in-school Lesson Study. The benefits of using a single case study for my study are numerous. However, the most notable is that it provides a platform for a deeper understanding of the phenomenon at hand to take place, and so a rich narrative description can be created (Yin, 2011).

The single-case study design included Grade 8 mathematics teachers from one public secondary school. Since the design focused on the teachers and their formative assessment practices, boundaries were provided by the case study (Yazan, 2015). The boundaries in relation to this study ensured that the participants were familiar with the process of Lesson Study beforehand, taught Grade 8 mathematics and practised formative assessment in their lessons.

3.6. Time horizon

Because the study used a single case study as the research strategy, the time horizon for the study constitutes cross-sectional. Essentially, my study made use of a "snapshot" (Saunders & Tosey, 2013, p. 59) of three Grade 8 Mathematics teachers who participated in two in-school Lesson Study cycles. An advantage of using a cross-sectional study is that it was inexpensive and relatively fast to conduct. In contrast, the disadvantage of using a cross-sectional study was that there were many variables to consider, including finding a suitable time for all the teachers to meet to plan the lesson and observe the lesson being presented.

3.7. Research techniques and procedures

3.7.1. Selection of participants and sampling procedures

For my study, purposive and convenience sampling was used, respectively. Firstly, from the six secondary schools in Pretoria that were selected to implement Lesson Study by the Gauteng Department of Education and the University of Pretoria, I selected one school as a case to conduct my research. Thus, I selected the study participants with the use of purposive sampling. The chosen participants were those of a deliberate choice (Etikan et al., 2016). In other words, the participants were selected since they met the specific criteria needed for the study. The participants had to meet two main criteria: involvement in Lesson Study and associated with Grade 8 mathematics. The main participants for my study were three Grade 8 mathematics teachers who constituted one in-school Lesson Study team, which participated in the study. The primary reason for Grade 8 being one of the main criteria is I believe that Grade 8 serves as the foundation for a learner's mathematics high school experience. Learners need to receive a strong foundation in mathematics to achieve well at the end of their high school career – they need to have a sound conceptual understanding of the basic principles and operations of mathematics.

Secondly, I used convenience sampling since the participants of the target population met "certain practical criteria" (Etikan et al., 2016). The participants met two primary practical criteria: close geographical proximity and easy accessibility.

3.7.2. Data collection instruments and procedure

Data were collected through video and audio recordings of observations and unstructured interviews. According to Ponelis (2015), observations allow researchers to integrate the theory behind the situation being observed and the actual happenings of the situation. Ponelis (2015, p. 238) further claims that observations are relevant to qualitative interpretivist studies because, within interpretivist research, there is a "need to understand the world as it is from a subjective point of view and seeks an explanation within the frame of reference of the participant". In addition, Thompson and Borrero (2011, p. 198) argue that observations are most useful in qualitative studies when the desired research outcomes are "identified and defined prior to [the] direct observation". Direct observations provide a platform to gain insight into how the teachers planned and implemented formative assessments without outside interference. During the direct observations, I used observation sheets (Annexures A and B) to guide my research and gain insight into how mathematics teachers plan and implement the formative assessment. The observation sheets were informed by my research questions. Essentially, I drafted the observation sheets as a means to guide my observations in terms of answering my research questions.

Unstructured interviews were conducted after the observations to triangulate my findings and address any uncertainties that the observations may have brought forth. When only one teacher could attend the interviews due to prior commitments, I conducted individual interviews with the teacher that could attend. The justification for conducting unstructured interviews is that "neither the questions nor the answer categories were predetermined" (Zhang & Wildemuth, 2009, p. 240). Zhang and Wildemuth (2009) state that questions for unstructured interviews rely on the interaction of some sort between the researcher and the participants. In the case of my study, the questions that I asked relied entirely on my observations. Essentially, I did not predetermine what I would ask before I collected data. However, once I had collected data, I was able to formulate questions based on what I had observed (Annexure C and Annexure D). Therefore, the unstructured interviews were used to gain more insight into what I had observed and ask questions to corroborate my observations. The unstructured interviews were conducted on the same day as the observations. The duration of each interview was approximately ten to fifteen minutes

and they were conducted on within the same venue that the teachers collaboratively planned and presented the two lessons.

The data collection procedure was done twice within two Lesson Study cycles. The first Lesson Study cycle dealt with equivalent fractions, and the second dealt with algebraic equations. I collected data through observations and unstructured interviews from two consecutive stages of each Lesson Study Cycle, namely Collaborative lesson planning and Lesson presentation and observation. From these stages, I collected data on the teachers' planning and implementation of oral and written formative assessment practices (Figure 7).

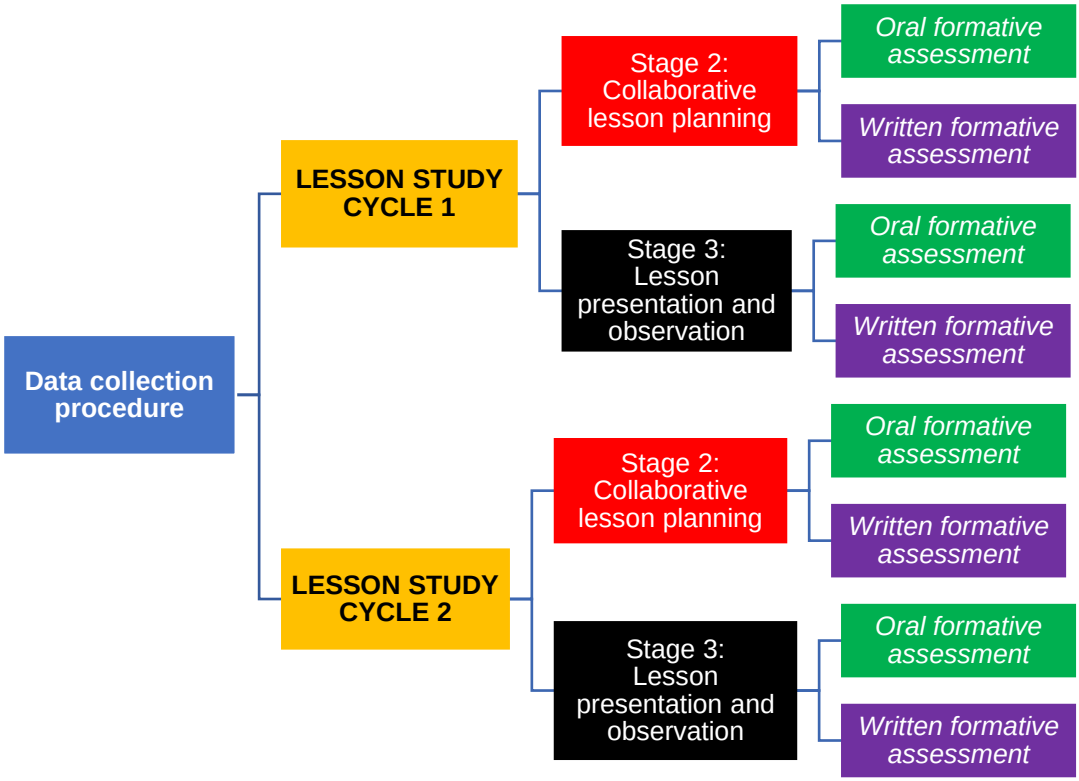

Figure 7: Data collection procedure

Table 1 indicates how the data gathered assisted me in answering my secondary research questions by linking the research questions, relevant Lesson Study stage, data collection methods and data collection instruments.

Table 1: Data collection method and documentation

SECONDARY RESEARCH QUESTIONS		STAGE OF LESSON STUDY CYCLE	DATA COLLECTION METHOD	DOCUMENTATION
1.	How do mathematics teachers collaboratively plan formative assessments during the Lesson Study cycle?	Stage 2: Collaborative lesson planning	Observation	Observation sheet
			Unstructured interviews	Unstructured interview schedule
2.	In what ways do mathematics teachers use formative assessment to facilitate mathematics learning?	Stage 3: Lesson presentation and observation	Observation	Observation sheet
			Unstructured interviews	Unstructured interview schedule
3.	How do teachers provide meaningful feedback to learners?	Stage 3: Lesson presentation and observation	Observation	Observation sheet
			Unstructured interviews	Unstructured interview schedule

Data collection – Stage 2: Collaborative Lesson Planning

The observation sheet, Annexure A, was used to collect data for Stage 2, Collaborative Lesson Planning of each Lesson Study cycle. Within this stage of the Lesson Study, the participants came together to prepare a mathematics lesson based on the topics *equivalent fractions* and *algebraic equations*. I observed the participants as they discussed and formulated the events of the lesson. Essentially, I used the observation sheet to guide my observations in terms of identifying what the teachers specifically discussed concerning formative assessment and how they would implement formative assessment in order to achieve the planned lesson outcomes, as demonstrated in my conceptual framework (Figure 5). The main aim of this was to determine whether or not teachers explicitly planned to use formative assessment within the lesson and if the success criteria, i.e., the learning outcomes, would be discussed with or made explicit to the learners. Also, if they did plan on specific formative assessment techniques, what formative assessment activities would be implemented, and how did they plan to provide feedback to the learners in a timely and meaningful manner?

Observing Stage 2 of the two Lesson Study cycles enabled me to answer my first secondary research question: *How do mathematics teachers collaboratively plan formative assessment during Lesson Study?*

Data collection – Stage 3: Lesson Presentation and Observation

The second observation sheet, Annexure B, was used during the observation of Stage 3 of the Lesson Study cycle, namely *Lesson presentation and observation.* This stage offered to be the most significant stage in both Lesson Study cycles to observe because, during this stage, formative assessment was put into practice. I observed one of the participants teach the collaboratively planned lesson and used the observation sheet to record how formative assessment practices naturally progressed within the lesson. Observing the lessons taught gave me first-hand experience of how the teacher used formative assessment to facilitate learning and develop learners' mathematical thinking and conceptual understanding. However, due to the fast-paced nature of the teaching and learning process, I could not write down all the information regarding the formative assessment.

For this reason, I used both audio and video recordings so that I could replay and watch the lesson to make up for what I may have missed. The observation sheet was used to record all emerging practices with regard to formative assessment in the real-life practice-embedded context of a Grade 8 mathematics lesson. Thus, as previously mentioned, the main aim of the observation sheet was to document how teachers used formative assessment to facilitate learning and how the teacher engaged the learners during teaching. As per my conceptual framework (Figure 5), within this phase of the data collection procedure, I was able to observe how the teacher presenting the lesson used elicitation techniques to collect information regarding learner understanding, how the teacher would interpret and respond to the learners' responses and lastly, I was able to observe and document how the teacher provided meaningful feedback to the learners' responses.

Observing Stage 3 of the Lesson Study cycles enabled me to answer the second secondary research question: *In what ways do mathematics teachers use formative assessment to facilitate mathematics learning*? Another aim of observing this stage was to determine how mathematics teachers use formative assessment to provide

insightful feedback to learners. This enabled me to answer the third secondary research question: *How do teachers provide meaningful feedback to learners?*

In order to gain more insight and understanding of the subjective interpretations of my observations, I conducted unstructured interviews with the participants. As previously discussed, the questions for the unstructured interviews were based entirely on my observations and so could not be predetermined before I began the data collection procedure. However, after I had observed each stage in each Lesson Study cycle, I was able to formulate questions (Annexure C and Annexure D) that allowed me to corroborate my observations and address any questions that may have arisen during the observations.

3.7.3. Data analysis and interpretation

Due to the prescripts of the interpretivist paradigm and the nature of qualitative research, as articulated in paragraphs 3.2 and 3.4, respectively, I analysed and interpreted the data guided by the participants' individual and shared experiences and perceptions (Thanh & Thanh, 2015). The data gathered from each observation sheet was analysed and interpreted separately. After that, the unstructured interview schedules were analysed and interpreted. This was done by transcribing the audio and video recordings of the observations and interviews. After that, important key takeaways such as the practice of oral and written formative assessment were highlighted and grouped to provide insight for my research questions.

The analysis of the observation sheets and the unstructured interview schedules for each stage observed in the Lesson Study cycles was done using the categories set out in my conceptual framework (Figure 5), guided by my research questions and supported by the literature. Since my study aimed to examine Grade 8 mathematics teachers' formative assessment practices within the context of Lesson Study, deductive analysis was used to determine whether or not the claims, as stipulated in my framework, applied to this specific instance. From the observations and deductive analysis, I could identify and interpret the relationship between the concept and practice of formative assessment and the participants (Saunders et al., 2019).

Additionally, the analysis of the unstructured interview schedules was done inductively. Because the interviews were based entirely on observations, trends that

were not stipulated in my conceptual framework became apparent and further explored. Through inductive analysis, I was able to gain a better understanding of the participants' perceptions of formative assessment and “establish different views of [the] phenomena” (Saunders et al., 2019, p. 155).

The research instruments, both the observation sheets and unstructured interview schedules, aided in organising the results of the observations in terms of identifying any trends to be further explored within the interviews. After that, the instruments aided in the discussion of this study. There were predetermined key takeaways during the observations. Lastly, the instruments aided in interpreting the results of the observations as they provided strategic guidelines on how to answer my three secondary research questions. Thus, the research instruments used in this study aided in answering my primary research question: *How do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 mathematics class?*

3.8. Quality criteria

When conducting qualitative research, a clear understanding of trustworthiness and all it encompasses must be demonstrated (Athanasou et al., 2012). Thus, various aspects of quality criteria, namely credibility, transferability, dependability and confirmability (Nieuwenhuis, 2016), must be considered to ensure my study's trustworthiness.

The first aspect of quality criteria applicable to my study was credibility. It is important to take note that my study held a high risk for credibility due to how few data collection instruments were used. Thus, in order to enhance the credibility of my study, as suggested by Nieuwenhuis (2016, p. 123), I conducted “detailed data collection”. Furthermore, I contacted my supervisors, who are experts in both fields of Lesson Study and Mathematics Education, frequently. Lastly, I submitted all field notes to the participants to ensure that I accurately recorded all the relevant information and verified facts with the participants during the unstructured interviews.

Additionally, the results of my study were ensured to be transferable. Essentially, the results I acquired are transferable to other contexts of formative assessment and

Lesson Study. To increase the transferability of my study, I provided thick descriptions of the “context, participants and research design” (Nieuwenhuis, 2016, p. 124). In addition, purposive sampling ensured my study was transferable as careful consideration was given to the participants for my study.

For my study to demonstrate dependability, each stage in the research process was accurately recorded, and the standard by which the research was conducted, analysed and interpreted had to be consistent and repeatable. Furthermore, I updated a day-to-day journal with all my research decisions to aid others in following my reasoning throughout the research process (Nieuwenhuis, 2016). Thus, if an external researcher were to be interested in my study, they would be able to access my thought process, research decisions and data collection, analysis and interpretations. If they were to repeat the study, they would obtain similar results.

Lastly, to ensure that the findings of my study were entirely based on the participants' subjective perceptions and not my own motivations, interest or bias (Nieuwenhuis, 2016), I had to use various strategies to ensure confirmability. One way in which I achieved confirmability was to reduce my own bias by means of admitting my inclinations. One way I achieved this was by asking an external researcher, an expert in the field of Lesson Study, to judge whether bias was evident by studying the original data collected. Another way that I achieved confirmability was by transcribing the process of the data collection, analysis and interpretation.

3.9. Ethical considerations

Approval to conduct my research study and ethics declaration after the completion of the study was obtained from the Ethics Committee of the University of Pretoria (Annexure F). The Gauteng Department of Education also granted permission to conduct the study (Annexure G). Written informed consent for the observations, interviews and audio and video recordings was obtained from the District Director, the principal of the public secondary school and the three Grade 8 mathematics teachers involved in the Lesson Study (Annexure I, Annexure J and Annexure K). Before each unstructured interview, I explained to the participants that their participation was voluntary and that they may withdraw at any time if they wished. I also explained to

the participants that the results of my study would be objective and would not cause any harm to the schools' or the participants' reputations.

While conducting my research, trust, accountability, anonymity, confidentiality and mutual respect were maintained as a top priority. I practised fairness throughout my study and treated all participants with the just and morally correct treatment. Privacy and anonymity were achieved by providing each participant with a pseudonym, e.g. School 1, Teacher 1, Teacher 2, etc. Moreover, where video recordings took place, the faces of the minor participants were concealed.

The data collected via audio and video recordings and all my field notes were protected and stored. I submitted all the data to my supervisor, uploaded it to google drive and stored it on a memory card.

3.10. Summary

Throughout this methodological chapter, I discussed interpretivism as the paradigm that underpinned my study. From this, the interpretation of the data collected was explicitly subjective and socially constructed. A multimethod qualitative design was used, and a single-case study design was adopted. My study used purposive sampling from the one selected secondary school in Pretoria. After that, convenience sampling was used to select the study participants. The data collection was done in two Lesson Study cycles and involved direct observations using observation sheets, followed by unstructured interviews. The observations were used to determine the extent to which teachers collaboratively planned to use formative assessment to meet lesson outcomes. In addition, the observation sheets were used to determine how teachers practice formative assessment in mathematics lessons as a method to improve the teaching and learning process of mathematical content while simultaneously developing learners' conceptual understanding, mathematical thinking and problem-solving skills. After that, unstructured interviews were conducted as a means to gain a deeper understanding of the observations. Categories obtained from my conceptual framework and the literature were used to interpret the data through deductive analysis, and any new trends established were interpreted through inductive analysis. Lastly, measures to ensure quality criteria and ethical considerations were discussed.

CHAPTER 4: PROCESS OF DATA ANALYSIS AND PRESNETATION AND RESULTS.

4.1. Introduction

As explained in Chapter 3, data collection was conducted in two Lesson Study cycles, each focusing on two consecutive stages: Collaborative lesson planning (Stage 2) and Lesson presentation and observation (Stage 3). In the current chapter, I have presented the findings relating to each stage of the two stages of interest separately. Further, I have organised and presented the findings relating to each stage in terms of oral and written forms of formative assessment.

With the guidance of my conceptual framework (Figure 5), I gained in-depth insight into the teachers' formative assessment practices within the context of Lesson Study. Each research question was guided by the processes as presented by my conceptual framework. Within Stage 2 of each Lesson Study cycle, I was able to gain insight into how the teachers collaboratively planned formative assessments and the lesson outcomes for each lesson. Within Stage 3 of each Lesson Study cycle, I was able to gain insight into how the teacher presenting the lesson used formative assessment to elicit learner responses and collect information on learner conceptual understanding, how the teacher interpreted the responses of the learners and lastly, how feedback was provided to facilitate learner mathematical thinking.

The three teachers who were studied have been given the pseudonyms of Teacher 1, Teacher 2 and Teacher 3. The pseudonyms given to each teacher are the same throughout the findings. The teachers' utterances during collaborative lesson planning, lesson presentation, and responses during interviews are provided verbatim. In addition, I used vignettes of some of the illustrations used during teaching to support what I observed - these too are unedited, therefore, represent the original illustrations used during lesson planning and/or lesson presentation.

4.2. Lesson Study Cycle 1

4.2.1. Stage 2: Collaborative lesson planning

Within this stage of the first Lesson Study cycle, the three Grade 8 Mathematics teachers came together to collaboratively plan a lesson on equivalent fractions. The teachers met after school hours due to a lack of time during the school day. Each teacher had their own skeleton of a lesson plan, which they discussed to plan the final lesson to be presented. Within Stage 2, I observed how the teachers planned the desired lesson outcomes for the lesson and how they planned for oral and written formative assessments.

4.2.1.1. Planning lesson outcomes

The teachers began their lesson planning by stating what they thought the lesson outcomes should be. The teachers based the proposed lesson outcomes on the learners' prior knowledge and what is stipulated in CAPS regarding the topic. The teachers first discussed what the learners should already know and be able to do at the beginning of the lesson. They collectively agreed that they would rely on the learners' prior knowledge, learnt in Grade 6 and Grade 7, as a foundation for the lesson.

Teacher 1 presented the following prior knowledge:

> *[Learners] "should be able to identify equivalent fractions using the fraction wall which they should have learnt in Grade 6 or Grade 7. They should also be able to identify a half and a quarter using different shapes and diagrams such as a circle. You cut it in half or a quarter."*

Once the teachers had discussed what the learners should already know at the start of the lesson, they began discussing what the learners should have learned by the end of the lesson.

Teacher 1 proposed four lesson outcomes as their learning goals for the end of the lesson:

> *[Learners] "should be able to add and subtract fractions with common denominators, should be able to explain what a lowest common denominator is, should be able to identify denominators as multiples of one another, should be able to order fractions in ascending and descending order."*

Teacher 2 pointed out that there were too many lesson outcomes for a single lesson. In agreement, the three teachers then collaboratively narrowed the lesson outcomes down to one. Teacher 2 stated, "This lesson is only for adding and subtracting equivalent fractions."

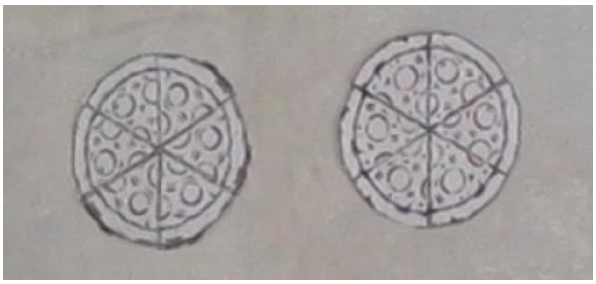

Figure 8: Physical model of designed cardboard cut-out pizzas

Figure 8 represents the physical model of two designed cardboard cut-out pizzas the teachers decided to use. The pizzas are the same size and have each been cut into six slices.

Justifying the choice and use of cardboard cut-out pizzas, Teacher 1 had this to say:

> *"The physical model will be used to "get [the learners] minds going, just to get them interested in the main topic. It will be used to get the learners curious about how the pieces work together and actually get a visual representation of how a fraction is part of a whole; see which pieces are the same and which pieces are not."*

Following the discussion of lesson outcomes, I asked Teacher 1 during the unstructured interview to clarify how exactly the lesson outcomes were planned. Through this question, I wanted to gain insight into whether the teachers collaboratively planned the lesson outcomes best suited to the needs of the learners.

Teacher 1 responded:

> *"The lesson outcomes were based on the CAPS lesson outcomes for Grade 8 learners with regard to common fractions. We focused on action words, the learners should be able to identify, to find or to be able to state."*

Thereafter, I questioned whether or not the teacher presenting the lesson will explicitly state the lesson outcome(s) to the learners at the beginning of the lesson. I asked this question to gain insight on whether or not the teachers will communicate their expectancies of the learners for the lesson and guide the learners to meet the success criteria of the lesson. This question was significant to my study because, according to the Formative Assessment framework (Antoniou & James, 2014), communicating expectancies and success criteria gives the learners an idea of what is expected of them and what to achieve from the lesson. In other words, they get an indication of what it is that they need to do in order to achieve mastery of the concept being dealt with. Essentially, explicitly stating the lesson outcomes to the learners will facilitate the implementation of formative assessment practices. Nonetheless, when responding to the question I posed regarding presenting the lesson outcomes to learners, Teacher 1 stated, "No, the learners will not be made aware of the lesson outcomes beforehand."

4.2.1.2. Oral formative assessment

While planning the lesson and using the physical model, the teachers discussed how they must encourage learners to seek assistance while doing the examples independently. Teacher 1 said:

> *"They can put their hand up and ask for help if they are stuck. The pizza cardboard can then be used to explain, and re-explain, adding. [We can] ask the learners how many pizzas there will be without cutting the pizzas into slices - linking this to normal addition."*

Although not implemented in the actual lesson, Teacher 2 suggested that in addition to the physical model, they could ask the learners to bring fruit with them, as a means to "divide their own food." Teacher 3 stated in the agreement that the cost of food needs to be considered, and oranges are relatively affordable."

Teacher 1 further explained how the physical model of designed cardboard cut-out pizzas (Figure 8) could be used to develop learners' conceptual understanding of equivalent fractions and the concept of lowest common denominators:

> *"We could ask if one pizza had one slice missing, it would no longer be a whole but rather five out of six, seven out of eight and so on. The numbers can then be used to support equivalent fractions as well as adding of fractions with the same denominator. With the same denominator, we would use the same size pizzas with the same slices, so two same size pizzas cut into six different slices, two out of six plus four out six will equal one whole pizza with some extra."*

These utterances and exchanges regarding how the physical model would be used were an indication of planning of oral formative assessment, which teachers would use to facilitate learning.

4.2.1.3. Written formative assessment

While the teachers discussed the consolidation of the lesson, they indicated that due to the duration of the lesson, this would be the shortest part. From the discussion on time, the teachers decided it would be best to inform the learners that whatever work they did not complete during class time would be homework. The specific questions for the work were not discussed or planned during the lesson.

During the unstructured interview, I asked Teacher 1 what specific formative assessment practices would be implemented during the course of the lesson. This question was asked to identify whether the teachers had specific formative assessment techniques and questions in mind to gain insight into learners' understanding of the concept of equivalent fractions.

Teacher 1 explained as follows:

> *"No specific questions have been planned but more along the lines of, if we are dealing with equivalent fractions, we will generally ask questions about a half or a quarter. This way it relates it to the knowledge that they acquired in Grade 6 and 7."*

From this response, it is clear that the actual written formative assessment questions to be implemented were not planned thoroughly.

4.2.2. Stage 3: Lesson presentation and observation

Within Stage 3 of the Lesson Study cycle, I observed how the planned lesson was implemented by one of the three Grade 8 Mathematics teachers. The lesson took place during the morning school hours. For this reason, only one of the other two teachers was able to observe the lesson because the third teacher did not have a free period and had to teach her own class at the same time. Teacher 1 presented the lesson and Teacher 2 observed.

From my observations of this stage, I organised my data into the categories of oral formative assessment, written formative assessment and feedback provided.

4.2.2.1. Oral formative assessment

The lesson began with Teacher 1 briefly introducing the concept of fractions to the learners and directed the learners' attention to a diagram of six equally sized pizzas presented on the board that had been cut into different size slices: $\frac{1}{2};\frac{1}{4};\frac{1}{6};\frac{1}{3};\frac{1}{5}\ and\ \frac{1}{7}$ (Figure 9).

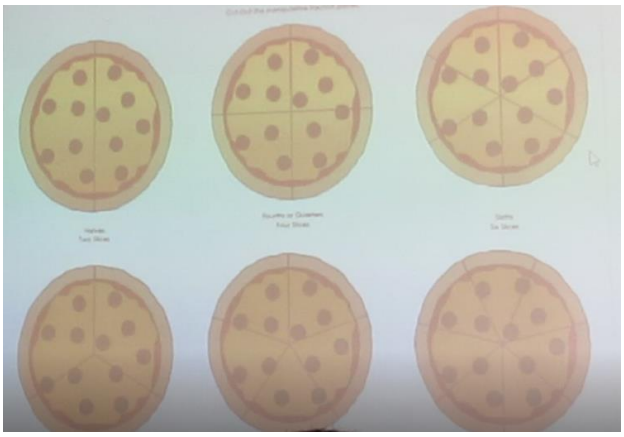

Figure 9: Six equally sized pizzas

It is important to note that Figure 9 is not the same activity as what was discussed during the lesson planning (Figure 8). The oral formative assessment techniques based on Figure 9 were in no way discussed among the teachers and were, therefore, not aligned with the originally planned formative assessment to be executed within the lesson.

For the first oral formative assessment, Teacher 1 stated:

> *"Two people can share a pizza in half, a family of four can share a pizza cut into quarters. If we had to put the quarters on top of each other, would they be the same?"*

At this point, Teacher 1 paused for a response from the learners. Once the learners responded "Yes", he stated that "Since they are [the same], everyone in the family will be getting an equal-sized slice."

Regarding Figure 9, Teacher 1 implemented the second form of oral formative assessment by asking the learners: "What do you notice about all six pizzas and their slices, as a whole?" He prompted the learners to identify any similarities and any differences that can be stated about the six pizzas.

The learners responded with a variety of answers:

> *"The more slices the pizza is cut into, the smaller the sizes; all slices are cut equally; cutting the pizza into three slices is more difficult than to cut four slices".*

Upon receiving and discussing these responses with the learners, Teacher 1 stated, "It is unconventional to cut a pizza into three, and one would need to know their measurements [well] to cut the pizza into three equal slices."

Teacher 1 redirected the learner's attention to the sizes of all six pizzas by saying: "They all have the same size." Once the learners agreed that all the pizzas were the same size, Teacher 1 asked: "If you were to order a pizza, would you prefer to have your pizza cut into six slices or eight slices of pizza?" The learners responded enthusiastically with eight slices. Teacher 1 did not immediately provide feedback on the learners' responses and instead prompted them to think about their answers. He then asked, "Is eight slices of pizza in fact more than six slices of pizza?" By asking the learners to think about the same-sized pizza being cut into different-sized slices, Teacher 1 implemented the third form of oral formative assessment for the lesson.

At this point, some learners were able to conclude that regardless of how many slices the pizza has been cut into, the pizza is still one whole pizza. Teacher 1 then referred to Figure 9 and said, "Even though these pizzas have been cut into different size pizzas, we will be eating the same amount of pizza for each pizza."

Teacher 1 began using the planned physical model of the designed cardboard cut-out pizzas. Figure 10 below indicates the cardboard cut-out pizzas that had already been placed on the whiteboard for the learners to see.

Figure 10: Cardboard cut-out pizzas on whiteboard

He asked the learners, “If we had to add these two pizzas together how would we go about adding these two pizzas together?” Teacher 1 did not answer himself immediately but instead waited for the learners to think about what he was asking of them. When the learners did not respond, Teacher 1 rephrased the question using different terminology, “How many pizzas have been ordered in total? One pizza and one pizza, therefore, two pizzas have been ordered.” At this question, it can be noted that Teacher 1 attempted to implement an oral formative assessment. However, Teacher 1 answered his own question as he asked it.

Teacher 1 further asked, from these two pizzas, “How many slices has each pizza been cut into?” When the learners identified that the pizzas had been cut into six slices, Teacher 1 removed one slice from the second pizza (Figure 11) and asked the fourth oral formative assessment: “Are we able to add the two pizzas in the same way as before?” The learners quickly realised that it was no longer one whole pizza plus one whole pizza. Teacher 1 confirmed this by stating, “A different way needs to be found to represent the second pizza.”

Figure 11: One cardboard cut-out pizza missing one slice

Teacher 1 provided the learners with some time to explore different ways that the second pizza can be represented, to which a handful of learners argued that it could be represented as a fraction. He further prompted them and asked, “How can the pizza be turned into a fraction?” This question constitutes the fifth oral formative assessment to be implemented in the lesson.

After having some time to think, a learner raised her hand and stated:

> *“You need to calculate how many slices there are in total of the second pizza and use that as the denominator of the fraction and use the number of slices left over as the numerator.”*

Teacher 1 positively agreed and rephrased this answer, so all learners heard and understood the concept.

Teacher 1 began the process of adding the two pizzas together. Regarding the whole pizza (Figure 11), Teacher 1 asked: “How many slices are there in total for the denominator? And how many slices have been eaten? So how many slices are left for the numerator?” Asking these questions form part of the sixth oral formative assessment, and as he asked these questions, the learners responded to them, and he wrote the answers on the board as a means for learners to visualise what he was verbally describing.

Teacher 1 obtained the solution $\frac{6}{6}$ and wrote this fraction underneath the whole cardboard cut-out pizza (Figure 12). Once this answer had been written on the board, Teacher 1 explained to the learners that “Fractions can be represented as whole numbers and whole numbers can be represented as fractions. Six out of six slices are a whole pizza”.

Teacher 1 then referred to the second cardboard cut-out pizza with one slice missing (Figure 11) and repeated the same oral formative assessment questions, constituting the seventh oral formative assessment: “How many slices are there in total for the denominator? And how many slices have been eaten? So how many slices are left for the numerator?” After having visualised this for the learners on the board, Teacher 1 wrote the answer of $\frac{5}{6}$ underneath the cardboard cut-out pizza with one slice missing (Figure 12).

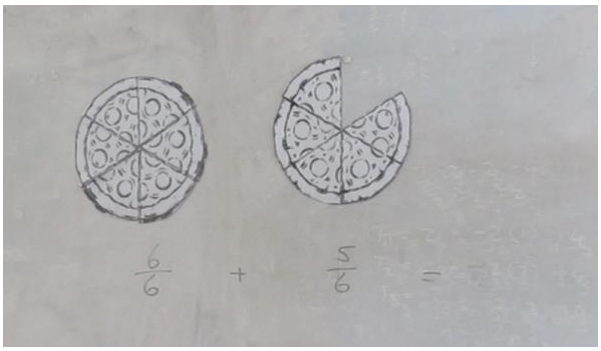

Figure 12: Fraction answers of both cardboard cut-out pizzas

With both cardboard cut-out pizzas represented as fractions on the whiteboard, Teacher 1 asked the learners, “Is it easier to add the two pizzas together now since both numbers are fractions?” He then described to the learners that since “Both fractions have the same denominator, this means that the answer of the sum will have the same number as the denominator.” From here, Teacher 1 implemented the eighth form of oral formative assessment by asking the learners, “How will you calculate the numerator for the answer?” The learners quickly stated that they could add the two numerators in the sum and obtain 11.

Teacher 1 wrote the final solution down as $\frac{11}{6}$ and asked the learners, “What do you notice about the fraction that is different from the two fractions in the sum?” When the learners state that the numerator is bigger than the denominator, Teacher 1 informed the learners that “This type of fraction is called an improper fraction.” He then informed learners that “The conversion from mixed fractions to improper fractions, and vice versa, is not the focus of this lesson but will be needed for future reference.” Teacher 1 also described to the learners what a mixed fraction means in terms of the cardboard cut-out pizzas; “We have one whole pizza and a pizza with one slice missing from six slices.”

Teacher 1 paused at this point and prompted the learners to ask any questions. When no questions were asked, he restated the basic requirement of having the same denominator when adding and subtracting two fractions.

Teacher 1 solved an additional sum with the learners, $\frac{3}{5}+\frac{1}{5}$. He began by asking the learners, “What do you think the first step is to complete this sum*?”* When a learner provided an incorrect answer, he redirected them by asking, “What should you first

check for before attempting to solve the sum?" This guidance serves as the ninth oral formative assessment practice as the learner, who previously provided the incorrect answer, could identify that they must first look if the denominators of both fractions are the same. Once the learner got this right, Teacher 1 responded with the positive interjection "Perfect!" and repeated the answer louder for all learners to hear: "You cannot add or subtract fractions unless the denominators are the same." He then pointed to the sum and stated, "Since the denominators are the same, the denominator of five can be carried over to the answer". After this, he stated that "Only now can the two numerators be added together."

But before he did so, he asked the learners, "Can anyone say why the denominator of five remains the same in the answer?" When the learners did not respond, he referred them to the cardboard cut-out pizzas (Figure 10) and told them to "Think in terms of the pizza slices." Teacher 1 implemented the tenth form of oral formative assessment by referring the learners to this frame of reference. Learners were allowed to relate the concept of common denominators to the physical model and, from here, were able to deduce that the denominator indicates how many slices there were in total for one pizza.

With the progression of the lesson, Teacher 1 introduced the concept of equivalent fractions, related it to a real-life example, discussed a simple fraction problem followed by a more complex fraction problem, $\frac{4}{5}-\frac{3}{5}+\frac{1}{5}$. This problem involved multiple operations in the form of addition and subtraction operations. Teacher 1 again began solving the sum by stating, "The first step one needs to do is to check if the denominators are the same before adding or subtracting the fractions." Once he confirmed with the learners that the denominators were the same in all three fractions, he described how "The denominator of the three fractions must be the denominator in the solution." Teacher 1 then explained to the learners how to "Solve for the numerator by subtracting and adding the numerators in the sum from left to right." Teacher 1 obtained two for the numerator. At this point, a learner asked him if, when solving the problem, they must apply BODMAS. Teacher 1 informed the learner that the question asked "Is a good question" and asked the learners, "What does BODMAS stand for?". The learners responded with "Brackets Of Division Multiplication Addition and Subtraction".

From this definition, Teacher 1 began solving the sum for the numerators by doing addition first and then subtraction. However, he intentionally ignored the signs of the numerators and obtained $\frac{0}{5}$, which is different from the previous solution. Teacher 1 then asked the learners, “Why are the two solutions different and which one is wrong?” After taking some time to think about it, the learners stated that they needed to include the signs of the numerators when performing the operations, and thus, the second solution is incorrect. Teacher 1 reiterated this and reminded the learners of “The importance of signs and how they should always be included when adding and subtracting integers.”

I sense that by intentionally ignoring the signs of the numerators, Teacher 1 used the eleventh form of oral formative assessment to encourage the learners to identify their mistakes, thus developing their mathematical reasoning and understanding of the significance of signs.

4.2.2.2. Written formative assessment

After discussing the concept and tenets of equivalent fractions with the learners, Teacher 1 provided them with four problems (Figure 13) to try on their own. These specific problems were not discussed and planned in the collaborative lesson planning. It is important to note that the four problems are of the same complexity as each sum only has one mathematical operation between two or three fractions; addition or subtraction.

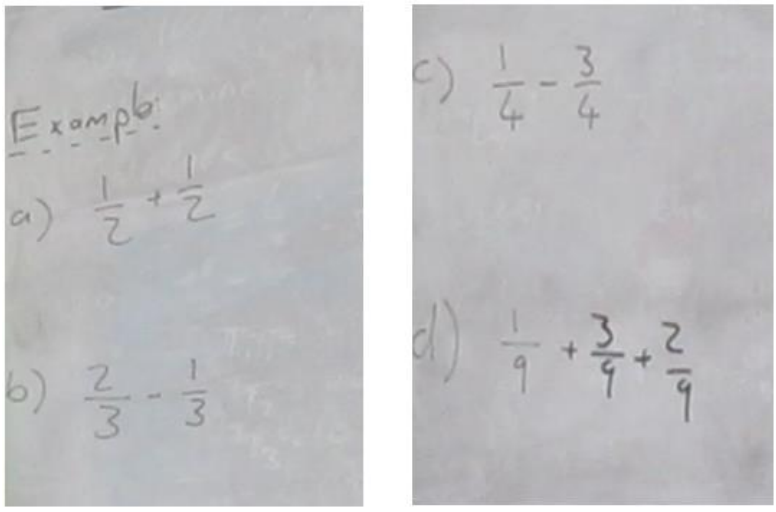

Figure 13: Written formative assessment problems

Providing learners with example problems to attempt on their own constitutes the first form of written formative assessment for the lesson. From these example problems, I asked Teacher 1 in the unstructured interview why he did not provide any examples with different denominators. I asked this question to gain insight into how Teacher 1 was planning on developing the learners' conceptual understanding of finding the lowest common denominator of two or more fractions. Teacher 1 stated that the reason for not introducing different denominators is that:

> *"Since it was an introductory lesson, I did not want to jump too far ahead or get them overwhelmed in anyway so I just kept it with same denominators and the answers for the examples, some of them had required learners to simplify thus, giving different denominators which reinforces the concept of equivalent fractions. I like to build up into the next few concepts for the next lesson."*

Teacher 1 concluded the lesson with the second form of written formative assessment and provided the learners with more complex examples for homework.

a) $\frac{3}{5} - \frac{6}{5}$
b) $\frac{1}{8} - \frac{3}{8} + \frac{5}{8} - \frac{7}{8}$
c) $4 + \frac{1}{2}$
d) $3\frac{1}{2} + 4\frac{1}{2}$

From these examples, I asked Teacher 1, in the unstructured interview, if there was a particular reason for giving the learners the examples that he did. The reason for asking this was because specific questions were not planned in the Collaborative lesson planning and to gain insight into whether Teacher 1 had purposefully chosen the examples to enhance the learners' understanding of the concept at hand. Purposeful questions form part of the tenets of Lesson Study. I wanted to gain insight on whether or not Teacher 1 had planned to ask about those specific examples with a reason behind it. Teacher 1 claimed that:

> *"Some of them were just because they looked good, others because they involved a negative [sign] or they involved a previous section of the work and the different operations."*

To further corroborate my observation of the oral and written formative assessment techniques, I asked Teacher 1 what he believed was the most effective type of

formative assessment and how it provided insight into the learners' understanding. The reason for asking this question was to determine if Teacher 1 was aware of the various formative assessment techniques he implemented throughout the lesson and how he would use the information gathered from the formative assessment techniques to regulate learning and develop learners' mathematical thinking. Teacher 1 responded that he believed, "Relating the concept of fractions back to the pizza definitely helped them get interested in the subject. And just constantly reminding them, as they are doing the examples, that if they are struggling, they [must] ask for help. And the walking around while they were doing the sums and just checking that they were following the correct steps."

Lastly, I asked Teacher 1 whether or not he believed that the forms of formative assessment that he had implemented were adequate to elicit learners' mathematical thinking and what he would do to improve them. This question was asked to gather insight on what information regarding learner understanding Teacher 1 gathered from the formative assessment techniques that he implemented and how he would use the information he gathered to regulate learning, provide effective feedback to the learners and improve upon future teaching decisions. Teacher 1 stated that "No. They [formative assessment techniques] could have been a lot better if I had ended the lesson with a mini test, say four fractions. So instead of the examples, given it to them as a little test that just to put more pressure on them, if I had the opportunity to do so."

4.2.2.3. Feedback provided

Regarding the written formative assessment techniques, Teacher 1 would give the learners a few minutes to attempt to solve the problems on their own and then, when discussing the solutions, he wrote all his actions while doing them on the whiteboard. Upon receiving the learners' responses to the oral formative assessment techniques implemented, Teacher 1 would either provide positive interjections such as "Awesome!" or "Perfect!" to correct solutions or, Teacher 1 would rephrase his own questions and redirect the learners' mathematical thinking.

4.3. Lesson Study Cycle 2

4.3.1. Stage 2: Collaborative lesson planning

Within this stage of the second Lesson Study cycle, I observed the three Grade 8 Mathematics teachers once again coming together to collaboratively plan a lesson on algebraic expressions. However, during this stage, the actual topic of the lesson was algebraic equations. When I questioned why the change in the topic after Stage 3 had been completed, Teacher 1 stated that "We decided it was best to try and teach the two [topics] at the same time especially considering [the learners] have been exposed to like terms already." It is important to note, however, that the focus of my study does not depend on the topic planned and taught but rather on the formative assessment practices implemented in the context of Lesson Study.

The teachers met during the break because they could not find a time that suited all three of them otherwise. After I had observed the Collaborative lesson planning, I interviewed two of the three teachers to collaborate on my observations. The third teacher had her own personal commitments to attend to. Within this stage, I once again observed how the teachers planned the desired lesson outcomes for the lesson and how they planned for oral and written formative assessments.

4.3.1.1. Planning lesson outcomes

The lesson outcomes for the lesson were formulated from the three teachers' prior experience in teaching algebraic like terms. From this point, Teacher 2 stated that the focus of the lesson would be based on:

> *"Present[ing] algebra in the idea of apples and oranges instead of variables. All the apples go together, all the oranges go together just as all the x's go together and all the y's go together."*

Because the lesson outcomes were not discussed in detail, I asked Teacher 1 and Teacher 2 in the unstructured interview to describe what they wanted the learners to know by the end of the lesson.

Teacher 1 responded:

> *"Just to start off with the rules of algebra, if it is times this is what happens, it is plus this is what happens, if you have brackets this is what happens. Kind of just get the main basics and then we can just build from that."*

In addition, Teacher 2 stated: "How to identify like terms."

4.3.1.2. Oral formative assessment

When discussing the concept of adding and subtracting like terms, Teacher 2 described how the learners become easily confused when using the distributive law. For this reason, the teachers agreed to use the oral formative assessment to relate the concept

> *"To something [the learners] know and give them actual pictures, because with the variables they are like why is there alphabet? With apples they can see [the] apple actually relates to something and it becomes easier for them to actually understand."*

The teachers then discussed common misconceptions such as simplifying an algebraic expression consisting of like terms. Teacher 3 provided pre-emptive insight by using the example of $x + 2x$. Teacher 3 described how the teacher presenting the lesson must be mindful of how the learners tend to think when solving such a problem:

> *"x+2x; okay it is x there, oh no! You said x+2x=3x. Where did the other x come from? So, what is this x. Now we saying we have an orange here and we have two oranges this side. You know you are going to consider that orange [when adding together and] there will be three [oranges] altogether. You can't just say there is no one in that orange so I am not calculating it. You need to add everything."*

From this example of learner thinking, the teachers agreed that relating the concept to fruit would best be suited to facilitate learning.

Further on, during the lesson planning, Teacher 3 stated that the learners need to be constantly reminded of the laws of exponents when dealing with algebraic like terms:

> "*Remind them of that; refer to the laws again, do you remember that, now we have the same base, what do we do to the exponents? Then they have to say the exponents add. If the teacher is going to write x^2, the learners must know where it came from. It means x times x, not just x plus x."*

4.3.1.3. Written formative assessment

While discussing the development of the body of the lesson, the teachers planned for the first written formative assessment for the lesson by providing the learners with an opportunity to simplify some algebraic expressions on their own. Teacher 1 suggested, *"Just give them a few, maybe six questions."*

After that, the teachers planned for the second form of written formative assessment by providing the learners with more complex problems that would require them to analyse the expression fully before attempting to simplify it.

Teacher 2 stated that she thought it would be best to:

> *"Also give them something that is straight. Something that they cannot do anything [with], just to see if they actually understand the concept and that analysis of them saying that, if it is apples plus oranges, you can't add them together, they are not the same. Instincts will kick in and they will want to do something to this, you know you have to solve this. But someone who knows and has the knowledge, because they have understood the food concept, then they will know that they are not supposed to do anything so they are just going to leave it as it is and then they are going to write it just as it is because that is how it goes."*

After the teachers agreed on the body of the lesson, they began to discuss the consolidation phase of the lesson, which included planning for the third form of written formative assessment.

Teacher 1 suggested that for the conclusion:

> *"We can do a mini test that will take 10 minutes, maybe [do] five or six questions of different forms. Starting with something simple like,* $x + x = 2x$ *and* $4 \times x = 4x$ *so that we can see if they can see [what to do] when solving something that is simple, and then increasing the difficulty level of the sums and increasing their cognitive levels."*

However, the questions to this mini-test were not discussed in detail.

From these three written formative assessment techniques, in the unstructured interview, I questioned two of the teachers on how the teacher presenting the lesson will gather information on learner understanding and what type of problems will be

provided to the learners. I asked this question to determine if the teachers had purposefully planned their formative assessment questions.

Teacher 2 explained that:

> *[The mini-test] "At the end of the lesson [would be used] to actually see if they have any key takeaways, from what was actually done in class. Because then, if we start from simple things like $x + x$ and we see that there is a problem there, and that there is no way they will be able to distribute and still group like terms. Because they can't group something that is plain and simple."*

4.3.2. Stage 3: Lesson presentation and observation

Within Stage 3 of the second Lesson Study cycle, I observed how Teacher 1 taught the collaboratively planned lesson on algebraic expressions (which was actually a lesson on algebraic equations), followed by an unstructured interview. The lesson took place during the morning school hours. Teacher 1 presented the planned lesson, but the other two teachers could not observe the lesson because they did not have a free period and had to teach their own classes at the same time. It is important to note that the implication of the other two teachers not being able to observe the lesson presentation deviates from the Lesson Study prescripts. Additionally, since the other two teachers did not observe the lesson being taught, they were not needed for the unstructured interview, which took place directly after Stage 3 of the Lesson Study cycle.

From my observations of this stage, I organised my data into the categories of oral and written formative assessment.

4.3.2.1. Oral formative assessment

Teacher 1 discussed the concept of algebraic equations using drawn diagrams of fruit, as seen in Figure 14 below.

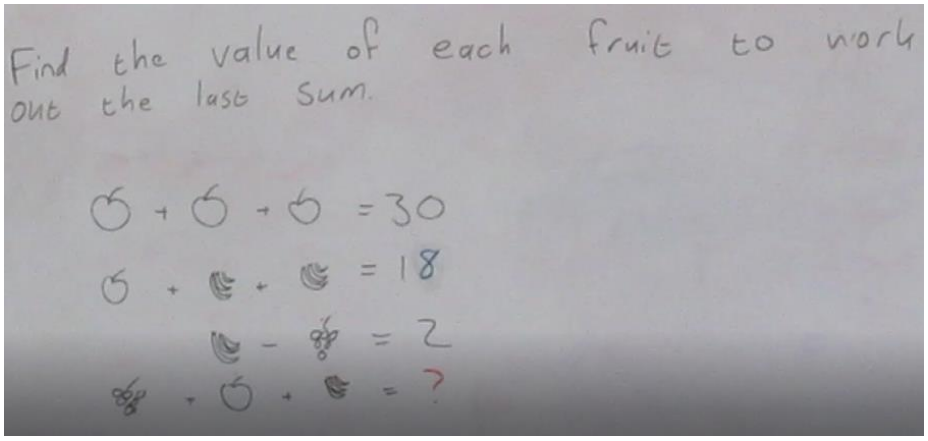

Figure 14: Fruit equations as oral formative assessment

Teacher 1 informed the learners that he would solve the problems on the board with two different methods:

> *"The purple way and the green way. The purple way is keeping the fruit, we are still using the fruit. Then once I am done with that, we will do the green way which is how you would solve the sum algebraically. Algebraically means when there are variables present."*

Teacher 1 then solved the first fruit equation (Figure 14). Once Teacher 1 had gone through how the first fruit equation must be solved, he explained how the rest of the fruit equations could be solved by gesturing to the board. He then implemented the first form of oral formative assessment by asking the learners, "How would you simplify the second [equation]?" Teacher 1 provided guidance with the first equation and then provided a platform for the learners to develop their own mathematical reasoning. To this question, some learners responded that there were "two bananas".

Teacher 1 explained how to solve the second fruit equation (Figure 14) if the learners simplified the fruit equation to two bananas. Teacher 1 further explained:

> *"We know the opposite of plus* 10 *is minus* 10 *[and] what you do to one side, you do to the other side of the equal sign.* $18 - 10 = 8$ *and* $10 - 10$ *will cancel out and give you* 0*. What you are then left with on the left-hand-side is* 2 *bananas which we can easily see needs to be divided by 2. Keep in mind, we are not looking for the value of* 2 *[bananas], we are just look for the value of one, so we have to take the* 2 *away. To do that we divide by* 2*; the* 2*'s cancels out [and] we are then left with just* 1 *banana, is what we are looking for, is then equal to* 4*, because* 8 *divided by* 2 *is* 4*."*

Throughout the whole explanation of how to solve the second fruit equation, Teacher 1 indicated the steps on the board for the learners to visually see what he was doing. However, Teacher 1 missed an opportunity to implement any form of formative assessment by not allowing the learners to attempt to solve the problem on their own first.

Teacher 1 then began the third fruit equation by discussing how to first simplify what had been given. However, throughout his explanation of the final fruit equation (Figure 14), Teacher 1 would answer his own questions and did not provide an opportunity for learners to explore their own mathematical reasoning. Only towards the end of the equation-solving process did Teacher 1 pause to allow the learners to engage with the work.

Teacher 1 then questioned the learners with the third form of oral formative assessment for the lesson on removing the negative sign in front of the grapes: "How can we turn a negative number into a positive number?" When a handful of learners responded that multiplication with -1 needed to take place. Teacher 1 further probed the learners by asking them, "What is a negative multiplied by a negative?"

To which the learners responded "Positive". After having explained the importance of negative signs, Teacher 1 continued to solve for the third and then fruit equations (Figure 14).

4.3.2.2. Written formative assessment

After completing the equations in terms of fruit, Teacher 1 asked the learners to complete the same set of equations in their workbooks, but now in algebraic terms. Teacher 1 rewrote the equations in terms of x, y and z in green on the whiteboard (Figure 15).

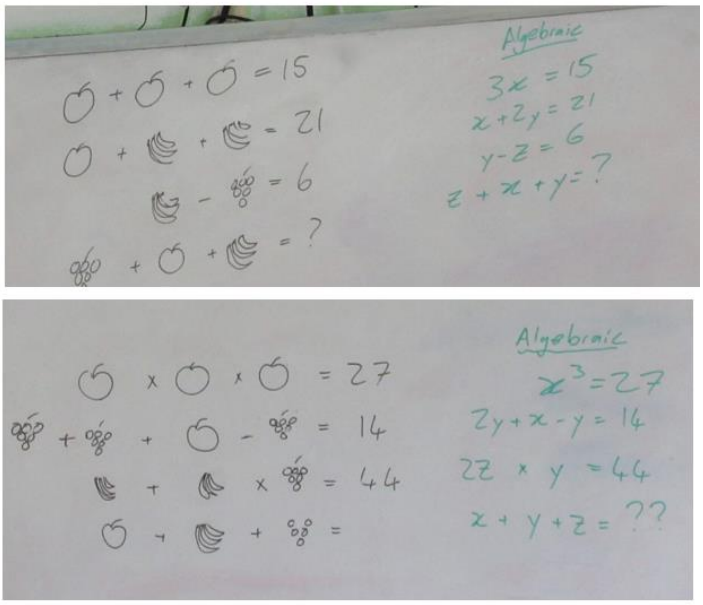

Figure 15: Algebraic equations as written formative assessment

After observing the written formative assessment provided by Teacher 1, I asked him in the unstructured interview if he thought the formative assessment, he applied was adequate. I asked the question to gain insight into whether Teacher 1 had a reason for presenting the learners with those specific equations.

Teacher 1 replied:

> *"No, in the sense that I can't really get immediate feedback from it, it is a bit delayed for a bit. If they do get it wrong, they will get it wrong for a day or so, until I am able to correct them. I would have liked to have just put more emphasis on questions like 3 and 4, [and] giving them another example to get them to understand."*

4.3.2.3. Feedback provided

Just as in the first Lesson Study cycle, Teacher 1 provided positive interjections to the learners regarding their responses to the oral formative assessment techniques. Additionally, when presenting the concept of integers through the example of grapes (as seen in Figure 15), learners would simply respond with “grapes”. To this response, Teacher 1 cautioned the learners to think deeper “Careful. What do you see next to the grapes?” when the learners responded that there was a negative sign in front of the grapes, Teacher 1 explained to the learners that negative signs do “Not fall away, [they do] not disappear.”

With regard to the algebraic equations as written formative assessment, a learner immediately asked, “Where did the x come from?” to which Teacher 1 responded:

> *“Instead of apples, we have replaced the apple with x. So, if you look, 3 apples is equal to 30, is the same way as $3x$ is equal to 30. Same [way] the y is your bananas and the z is your grapes.”*

4.4. Summary

In this chapter, the data collected was presented for two Lesson Study cycles consisting of two stages, namely Stage 2: Collaborative lesson planning and Stage 3: Lesson presentation and observation. Each stage’s data were recorded and presented in the categories of oral formative assessment and written formative assessment.

CHAPTER 5: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

The primary purpose of the current chapter is to discuss the findings. I begin with an overview of the previous chapters and then address each research question regarding the findings and the relevant literature. A reflection on the theoretical framework is then provided, followed by the limitations of my study and, thus, possible implications for similar future studies. Recommendations for future research are also discussed. Finally, a reflection of the study as a whole is provided.

5.2. Overview of previous chapters

In Chapter 1, my study was introduced, and the purpose and aims were discussed. The primary purpose of my study was to examine Grade 8 Mathematics teachers' use of formative assessment during the implementation of the Lesson Study Cycle. The rationale for the need to teach for learner understanding was also discussed. The primary research question and three secondary research questions were formulated and presented.

Chapter 2 presents an in-depth literature review on the tenets of formative assessment and the Lesson Study practice. The literature review emphasised the process of formative assessment. Thus, the focus was placed on the significance of eliciting responses from learners, providing effective and timely feedback, and regulating learning to improve learners' mathematical understanding. A conceptual framework was compiled by integrating the underpinnings of Situated Learning Theory (Lewis et al., 2009) and the five processes of the Formative Assessment framework (Antoniou & James, 2014) within the context of the Lesson Study cycle process.

In Chapter 3, I discussed the methodologies that I used for my study. Firstly, I discussed the interpretivism paradigm, which served as an underpinning for my study. After that, I discussed using a qualitative single case study design within my study, followed by the data collection process. Three Grade 8 Mathematics teachers from one secondary school in Pretoria were selected, whereby they participated in two in-school Lesson Study Cycles. Observation of two consecutive stages of the Lesson Study cycles took place, followed by unstructured interviews to corroborate my

observations. I also discussed the quality criteria and ethical considerations for my study.

In Chapter 4, I presented the findings of the collected and recorded data. The data collection procedure from each Lesson Study cycle was presented individually. The observations were deductively analysed to interpret the relationship between the concept of formative assessment and the actual implementation of formative assessment. The unstructured interviews were analysed inductively to interpret the participants' perceptions of formative assessment.

5.3. Discussion of findings

5.3.1. Collaboratively planning for formative assessment

As discussed in my literature review, the benefits of purposeful formative assessment are many and aim to ensure effective mathematics teaching and learning (Black & Wiliam, 2010). From the literature, I perceive formative assessment as a vehicle to promote socio-mathematical discourse, develop learners' conceptual understanding and enhance their mathematical thinking and reasoning. For this reason, teachers should meticulously plan the types of formative assessment techniques they wish to implement in a lesson to facilitate learning. Essentially, teachers must be aware of and understand the reasoning behind choosing a specific formative assessment to be implemented. Black and Wiliam (2010, p. 86) state that formative assessment techniques should be “thoughtful, reflective, focused to evoke and explore understanding, and conducted so that all [learners] have an opportunity to think and express their ideas”.

Additionally, providing learners with an indication of the desired learning outcomes is a prescript for successful formative assessment (Antoniou & James, 2014). Learners need to be informed of what is expected of them to achieve so that they can take responsibility for their own learning, identify the gap between their current levels of understanding and the desired levels of understanding and set small obtainable goals to meet the desired learning outcomes (Chan et al., 2014).

Throughout both collaborative lesson planning stages, the teachers did not specifically state what formative assessment techniques would be used in the lesson. However,

there was an underlying discussion of the oral and written formative assessment practices. As evident in the findings of the first collaborative lesson planning, where the focus was on fractions, the teachers stated that they would ask the learners questions based on the physical model, real-life examples and equivalent fractions. I sense that planning to ask fraction questions constitutes planning for oral formative assessment. In addition to this form of oral formative assessment, the teachers also planned to provide learners with a chance to complete some fraction questions to complete on their own in their workbooks, which constitutes a written formative assessment. According to Takahashi and McDougal (2016), when teachers collaboratively plan formative assessment, the teaching and learning process shifts, focusing on the learners' mathematical understanding. Therefore, by planning for both forms of formative assessment, the teachers aimed at developing the learners' mathematical thinking. Further, as presented in the literature review, Singh et al. (2018) claim that with various formative assessment practices such as oral and written formative assessment, learners' problem solving and critical thinking skills are enhanced.

Within the second collaborative lesson planning, where the lesson's focus was planned to be on algebraic expressions, the teachers again did not discuss and plan for specific formative assessment practices to use within the lesson. The teachers instead focused on the common learner misunderstandings and how to address the misunderstandings by creating a connection to the learners' prior knowledge. By discussing the common misunderstandings, the teachers were pre-emptive and discussed a possible oral formative assessment to combat the misunderstanding. Being pre-emptive is a key issue advocated by Lesson Study during collaborative lesson planning. Teachers contribute to the planning of the lesson by adding their own experiences (Sekao & Engelbrecht, 2021) by stating what learners grasp easily and what tends to be a challenge with regard to the topic being dealt with. The skill of being pre-emptive is an important skill for mathematics teachers to have, especially in the context of Lesson Study. Being pre-emptive implies that a teacher can foresee the challenges that learners generally have with certain topics. This, in turn, provides enough information for the teachers to plan how to teach the topic to address said challenges and develop the learners' mathematical thinking. Additionally, the teachers

discussed providing learners with mixed cognitive questions to complete on their own, which constitutes a written formative assessment.

However, it is important to note that the questions the teachers discussed to give the learners, both the oral and the written questions, were not discussed in detail. The teachers simply stated that they would give the learners some problems to do. But they did not plan exactly what questions to ask the learners. According to Elliott (2019), when formative assessment techniques are purposefully thought of and designed, learners are provided with a more sturdy platform to actively engage and participate in the lesson. From my observations and the interviews conducted afterwards, the teachers had not carefully thought through the questions that would be best suited to elicit learner responses and develop their mathematical learning. Instead, the questions would simply be general questions based on the lesson as it naturally progressed. I believe that by not having scrupulously planned the questions to pose to the learners, the teacher presenting the lesson would not be able to actively gather information on the learning taking place within the lesson, hence, detracting from the facilitation of mathematical learning. Through planning formative assessment practices, teachers can create a benchmark they wish to see the learners achieve. Without planning the formative assessment, teachers will not be able to see if the learners have obtained the required knowledge for the formative assessment.

5.3.2. Formative assessment as a means to facilitate mathematics learning

Throughout both lessons, Teacher 1, whether knowingly or not, implemented various formative assessment techniques. Within the first lesson concerning the topic of equivalent fractions, Teacher 1 often related the concept of equivalent fractions to the physical model of the cardboard cut-out pizzas (Figure 10) and facilitated a discussion with the learners by posing various questions to them that related to real-life examples. This relation served as an oral formative assessment, as it provided a platform for the learners to make the relevant connections between the real world and fractions. As argued by Singh et al. (2018), it is imperative for learners to be able to make connections between mathematical concepts to real life. By doing so, learners are encouraged to “think critically and creatively and beyond their foundational knowledge” (Singh et al., 2018, p. 299).

In my opinion, by providing the learners with a real-world example, the learners' mathematical understanding of equivalent fractions was deepened. Learners could think about something they were already familiar with in terms of mathematics.

Additionally, when Teacher 1 asked the learners whether 8 slices of pizza is more than 6 slices, the learners were engaged in critical thinking. The learners had to think about the actual sizes of the pizza slices if the pizza was divided into 8 and 6, respectively. Naturally, the learners would assume that 8 slices would be more since 8 is a whole number greater than 6, but the learners were required to think in terms of fractions and not whole numbers. Questions like these create a platform for dialogue to flourish (Black, 2015). Essentially, the correlation between the classroom and real life was made evident to the learners to develop their mathematical learning (Singh et al., 2018).

Teacher 1 used two methods in the second lesson to present the various equations provided. He first used fruit as a means to make the topic more relevant to the learners and in order to gain the attention of the learners. The learners could relate to what he was explaining and then make the connection between fruit that is the same and variables that are the same.

In addition to relating the concept to what the learners are already familiar with in the real-world, Teacher 1 related the new work to the learners' prior mathematical knowledge also. Relating new concepts to concepts that learners are already familiar with is a key attribute of formative assessment. Additionally, Black and Wiliam (1998) claim that relating learners' prior knowledge to new work enhances their conceptual understanding of the topic. As Konicek-Moran and Keeley (2015) put forward, evidence of conceptual understanding is when a learner can apply their current mathematical knowledge to new mathematical concepts. The learners were required to think about their understanding and apply it to the new work. The relation of the new work to the learners' prior knowledge was clearly evident in solving the algebraic equations in the second Lesson Study cycle. Without the knowledge of algebraic-like terms, the learners would not have been able to solve for an unknown variable, and so Teacher 1 constantly reminded them of the rules and operations when dealing with algebraic-like terms. By reinforcing the learners' prior knowledge while teaching new work, learners' conceptual understanding of the work was developed.

Another means by which Teacher 1 used oral formative assessment to develop the learners' conceptual understanding was by purposefully obtaining two different solutions for a fraction problem in the first Lesson Study cycle. Teacher 1 encouraged the learners to identify the correct solution and provide justification and reasoning for their choice. The learners were required to make the relevant connection between their prior knowledge of the order of operations, BODMAS (Bracket, Order, Division, Multiplication, Addition and Subtraction) and their newly gained knowledge. Furthermore, the mistake that Teacher 1 made is a very common misunderstanding of BODMAS and the signs of integers. Hence, the learners who could identify the mistake could apply their conceptual understanding and mathematical reasoning to a different mathematical concept and realise that no concept works in isolation. By realising that mathematics is a subject where all concepts are interrelated, learners' mathematical learning is developed as they are encouraged to think mathematically about the concepts and apply the necessary rules (Singh et al., 2018).

Various elicitation techniques are suggested throughout the literature (Boston, 2002). However, one of the most notable elicitation techniques used by Teacher 1 was pausing and allowing the learners to think for themselves before providing the correct solution for the learners. The Department of Basic Education (2011) states that simply pausing within a lesson to observe and discuss with learners how the learning is progressing serves as a beneficial elicitation technique. Further, I sense that pausing and prompting the learners to engage and ask questions encourages socio-mathematical discourse.

Within the first Lesson Study cycle, Teacher 1 occasionally paused and encouraged the learners to explore, discover and discuss their understanding of the pizza sizes by themselves before responding to questions related to equivalent fractions. It is my opinion that pausing the flow of the teaching and learning process in order to ensure that there are no misunderstandings before continuing with the lesson constitutes an oral formative assessment practice. The Department of Basic Education informs teachers that pausing in a lesson to check for understanding and to facilitate socio-mathematical discourse is an essential attribute of formative assessment and needs to be implemented continually within a lesson. The benefits of pausing are numerous. Pausing allows learners to express their levels of understanding and teachers to gauge what is being misunderstood and thus needs to be re-explained. In other words,

pausing allows for the teaching and learning process to be slowed down and adapted to the needs of the learners.

Another form of pausing was seen by Teacher 1 when he did not solve the given problems immediately. For instance, he would write the problem, whether it was an equivalent fraction question or an equation question, on the whiteboard and discuss the correct steps to solving the problem with the learners. Regarding the equivalent fraction questions, Teacher 1 would ask the learners what needed to be done first to solve the question and then highlight the significance of finding the lowest common denominator before solving the question. Regarding the equation questions, Teacher 1 would once again ask the learners what needed to be done first to solve the question and then highlight the significance of adding and subtracting like terms. Through this type of pausing, Teacher 1 engaged the learners with critical thinking; the learners were required to make the relevant connections between what steps needed to be taken before one could solve the actual problem. In other words, the learners did not just copy what Teacher 1 did but were given an opportunity to explore their own mathematical understanding and reasoning to obtain a solution. The practice of stopping within a lesson to observe for learner thinking is a necessary formative assessment practice to obtain information on how learning is progressing and what requires improvement (Department of Basic Education, 2011).

Elicitation questioning techniques evoke responses from learners and engage them to think critically and apply their problem-solving skills. Questions posed that evoke responses are in line with the prescripts of Lesson Study, where learners' mathematical thinking is the main focus of the teaching and learning process. Within Stage 2 of the Lesson Study cycle, teachers are expected to gather and plan questions to pose to learners to gain insight into learners' mathematical thinking (Sekao & Engelbrecht, 2021). The types of formative assessment questions planned within Lesson Study, according to Fernandez (2002), must be planned with the purpose, as to enhance learners' conceptual understanding and mathematical thinking. Asking questions to evoke responses transforms the teaching and learning process into learner-centred and places focus on mathematical thinking (Takahashi & McDougal, 2016).

However, although there were many opportunities to develop and enhance the learners' mathematical thinking, Teacher 1 provided many platforms for misconceptions and confusion. For instance, in the first Lesson Study cycle and with regard to Figure 14 in specific, many misconceptions can occur. The most notable is the number of bananas and grapes drawn, which is presented as one single banana and one single grape. Teacher 1 has provided a gap for misunderstandings to occur, as some learners may count each banana and conclude that within the second fruit equation (Figure 14), the equation is one apple plus four bananas plus three bananas is equal to 18 and not one apple plus one banana plus one banana is equal to 18. Within the third fruit equation (Figure 14), learners may assume the equation is three bananas plus six grapes are equal to 2, and not one banana plus one grape is equal to 2. In the final fruit equation (Figure 14), learners may assume that the equation is six grapes plus one apple plus three bananas is equal to however many and not one grape plus one apple plus one banana is equal to however many. Thus, teacher 1 has not considered the many different interpretations of the learners for this type of example.

The implications of ambiguous representations such as this one for mathematics learning is that more misconceptions can occur than actual understanding. A teacher may unintentionally make the mathematical topic being dealt with more difficult than it needs to be for the learner by allowing room for misconceptions to occur. Formative assessment should facilitate learning and aim to guide learners in identifying the gap between the knowledge they currently possess and the desired knowledge (Farrell & Rushby, 2016). However, when ambiguous representations are used within the formative assessment, the learning that takes place may not be a true reflection of the learners' conceptual understanding. For this reason, formative assessment practices to be implemented within a lesson need to be meticulously planned in the collaborative lesson planning stage of a Lesson Study cycle (Norwich et al., 2014).

In some instances, Teacher 1 tended to ask more than one question at a time. For example, when asking questions concerning the pizza slices, he would ask three questions back-to-back. The implication is that learners will be unsure of what is being asked and how to answer the questions. Questions asked need to be clear and concise.

From the findings, one can see that Teacher 1 had not planned any questions purposefully. Instead, as he said in the interview, he posed certain questions “because they looked good.” Choosing questions to ask learners because they “look good” is not an adequate reason to implement the question.

5.3.3. Tenets of meaningful feedback

For assessment to be formative, feedback is required (Taras, 2005) and only through specific feedback can new skills be learnt and developed (Chan et al., 2014). Teacher 1 provides feedback to the learners as soon as the learners asked any questions or provided responses to his questions. In agreement, Sadler (1998) concurs by stating that the nature, contextualisation and timing of feedback provided an important aspect of quality feedback. Essentially, Teacher 1 used feedback to encourage an interactive dialogue between himself and the learners and ensured that all learners’ responses were acknowledged. According to Wiliam and Leahy (2016), with interactive dialogue, learners feel encouraged to continue to engage within a lesson and thus act on any feedback provided.

The most prominent forms of meaningful and effective feedback that Teacher 1 implemented in both lessons were positive interjections and constructive and corrective reinforcement advocated by (Owen, 2016). Constant positive interjections such as *Awesome! Well-done! Good one!*, were provided to any of the learners’ correct responses. I believe that using these interjections as feedback promotes the self-esteem and motivation of the learners.

Constructive and corrective feedback were provided to both incorrect and correct responses. Although the learners were unaware of the desired learning outcomes, the feedback indicated what was considered ‘good’ performance in terms of the desired learning outcomes (Owen, 2016). Praising learners’ correct solutions serves as a means to encourage the learners to continue to engage in the lesson and partake in socio-mathematical discourse. Similarly, when learners provided incorrect solutions, Teacher 1 did not dismiss the learners' responses but rather redirected the learners’ train of thought. Essentially, Teacher 1 provided feedback to bridge the gap between the learners’ current level of understanding and the desired level (Nicol & Macfarlane-Dick, 2006).

Ultimately, Teacher 1 used feedback to guide the learners to identify their own strengths and weaknesses (Owen, 2016) and to provide teaching information so that he could adapt his teaching methods (Nicol & Macfarlane-Dick, 2006). Teacher 1 did so by rephrasing the questions he posed, using different terminology to ensure the learners knew what was being asked of them. Teacher 1 could have easily answered his own questions, especially when learners provided incorrect solutions, but by rephrasing the questions, the learners could understand the question from a different perspective and apply their critical thinking to the problem. It is my view that Teacher 1 was able to guide the learners toward the correct methods to obtain the correct solutions by redirecting, and by doing so, learners were encouraged to dig deeper in terms of their mathematical thinking and reasoning.

However, despite all the positive aspects of Teacher 1 feedback on the learners' responses, there were some incidents whereby he answered his own questions and did not allow the learners to explore their own mathematical ideas. By doing so, Teacher 1 encourages learners to simply rote learn procedures and not to develop their own conceptual understanding of the topic at hand. Teachers posing and answering their own questions contradict the prescripts of Lesson Study to promote learners' mathematical thinking and the affordances of formative assessment to encourage socio-mathematical discourse.

5.4. Responding to the secondary research questions

This study aimed to examine Mathematics teachers' formative assessment practices within the Lesson Study cycle. As such, the primary research question was crafted as follows: *How do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 mathematics class?* The following three secondary research questions were used to address this question:

1) How do Mathematics teachers collaboratively plan formative assessment during the Lesson Study cycle?
2) In what ways do Mathematics teachers use formative assessment to facilitate mathematics learning?
3) How do teachers provide meaningful feedback to learners?

Observations and unstructured interviews were conducted to answer the above research questions. The research questions were aligned with the data collection instruments (Table 1), and each question was contextualised within my conceptual framework (Figure 5). The data analysis from Stage 2 of each Lesson Study cycle was used to explore how the mathematics teachers planned for formative assessment, and the data analysis from Stage 3 of each Lesson Study cycle was used to examine and gain insight into how formative assessment is used within a lesson and how the tenets of formative assessment facilitate mathematics learning.

5.4.1. First secondary research question

To address the first secondary research question of *how do mathematics teachers collaboratively plan formative assessment during the Lesson Study cycle*, data were collected by observing the three teachers collaboratively plan a lesson and, after that, conducting interviews. Using the observation sheet and the interview, I was able to specifically focus on what the teachers discussed, how they formulated their lesson outcomes and what forms of formative assessment they planned to implement within each lesson.

From my findings and the above discussion, the following two key takeaways arose: 1) the teachers may have collaboratively planned the lesson outcomes but did not plan on sharing the desired learning outcomes with the learners. In other words, the teachers planned for what they wanted the learners to achieve by the end of the lesson, but they did not explicitly plan how they wanted to ensure that the learners would achieve it, and 2) it is clear that planning for formative assessment is not at the forefront when planning a lesson. The teachers may have planned for oral and written formative assessments, but such planning was very vague, and no specific problems to implement or questions to pose were discussed. Planning only in a broad sense is not a prescript of Lesson Study.

Based on the discussion and these two key takeaways, the teachers did not collaboratively plan the formative assessment efficiently and purposefully during the two Lesson Study cycles but instead discussed vague occurrences of formative assessment to implement.

5.4.2. Second secondary research question

To address the second secondary research question, *in what ways do Mathematics teachers use formative assessment to facilitate mathematics learning*, data were collected by observing one of the three teachers presented the collaboratively planned lesson for each Lesson Study cycle and once again conducting an interview after. Using the observation sheets and interviews, I could specifically focus on how, if at all, the teacher communicated the expected learning outcomes of the lesson to the learners and how the teacher used formative assessment to elicit learners' mathematical thinking.

Based on the above discussion, it is clear that formative assessment is the most natural form of assessment within the teaching and learning process (Department of Basic Education, 2011). Teacher 1 used oral and written formative assessment continually throughout both lessons to elicit the learners' conceptual understanding and mathematical thinking. Teacher 1 allowed for and promoted socio-mathematical discourse whereby the learners could discuss and explore their own mathematical ideas and reasoning. However, Teacher 1 also missed many opportunities to implement a formative assessment to enhance the learners' mathematical thinking and instead created a platform for misconceptions to occur. For this reason, I argue that the formative assessment implemented was not done effectively to facilitate mathematical learning. If the questions posed to the learners had been meticulously planned and planned with a purpose, the misconceptions might have been avoided, and better-suited questions could have been formulated to develop the learners' mathematical understanding.

5.4.3. Third secondary research question

To address the third secondary research question, *how do teachers provide meaningful feedback to learners*, data were collected by observing one of the three teachers present the planned lesson for each Lesson Study cycle and conducting an interview. With the use of the observation sheets and interviews, I was able to specifically focus on what the quality of the teacher's feedback was like towards the learners' engagements throughout both lessons in each Lesson Study cycle.

However, since the desired learning outcomes were not made clear to the learners, an essential element of feedback was overlooked. The learners were not allowed to take responsibility for their own learning. However, the feedback that was voided during both lessons proved constructive and encouraging. Through the feedback provided, the learners were informed immediately if they had misunderstood something and afterwards received guidance to rectify it. Additionally, if a learner responded with a correct solution, they received feedback that encouraged interactive dialogue to flourish and active engagement to continue.

5.5. Responding to the primary research question

From the discussion of the three secondary research questions, light can be shed on the primary research question: *how do teachers use formative assessment during the implementation of the Lesson Study cycle in a Grade 8 mathematics class?*

Numerous studies and researchers have shown that the practice of formative assessment is highly beneficial in Mathematics Education (Wiliam & Leahy, 2016). However, what was most notable in my study is that teachers do not realise the significant impact of formative assessment and do not plan formative assessment techniques with purpose. For the case of my study, it can be argued that the implications of teachers not realising the affordances of planning for and using formative assessment are alarming because:

- formative assessment expectancies and success criteria are not shared with the learners, hindering their ability to identify the gap between their current mathematical understanding and the desired level.
- learners cannot interpret feedback successfully, as they are unaware of the desired mathematical learning outcomes.
- mathematics teachers cannot interpret learners' responses adequately because, the formative assessment techniques implemented were implemented with no purpose and hence, hinder the teaching decisions.
- without implementing purposeful formative assessment practices, mundane and rote activities and exercises are given to learners that do not elicit learners' mathematical thinking and do not collect information on learners conceptual mathematical understanding.

- mathematics teachers cannot teach for understanding, as they do not collect adequate information on learner understanding and, in turn, do not provide meaningful feedback and adjust teaching decisions.

Based on the implications mentioned above, I assert that teachers generally do not view and use formative assessment as a powerful vehicle to teach mathematics for understanding.

5.6. Reflection of the theoretical framework and the study

The two theoretical lenses underpinning my study are the Situated Learning Theory (Lewis et al., 2009) and the Formative Assessment framework (Antoniou & James, 2014). They were used to guide my study on how formative assessment techniques are used within the context of Lesson Study. These two theories aided me in formulating my research questions, identifying the relevant literature to shed light on formative assessment practices and organising, analysing and interpreting the research findings.

The Situated Learning Theory presented by Lewis et al. (2009) provided a fertile platform for Lesson Study to be situated within. This framework postulates that (teacher) learning takes place effectively when it is situated in authentic contexts, which in the case of my study is the classroom or the school environment. That is to say, instead of simply informing the teachers of the tenets of Lesson Study, the Situated Learning Theory (Lewis et al., 2009) allowed for teachers to be exposed to the tenets in a practical manner. The teachers were required to collaboratively plan a lesson and then were expected to actually teach the lesson.

Additionally, the Formative Assessment framework presented by Antoniou and James (2014) provided theoretical guidance on how formative assessment practices should unfold within a lesson and be used to adapt and regulate the teaching and learning process. Essentially, this theory guided me in understanding the affordances and the formative assessment process. The framework was directly linked to crafting my research questions and data collection instruments.

Using the two theoretical lenses, I collected data in the form of direct observations followed by unstructured interviews with the teachers involved. The data collection instruments used provided a platform to gain insight into how formative assessment is

planned and how it can be used to elicit learners' mathematical thinking. The Formative Assessment framework (Antoniou & James, 2014) was used during the data analysis to determine whether or not the formative assessment process was carried out as intended. The findings from the data collection procedure indicate that the teachers did not adequately or intentionally 1) share the formative assessment expectancies and success criteria with the learners, 2) use formative assessment techniques to gather information on learner mathematical understanding, 3) interpret responses from learners adequately and 4) to provide meaningful feedback to develop learners mathematical learning.

5.7. Limitations of the study

Although undoubtedly valuable, the findings of my study are subjected to certain limitations. COVID-19 put many restrictions on schools such as implementing rotational timetables stating that only 50% of the school's learners may be on the premises at a time. This, in turn, hindered my ability as a researcher to 1) gain access to the school and 2) gain insight into how all the learners responded to the lessons being taught. The second limitation of the study is attributed to Lesson Study not being institutionalised. Lesson Study and the tenets thereof are a relatively novice practice. Therefore, the teachers are still in the process of perfecting the practice of it. The third limitation of the study was the time allocation of the Collaborative lesson planning and the Lesson presentation and observation. Due to the teachers' private commitments after the Collaborative lesson planning, I could not interview all three of the teachers but only one for the first Lesson Study cycle and two for the second Lesson Study cycle. The prescripts of Lesson Study state that the teachers who are not presenting the planned lesson should observe the lesson to reflect on learner engagement and think in the next stage of the Lesson Study cycle. However, because the planned lessons took place within school hours, the other two teachers could not observe the lessons as they had their own classes to attend to during that time allocation. The fourth limitation of the study was the fact that only one out of three teachers presented both lessons, as previously mentioned due to time issues, the other two teachers were not given a chance to teach the planned lesson but rather Teacher 1 presented both lessons. This limitation detracts from the prescripts of Lesson Study as the aim behind planning a lesson together to create a shared lesson and not an individualised lesson.

The study was a qualitative interpretivist study and used a single case study design. The data were collected from only one school with three teachers. This sample is not large enough to allow for generalisability. However, the findings are sufficient for me to gain insights into the use of formative assessment in the context of Lesson Study.

5.8. Recommendations for further study

This study only focused on formative assessment during collaborative lesson planning and lesson presentation in Lesson Study. Lesson Study is a teacher development practice of teachers collaboratively working together to enhance learner mathematical thinking. Further studies can be done with regard to all the five stages of the Lesson Study cycle and their respective tenets. Additionally, an exploration of how teachers use the information gathered from formative assessment to regulate learning and adapt teaching decisions can be done. Lastly, more than two Lesson Study cycles can be examined and perhaps, researchers who are interested in the field of study can examine a larger Lesson Study cycle cluster, that is to say, more than teachers from just one school participating. If teachers from various schools were to participate in Lesson Study, the inputs from the teachers on how the lesson should be taught to facilitate and develop learners learning would be much greater. A further recommendation is to research formative assessment practices across a variety of grades, and perhaps even other subjects, and not just Grade 8 and mathematics.

5.9. Implications

The study's findings indicate that formal training on formative assessment techniques could enhance teachers' formative assessment knowledge and practices. Additionally, formal training on Lesson Study could be beneficial for teachers to understand the concept and what it is set to achieve more fruitfully. From the results of this study, it can be deduced that if formative assessment techniques are planned for and implemented effectively and continually, teachers will be able to teach mathematics for understanding, gain insight into learners' mathematical thinking and provide feedback to guide learners to success.

5.10. Final reflections

From the beginning of my career as a mathematics teacher, I have always been interested in how we can assist learners in learning mathematics with understanding. I have always believed that formative assessment is a way to ensure this. Therefore, through the current study, my aspiration was that it would assist mathematics teachers in implementing purposeful formative assessment practices within the teaching and learning of mathematics. I hope with the use of my study, teachers will provide learners with problems, exercises and activities with meaning and not just 'busy work.' This study has, in turn, had a significant influence on how I currently implement formative assessment and the questions I pose to learners. I believe that this study sheds light on the significance formative assessment techniques have on the teaching and learning process and that mathematics teachers should strengthen their formative assessment practices.

5.11. Conclusion

In this study, I explored Grade 8 mathematics teachers' formative assessment practices with the Lesson Study cycle. Because this study was a qualitative interpretivist study through the single-case study design, it was conducted by observing the participants in their natural settings. The theoretical frameworks that guided the study were the Situated Learning Theory (Lewis et al., 2009) which is centred around learning through participation in authentic contexts; and the Formative Assessment framework (Antoniou & James, 2014), which is concerned with the process of formative assessment practices.

The key findings of the study can be summarised as follows:

- Teachers do not plan for formative assessment. They implement formative assessment as the lesson naturally progresses.
- Learners are not made aware of the formative assessment expectancies and success criteria.
- Feedback to learners' responses is critical in guiding learners to achieve the desired learning outcomes.

These findings and the implications thereof suggest that teachers are not fully aware of the affordances that formative assessment practices have to offer. This could be attributed to the pressure of teaching for summative purposes and not teaching for conceptual mathematical understanding. However, it is salient to note that although I cannot make definitive generalisations and conclusions with regard to the study of mathematics teachers' formative assessment practices, I can formulate valuable lessons from my study:

- There is a dire need for teachers to place more emphasis on teaching for understanding through the use of formative assessment practices. Teaching for a test yields momentary rewards, whereas teaching with formative assessment yields conceptual understanding.
- Planning for formative assessment is as crucial as implementing formative assessment. Teachers need to be mindful of the questions that they pose to learners and have a reason for providing learners with certain problems.
- Learners need to be made aware of what is expected of them to achieve the desired mathematical learning outcomes. Learning outcomes serve as a 'map' for learners to follow and take responsibility for their own learning.
- Feedback is only effective if it is targeted in a timely manner, promotes socio-mathematical discourse and is actionable. Feedback must encourage learners to engage with the lesson and explore their mathematical understanding and reasoning.
- For effective teaching and learning of mathematics to take place, continual and purposeful formative assessment must be followed by adaption of teaching decisions to meet the needs of the learners.

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Annexures

Annexure A: Observation Sheet for collaborative lesson planning

OBSERVATION SHEET		
STAGE 2: Collaborative lesson planning		
What is discussed among the teachers involved?	How are the lesson outcomes formulated?	What types of formative assessment are planned to be used?
Researcher observation notes	**Researcher observation notes**	**Researcher observation notes**

Annexure B: Observation sheet for lesson presentation and observation

OBSERVATION SHEET		
STAGE 3: Lesson presentation and observation		
How does a teacher communicate the expected outcomes of the lesson to the learners?	How does the teacher implement the decided upon formative assessment within the lesson to elicit learners mathematical thinking?	What is the quality of the teachers' feedback to the learners? (i.e. is it timely? is it insightful? does it address the misunderstandings? etc.)
Researcher observation notes	**Researcher observation notes**	**Researcher observation notes**

Annexure C: Interview schedule for Lesson Study cycle 1

UNSTRUCTURED INTERVIEW SCHEDULE **Lesson Study cycle 1**
STAGE 2: Collaborative lesson planning
1. How were these lesson outcomes formulated? Were they formulated as a group based on what the learners require? Will the lesson outcomes be stated to the learners? 2. Will the teacher presenting the lesson introduce the lesson by explicitly stating the lesson outcomes to the learners? 3. What specific formative assessment questions will the teacher presenting the lesson ask? 4. What will be done for the learners who cannot afford to buy a chocolate or forget to bring one?
STAGE 3: Lesson presentation and observation
1. Was there a particular reason for having chosen the given example to the learners? 2. What questions did the learners ask you during the lesson presentation? 3. Why were no examples with different denominators provided? 4. Do you think the learners achieved the lesson outcome, namely identify the denominators as multiples of one another? In other words, identifying the LCD. This was a lesson outcome that you planned in the lesson planning but was not covered in the lesson. 5. You managed to address stronger learners and provide them with extended opportunities with more complex sums. But what about weaker learners? The ones that could not keep up or couldn't solve the sums by themselves, did you do anything to address their needs? 6. What do you think your strongest/ most effective form of formative assessment was? What provided insight into their understanding for you? 7. What was your actual overall lesson outcome that you wanted to be achieved by the end of the lesson? 8. What do you believe the learners actually did take away from the lesson? 9. Do you think that your forms of formative assessment were adequate?

10. How would you have improved on them?

Annexure D: Interview schedule for Lesson Study cycle 2

UNSTRUCTURED INTERVIEW SCHEDULE **Lesson Study cycle 2**
STAGE 2: Collaborative lesson planning
1. What are your desired lesson outcomes? What do you want the learners to know by the end of this lesson? 2. How will you check learner understanding? What will you do to make sure that they understand? Like what kind of questions would you ask them? 3. When you get your key takeaways, are you going to address the issues in the next lesson?
STAGE 3: Lesson presentation and observation
1. What were the planned lesson outcomes? 2. Do you think that the lesson outcomes were achieved? 3. Do you think that the formative assessment that you applied was adequate? 4. Do you promote discussion and sharing of ideas while learners are working individually? 5. Once you have received this information about whether or not learners understand like terms, to improve your future teaching? 6. Do you think that learners are aware of mark allocation? 7. How do you plan your board work?

Annexure E: Declaration of responsibility

PERSONAL DECLARATION OF RESPONSIBILITY

Title of research project: Lesson Study - a teacher development model

1. I/we declare that I am/we are cognisant of the goals of the Research Ethics Committee in the Faculty of Education to
   - ❑ develop among students and researchers a high standard of ethics and ethical practice in the conceptualisation and conduct of educational research;
   - ❑ cultivate an ethical consciousness among scholars especially in research involving human respondents; and
   - ❑ promote among researchers a respect for the human rights and dignity of human respondents in the research process.

2. I/We subscribe to the principles of
   - ❑ *voluntary participation* in research, implying that the participants might withdraw from the research at any time.
   - ❑ *informed consent*, meaning that research participants must at all times be fully informed about the research process and purposes, and must give consent to their participation in the research.
   - ❑ *safety in participation* put differently, that the human respondents should not be placed at risk or harm of any kind e.g. research with young children.
   - ❑ *privacy*, meaning that the *confidentiality* and *anonymity* of human respondents should be protected at all times.
   - ❑ *trust*, which implies that human respondents will not be subjected to any acts of deception or betrayal in the research process or its published outcomes.

3. I/we understand what plagiarism entails and am/are aware of the University's policy in this regard. I/we undertake not to make use of another person's previous work without acknowledgment or to submit it as our own. I/we also undertake not to allow anyone to copy our work with the intention of using it as their own work.

4. I/we understand that the data collected in the course of our research become the institutional property of the University of Pretoria and I/we undertake to transfer all raw data and documents related to our research for safekeeping as required by the Faculty of Education.

5. I/we understand that any amendment to the approved protocol needs to be submitted to the Ethics Committee for review prior to data collection. Non-compliance implies that approval will be null and void.

L Neuhoff	L Neuhoff	08/09/2020
Applicant	**Signature**	**Date**
Dr RD Sekao (Project leader)		07/09/20
Supervisor (if applicable)	**Signature**	**Date**

Annexure F: Ethics approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Amendment

Ethics Committee

28 September 2020

Miss L Neuhoff

Dear Miss L Neuhoff

REFERENCE: UP 19/03/01SEKAO20-01

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. Noncompliance 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 19/03/01SEKAO20-01 in any communication with the Ethics Committee.

Best wishes

Prof Funke Omidire
Chair: Ethics Committee
Faculty of Education

Room 3-63, Level 3, Aldoel Building
University of Pretoria, Private Bag X20
Hatfield 0028, South Africa
Tel +27 (0)12 420 5656
Email edu.ethicsadmin@up.ac.za
www.up.ac.za

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Annexure G: GDE research approval letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**06 October 2020**
Validity of Research Approval:	**08 February 2021– 30 September 2021** **2019/631**
Name of Researcher:	**Neuhoff L**
Address of Researcher:	**2115 Cura Avenue ,Equestria Estate**
	3 Cederberg
	Pretoria
Telephone Number:	**082 495 5308**
Email address:	**U13107799@tuks.co.za**
Research Topic:	**Examining Grade 8 Mathematics teachers formative assessment practices within the lesson Study cycle**
Type of qualification	**Med-Mathematics Education**
Number and type of schools:	**6 Secondary Schools**
District/s/HO	**Tshwane South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

06/10/2020

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of COVID 19 pandemic researchers can ONLY collect data online, telephonically or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate. The approval letter will then indicate the type of arrangements that have been made with the school.***
4. ***The Researchers are advised to make arrangements with the schools via Fax, email or telephonically with the Principal.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

pp .....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 06/10/2020

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Annexure H: Title registration

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

baatseba.mphahlele@up.ac.za *Tel.: 012-420 5582*

26 October 2020

Student no: 13107799

Ms Lauren Neuhoff laulenneuhoff@gmail.com
u13107799@tuks.co.za

Dear Lauren

APPROVED TITLE AND SUPERVISOR

I have pleasure in informing you that your approved title and supervisor for the MEd is:

Title: Examining Grade 8 mathematics teachers' formative assessment practices within the Lesson Study cycle

Supervisor: Dr RD Sekao
Contact details: 012 420 4640, david.sekao@up.ac.za

You are advised to acquaint yourself with Regulations in the publication 'General Regulations and information'.

Your registration as a student must be renewed annually before 28 February until you have complied with all the requirements for the degree. You will only be entitled to the guidance of your supervisor if annual proof of registration is submitted.

Yours sincerely

Baatseba Mphahlele

Mrs Baatseba Mphahlele *for*
Dean

Annexure I: Permission from district director to conduct research

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

Enquiries: Lucky Rapudi
Tel: (012) 401 6317
Fax: 0866 522 388
Email: Lucky.Rapudi@gauteng.gov.za

TO: **The Principal**
TS District Secondary Schools

FROM: **Mrs. Hilda Kekana**
District Director: Tshwane South

DATE: **22nd February 2021**

SUBJECT : **PERMISSION TO CONDUCT RESEARCH AT AN EDUCATION INSTITUTION**

Dear Sir/ Madam

Permission is hereby granted to **L. Neuhoff** to conduct an academic research at your institution.

The researcher shall make arrangements for research with the school management. The school staff, learners and SGB are requested to co-operate with and give support to the researcher. Research findings and recommendations are critical for policy review in public education sector.

The researcher may however not disrupt the normal school programme in the course of research. The research may only take place between the months of February and September. Attached are other conditions to be observed by the researcher.

The school may request for the research outcome presentation directly from the researcher or obtain research document from Research & Knowledge Management Directorate at GDE Head Office.

Regards

Mrs H.E. Kekana
District Director: Tshwane South
Date: 2021 /02 /23

Making education a societal priority

Office of the District Director: Tshwane South
(Mamelodi/Eersterust/Pretoria East/Pretoria South/Atteridgeville/Laudium)
President Towers building, 265 Pretorius Street, Pretoria, 0002
Private Bag X198, Pretoria, 0001 Tel: (012) 401 6317; Fax: (012) 401 6318
Website: www.education.gpg.gov.za

Annexure J1: Letter to the principal

Faculty of Education

Eng: Ms L. Neuhoff
2115 Cura Avenue
3 Cederberg, 0084
Email: laurenneuhoff@gmail.com

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: ***Examining Grade 8 Mathematics teachers' formative assessment practices within the Lesson Study Cycle***. The purpose of the study is to explore the formative assessment practices of Mathematics teachers who implement a professional teacher development model known as Lesson Study. This letter serves to request your permission for your Mathematics teachers who participate in Lesson Study to participate in the afore-mentioned research study.

If permission is granted, the Grade 8 Mathematics teachers will be invited to participate in this study by:

a) being observed during three of the five stages of the Lesson Study Cycle i.e. *collaborative lesson planning*, *lesson presentation & observation* and *post-lesson reflection* stage. A total of two (2) lessons will be observed and audio/video recorded.
b) being part of the **interview** session (approximately 30 minutes) that will be audio/video recorded.
c) availing their collaboratively prepared lesson plan for analysis.

Note that *participation* of the teachers is completely *voluntary* and if they agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* teachers' consent 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 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 practice.
- *Privacy*: The names of the teachers and the data they provide will be kept confidential and anonymous.
- *Trust*: the teachers will not be subjected to any act of deception or betrayal in the research process or its published findings.

I would also 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, Lauren Neuhoff, at 082 495 53078 or my supervisor, Dr RD Sekao, at 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

_____ _____

Ms L Neuhoff Dr RD Sekao (Supervisor)

Annexure J2: Letter to the teachers

Faculty of Education

Eng: Ms L. Neuhoff
2115 Cura Avenue
3 Cederberg, 0084
Email: laurenneuhoff@gmail.com

Dear Mathematics teacher

INVITATION TO PARTICIPATE IN THE RESEARCH STUDY

I am an MEd student at the University of Pretoria, and I am conducting a research study titled: ***Examining Grade 8 Mathematics teachers' formative assessment practices within the Lesson Study Cycle***. The purpose of the study is to explore the formative assessment practices of Mathematics teachers who implement a professional teacher development model known as Lesson Study. This letter serves to request your participation in the afore-mentioned research study.

Your participation will involve:

d) being observed during three of the five stages of Lesson Study Cycle i.e. *collaborative lesson planning*, *lesson presentation & observation* and *post-lesson reflection* stage. A total of two (2) lessons will be observed and video recorded.

e) being part of the **interview** session (approximately 30 minutes) that will be audio/video recorded.

f) availing your collaboratively prepared lesson plan for analysis.

Note that your *participation is* completely *voluntary* and if you agree to participate, I will ensure that the following ethical principles are adhered to:

- *Informed consent:* your consent to participate will be based on your understanding of the purpose and process of the study, as I would have explained them.
- *Safety in participation:* you will not be exposed to any risk or harm of any form since data will be collected during the normal Lesson Study process, and you

will not be required to deviate from your day-to-day teaching and learning practice.

- *Privacy*: your names and the data you provide will be kept confidential and anonymous.
- *Trust*: you will not be subjected to any act of deception or betrayal in the research process or its published findings.

I would also like to request your permission to use the data you will provide, 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, Lauren Neuhoff, at (082 495 53078) or my supervisor, Dr RD Sekao, at 012 420 4640 or david.sekao@up.ac.za.

Yours sincerely

_____ _____

Ms L Neuhoff Dr RD Sekao (Supervisor)

Annexure K1: Letter of consent – school principal

Faculty of Education

Eng: Ms L. Neuhoff
2115 Cura Avenue
3 Cederberg, 0084
Email: laurenneuhoff@gmail.com

Dear Ms Neuhoff

LETTER OF CONSENT TO CONDUCT THE RESEARCH STUDY

I,……., principal of ……, voluntarily and willingly permit Ms L Neuhoff to conduct a research study titled: ***Examining Grade 8 Mathematics teachers' formative assessment practices within the Lesson Study Cycle***. I understand that the participation of the Grade 8 teachers in the afore-mentioned study to which I am consenting will involve:

a) being observed during three of the five stages of the Lesson Study Cycle i.e. *collaborative lesson planning, lesson presentation & observation* and *post-lesson reflection* stages.
b) being part of the **interview** session (approximately 30 minutes) 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 subscribe to the ethical research principles, including the following:

- *Informed consent*
- *Safety*
- *Privacy, confidentiality and anonymity*
- *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 give consent for our participation in the study.

_____ _____ _____
(**Name** and **surname**) Signature Date

Annexure K2: Letter of consent – teacher as participants

Faculty of Education

Eng: Ms L. Neuhoff
2115 Cura Avenue
3 Cederberg, 0084
Email: laurenneuhoff@gmail.com

Dear Ms Neuhoff

LETTER OF CONSENT TO PARTICIPATE IN THE RESEARCH STUDY

I,……..……., a Mathematics teacher at……..……, voluntarily and willingly agree to participate in the research study titled: ***Examining Grade 8 Mathematics teachers' formative assessment practices within the Lesson Study Cycle***. I understand that my participation in the afore-mentioned study to which I am consenting will involve:

d) being observed during three of the five stages of The Lesson Study Cycle i.e. *collaborative lesson planning, lesson presentation & observation* and *post-lesson reflection* stages.
e) being part of the **interview** session (approximately 30 minutes) that will be audio/video recorded.
f) availing the collaboratively prepared lesson plan for analysis.

I declare that I understand the purpose of the study and that you subscribe to the ethical research principles, including the following:

- *Informed consent*
- *Safety*
- *Privacy*, confidentiality and anonymity
- *Trust*

In addition, I grant the University of Pretoria permission to use the data I will provide 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 give consent to voluntarily participate in the study.

_____ _____ _____

(**Name** and **surname**) Signature Date

Annexure L: Integrated declaration

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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Faculty of Education

Form D08

Faculty of Education Ethics Committee
Integrated Declarations Form

Ethics Reference No: UP 19/03/01SEKAO20-01

Investigator's Declaration

I, the investigator (Name and Surname), Lauren Neuhoff
Degree completed (if applicable): MEd (General)
E-mail address: laurenneuhoff@gmail.com

Supervisor's declaration (If applicable)

I, the supervisor, Dr David Sekao of the following study, titled: Examining Grade 8 Mathematics teachers' formative assessment practices within the Lesson Study cycle hereby declare that:

1. The research activities for which ethics approval was provided by the Ethics Committee were conducted in accordance with the conditions of approval and the regulations of the University of Pretoria and Faculty of Education.
2. There have been no significant changes to the project which render the approval of the Ethics Committee invalid.
3. The investigator obtained formal permission and informed consent/assent from all parties involved in this project and will submit these for inspection if required.
4. There were no adverse experiences or undue risks experienced by participants in the course of the study that require the attention of the Ethics Committee.
5. The title registered with the Postgraduate Committee of the Faculty of Education has been submitted.

Storage of research data and/or documents

We declare that research data and/or documents referring to the above-mentioned study have been submitted to the supervisor and will be stored at the following address(es):

University of Pretoria, Groenkloof campus, George Storrar Dr &, Leyds St, Groenkloof, Pretoria, 0027.

We understand that the storage of the abovementioned data and/or documents must be maintained for a minimum of 15 years from the commencement of this study.

Start date of study: January 2020 Date of submission of thesis/dissertation: August 2022

Until which year will data be stored: 2035

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Name of Investigator	Signature	Date
Lauren Neuhoff		11 May 2022
Name of Co-Supervisor (if applicable)	**Signature**	**Date**
Dr David Sekao		18/05/2022
Name of Supervisor	**Signature**	**Date**
Dr Hanlie Botha		18/5/2022