

A Case Study of selected Grade 7 learners using Argumentative Frames for solving word problems

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Thesis accepted in fulfilment of the requirements for the degree *Doctor Philosophy* in *Mathematics Education* at the North-West University

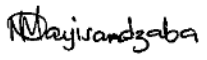
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DECLARATION BY CANDIDATE

I, Nothile Tivelele Kunene, hereby declare that this thesis, submitted for the qualification of Doctor of Philosophy - Mathematics Education at North-West University, has not previously been submitted to this or any other university. I further declare that this is my own work and that, as far as is known, all material has been recognised.

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Date: November 2019

ACKNOWLEDGEMENTS

I would like to thank all those who have contributed to the successful completion of this study. They are as follows:

My greatest appreciation goes to my supervisors, Professor Hercules Nieuwoudt, and previously Professor Percy Sepeng. Thank you for the support and guidance that you have shown during the undertaking of this research study. You shaped me from the inception of this research and gave me support whenever I needed you. Without your professional guidance, this study would have not been a great success.

I also express my gratitude to the principals of two primary schools, their teachers and learners in Montshiwa Township who participated in this study by openly sharing the challenges that they are facing in their journey on issues of teaching and learning Mathematics, word solving problems in particular.

To my colleagues, thank you for your words of wisdom and encouragement.

My appreciation also goes to my family/ relatives and friends for their endless support, for their words of encouragement and prayers. I wish to thank all the people who were directly or indirectly involved in this study.

I have to make a special mention of my husband, Hezekiel Sabelo, my son Lindelani Lovington and my daughter Nothando Loveness. Thank you so much for your inspiration, emotional support and patience you have given to me in the demanding journey of this research work. I would not be what I am and where I am without your endless support. May God richly bless you.

My greatest appreciation goes to my Language Editors, Mrs Hettie Sieberhagen and previously Mr Jack Chokwe; Statisticians, Dr Maupi Letsoalo and Mr Martin Chanza; Librarian, Ms Dina Mashiyane; and Bibliographic and Style Editor, Mr Kirchner van Deventer.

ABSTRACT

The absence of *talk* in the classroom shows a gap in the level of syntactic knowledge which relates most centrally to mathematical modes of inquiry and the kinds of practices that point towards the practices of Mathematics as a discipline. Issues of learners' abilities of word problem-solving, abilities of sense making, the art of argumentation and discussion in mathematics classrooms emerged as issues of concerns too, and were explored in this study.

This study sought to explore the use of argumentative writing frames (AWFs) in a case of G word problem-solving in Grade 7 classrooms, and how it influenced the learners' academic performance in Mathematics. This study followed an interpretive mixed-method case study design. I sought to explore the case of learners' utterances as they solved word problems in their natural setting (classroom). Within the mixed method approach, I also used a pre-test – intervention – post-test (PIP) making use of quantitative and qualitative data. The data collection strategies used in this study included tests experimental group [42]) and (comparison group [n=36], learners' focus groups with the experimental group [n=11], and intervention (video and exercise books) with the experimental group in Montshiwa Township in the North-West Province. The study is methodically underpinned by the pragmatic paradigm that asserts the construction of knowledge and meaning from different perspectives (researchers and participants), multiple realities, and values attached to the study findings, participants' utterances, and the use of triangulation, requiring interpretivist and positivist approaches.

Data analyses were conducted in an integrated fashion where concurrent triangulation was followed. Data generated from pre- and post-tests, learners' focus group interviews and the intervention suggest that the interventional strategy appeared to enhance *talk* (discussions and argumentation), to improve learners' abilities to solve word problems as well as sense making in the experimental group where there was minimal *talk* before the intervention. *Talk* enabled learners to engage in effective discussion and argumentation during teaching and learning. The findings of this study also suggest that the experimental group performed better than the comparison group in the post-test. The experimental group demonstrated a tendency to include reality when solving multiplicative word problems in particular, and consequently improved sense-making abilities.

The statistical analysis of Wilcoxon-Mann-Whitney test delineated statistical significance regarding the intervention: the experimental group (n=42), *obtained a bigger median of 15.50 in the post-test from a median = 8*, higher than the comparison (n=35) which obtained a median = 13 in the post-test from a median = 8 in the pre-test.

The experimental group's performance in the post-test of item 2.4 was higher ($p=0.0100$) as compared to the comparison group ($p = 0.3613$). In item 2.2, the experimental group had a higher performance as it managed to perform the same as the comparison group that earlier demonstrated a significant difference over the experimental performance. The mean of the experimental group (16.78571) and the comparison group was (14.91529) and the difference (1.87042) in favour of the experimental group in the post-test. The experimental group had an observed higher mean and median after the intervention. This implied that the intervention seemed to have favoured the experimental group.

Analysis of learners' interviews suggest that the use of AWFs improved the learners' comprehension of language in word problems where they felt that teachers should also code-switch when teaching. Learners confirmed that the use of AWFs brought about success or improvement in their performance as far as word problem-solving and taking reality into consideration was concerned.

This study has shown that issues of *talk*, (*discussion* and *argumentation*), *word problem-solving* and *sense-making* seem to be of utmost importance in the teaching and learning of multiplicative word problems in particular in mathematics classrooms. The reflection from the implementation of the intervention suggests that the use of AWFs yields somewhat positive benefits in the academic performance of a participating group. It is on this basis that any study that investigates on the influences of AWFs can have all types of word problems involved. In addition to this, the nature of the impact of the use of second language learning on learners' academic performances in word problems should be studied within the contexts of using *English* as the primary language of learning and teaching in the majority of South African schools. The findings of the study strongly suggest using the AWFs in mathematics classrooms when any topic related to solving (multiplicative) word problems is taught. In doing so, there exists a likelihood of improved *talk* during the lessons, which may result in better learners' academic performances in word problems generally. Both the quantitative and qualitative data analysed appeared to suggest that promoting more *talk* (*discussion* and *argumentation*) in the teaching and learning of multiplicative word problems influenced learners' argumentation and problem-solving abilities and sense making. In addition, mathematics teachers may be equipped with an alternative pedagogy to employ when dealing with story problems in mathematics curricula, which may improve how word problems are dealt with in the classroom.

Key terms

Argumentative frames; word problems; word problem solving; mathematics classrooms; mixed-methods research

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CHAPTER 1

INTRODUCTION TO THE STUDY, BACKGROUND AND MOTIVATION FOR THE RESEARCH

1.1 Introduction

Learners' academic performances in primary school mathematics appear to be a concern in most schools worldwide (Jaafar, 2015; Lemke, Sen, Pahlke, Partelow, Miller, Williams, Kastberg & Jocelyn, 2004; DBE, 2014a). For example, Planas (2014) reports that a significant number of learners in Catalonia, Spain experienced interpretation problems in the language of instruction, exacerbated by cultural misunderstandings and barriers in Mathematics. Therefore, learners' poor academic performance in Mathematics seems to be a global issue (Planas, 2014; Sepeng, 2013b; Sepeng & Madzorera, 2014; DBE, 2011; 2013; Xin & Zhang, 2009). According to a study conducted by Jaafar in the United States of America (U.S.), the proficiency rate of 32% in Mathematics was compared with countries such as Germany, which scored 44% and 58% for Korea in the graduation class of 2011, which is an example of a low pass rate, globally (Lemke *et al.*, 2004; DBE, 2011; Xin & Zhang, 2009).

In other countries such as China, Xin and Zhang's (2009) study suggests that learners found it difficult to solve realistic problems as they struggle to consider real-world knowledge and context in the solutions. In addition, these researchers argue that such difficulties may be attributed to fluid intelligence and learners' previous mathematical achievements. The learners' general reasoning and problem-solving abilities are called "fluid intelligence" (Xin & Zhang, 2009:125). These problem-solving abilities were related to the learners' educational settings, which eventually impacted their learning affecting their academic success. They further report that Chinese learners' performance was much worse on realistic problems than on standard problems. The argument was that the Language of Learning and Teaching (LoLT) was not their first language, subsequently, creating comprehension problems during teaching and learning.

In 2003, the U.S. performance in Mathematics Literacy and problem-solving was lower than the average performance for most Organisation for Economic Cooperation and Development (OECD) countries (Lemke *et al.*, 2004). According to Lemke *et al.* (2004), the importance of applying Mathematics to reality is emphasised by the subject Mathematical Literacy, in which the importance of real context fosters comprehension and transfers learning according to theories such as the constructivist approach where the learning process was connected with authentic problems. Difficulties were rooted in underlying reading deficiencies that required learners to fully understand the information given in a problem formulation (Große, 2015; Schäfer, 2010; Setati &

Adler, 2000). In addition, Aksu (1997), Jitendra, Petersen-Brown, Lein, Zaslofsky, Kunkel, Jung and Egan (2013), Saleme and Etchells (2016) and Sepeng (2013b) clearly outline the major sources of the difficulties as arising from inadequate understanding of the language of Mathematics with regard to mathematical concepts and computing skills. The difficulty of understanding a word problem and not knowing which arithmetic operation to use, is further emphasised by Wenger (1992); Sepeng and Madzorera (2014) and Verschaffel, Van Dooren, Greer and Mukhopadhyay (2010). Furthermore, Frankenstein (2010); Bernardo (1999); Botes and Mji (2010) and Wheeler and McNutt (1983) suggest that the barriers to learning Mathematics include learning how to write symbols, understanding mathematical concepts, organisational strategies and skills of numbers, computational skills and inadequate knowledge of the basic vocabulary.

In actual fact, word problems have been problematic from the inception of formal education as learners seemed and still seem to experience difficulties in solving arithmetic word problems (DBE, 2011). According to the Department of Basic Education (DBE, 2011), learners from as early as the Foundation Phase (Grade 1, 2 and 3) of the basic education system were reported to demonstrate poor understanding and knowledge of solving word problems. They could not solve money problems involving totals and change or differences in SA Rands and Cents. This resulted in the average percentage score in Mathematics dropping from 63% at Grade 1 to 31% at Grade 6 level. Learners solved their tasks by merely copying and rewriting the word problem showing poor knowledge of strategies for solving word problems (DBE, 2013). Their weaknesses manifested in their responses in the following areas: Word problems involving addition and subtraction up to 20; word problems involving equal sharing without a remainder; Word problems (money, $\times$, $-$, $+$) based on comparison and word problems involving equal sharing in 3s, 4s in the number range up to 99, combination, repeated addition, grouping and sharing (DBE, 2013; 2014a).

The learners' inability to solve arithmetic word problems created a concern as learners grew with this weakness that eventually adversely affected their performance in Mathematics. In the Intermediate Phase (Grades 4 – 6) in the exit Grade 6, which precedes Grade 7, learners were reported to experience difficulties in word problems as far as interpreting word problems correctly was concerned. Other difficulties involved using given information appropriately; translating language into Mathematics language and writing correct Mathematics sentences (DBE, 2013). The difficulties mentioned above as weaknesses appeared to be transferred to Grade 7 classrooms and negatively affected the academic performances of the learners, their self-esteem as well as failure to progress to the next grade.

For the purposes of this study, *academic performance* is defined as an amorphous term that involves many different abilities and skills (Bentley, 1966). *Academic performance* includes creative abilities, such as divergent thinking and evaluation as well as the non-creative abilities of memory, cognition, and convergent thinking. On the other hand, Xin and Zhang (2009) assert that students' mathematical *academic performance* involves assessing the students' basic arithmetic knowledge that includes procedural and conceptual knowledge and skills.

It was further reported that Grade 9 learners demonstrated a lack of understanding of how mathematical word problems were solved such as in the concept rate that required multiplicative knowledge, which was rich in language (DBE, 2013). In actual fact, the majority of learners struggled to make sense of phrases like 'How long', which resulted in them calculating *distance* (even though it was already given) instead of calculating *time* (DBE, 2013).

According to the DBE (2014b:97), the Ngaka Modiri Molema Region of the North-West Province scored 39.0% in 2013 and 41.2% in 2014 Annual National Assessments (ANA), respectively in their average percentage marks in Grade 6 Mathematics as a district. In the above Department's analysis, the learners' achievements were not reported per subject contents. In Grade 9, the District obtained 14.4% and 10.4% in 2013 and 2014 respectively (DBE, 2014b:100). The analysis was done uniquely through the diagnostic and the systemic evaluation, ANA, which remains an important national mechanism to monitor and improve performance in schools so that learning gaps are identified and addressed. The Department of Basic Education (DBE, 2011) stipulates that in a primary school with specific reference to Grade 7, a learner has to attain a minimum mark of level three (40%) in Mathematics in order to progress to the next class. That implies that failure to secure key level three in Mathematics means that the learner is not able to progress to the next level. Reddy, Visser, Winnaar, Arends, Juan and Prinsloo, and Isdale, (2016) in their 2015 TIMSS report show that despite South African learners underperforming in mathematics, there is some improvement from 2003 to 2015. In the 2015 TIMSS report, South Africa was amongst the five lowest performing countries out of 39, while North West province ranked second from the bottom in all nine provinces with 25% pass rate (Reddy, 2016:9).

Despite the fact that South African learners underperform in mathematics, a TIMMS report by Reddy, Visser, Winnaar, Arends, Juan and Prinsloo, and Isdale, (2016) show that there has been some improvement from 2003 to 2015. This report ranks South Africa amongst the five lowest performing countries from 39. The North-West province ranks second last from all nine provinces, with a pass rate of 25%. (Reddy, 2016:9).

In my experience as a primary school Mathematics teacher, the problems associated with learners' poor academic performances are made more complex by the fact that the majority of these learners learn Mathematics via English, a language that is not spoken at home by either learners or teachers. According to Howe and Abedin (2013); Orosco and Abdulrahim (2018); Planas (2014); Sepeng (2013b) and Setati, Molefe and Langa (2008), English is used as a language of teaching and learning in most township and rural schools in spite of the fact that there is limited contact with and access to English. Reddy, *et al.* (2016) report that there is a difference of 60 points in the performance of learners who frequently use the language of learning and teaching in spoken language outside class and the performance of those who are only exposed to the language at school. This leads to the complexity of the learners' poor academic performances. Moreover, the issue of South African learners' low abilities to read, speak and write has been raised as a concern (Sepeng, 2013b). In addition, Sepeng and Sigola (2013:325) argue that learners need to "undress" and solve mathematical tasks included in mathematical word problems.

In instances where *talk* is used successfully, it enhances coherence of teachers' teaching, enabling effective teaching that assists learners to understand what has been taught (Venkat & Askew, 2016). The success of *talk* appears to be made possible by the teaching and learning interaction, new knowledge that has been constructed to rethink ideas, to argue, evaluate, share, examine, as well as learners' understanding the conceptual underpinnings of Mathematics as they became better problem solvers (Brenner, 1998; Hart, 1999). It was therefore against this background that I sought to investigate the use of argumentative writing frames (AWFs) in a case of Grade 7 classroom learners' word problem-solving and how it influenced the learners' academic performance.

1.2 Problem statement and research questions

From my experience in teaching and interaction with primary school Mathematics teachers, solving multiplicative word problems in Grade 7 appears to be complex in the teaching and learning process. According to the DBE (2013; 2014a), among other things, learners' weaknesses manifested in their responses to word problems involving repeated addition (multiplication strategy). For example, learners found it difficult to solve real wor(l)d problems; interpret them correctly; use given information appropriately and translate language into mathematics language in making sense of real-life application (DBE, 2013). In addition, it seemed as if primary school Mathematics teachers on the other hand were unable to display an effective teaching strategy to assist learners to understand what was taught (Venkat, 2013). The author pointed to the nature

of the gaps in Foundation Phase teachers' content knowledge. In my experience of teaching Mathematics in Grade 7, I observed that learners did not achieve at the expected key level 3 (which was 40%) in Mathematics when solving word problems, and that led to learners not progressing to the next grade. Therefore, from the reports by the DBE (2013; 2014a) and Venkat (2013) and others; as well as from my experience, this led to poor performance of learners in multiplicative word problems, which led to underperformance in Mathematics in some South African schools. For the purpose of the study, underperformance refers to the attainment of a mark lower than 40%, which was key level 3 (DBE, 2011).

In a study that was conducted by Venkat (2013), learners were not involved by teachers during the process of teaching and learning but were only instructed to get to the answers. Learners had to know that what they were told were the answers. Therefore, they could not understand the rules of solving problems, wrote incorrect answers or left the problem unanswered (Venkat, 2013). According to Venkat and Askew (2016), learners were basically involved in a high rote learning approach where lack of coherence was evident in teachers. The absence of *talk* in the classroom showed a gap in the level of syntactic knowledge which relates most centrally to mathematical modes of inquiry and the kinds of practices that point towards the practices of Mathematics as a discipline (Mercer & Sams, 2006; Norenes & Ludvigsen, 2016; Nussbaum, 2011; Venkat, 2013; Webb, Williams & Meiring, 2008). The above classes with limited, or absence of, *talk* during teaching and learning of multiplicative word problems are common in South African schools. Against this background and contexts this study sought to investigate the use of AWFs in a case of Grade 7 classrooms learners (multiplicative) word problem-solving and how it influenced the learners' academic performances.

The study sought to answer the following research question:

- What were the nature and extent of the influence of using argumentative writing frames (AWFs) to support dialogue and written problem-solving (teaching and learning) techniques on Grade 7 learners' academic performances in multiplicative word problems?

The researcher used the following sub-questions emanating from the primary research question in order to answer it:

1. What was the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?
2. In relation to the literature and theory, what was implemented across series of lessons?
3. How did learners' talk in argumentation change across the implemented lessons?

4. What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post-intervention lessons?
5. What were the implications for the pedagogic practice of these findings?
6. What was the nature and influence of the intervention?

To respond to the research questions stated above, the following objectives were identified:

1. To understand the nature of the learners' academic performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons.
2. To understand, in relation to literature and theory, what was implemented across the series of lessons.
3. To understand how learners' talk in argumentation changed across the implemented lessons.
4. To investigate the nature of the learners' academic performance and argumentation in relation to multiplicative word problems in post-intervention lessons.
5. To explore the implications for the pedagogic practice of these findings.
6. To understand the nature and influence of the intervention.

1.3 Theoretical-conceptual framework

The social constructivist perspective underpinned this study. The perspective is anchored on the view that learners are more likely to discuss Mathematics with their peers and their teachers in Mathematics classrooms (Brenner, 1998; Cohen, Manion & Morrison, 2018). This theory views learning as an effective social interacting process between learners and teachers. Furthermore, it requires the learner to collaborate with the adult at the *zone of proximal development* (ZPD) to accomplish a task. As Vygotsky's ZPD postulates, "the distance between the actual developmental level is determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978:86). In their teaching and learning interaction, new knowledge is constructed to rethink ideas, argue, evaluate, share, examine, as well as for the learners to understand the conceptual underpinnings of Mathematics as they become better problem solvers (Brenner, 1998; Greig, Taylor & MacKay, 2007; Hart, 1999).

Social constructivist perspective is a variant of constructivism that is grounded in the research of Piaget, Vygotsky, Gestalt psychologists, Bartlett, and Brenner as well as the philosophy of John Dewey. These theorists posit that learners must be active in constructing their own knowledge, and that social interactions are to be enhanced as they are important to knowledge construction (Woolfolk, 2007). Social constructivism is grounded in Vygotsky's socio-cultural inclination

towards learning as motivated by Peled-Elhanan and Blum-Kulka (2006) and Dobber and van Oers (2015). This places instructive dialogue at the core of successful meaningful engagement of learners in teaching and learning with observations of inquiry practices in different schools for Developmental Education that are observed in countries such as the Netherlands.

Howe and Abedin (2013:327) regard dialogue as the main component for effective pedagogy in the western context. They further describe dialogue as comprising answer, argumentation, communication, conversation, dialogic discourse, discussion, feedback, ground rules, interaction, language, oracy, question, reciprocal response, recitation, speaking and listening, talk, and turn taking. In addition, a dialogue classroom set comprises classroom education, educational instruction, instructional learning, peer, promotive learner, school, small group, student, teacher, teaching, as well as the whole class. The aim of teaching is to enable learners to learn to argue in a sophisticated everyday mathematics instructional class; and this makes learning Mathematics *argumentative* learning (Krummheuer, 2007).

In this study, AWFs were used as teaching and learning techniques. AWFs are templates that consist of starters, sentence modifiers and connectives which offer children a structure for communicating what they want to say. AWFs ask children to select and think about what they have learnt by re-ordering information and demonstrating their understanding rather than just copying out text (Lewis & Wray, 2002; Rawson, 1997; Ross, Fisher & Frey, 2009; Subramaniam, 2010; Warwick, Stephenson, Webster & Bourne, 2003; Webb *et al.*, 2008).

1.4 Research methodology and design

In this study, the researcher followed an interpretive mixed-method case study design (Greig *et al.*, 2007; Johnson & Christensen, 2017; Maree, 2007; Merriam, 2002; Sargeant & Harcourt, 2012). The researcher used the two-phase approach in order to collect the quantitative data in the first phase, analysed the results, and then used the results to plan (or build on to) the second, qualitative phase (Creswell, 2014). The two-phased approach followed an explanatory and sequential process (Creswell, 2014), which was elaborated in Chapter four. Data collection involved gathering of both numeric (e.g. on statistical instruments) as well as textual information (e.g. from interviews) so that the final database represented both quantitative and qualitative information. In other words, the qualitative data helped to explain in more detail the initial quantitative results. In addition to this, the mixed methods provided a more complete understanding of a research problem than either approach alone would. The mixed methods approach strengthens the understanding of the research question and the combination of qualitative and quantitative database overcomes the limitations of the single other approach (Cohen *et al.*, 2018; Creswell, 2014).

The researcher also used the pre-test–intervention–post-test design (PIP) design. The PIP design emanated from a quasi-experimental design which crafted the non-equivalent (Pre-test and Post-test) comparison-group design. In addition, the researcher purposefully selected an experimental group and a comparison group, which were subjected to both a pre-test and a post-test, with the experimental group receiving the treatment in the form of an intervention, using AWFs as a technique to word problem solving in the teaching and learning process at learner level (Creswell, 2014; Johnson & Christensen, 2017). A purposive sampling that consisted of 77 learners at two schools with 42 learners at one school as experimental group and 35 learners at the comparison school, was used to select one Grade 7 class from each of the two primary schools. In the study, the stratified purposive sampling as one type of non-probability sampling method was used in order to obtain the individuals and groups to be studied while endeavouring to understand all the aspects of the research topic.

A quantitative pre-test consisting of seven test items was administered to learners in both the experimental group and comparison group before the intervention (Okeke & Van Wyk, 2015). The pre-test was used to better understand the nature of the learners' performance and problem-solving abilities in relation to multiplicative word problems prior to a sequence of intervention lessons. Furthermore, the item analyses of learners' written work showed the ability (or inability) to make sense of word problem-solving, and realistic considerations (or lack thereof) were also assessed. A pre-intervention learners' focus group interview was conducted with eleven learners from the experimental group. This qualitative learners' focus group was conducted in order to investigate the nature of learners' problem-solving abilities and the reasons for their answering the test items the way they did, gaining more understanding in their pre-test responses. The documents, in the form of learners' exercise books and video recording, produced qualitative data. This was done in order to check the progress on learners' written work by using the AWFs to support the learners' abilities in solving word problems.

The post-test, which was the same as the pre-test, was administered by the researcher to both the experimental and comparison groups in order to establish if there was any change in the dependent variable(s) condition(s), which was the learners' mathematical performance (Okeke & Van Wyk, 2015). This yielded quantitative data which helped the researcher to measure the effectiveness of using AWFs in a case of Grade 7 classroom learners (multiplicative) word problem-solving and how this influenced the learners' academic performances. The researcher carried out a qualitative learners' post-intervention focus group interview with the same eleven learners who participated in the pre-intervention focus group interview. The post-intervention interview was done in order to explore the nature, effect and implications of the pedagogic practice of the study as well as learners' perceptions about the intervention.

Data analysis in this approach had the quantitative and the qualitative datasets analysed separately (Creswell, 2014; Maree, 2007). Data analysis was conducted simultaneously during and after data collection processes. Qualitative analysis is defined as a relatively systematic process of coding, categorising, and interpreting data to provide explanations of a single phenomenon of interest (Johnson & Christensen, 2017; McMillan & Schumacher, 2010). In the study, inductive analysis was used in order to synthesise and make meaning from the data, starting with specific data on the attainment of the test marks and ending with categories and patterns. Data gathered through learners' focus group interview and implementation of the intervention by the researcher, using video recorder, were transcribed. For this study, the learners' focus-group interview data were analysed through the use of semantic analysis.

The researcher recruited social cultural tools that included the Zone of Proximal Development (ZPD), mediation and social interaction projecting the analytic observable units or indicators (argumentation and discussions) to analyse the visual data (observations). The solving abilities were used to analyse the documents (exercise books).

Quantitatively, data collected were coded and statistical analysis was used. The test results gathered from the learners' test responses were coded into *SA*, *SPC*, *SI*, *MA*, *PC*, *IR* and *NR* with further elaborations in Chapter four (Sepeng, 2010; Sepeng & Sigola, 2013; Verschaffel, De Corte & Lasure, 1994). Descriptive statistics were used to present the data; the frequency (*f*) distribution of scores, percentages, tabular formats (McMillan & Schumacher, 2010; Sepeng & Sigola, 2013). The pre-test and the post-test generated data were subjected to a Statistical Package for Social Sciences (SPSS) software to produce the statistical results as it was recommended for experimental and comparison of groups. The Wilcoxon Signed Test and the Chi-Square were computed to compare the mean scores of the comparison and experimental groups. The descriptive statistics calculated for observations and measures at the pre-test or post-test stage of experimental designs consisted of means, medians, minimum scores and maximum scores. Pearson's chi-square test was used to test for association between any pair of categorical variables. The association was declared significant for any p-value of less than 0.05. The analysed data were received in Excel format and transferred to Stata format wherein statistical analysis was performed. The results were presented in tabular format.

The research design and methodologies, research site, participants and data collection strategies used in this study are discussed in greater detail in Chapter 3.

1.5 Ethical concerns

Participants entered the research project voluntarily, understanding that there were no obligations involved (Bogdan & Biklen, 2007; Johnson & Christensen, 2017). They were assured of confidentiality and anonymity and given a guarantee that they could withdraw from the study at any time. In addition, informants' interests of those who were ready and willing to take part in the research were protected as no personal details were disclosed (Cohen *et al.*, 2018; Okeke & Van Wyk, 2015). More importantly, ethical issues needed to be addressed in relation to the different phases of the inquiry including issues prior to conducting the study; beginning a study; during data collection and data analysis; and in reporting, sharing, and storing the data (Creswell, 2014).

The researcher submitted the proposal for an institutional review board (IRB) approval at the NWU and Ethical Clearance was granted by North-West University (see addendum M), for the researcher to undertake the research (Mertens, 2015). Permission was granted by the Department of Education Area Manager of Rekapantswe Region at Montshiwa Township to carry out the research in those selected schools. Furthermore, the researcher requested permission from the principals in two schools within Rekopantswe Area Office at the Montshiwa Township in Mahikeng (Mmabatho), Ngaka Modiri Molema District in the North-West Province to conduct the research study to work with at least one class of Grade 7 Mathematics learners in that particular school to be part of the study. Letters of consent were sent to parents to request their children to participate in the study, to be part of the focus group interviews as well as to be videotaped in the case of the experimental group. Signed consent forms from learners were received after they were issued the consent letters to ask them to be part of the study. Disclosure of sensitive information was avoided, and no portion of the data collection was used for any purpose other than this research.

Everything that was reported to have taken place in this study happened as stated. I reported the description of events, learners' behaviours and the classroom settings accurately, hence adhered to *descriptive validity* (Johnson & Christensen, 2017). I was the *research instrument* in the data gathering process (Maree, 2007). I consciously engaged in critical self-reflection about my potential biases as a researcher evolving interpretations (Johnson & Christensen, 2017). Data interpretations were warranted by the evidence used in addition to the theories used (Cohen *et al.*, 2018). I triangulated the multiple collected data in *avoidance of bias* expectations. Validation issues were adhered to (Maree, 2007).

1.6 Chapter summaries and thesis outline

This chapter provides the background and overview of the rationale to investigate the use of Argumentative Writing Frames (AWFs) within the contexts of teaching word problem-solving and how it influenced Grade 7 learners' mathematics academic performance. Issues of word problems (solving) in mathematics classrooms, what is entailed, difficulties that learners experienced when solving mathematical word problems, underlying reading deficiencies arising from, among other things, issues of inadequate understanding of the language of Mathematics regarding mathematical concepts and computing skills, were highlighted. The chapter captures the essence of the lack of talk in the classroom, hence the need to undertake this study.

The research questions, the aims of the research study, theoretical-conceptual framework, research methodology and design as well as the ethical issues were also presented. The next chapter brings insight into the review of existing literature that was relevant and appropriate to the study. The organisational structure of the study is outlined below:

Chapter 1: Introduction to the study, background and motivation for the research

This chapter introduces the study and gives an overview of the factors that prompted it. The chapter involves the background, the problem statement, the aims and the objectives, the research question as well as the significance of the study. It also outlines the research methodology, the research design, the literature review as well as the list of acronyms used.

Chapter 2: Literature review of word problem-solving with language using argumentative writing frames

This chapter reviews the existing literature that was relevant and appropriate to the study and the theoretical underpinnings. This covered the solving of word problems, language (mathematics) issues in Grade 7 mathematics classrooms, argumentative writing frames in the learning and teaching of word problem-solving, and strategies to improve the situation.

Chapter 3: Theoretical-conceptual framework

Chapter 3 presents detailed definitions of all key variables and concepts used in the proposed study. In addition, it provides an overview and synthesis of theoretical foundations of the study. In fact, appropriate paradigms and theories adopted for the study are discussed in order to provide a sense of how data were framed within the contexts of phenomena under investigation.

Chapter 4: Research methodology

This chapter focuses on the discussion of the research methodology, research design and data collection techniques. In brief, all the methodological tools are outlined in this chapter. Furthermore, it describes the mixed method research approach that adopted the interpretive case study design. The researcher used a two-phase approach in order to collect the quantitative data in the first phase, analysed the results, and then used the results to plan (or built on to) the second, qualitative phase, sampling strategies, purposive sampling, and convenience sampling. The instrumentation; pre- and post-test, pre- and post-intervention learners' focus groups interviews conducted were explored.

Chapter 5: Results

This chapter presents the data analysis methods and interpretation of the data. Data were analysed and interpreted quantitatively and qualitatively, qualifying the mixed method methodology. Descriptive statistics were in forms such as percentages, frequency distribution of scores, minimum scores, maximum scores, means and medians. For experimental designs with categorical information (groups) on the independent variable and continuous information on the dependent variable (s^2), researchers used the Pearson's chi-square test to test for association between any pair of categorical variables. The association was declared significant for any p-value of less than 0.05. Qualitatively, the semantic and thematic analyses were used as well as transcription of data recorded via the video camera.

Chapter 6: Discussion of results

Chapter 6 presents an in-depth discussion of the results and findings from the quantitative and qualitative results, presented with reference to the research objectives outlined in Chapter one of the study above. The results interpreted the findings regarding the pre- and post-tests, learners' focus groups interviews, documents analysis (learners' exercise books), video recordings, as well as the use of AWFs in a case of learners in Grade 7 classrooms' (multiplicative) word problem-solving and how it influenced the learners' academic performances.

Chapter 7: Conclusions, recommendations and limitations of the study

This chapter gives the conclusions from the results and findings according to the data that were collected, analysed and presented. Recommendations of strategies for future research to remedy the problem of learners' underperformance in mathematics word problem-solving were presented based on the findings. The limitations of the study are presented which could be from any aspect of the actual research actualisation. Furthermore, the potential significance and implications of this research that could improve the teachers' educational practices, create conducive teaching and learning platforms in the teaching and learning of Mathematics word problems, and

multiplicative word problems, are dealt with. The study suggests improving teachers' effectiveness by giving them enough insight and understanding as they employed the AWFs as a teaching technique when teaching multiplicative word problem-solving in particular in Grade 7 Mathematics classrooms.

CHAPTER 2

LITERATURE REVIEW OF WORD PROBLEM-SOLVING WITH LANGUAGE USING ARGUMENTATIVE WRITING FRAMES

2.1 Introduction

Literature confirms that in studies conducted in the USA (Jaafar, 2015; Lemke *et al.*, 2004; Xin & Zhang, 2009), Spain (Planas, 2014), and South Africa (DBE, Sepeng, 2013b; Sepeng & Madzorera, 2014; 2011; 2013; 2014b), some learners were notably deficient in their ability to solve mathematical problems. These learners were said to experience difficulties to transfer skills that they learned in solving simple word problems to complex problems involving various situations, such as problems with multiple steps (Agostino, Johnson & Pascual-Leone, 2010; Jaafar, 2015). These learners were also reported to have difficulties in interpretation problems in the language of instruction. As a result, the difficulties experienced by these learners led to problems in identifying relevant information in problem representation. Furthermore, the difficulties could exacerbate the learners' poor performance, hence they could face the possibility of not progressing to the next Grade (DBE, Lemke *et al.*, 2004; 2011; Xin & Zhang, 2009).

This chapter provides an overview of literature on issues that relate to word problem-solving, the use of language and the use of Argumentative Writing Frames (AWFs) within the contexts of teaching word problem-solving Mathematics in Grade 7 classrooms. In this chapter, issues of what a word problem is and what it entails, word problem-solving in a Mathematics classroom are discussed. I discuss the use of language in the learning and teaching of word problems in mathematics. I also shed light on what AWFs are, and how they are used in a mathematics classroom. Word problems are expressed in language by nature (Boonen, van der Schoot, van Wesel, de Vries & Jolles, 2013; Sarmini, 2009), and in order to solve them, learners need a form of mediation such as the AWFs (Subramaniam, 2010) that I believe in. Language frames were used to help in developing learners' thinking to hold meaningful discussions in written Science classrooms (Ross *et al.*, 2009; Webb *et al.*, 2008)}. Writing frames have been used in English language to assist learners in demonstrating their understanding of oral language and written language (Lewis & Wray, 2002). Hence, AWFs might assist learners in comprehending and making sense of mathematical word problems that they need to solve, and the know-how to solve these.

2.2 Word problems in mathematics classrooms

This section explores word problem solving in the context of learning and teaching of mathematics in the Grade 7 classrooms. Issues discussed are the definition of a word problem, how a word problem is solved in a mathematics classroom and why it is necessary to do so.

2.2.1 Defining word problem-solving in mathematics

This section illuminates the concept of a word problem as a text and a process that are experienced by learners and, also, as a unit that is an independent text that simulates daily life events.

2.2.1.1 Word problems as text

A word problem is any mathematical task where the significant background information of the problem is presented as text rather than as mathematical notation (Boonen *et al.*, 2013). On another note, a mathematical task is said to posit learners' cognitive thinking and reasoning (Smith & Stein, 1998) via instruction and thinking that have been extensively employed to study the connections between teaching and learning in classrooms (Stein, Grover & Henningsen, 1996). Moreover, the word problems used in this study were narrative in nature hence they are sometimes referred to as "story problems" (Boonen *et al.*, 2013:217). For the above reasons, the author attempted in this study wanted to explore learners' experiences as far as difficulties in understanding the text of the given problem. Similarly, Driver and Powell (2017) define a word problem as a mathematics calculation that is embedded in and presented via/with sentences.

According to Greer, Verschaffel and De Corte (2002), a word problem is a text which is typically quantitative, describing a situation which is assumed familiar to the reader and posing quantitative questions, from which mathematical operations can be performed on the data provided in the text in order to find an answer. Greer *et al.* (2002) explored how beliefs about word problems influenced the teaching and learning culture as learners and teachers respond to solving word problems, and the authors argue that a compelling example of how classroom mathematics is shaped by beliefs is through word problems. As a text, the main purpose of word problems is to give learners practice in solving classes of problems represented in mathematics. These representations of applications in mathematics are relayed through means of describing and, also, drawing inferences about aspects of reality embedded in the word problems (Greer *et al.*, 2002). Learners develop their beliefs of mathematical word problem solving from their experiences and interactions in class as they engage in activities (Greer *et al.*, 2002).

Greer *et al.* (2002) view belief as a fundamental aspect in solving word problems; hence, they suggest that learners should be balanced in mathematics concepts. This means that teaching word problems to learners will embrace a positive attitude against the suspension of sense-making in word problem-solving and establish positive mathematical attitudes and beliefs.

2.2.1.2 Word problems as a learner's experience process

According to Wenger (1992), word problems are sometimes called *story problems* or *verbal problems*. It is also stated that mathematics problem solving builds logical reasoning skills that can be applied in many situations. Furthermore, mathematics has been referred to as the foundation for future studies in most school subjects as per the Trends in International Mathematics and Science Study (TIMSS) 2011 (Mullis, Martin, Foy & Arora, 2012). Problem-solving was identified as a cornerstone for Mathematics instruction, and it is a fact that needs to be a focus of Mathematics teaching and learning processes (Xin, 2007). Wenger (1992:5) notes that word problems “provide a context through which learners practise the algorithms and apply the formulas which they are learning”.

However, as a process, solving mathematical word-problems in the real world is defined as a useful complex thought using several phases (Verschaffel *et al.*, 2010). Verschaffel *et al.* (2010) elaborate on the process as being characterised by key elements in the problem situation that the problem solvers must understand. Moreover, learners must construct mathematical mental models that they will use to get to the solutions. Learners in this study were expected to interpret and evaluate the outcome of the computational work to determine if it was appropriate and reasonable, and finally to communicate the solutions of the real-world problem.

2.2.1.3 A word problem as an independent unit of text

Ilany and Margolin (2010:139) assert that a word problem in Mathematics is an independent unit that comprises a speech event and a question sentence, which is divided into two types according to the topics they relate to. There are mathematical word problems that deal with mathematical relationships between objective sizes such as, “*What is the number that is twice as big as the sum of 25 and 17?*” and those that deal with real life situations. For example, “*It takes 3 workers 5 hours to plough a field. How many hours would it take 2 workers to plough the same field?*” (Ilany & Margolin, 2010:139). On the other hand, a word problem is defined as not a problem unless the learner is interested in solving it (Hanley-Maxwell & Bottge, 2006). Hanley-Maxwell and Bottge (2006) further note that a word problem can be defined in relation to the effect on the learner as a task that the learner is engaged in, working towards obtaining a solution, for which the learner does not have easily accessible mathematical strategy and means to achieve the

solution. The problem and the word problem should have the capacity to evoke genuine interest within the learners to solve the problems as a school activity that connects with everyday experiences (Hanley-Maxwell & Bottge, 2006).

In summary of the above, one can say that word problems viewed as part of mathematical tasks engage learners in cognitive thinking and reasoning. The learners' performance gain can however be adversely affected by the attitudes the learners and teachers have towards mathematics as a subject. Word problems text carries a situation which is told as a *story*. The *story* comprises a speech event and a question sentence which should be based in the real-world context. Learners need to be competent in word problems calculation tasks as they carry descriptions and mathematical operations that are embedded in the problem.

2.2.2 Word problem-solving in Grade 7 mathematics classrooms

This section explores how a word problem is solved in the learning and teaching of mathematics. Issues of what is entailed in solving a word problem, word problem as a process involving numbers and learners' cognitive experience, independent unit, hidden curriculum, the use of algorithm, the use of arbitrary scenario as well as word problem solving modelling are discussed.

2.2.2.1 What does word problem-solving entail?

A review of what is entailed in solving mathematical word problems within South African classroom contexts form part of recent reports from studies that explored learners' abilities in solving word problems (see for example Sepeng, 2013a; Sepeng & Sigola, 2013). Word problems form part of the South African Mathematics curriculum and are used as a vehicle to teach learners how to model problems in primary Mathematics classrooms (Sepeng & Sigola, 2013). These researchers agree that solving word problems in Mathematics is part of a unit of the text comprising a question and a speech accompanied by an authentic background story, and the syntactical and rhetorical structure needs to be explicitly clear to enhance understanding. Such studies were conducted in relation to other studies elsewhere in the world (e.g. Jamison, 2000).

Other scholars such as Pape and Wang (2003) allude to the idea that problem-solving begins when the solver reads the problem text for the solution process that leads to success as the schemas for problems are activated. Pape and Wang (2003) highlight that successful word problem solvers actually transfer the problem text to form and evoke internal representations for the problem by using either concrete or semi-concrete external representations to aid in the constructive process. These authors also argue that learners who are less successful problem solvers do not form cognitive representations, but often translate the problem elements directly to

the solution without creating an image of the problem. In fact, the reading of the text and analysing the problem stimulate the activation of knowledge structures and mathematical problem-solving strategies, creating the mental representations which are an ongoing process (Pape & Wang, 2003). In a report presented by the Organisation for Economic Co-Operation and Development (OECD, 2003:15), on the Programme for International Student Assessment (PISA), problem-solving is defined as:

An individual's capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the literacy domains or curricular arrears that might be applicable are not within a single domain of mathematics, science or reading.

Learners' skills of working towards a solution and communicating the solution to others through representations were assessed. In solving the problems, learners were given exercises assessing capabilities to make decisions, to understand the reasons for systems, and to analyse the procedures and structures of a problem by applying reasoning processes (Lemke *et al.*, 2004). In this study it is reported that US learners scored lower in problem solving than their peers in 25 of the other 38 countries that participated in the study (Lemke *et al.*, 2004:29).

Wenger (1992) defines word problem-solving as a process by which the learners experience the power and the usefulness of Mathematics in the world around us. More importantly, word problems help develop the learner's ability to compute and to recognise the need for applying a concept or procedure. Reikerås (2009) alludes to solving word problems as calculation tasks that are embedded in text and whose words and structure create problems that are called word problems. Moreover, solving word problems involves calculation tasks that are embedded in the text and whose words and structure create problems that are called word problems. In solving word problems, learners in this study used the text that was presented in English language to identify the missing information, planned and solved the word problems to get the solutions. This process is similar to the findings by Driver and Powell (2017).

Solving word problems has been concluded to involve exploring learners' abilities to encode a *story sum*, using procedures, structures, strategies, and cognitive representations by reading the text to get to the solutions. As learners experience the process, word problem-solving captures the power and usefulness of mathematics in our context. Learners interpret, solve, evaluate as well as communicate the situational problem which they engage in. It is the language and the calculations inherent to the word problems that pose difficulties for Grade 7 native English language speakers (learners).

2.2.2.2 Word problem-solving as a process involving numbers and cognitive processes

Jitendra *et al.* (2013) explain mathematical word problem-solving as a process involving the integration of several cognitive processes such as attention, memory and language. Mathematical word problem-solving also involves metacognitive processes such as self-questioning, self-monitoring and self-evaluation. The authors further explained that solving word problems requires comprehending the text, representing the nature of the problem correctly, planning a strategy, executing the plan, and verifying the solution, in addition to retrieving an answer from memory.

On the other hand, Wheeler and McNutt (1983) argue that mathematical word problems require learners to read sentences, decide how to organise them, which numbers to use in what order, what operation to apply as well as how to solve the problems. Wheeler and McNutt further argue that even though word problems are considered an integral part of mathematics, most learners have difficulty in solving them. Learners' difficulties are rooted in unfamiliar vocabulary or computational abilities and skills that are beyond the learners' capabilities that eventually prevent some learners from understanding the problems. Wheeler and McNutt (1983) conducted a study on low-achieving eighth-Grade learners to determine the influence of syntax complexity of the learners' abilities to solve mathematical word problems. The participating learners were found to be functioning at a minimum fourth-Grade achieving level for both reading and mathematical computations (Wheeler & McNutt, 1983).

Similarly, in a study conducted by Bernardo (1999) some learners in Philippines experienced difficulties with solving word problems. These difficulties emanated from understanding the problem structure embedded in the problem text. The challenges led to errors in the choice of strategies the learners used to find the solutions. Bernardo looked into language, grade and re-wording of the problem issues to find the effect on arithmetic word problem understanding and solution in Grades 2, 3 and 4. In Bernardo's study, the results showed that on problems that were re-worked to state the word problem more explicitly pertaining to the relationship of the known and unknown quantities, learners showed better understanding and solution performance. Learners' performance was also better in higher Grades (Grade 4 as compared to grade 3 and 2), and when problems were written in learners' first language (Bernardo, 1999).

Jitendra, Griffin, McGoey, Gardill, Bhat and Riley (1998) report that the majority of U.S. learners perform poorly in mathematical word problem solving in all ages of learners in (grades 2, 3, 4 and 5) and ability levels. The report was as per the findings of the 1992 National Assessment of Educational Progress as well as the National Center for Education Statistics (NCES) in 1991.

Jitendra *et al.* (1998) report that learners with disabilities in particular had difficulties in computing basic facts, completing all the necessary steps in solving word problems, representing word problems in mathematical equations as well as reading the word problems with understanding. The problems mentioned above widen the gap in performance between the learners with difficulties and the normally achieving peers as the learners moved from elementary to secondary grades. Jitendra *et al.* (1998) recommend in their study that the schema-based strategy offers promise for improving the mathematics instruction used with learners who struggle to solve word problems. A schema-based strategy is an intervention that uses visual representations, heuristics, and direct instruction to facilitate mathematical word problem solving for learners with mild disabilities and those who are at risk of mathematics failure (Jitendra, et al., 1998; Rockwell, Griffin & Jones, 2011).

Word problem-solving has been presented as a process involving numbers and cognitive processes. Cognition requires the learner to read and comprehend the text. I agree with literature on this note, because for learners to plan a strategy to engage in the computations, learners need basic facts to apply when decoding the text to engage the correct operation and correct steps in solving the word problem.

2.2.2.3 Word problem-solving as a “hidden curriculum”

There is a concern and argument around the issue of the unwritten social contrast between Mathematics learners and their teachers that stipulates that “when you solve a mathematical problem...you use the numbers given in the story” (Puchalska & Semadeni, 1987:15). Frankenstein (2010) conducted a study on concerns of the non-neutral “hidden” curriculum. The study resulted in selections of real-life data used to create contrived and/or context-narrow word problems, and in addressing the question of teaching difficult, pessimistic perspectives. The author argues about “problems with real-life mathematical word problems” (Frankenstein, 2010:249) and how they frequently only are “real-life mathematical word problems without real meaning” (Frankenstein, 2010:249). She illustrates this by citing a French study (de Grenoble as cited by Frankenstein, 2010:249) who presented the following example of a question posed to a seven-year-old learner: *You have 10 red pencils in your left pocket and 10 blue pencils in your right pocket. How old are you?* The learner responded *20 years old* to the question. This was a case where a seven-year old learner was used. The learner knew that he was seven years old, but he gave an illogical answer to an irrelevant question with irrelevant data. This implies that the learner believed that mathematics does not make any sense. Consequently, the author describes such a scenario as “window-dressing” because of the “hidden curriculum” which gives a message that using mathematics is not useful in understanding the world. Mathematics is just pushing

around numbers, writing them in different ways, depending on what the teacher wants. The author also refers to *understanding the meaning of numbers* and *understanding the calculations* in which numbers could be used by learners to understand how to use mathematical ideas.

The *real* real-life mathematical word problems whose solutions involve understanding the meaning of numbers focus on using different kinds and arrangements of numbers such as fractions, percentage, and graphs, capture understanding the meaning of numbers better. In this kind of situation, learners were expected to describe the world situations with accurate descriptions using sizes of numbers. Learners have to understand the numbers that usually hide in the descriptions of the world situations and understand the meanings that the numbers cannot convey in the descriptions that illuminate the world context structure (Frankenstein, 2010). In addition, learners need to understand the calculations embedded within the *real* real-life mathematical word problems. The calculations are an integral part of understanding a situation that is focussed on verifying and following the logic of an argument, understanding how numerical descriptions originate by using calculations to restate information. The problem solvers are requested to use calculations to explain information as well as to reveal the unstated information in the given situation. The purpose underlying all the calculations is to understand the information and the arguments better, and to be able to question the decisions involved in choosing which numbers to use and which calculations to perform (Frankenstein, 2010).

2.2.2.4 Word problem-solving by use of an algorithm

Confidence is essential for learners to learn Mathematics, and to be motivated to reason quantitatively about public and political issues and understand concepts behind algorithms underlying mathematical concepts such as in the meaning of whole numbers, fractions and percentages (Frankenstein, 2010). Understanding the concepts behind the algorithms will enable learners to use the correct rules in many different ways in a comfortable manner as they solve word problems. As such, in this study, the researcher intended to have a better understanding of the nature of algorithms learners applied in their responses in solving multiplication word problems.

2.2.2.5 Syntax in word problems

Wheeler and McNutt (1983) conducted a study where they attempted to determine the influence of syntax on the difficulty of written mathematics problems in a grade eight class. The authors gave the learners tests that were developed at a fourth-grade level in reading vocabulary and mathematical computational skills of addition, subtraction, multiplication and division. These word problems required students to read the sentences and decide on the computation to use, the

numbers to use as well as the order of those numbers to finally solve the given problem. Wheeler and McNutt reported in their study that syntax and vocabulary affected the mathematical performance as well as the learners' abilities to solve mathematical word problems of the eighth-grade learners. This could be seen in the learners' computations as well as the learners' reading vocabulary levels. The low performance was more eminent in complex sentences in these cases. Syntax is defined by Peake, Jiménez, Rodríguez, Bisschop and Villarroel (2015) as the learners' abilities to manage the grammatical structures of language in a given sentence. Syntax influences word problems because of the integration of verbal and numerical information within the word problems.

In a study conducted by Xin (2007) to work simultaneously with multiplication and division word problem solving with selected U.S. and Chinese learners, academic performance was clearly affected. U.S. learners were reported to experience more difficulties than did the Chinese learners in solving word problems involving that had no straightforward meaning or could be answered in more than one way (Xin, 2007). Syntax in word problem-solving does indeed affect learners' performance. If learners do not read the word problem properly, they miss the essence of the question. Learners who are unsuccessful in solving word problems tend to focus on the surface features of the problems. An example is where the use of the keyword *times* did not cue the operation of multiplication. It is difficult for the learners to transfer their learning to a wide range of structurally similar problems (Xin, 2007). The following example illustrates Xin's argument (2007:348): "*Larry made 12 baskets in the basketball game last night. He made 3 times as many as Tom. How many baskets did Tom make?*" From the example, the word "times" implies multiplication. However, division is the correct operation to solve the problem correctly (Xin, 2007). Xin further contends that underperformance is caused by the curriculum and instructions that do not attend to different strategies of solving word problems during teacher-mediated instruction (Xin, 2007). Learners have to go beyond the surface features of the problem, which might come just from the curriculum or from the teachers. Learners need to be engaged in reading with understanding, hence mediators such as AWFs aid the understanding so that they can apply the correct strategy with the correct computational operations to solve the word problems.

2.2.2.6 Factors associated with interpretation of word problems

Salemeh and Etchells (2016) claim that the inability of learners to interpret word problems if they do not visualise the key elements is one of the major sources of difficulty in solving word problems. Other problems highlighted pertain to learners not understanding the assumption in the question, which hinders them (learners) from proceeding and translating the word problem into a mathematical problem (Salemeh & Etchells, 2016). Learners were reported to lack

comprehension, which leads to confusion. Learners look for key words, which leads to incorrect translation of the word problem, and subsequently end up with solutions with computational errors. Another problem is that learners work on their problem mentally instead of writing it down (Salemeh & Etchells, 2016). Finally, yet importantly, the authors report that learners work out word problems with reality consideration. Word problems with reality are those word problems that are not unproblematically modelled by routine application of a single arithmetic operation (Greer, 1997). These type of word problems require more extensive consideration of how the situation (or context) should be modelled, and whether the information provided is relevant and sufficient for solving the problem (Sepeng, 2014). In word problems with reality, learners give solution processes and generate conclusions that are mathematically correct as well as situationally appropriate (or accurate) even if they do not seem to make sense in real world (Sepeng, 2014).

Salemeh and Etchells (2016) report that learners experience issues of vocabulary as a challenge. Learners experience teachers' inadequate explanations of the complex words in the word problem; understanding these could help the learners understand the procedures to be carried out. Some learners rush into solving the word problems without carefully reading and understanding what is required of the word problem.

On the same note, Agostino *et al.* (2010) note that learners' errors on mathematical word problems are mainly owing to problem misrepresentations of identifying the correct operation, regardless of the computational knowledge and skill. Furthermore, the same authors highlight that learners often adopt "short-cut" strategies as opposed to more meaningful approaches. In addition, they suggest that learners must understand the nature of the problem, plan a method or strategy, execute the plan, and verify the solution in order to solve a word problem. According to Van Garderen (2007), the difficulty in solving a word problem can be attributed to the representation used as compared to the assumption of a lack of understanding of the mathematical concept involved. Van Garderen explains representation as focusing on conceptual understanding of a diagram and the use of diagrams as tools to reason with.

I believe that language practices should be integrated with mathematics learning opportunities in order to enhance spoken language which is obviously one communication mode that learners can use in providing mathematical explanations in the classroom. This is necessary because I believe *talk* in the classroom increases learners' understanding of mathematics concepts taught.

2.2.2.7 Learners' conceptions and preconceptions of learning mathematics

Aksu (1997) comments on learners' conceptions and perceptions of Mathematics. The latter author underscores that it is a general belief that Mathematics is a difficult subject, both to teach and to learn. In addition, Aksu further posits that learners perform in a declining pattern in all four operations when they are presented as word problems. A special mention is made to the effect that the "greatest performance was observed for the multiplication operations" (Aksu, 1997:379). Learners had difficulties in explaining what a multiplication computation means as well as "lack of understanding of different ways operations are embodied in word problems" (Aksu, 1997:375).

2.2.2.8 Lack of proper decoding and interpretation when solving word problems

Sepeng and Sigola (2013) argue that most learners commit errors because of lack of strategies to a solution, whereby they apply rules without understanding the basic concepts in solving word problems, as opposed to being weak.

They further aver that, because learners are not given enough time to exercise and practise essential skills of problem-solving such as decoding and interpreting, they (learners) are exposed to producing errors when solving word problems. Moreover, learners are also faced with the use of words that had multiple meanings in the mathematical classes, which is posed as a barrier to solving word problems (Sepeng & Sigola, 2013). They further maintain that learners struggle to translate word representations into mathematical representations and cannot see a connection between the mathematical problems they encounter at school and their real-life Mathematics (Sepeng & Sigola, 2013). Sepeng and Sigola (2013) further contend that learners exclude reality and common sense in their solution of word problems. They mention that the classroom practice is characterised by poor and stereotyped word problems which need simple operations to solve. This study underway pertains multiplicative word problems where learners were expected to translate the word representations into mathematical representations.

2.2.2.9 Lack of exposure to conceptual ideas in word problems

Jaafar (2015) argues that the lack of learners' exposure to conceptual ideas as compared to exposure to only algorithms poses a problem to learners to solve word problems. Learners tend to keep on expressing that they are "confused" because they do not know whether to multiply or divide in given word problems to solve. The author confirms that learners show signs of lacking skills to "*solve real life problems requiring a full range of arithmetic skill*" (Jaafar, 2015:210). In Jaafar's study, some learners actually claimed, in a questionnaire that was administered to them, that they hated word problems because they were "confusing" and "time-consuming" (2015:211).

Mathematics can influence learners' success in upper grades, hence both the conceptual ability and procedural understanding of mathematics concepts are necessary for learners' success (Jaafar, 2015).

2.2.2.10 Factors associated with memory deficiency in word problem-solving

Steele (2002:104) asserts that learners often "shut down" mentally when they encounter word problems because they associate these tasks with failure. Steele further argues that memory deficiencies cause learners to have difficulties in learning mathematical facts and remembering the correct sequence of steps for a particular mathematical skill, such as memorising the multiplication tables. Learners often experience other factors that are obstacles to Mathematics learning, which are auditory processing, visual processing problems and motor processing problems. Learners with auditory barriers often have difficulty in understanding oral explanations of mathematical content and vocabulary. On another note, learners with visual processing problems manifest working in the wrong direction and reverse negative and positive numbers on a graph (Steele, 2002).

Learners who have motor processing difficulties often experience a hard time in writing numerals and that leads to errors in Mathematics assignment and tests. Learners are also frustrated by problems that are complex and multistep. Other factors mentioned are organisational deficiencies, which are characterised by learners who have difficulty in selecting and using the appropriate strategy to get solutions, hence such learners only master one strategy and then apply it to all problems even when the strategy is not called for (Steele, 2002).

The fact is that learners use previously learned knowledge or similar problem-solving experiences and strategies to structure and formulate solutions in solving new word problems. They (learners) are subsequently exposed to high possibilities of applying the wrong "rote" algorithm, hence causing low academic performances in mathematics (Huang, 2004:279). Huang further argues that poor problem solvers tend to concentrate on information of salient superficial features of the word problem-solving, which prevents them from making an appropriate adaptation (Huang, 2004).

2.2.2.11 Lack of sense-making in word problem-solving

Verschaffel *et al.* (2010:12) intended to present studies documenting and illuminating the phenomenon of "suspension of sense-making" when doing school arithmetic word problems in Mathematics problem solving classrooms as they review and discuss research.

The above explanation incorporates reviewing recent design experiments wherein the modelling perspective has been implemented and tested. In an example of “*There are 26 sheep and 10 goats on a ship. How old is the captain?*” most learners gave a numerical response while a minority questioned whether the answer was possible (Verschaffel *et al.*, 2010:12).

The fact that most learners were prepared to give a computed answer was a manifestation of “suspension of sense-making”. The study was carried out in Northern Ireland and in Flanders; pencil-and-paper studies, with upper elementary and lower secondary school learners. Learners were given word problems that required sense-making. These problems were termed “problematic” (P), in the sense that they required the application of judgement based on real-world knowledge and assumptions, rather than only the routine application of basic arithmetical operation(s) cued by the problem. The authors collected data through tests and recorded lessons. The authors recommend that in the teaching and learning of mathematical word problems, a modelling stance should be adopted. Similarly, Greer, Verschaffel, Van Dooren and Mukhopadhyay (2009:xii) note that some word problems would ask learners questions such as: *On a boat there are 20 sheep and 6 goats. How old is the captain?* In such instances, learners would start attaching an operation such as addition, etc. instead of realising that the question was not nonsensical in what is asked, but their responses were, as they failed to make sense of the fact that the situation asked was un-problematically mapped to any operation.

2.2.2.12 Learners’ performance and cognitive holding power and fluid intelligence

Xin and Zhang (2009) discuss the power of cognitive holding power and fluid intelligence of Grade 4-6 Chinese learners when solving realistic word problems to have an effect on the learners’ mathematical performance. According to Xin and Zhang (2009:124), “[c]ognitive holding power is defined as a setting characteristic referring to the extent to which the learning settings press learners into utilising certain levels of procedural knowledge; for example, first or second order cognitive procedures.” Fluid intelligence on the other hand is defined by Xin and Zhang (2009:125) as “the learners’ reasoning and problem-solving abilities independent from specific knowledge and culture”. In a first order procedure usually referred to as first order cognitive holding power (FOCHP), learners would apply an algorithm while in a second procedure, second order cognitive holding power (SOCHP), learners would select, combine, modify, and apply a series of specific procedures in solving word problems (Xin & Zhang, 2009). In Xin and Zhang (2009) study, learners evidently showed consistency in neglecting realistic context and real-world knowledge when understanding and solving realistic word problems. These authors report that in their study, fluid intelligence was a prominent hindrance to learners’ solving of realistic word problems in particular and, hence, adversely affected their academic success. Moreover, learners could not

give realistic answers, which gave teachers a challenge to strengthen second order cognitive holding power by encouraging learners to explore with unfamiliar word problems situations as well as to promote them to find patterns, and relationships that work as they check their answers against reality (Xin & Zhang, 2009). Learners were required to explain how they arrived at the answers as well as to write the computational answers for their word problems test during data processing and analysis (Xin & Zhang, 2009). I used real-life word problems as an introductory exercise as these probed learners to talk when they justify how they reached their solutions or answers.

2.2.2.13 Word problem-solving modelling

Instructional interactive teaching and learning word problem-solving demonstrational strategies or techniques are an integral part in any mathematics classroom. Learners often get a basic sense experience in mathematisation and mathematical modelling from solving word problems which promotes in them the exclusion of realistic considerations and a “suspension” of sense making, rarely reaching the idea of mathematical modelling (Bonotto, 2013). Bonotto argues the reasons for lack of use of everyday-life knowledge as textual factors relating to the stereotypical nature of the most frequently used textbook problems. The presentational or contextual factors associated with practices, environments and expectations related to the classroom culture of mathematical problem-solving are also a result of the lack of use of everyday-life knowledge. They are relegated to classroom activities, having meaning and location, in terms of time and space, only within the school; rarely will students encounter these activities in this form outside of school (Bonotto, 2013).

Bonotto (2013:401) defines modelling as a situation that requires the learner to already have at his disposal at least some mathematical models and tools to mathematise. Model-eliciting activities are used as a vehicle for *the development* rather than the application of mathematical concepts, which he terms “emergent modelling”. Bonotto further argues that problem-posing has evidently positively influenced learners’ abilities to solve word problems. This happens provided a chance to gain insight into learners’ understanding of mathematical concepts and processes is enabled, and provided learners are prepared to be intelligent users of Mathematics in their everyday lives. Learners express and create their own Mathematics problem-solving understanding of concept development and positive attitude towards the Mathematics discipline through problem-posing.

Bonotto (2013) reports that the basic characteristics of the teaching and learning environment in the classroom were brought forth as an application of a variety of complementary, integrated and interactive instructional techniques. These applications involved learners’ own written descriptions of the methods they use, working individually or in pairs, whole class discussions,

and the drafting of a text by the whole class. In addition, an attempt to establish a new classroom culture through new socio-mathematical norms was created. The norms were about what counts as a good or acceptable response or solution procedure. This was done in order to undermine some deeply rooted and counterproductive beliefs and attitudes such as mathematical problems have only one right answer or there is only one correct way to solve any mathematical problem (Bonotto, 2013).

The results proved that presenting the learners with activities that were meaningful because they involved the use of material familiar to them increased their motivation to learn, even among the less able ones. A good example was the case of an immigrant child with learning difficulties related chiefly to linguistic problems. For her, as for many other learners who were given a well-known everyday problem to solve with “few words and lots of numbers” *talk* acted as a stimulus (Bonotto, 2013:407). Learners exhibited flexibility in their reasoning by exploring different strategies. They were often sensitive to the context and quantities involved, in a way that was meaningful and consistent with a sense-making disposition and closer to the procedures emerging from out-of-school Mathematics practice. The learners also ignored the relevant, plausible and familiar aspects of reality, and did not include real-world knowledge from their observations and reasoning (Bonotto, 2013).

In a study conducted in Turkey by (Erbaş, Kertil, Çetinkaya, Çakiroğlu, Alacaci & Bas, 2014), the importance of mathematical modelling was further emphasised. This approach was known as a process in which real-life problems are translated into mathematical language, solved within a symbolic system, and the solutions were tested back within the real-life system. In addition to the above, modelling is said to consist of both conceptual systems in the learners’ minds and the external notation systems of these systems such as ideas, representations, rules, and materials. The authors classified modelling in their study by its purpose in Mathematics Education, such as (i) modelling as the purpose of teaching Mathematics or (ii) modelling as a means to teach Mathematics. The emphasis was on improving learners’ modelling competency from a “model of” to “model for,” which is called as *emergent modelling* (Erbaş *et al.*, 2014:1625). In their first perspective, which was *modelling as the purpose of teaching Mathematics*, learners “are provided with predetermined models and are expected to apply these models to real-life situations”. In the latter one, learners “learn fundamental mathematical concepts meaningfully through a modelling process in which they need and intuitively discover mathematical concepts while addressing a real-life problem-solving situation” (2014:1625). Erbaş *et al.* preferred the latter perspective because they felt that it was more developed for pedagogical purposes.

I believe in the problem modelling that is integrated with problem-solving for teaching mathematics. Learners learn fundamental concepts meaningfully; more concepts emerge and

learners discover them while addressing a real-life situation. In that way, both the conceptual systems in the learners' minds and the external notation systems of these systems such as ideas, representations, rules, and materials are taken into cognisance by the problem-solver.

As such, the current study also looked at the conceptual system where learners engaged their ideas in expressing real-life situations effectively in mathematical language. Learners also engaged in having higher-level mathematical problem-solving abilities beyond just computational and arithmetical skills. The arithmetic skills involved spatial reasoning and interpretation as they learn to interpret and solve multiplicative word problems. Moreover, this approach takes constructivist and socio-cultural theories as its theoretical foundation.

2.2.2.14 Multiplicative word problems as an exemplar of word problem-solving in Grade 7

For purposes of this study, I am cognisant of the fact that word problem-solving is found in all four operational signs (addition, subtraction, multiplication and division). I will however, direct my attention to multiplicative word problems as an example as the one concept where Grade 7 learners experience more difficulties, comparatively speaking. Multiplicative word problems mostly make use of the multiplication operational sign. Multiplication is a problem that consists of a multiplicand and a multiplier (Bell, Greer, Grimison & Mangan, 1989). They further state that the multiplier is, by definition, the number of repetitions. According to De Corte and Verschaffel (1996), multiplicative word problems involve decimal multipliers, which denote and determine a higher level of difficulty when learners solve multiplicative word problems. According to Christou and Philippou (1998), multiplicative concepts are rate, compare, Cartesian-product and rectangular-area problems. More importantly, learners are expected to monitor their thinking and transfer and apply previously learned strategies to new problems in solving multiplicative mathematical word problems.

Multiplicative word problems can be categorised into two levels of difficulty: one-step and multi-step word problems (Agostino *et al.*, 2010). One-step problems are applied in routine problem-solving where learners are required to apply a simple computational procedure. On the other hand, multiple-step word problems are more complex, requiring learners to formulate a plan and coordinate procedures in their solutions rather than simply applying a single operation. The multiplicative word problems used in this study required learners to monitor their thinking and transfer and apply previously learned strategies to those new problems. Hence, learners needed to use more meaningful strategies to solve those type of mathematical word problems (Agostino *et al.*, 2010; Zhang, Xin & Si, 2011).

2.3 Language in Grade 7 mathematics classrooms

This section gives more insight into issues of language as used in South African Grade 7 classrooms and describes the significance of language in Grade 7 mathematics classrooms. Language and teaching of word problems in grade 7 classrooms and factors that pose difficulties for learners in language and mathematics language in word problem-solving are also discussed.

2.3.1 Language as used in South African Grade 7 classrooms

Language is the means by which a person learns to organise experiences and thoughts that shape learning through cognitive, affective as well as social issues (DBE, 2010). In a report by the DBE on the status of the language of learning and teaching (LoLT) in South African Schools, the governing bodies are responsible for drawing up the language policy which will stipulate the LoLT of the that specific school. The language policy for South African schools is guided by principles derived from the Constitution of the Republic of South Africa (1996a) and the South African Schools Act (1996b) (SASA). Subsequently language is a core element in any school for the school to function communicatively.

The language of learning and teaching is normally termed the LoLT. The LoLT of a school is the medium of instruction or the language of instruction which is the language that is used in the classroom throughout the school day, implementing the curriculum (Stein, 2017). This implies that learners must have a good understanding of the LoLT to understand the subject matter as it also covers the assessment component in the process of learning and teaching. Using language in the classrooms is also for the recognition of equality and diversity and the necessity to depart from a history in which education was used as a vehicle to implement and strengthen apartheid (Stein, 2017). It was through this education right that learners' diversity as well as individuality was recognised, and this in turn maximises the engagement potential in learners in Mathematics classrooms.

2.3.2 How language is used in Grade 7 mathematics classrooms

In a report by the DBE on the status of the language of learning and teaching (LoLT) in South African Public Schools, Language in Education Policy (LiEP) maintains the use of home language as LoLT in the early years (Grade 0-3) of learning (DBE, 2010). Home language is the language that is spoken most frequently at home by a learner. From Grade 4 onwards, all learners shall be offered their LOLT (DBE, 2010; Stein, 2017) as per the school language policy. The LoLT which is part of the language policy of a school is determined by the school governing body (SGB). In the South African public schools, the LoLT is usually English because of its association with the economic growth, and being a global language. English is also useful for future studies, as tertiary

education tends to be offered in English. English is also a common language in the work environment. In the draft language policy (DBE, 2015), the department of education proposes that multilingualism and respect for all languages be promoted in order to redress previously disadvantaged languages by allowing provinces to formulate their language policies. The Department of Basic Education further proposes that “[i]n the Intermediate Phase (Grades 4 - 6), Senior Phase (Grades 7 - 9) and Further Education and Training (Grades 10 -12) documents related to the teaching and learning of languages will be provided in all the official languages of the Republic of South Africa” (2015:5). In South African schools, the majority of learners do not learn in their home language from Grade 4 onwards and English and Afrikaans are the most used LoLTs after Grade 3 (DBE, 2010).

2.3.3 Why language is significant in Grade 7 mathematics classrooms

In mathematics classrooms, Grade 7 included, communication is conveyed through language. In the South African context, there are 11 languages in use. The Language-in-Education Policy insists that the LoLT in the first four years of schooling is mother-tongue and thereafter English language plays a crucial role. In Mathematics concepts and procedures are conveyed via language, through which the problems (word problems) in the text are read, comprehended and solved. To determine sense-making by learners in multicultural mathematics classrooms, language is used. Language provides a medium for activities involving reading, listening and writing during teaching and learning. This position resonates with research carried by (Essien, 2018) whose study into exploring the role of Language in the Teaching and Learning contends that use of multiple languages could be an ideal strategy to mediate teaching and learning that would enable learners to have access to mathematics materials and questions in their home language and English simultaneously. Stein (2017) mentions that language offers augmentative communication via oral speech that is used to express ideas, thoughts and feelings. Argumentations and discussions are conveyed in language. It is through the activities conducted in language that we measure the performance and achievement of learners in Mathematics. Essien (2018) contends for a better training of teachers so that they could be well equipped and competent in the teaching and learning that takes place in the Mathematics classrooms. Hence, language is key in the mathematics discipline.

Adler (1998) reports on the dilemma of code-switching experienced in using language in learning and teaching of mathematics. This resonates with my experience in teaching Mathematics, word problem solving in particular, and during the research data collection. English language was used as medium of instruction in a black township where the learners and me were African and were not English language first speakers.

As a medium of instruction, English was necessary; learners should understand English as all the assessments were in English. Learners in the schools engaged in this study had to express their views, ideas, argumentations and discussions in English, enhancing their *talk* which was the aim of the intervention. It was suggested that learners do perform better when they have acquired better language skills and are better adapted to their new homes (Yu & Shandu, 2018) which is a context of being familiar to a second language which happens not to be the home language. Yu and Shandu (2018) further emphasise that a learner's inability to use his/her home language at school is said to impede his or her capacity to perform to the best of his or her ability and therefore may result in underperformance.

Similarly, Setati *et al.* (2008) argue for the use of home language as a transparent resource for teaching and learning Mathematics for learners to gain mathematical knowledge in multilingual classrooms. By so doing, these authors are in favour of code-switching in Mathematics classrooms, which is also encouraged by the South African Language in education policy (LiEP). However, code-switching is viewed as a translation (Setati *et al.*, 2008) to harness learners' main language as a learning resource. Setati and Adler (2000) agree that this is a complex process as it is not a straight forward task. The authors acknowledge that language is a necessity in learning and teaching of mathematics, but it poses problems for the successful learning of mathematics. The problems come in the usage of the language, as many South African learners, in particular, have a low level of fluency that hinders them to engage effectively in mathematical activities in the classrooms. The learners, who were part of this study, experienced the same difficulties engaging in set activities such as understanding the language in the text and vocalising their responses to questions asked; this implies a low level of fluency in English language.

Central to Schafer's report (2010) is the issue of difficulty in understanding mathematical contents and concepts inherited in the English language as the language of learning and teaching (LoLT). Schäfer (2010) contends that code-switching is an ideal strategy in the teaching and learning of mathematics amongst other disciplines. Code switching enables the teacher and learners to involve their mother-tongue and English at the same time in enhancing their conceptual understanding in mathematics. This betters the language proficiency, as learning in an additional language (a language other than the first language) can pose problems if one is not proficient in that particular additional language. Hence, learners in multicultural and multilingual contexts, such as in South Africa and in the location where my study was conducted can benefit from the use of dual languages for better understanding and vocalisation within the mathematics classrooms (Schäfer, 2010).

In the same manner, it was accurately reported that learners whose home language is the same as the LoLT were in a more advantageous position as they were familiar with the linguistic

structures they encountered in the Mathematics classrooms (Essien, 2018). Learners whose home language is not the LoLT have to learn the language in which the mathematical concepts are embedded in, in addition to learning the mathematical contents (concepts).

Newkirk-Turner and Johnson (2018) define the role of language of mathematics as that of supporting learners within a mathematics curriculum particularly in word problem solving. The performance gap caused by language between English speaking and non-English speaking learners when solving word problems is a concern as the participants in this study were non-English speaking, as echoed by Newkirk-Turner and Johnson (2018). Newkirk-Turner and Johnson (2018) further argue that the achievement gap could be caused by issues such as maternal education, household income, quality of schools and teachers, lower expectations for minority learners, educational policies, leadership, and internalised negative stereotypes by minority learners. In relation to my study, the language aspect became a barrier to the learners; in a way of having low expectation and possibly internalised negative stereotyping.

Language tends to affect the learners' mathematical learning as they engage their abilities to decode and comprehend the syntax in the word problems text, which is also argued by Earp and Tanner (1980). Similarly, Sibanda (2017) reports on poor performances of learners in Mathematics owing to language complexity for English language learners (ELLs) in activities such as the solution of mathematics word problems. Difficulties experienced from the linguistic perspective lead to learners lacking opportunities to reason in English, hence lack of interaction when problems are presented in English language which is different from the everyday English language (Sibanda, 2017). Sibanda also reports that the inability of learners to solve most of the mathematical problems in the 2013 ANA was recorded. It is in such bilingual and multilingual South African classrooms where the intervention in the research is under way. Many learners were unable to express their reasoning in English language (Sibanda, 2017).

2.3.4 Language and teaching of word problems in Grade 7 classrooms

Comprehending the language in word problems in order to solve them is of vital importance both to the learners and the teachers. Subsequently, teachers have to bring in some kind of assistance in a form of mediation or intervention to alleviate the challenge of low proficiency in English of learners from a multicultural context such as the participants of this study at hand. The language challenge resulting in poor mathematics could be caused by learners who demonstrate characteristics of being inactive during problem solving activities. According to Orosco and Abdulrahim (2018), inactive learners are those learners who have not developed the cognitive awareness that is necessary to assess their understanding as they read word problems in formulating a solution.

Another possibility of the language barrier could be the lack of exposure to comprehension strategies to effectively improve in solving of word problems (Orosco & Abdulrahim, 2018). Learners who experience problem-solving challenges need teachers to help them acquire strategies that would help them understand the text, the vocabulary and interventional support in the mathematics content, as word problems demand them to read and learn the mathematics text. Teachers can support by providing examples of word problem solving modelling and oral language development. They could also provide questioning support that will assist learners in understanding the text, as well as motivate learners to engage in a collaborative way in classroom activities as they answer word-problem questions. This resonates with a study conducted by Orosco and Abdulrahim (2018). They raise a concern that there is limited research about teachers engaging with learners who struggle with word-problem solving, and they suggest the need for explicated instructional scaffolding practices.

Teachers would have to teach learners on how to restate the problem orally, construct meaning in order to understand and clarify misunderstandings within and about the word problem through collaboration (Orosco & Abdulrahim, 2018). Eventually the intervention will help respond to the learners' shortfalls and challenges in the understanding of the word problem-solving.

In the same vein, Newkirk-Turner and Johnson (2018) argue that the ability of a learner to solve word problems depends on his or her ability to draw on skills from language, symbolic representation, working memory as well as executive functioning computations. This clearly shows that learning and teaching mathematics requires both the learners and the teachers to be conscious about and constructive in engaging the incorporated mathematical concepts, which are embedded in word problems in this case, and the linguistic structures which are embedded in the English language. Newkirk-Turner and Johnson (2018) emphasise that, when we do mathematics, we simultaneously do mathematics and language. This was very evident when the Grade 7 classes engaged in word problem-solving; they actually computed some solutions after they had read the language in the text with understanding, because language is part of the word problems in mathematics. Learning as well as understanding language in mathematics promotes the educational growth which talks to the performance or achievement growth in the mathematics discipline. Learners who are challenged in language show difficulties in solving mathematical word problems as well as with other concepts such as geometrical reasoning (Newkirk-Turner & Johnson, 2018).

One of the most significant effects as a predictor of the performance of learners in Mathematics was the low proficiency in English language as reported in Howie (2003).

It was reported that amongst other factors leading to learners performing low in Mathematics were inadequate subject knowledge of teachers and inadequate communication ability of learners in the language of instruction. Difficulties in the language and communication problems were more significant with South African learners learning mathematics in a second language in a study conducted by Howie (2003) on Language and other background factors affecting secondary pupils' performance in Mathematics. Learners in Grade 7, 8 and 12 showed lack of understanding of mathematics questions, and an inability to communicate their answers in questions requiring a written answer in particular. Learners' attitudes towards mathematics, time spent on homework, learners' anxiety, their cognitive ability as well as reading ability were highlighted as other factors that registered as posing positive and negative effects on learners' Mathematics achievement. Howie (2003) reported findings on South African learners' Mathematic tests showing that learners who did not speak Afrikaans or English at home attained lower than those who did. Those learners speaking African languages at home attained 100 points less than the other group of second language speakers in mathematics tests, and this led to no group of learners coming close to attaining the international average for mathematics in the Third International Mathematics and Science Study (TIMSS) repeat in 1999 (Howie, 2003). In short, learners with high English language proficiency attained higher scores in comparison with learners with low proficiency in English language.

2.3.4.1 Language (mathematics)-related factors that pose difficulties for learners in word problem-solving

Section 2.3.5 gives more insight into issues of language comprehension, Language of Learning and Teaching (LoLT), terminology, and also integration of linguistic information and mathematics representation processing skills.

2.3.4.2 Factors related to language comprehension

According to Sepeng (2013b), learners have little contact with and access to English as well as low reading and speaking abilities and struggle to comprehend texts that are written in English. In Sepeng's (2013b) study, Grade 9 learners (N=107) from six township junior secondary schools in the Eastern Cape Province were studied under the notion of Mathematics discourse and mathematical modelling in multilingual classroom settings, both theoretically and methodologically. The six schools were a convenience sample as they came from the same cluster of schools. The author wanted to understand mathematical discourse that takes place when learners solve word problems in groups and / or pairs. The issue was for teachers to decide

whether to promote code switching between two languages when teaching word problems in arithmetic. The socio-cultural perspective underpinned the study.

Data were collected using a test and interviews following a mixed-method design with qualitative data informing the quantitative data (Sepeng, 2013b). Quantitative data were collected using a test in English and isiXhosa. Sepeng coded his Problem-solving (PS) test under three classification schema (2013:53-54): Realistic reaction (RR), No reaction (NR) and other reaction (OR).

- *Realistic reaction* meant all the cases wherein a learner either gave the most correct numerical solution that also considered the real-world aspects of the problem context. It also defined all the cases wherein there was a clear indication that the learners tried to consider these real-world aspects, without giving the mathematically and situationally most accurate numerical answer.
- *No reaction* was for all those cases without any indication that the learner was aware of the realistic modelling difficulty. For example, mathematically correct but situationally inaccurate and/or incorrect or inappropriate responses, computational errors, etc. This category also provided a measure of the word problem-solving abilities of the learners.
- *Other reaction* defined all the cases wherein a learner did not provide a numerical response and did not give any further written comment that indicated that the learner was aware of the realistic modelling difficulty that prevented them from answering the problem, as well as instances where learners generated incorrect responses with mathematical (or computational) errors.

Sepeng reports findings from his study (2013:58):

Learners preferred both LoLT (English) and home language (isiXhosa) in mathematical word problem-solving, they performed better in English, which could be attributed to the fact that the everyday teaching of mathematics, and other subjects in general, were facilitated in English. However, learners' sense-making of word problems significantly improved in their home language

The study above confirms that the source of difficulty for learners when solving Mathematics word problems can be attributed to the common language (LoLT) English as well as the home language. On the other hand, (Xin & Zhang, 2009) discuss problem-solving skills as a transfer-in-pieces perspective from which the learners work on their own (independent practice) in transferring the skills to solve problems and the educator acknowledges the existence of transfer between tasks and the importance of situated contexts.

The process of comprehension of the language that is constructed by learners during an attempt to solve a word problem is one of the factors that adversely influence learners' performance. This

is reported in a study conducted in Grade 6 Francophone (learners were taught French as a first language and encouraged to be bilingual) schools, located in the Province of Quebec in Canada (Voyer, 2011). In Voyer's study, learners experienced difficulties with situational model, which is defined as the process of problem comprehension that is less mathematical representation, by using one's real-world knowledge and personal experience to interpret the context and the content contained in the actual text (Voyer, 2011).

2.3.4.3 Factors associated with the Language of Learning and Teaching (LoLT)

Planas (2014) contends that mathematical difficulties and obstacles reported in Catalonia., Spain in 2014, emanate from the use of bilingualism in the learning and teaching of Mathematics. Bilingualism in this case entails the teaching and learning of learners whose home language is not the language of instruction, which makes language a source of difficulties in learners' learning of Mathematics. Planas, in this instance, mentions Catalan, which is spoken by most people in Catalonia and is the only official language of instruction versus Spanish, which is known mostly by the marginalised. Hence, misunderstandings and barriers exacerbate interpretation problems in the language of instruction by multilingual learners of Mathematics (Planas, 2014). A poor knowledge of the language of instruction, which is exacerbated by cultural misunderstandings and barriers when it comes to interpretation during teaching and learning does indeed interfere with the success of learners' performance (Planas, 2014).

2.3.4.4 Factors associated with lack of terminology of mathematics learners

Literature suggests that most learners do not receive correct mathematical terms in English. This comes as an inherited error from teachers who had not studied Mathematics, hence making errors in their mathematical terminology in their explanations (Brenner, 1998). Therefore, the above argument implies that the language minority learners did not receive appropriate language input in their Mathematics instruction. Learners who were caught up in this unfortunate scenario manifested extreme difficulties in verbalising definitions of the terms as well as verbalising procedures they used in order to obtain the solutions of their problems, even if they possessed the correct operational definitions (Brenner, 1998). The above problem was caused by teachers who failed to train the learners in the language of mathematics, as teachers could not correct the learners when they used incorrect mathematical terms in English (Brenner, 1998).

The above situation is also more evident when learners seldom read or consult textbooks that are available to even assist them as sources of mathematical language and vocabulary; hence they answer briefly such as simple one-word answers to the teachers' questioning, seldom ask questions and lack skills of elaboration in peer discussions (Brenner, 1998).

2.3.4.5 Integration of linguistic information and mathematics processing skills

According to Xin, Jitendra and Deatline-Buchman (2005), learners experience problems in reading and in basic computation skills, which eventually result in the learners' poor performance, difficulties in problem representation and failure to identify relevant information and operation, may exacerbate their poor performance. According to Peake, Jiménez, Rodríguez, Bisschop and Villarroel (2014), most of the problems that involve measuring arithmetic performances are a result of verbal and quantitative processing, as in the case of arithmetic word problem (AWP) solving. This requires the integration of linguistic information and mathematics processing skills.

According to Reikerås (2009), the low reading ability has been found to influence the growth in learners' academic performances to a greater extent. The low academic performance is eminent in word problems because this area is dependent on the integration of linguistic abilities, which among other things include reading word problems and arithmetic processing skills. There are also computational errors that are of concern, which arise from incorrectly solved word problems. Reikerås (2009) further buttresses that there is a different degree of difficulty in solving word problems that hinge on the fact that there are different semantic structures entailed in the order of the information in the text of word problems (Reikerås, 2009). The performance of learners is also affected by solving multistep word problems as it requires several steps, which are necessary in the solution process as compared to solving one-step word problems (Reikerås, 2009).

Literature has also shown that learners' reasons for of underperformance in mathematical problem-solving are more of a linguistic nature rather than intellectual nature (Sarmini, 2009). In the study conducted by this author, Grade 7 Arab-American learners who were labelled as Limited English Proficient (LEP) were unable to understand the language of instruction, which was English. LEP learners were attached to a connotation of being a "minority" or "inferiority" group because they were not native-born English speakers (Sarmini, 2009:2). The Arab-American learners' underperformance was manifested in word problems with hidden information, word problems that required multi-step solutions (thinking backwards as well), word problems involving double comparisons as well as difficulty in vocabulary and syntax (Sarmini, 2009).

2.3.4.6 Mathematics language in word problem-solving

The process of problem solving, discovery, applying mathematics in real-life contexts as well as identifying mathematical context, all point to the fact that mathematics as a discipline has its own language (Wilkinson, 2018). Mathematical language is characterised by its own distinct linguistic and discourse repertoire for cultivating “reading, writing, speaking, thinking, and reason about the disciplinary content. This embraces precise use of vocabulary, symbols, representations of mathematical knowledge, argumentation and proof” (Wilkinson, 2018:169). Mathematical language comes with specialised vocabulary such as irrational numbers, specialised ways of presenting arguments such as justifications and reaching a consensus, and dense noun phrases such as area under a curve. Hence, learners need to learn the mathematical language which is precise and technical by integrating the language of the mathematical knowledge with mathematical procedures (Wilkinson, 2018). In the same vein, Sarabi and Gafoor (2017) argue that learners develop an attitude of hating mathematics if they do not come right with the pragmatics of the mathematics language. This addresses identifying an operation to solve a problem in word problem-solving in particular. The authors further state that mathematics language is characterised by terminology, symbols and syntactic principles that are essential components in the learning and teaching of mathematics.

Leshem and Markovits (2013) define mathematics as a language of science that is also used every day to communicate and describe everyday situations. It also means explaining to make sense of problems in mathematics. Mathematics language is a language of using symbols notations and numbers as in words and sentences which forms a mathematics story, which is the mathematical grammar that needs solutions. Similarly, mathematical language can be defined as a language of symbols, concepts, definitions, and theorems (Ilany & Margolin, 2010). In word problem-solving, the learner is faced with two languages that are mixed together in finding the solution to the mathematical problem, all accompanied by text; the two languages being the natural language and mathematical language. The mathematical language requires the learners to be aware of the mathematical components while the natural language requires the learner to have a literacy approach to the whole textual unit (Ilany & Margolin, 2010). Ilany and Margolin (2010) further contend that mathematical language is more precise and less flexible as it brings in a deep structure of statements that are unambiguous, such as fractions, numbers, and equality and inequality signs.

Jamison (2000) shares a very interesting observation on the language of mathematics: that it is non-temporal, meaning that it is, implying there is no past, present or future.

However, mathematical language makes use of learning tools that are the same as those in any language class such as writing, speaking, listening, memorising models, and learning the history and culture. In mathematics language, one starts by learning the definitions in the communication discourse, then a definition-theorem-proof format where learners apply procedures, claim, justify and reach consensus (Jamison, 2000). On the same note, Lager (2006) defines mathematical language as contextualised by interactions that learners work on, related to algebraic items. The mathematics register language acquisition framework requires learners to translate problem situations from everyday language to algebraic expressions. Mathematical language is linked to the rational constructivist mathematics learning framework where the learner integrates new information into existing cognition to acquire higher-order concepts. The rational constructivists believe that while some mathematical knowledge can be transmitted at sometimes the abstraction of a concept still has to be achieved by the learner (Lager, 2006).

Mathematics language requires learners to “be able to read long words included in the mathematical vocabulary (such as equation) and also to interpret grammatical constructions representing mathematical relations (such as twice the size of), even if they are more unusual in colloquial language” (Bergqvist, Theens & Österholm, 2018:46). The authors highlight the importance of reading ability as it is always needed to solve a written task. The students need to be able to read the language in the mathematics in order to solve the problem (Bergqvist *et al.*, 2018). Galligan (2016) recommends features of mathematics language as the mathematics register, language in the classroom as well as the technical communication. The mathematics register is the etymology of the words, phrases, syntax, semantics and associated meanings used to express mathematical ideas. The language in the classroom is the mathematical language that is used to communicate ideas and dialogue that learners use to communicate when learning mathematics, while the technical communication is the oral and written form of the accepted standard language and symbols used to communicate the ideas (Galligan, 2016). Since mathematical concepts are often encapsulated in words (language), adequate grasp of the correct terminology in mathematics is crucial. Galligan (2016) accordingly asserts that, it is important to have a correct word for a concept because it provides immense assistance in the understanding of that concept.

Hornburg, Schmitt and Purpura (2018) in their study of relations between pre-schoolers’ mathematical language understanding and specific numeracy skills, established that mathematics language is critical for numeracy development skills, which are important for later academic achievement.

These authors define mathematics language from the numeracy perspective; learners’ understanding of key words in mathematics that include quantitative words such as “more” and

“less” and spatial words such as “before” and “after” (Hornburg *et al.*, 2018:85). They further state that mathematical language mediates the relation between general language and early numeracy skills. In word problem-solving, learners must first comprehend the problem before they select the correct operation to execute the calculation. Hence, mathematics language influences the learners’ performance on word problem solving. For learners’ comprehension of the word problem, they need to think about the question that the word problem is asking, find and understand the relevant/irrelevant information in the word problem, as well as collaborate with other students to find problem-solving solutions (Orosco & Abdulrahim, 2018).

In word problem-solving, a language of the discipline which is mathematics language is the engine and catalyst of the instructional process. The linguistic, disciplinary content, mathematical procedures, the definition-theorem-proof format and mathematical register are all within the rational constructivist mathematics learning framework. When learners construct their knowledge as they learn during word problems solving, all the above listed constructs become the gist of the text and the talk that is involved. The above collection confirms the necessity of the mathematics language driving the discourse of learning and teaching within the mathematics discipline.

2.4 Argumentative writing frames (AWFs)

In this section, the concept of argumentative writing frames is discussed under the following sub-headings, what are argumentative writing frames, how do AWFs work (are used), the benefits of using AWFs, as well as defining argumentation, dialogue and discussions as concepts that are more prominent in the use of AWFs.

2.4.1 Defining argumentative (writing) frames

Literature elucidates clearly on mostly writing frames which were initially in written text (Lewis & Wray, 2002; Ross *et al.*, 2009; Webb *et al.*, 2008), however, they were argumentative in the nature of how they were presented in this study, hence I named them argumentative writing frames (AWFs) for purposes of my study at hand. Hence, the following definitions were presented.

Writing frames are templates that consist of leads, clues, cues and insights that provide a skeleton outline that teachers use to scaffold their writing tasks in a science classroom (Subramaniam, 2010). As a skeleton outline, writing frames comprise starters, connectives and sentence modifiers that learners use to redress the balance in making efforts to communicate through writing (Warwick *et al.*, 2003). Rawson (1997) argues that writing frames are one strategy that offers generic structures and language that feature explanation, procedure, recount, and report as well as discussion language. Writing frames offer prompts for learners to communicate what

they want to say. These skeleton outlines of starters and connectives allow the teacher to model and engage learners in discussions using the writing frames.

On the other hand, Ross *et al.* (2009) define language frames as templates that are effective in developing learners' thinking and writing skills. Ross *et al.* (2009) further explain that the language frames are effective tools for enhancing meaningful discussions that need teacher modelling to capacitate the learners' communication and highlight the academic language and syntax required in the art of argumentation. In the same vein of defining AWFs, it is argued that they are *speech genres* which also include written genres like mathematical word problems which are “relatively stable types of utterances” within a particular sphere in which language is used (Bakhtin, 1986:60).

Argumentative writing frames can be defined as writing frames, speech genres, and/or templates that inherit language that needs to be understood by learners. AWFs are captured in the discussions and argumentations and communication which are vital components in the dialogue discourse, which is characterised by *talk* which is what the study at hand intends to achieve in the intervention.

2.4.2 How AWFs function

AWFs unearth dialogue skills (the art of argumentation and discussions) within learners in a mathematics classroom. Argumentation is explained as a process where learners make a claim, provide suitable evidence to justify it, and defend the claim in a logical way (Webb *et al.*, 2008). Argumentative writing frames can be a single sheet of paper with a heading of your choice but capture the essence of the argumentation art (see Table 2-1 below). AWFs are mostly written, whether to be used as writing frames or verbalised frames. The writing frames are written in such a way that it captures the argumentation in them. AWFs are written as starters, connectors, etc. The teacher teaches learners how to read them verbally, whether they will use them in writing or oral argumentation. The teacher explains what they mean and teaches the learners how they are used to frame their *talk*. In fact, the teacher uses AWFs to support dialogue (writings or orally) as essentially mediation and scaffolding tools. AWFs come in templates. The template is a sentence that has spaces either in the middle of the sentence or at the end of the sentence. As starters, they start a sentence, conversation, statement, argument, or a claim, that the learner can use to start his/her sentence and finish off the sentence by his/her answer in responding to the argument. In the dialogue (argumentation, discussion), the learner could be a learner '**making a claim**' (see the sentences on the right hand side) on Table 2-1 below, *I observed _____ when _____* (Verschaffel, Van Dooren, Greer & Mukhopadhyay, 2009). From the same table you

can note the same learner, **providing evidence** of the claim he/she made prior, *I believe (statement) because _____* (justification).

Providing evidence by the learner, is actually giving a statement of why you (learner) believe in the answer you gave in the *claim*. The learner is justifying the claim made. The justification could be out of the learners' knowledge or based on observation made.

In developing the argumentation, another learner or the teacher poses an AWF that **asks for (more) evidence**, *what causes _____ to _____*? In this frame, the learner or teacher asks for more clarity from the claim made. In asking for evidence, the learners/teacher is asking for more elaborate information in addition to what has been given already, such as, *What causes _____ to _____*? The same learner/teacher asking for more clarity or another learner/ teacher, **offers a counter claim**, *I disagree with _____ because _____*. A counter claim is a disagreement that probes more justification from the claim or brings another view point of the issue or problem at hand. The next step is **inviting speculation**, *I wonder what would happen if _____*. This step is like a tester, where learners or the teacher wants to get assurance of what has been said, *we want to test to find out if _____*. The final state is **reaching consensus**, *I agree with _____ because _____*. This is the part where the participants in the argument agree with each other based on the given view-points brought together with the justifications to make sense of the point of argument. Reaching consensus could also mean bringing another view point in addition to what has been agreed about such as, *How would this be different if _____*? See examples of language frames on the following page (Ross et al., 2009):

Table 2-1: Language frames for argumentation in science

Making a claim	I observed _____ when _____. I compared _____ and _____. I noticed _____, when _____. The effect of _____ on _____ is _____.
Providing evidence	The evidence I use to support _____ is _____. I believe _____ (statement) because _____ (justification). I know that _____ is because _____. Based on _____, I think _____. Based upon _____, my hypothesis is _____.
Asking for evidence	I have a question about _____. Does _____ have more _____? What causes _____ to _____? Can you show me where you found the information about _____?
Offering a counter claim	I disagree with _____ because _____. The reason I believe _____ is _____. The facts that support my idea are _____. In my opinion _____. One difference between my idea and yours is _____.
Inviting speculation	I wonder what would happen if _____. I have a question about _____. Let's find out how we can test these samples for _____. We want to test _____ to find out if _____. If I change _____, (variable in experiment) then I think _____ will happen, because _____. I wonder why _____? How would this be different if _____? What do you think will happen if _____ next?
Reaching consensus	I agree with _____ because _____. How would this be different if _____? We all have the same idea about _____.

In the progression of the argumentation, using the AWFs as outlined by Verschaffel *et al.* (2009) on Table 2-1 above, variation can be considered. It is possible that the argumentation does not include all five steps. Crucial to the argumentation are AWFs on making a claim, providing evidence or alternated by Asking for evidence, offering a counter claim as well as reaching consensus. Inviting speculation can be optional as it is just an extension of offering a counter claim. These tools (AWFs) offer learners a structure for communicating what they want to say, by asking learners to select and think about what they have learnt by re-ordering information and demonstrating their understanding, rather than just copying out text (Lewis & Wray, 2002). Rawson (1997) states that learners might want to communicate what they say outside the given skeleton outline of writing frames, which is something that needs to be researched in greater detail.

After a study conducted by Webb *et al.* (2008) on cartoons and argumentation coupled with writing frames used in science classrooms, they report that in these Science classrooms, learners expressed their views based on their claims but could not support those claims and rarely opposed each other's ideas. Learners just agreed with each other instead of arguing (Webb *et al.*, 2008). However, after the intervention, their findings were that linking these cartoons with writing frames to scaffold learners' thinking added value to the process in a number of cases. In fact, the data suggested that there was promise in using concept cartoons in science classrooms to provoke argumentation and to stimulate learners' thinking, and they also suggest linking these cartoons with writing frames to scaffold learners' thinking added value (Webb *et al.*, 2008).

The writing frames templates activate learners' prior knowledge and enable them to organise and construct knowledge using the sentence starters, connectives, sentence modifiers as well as the language information (Subramaniam, 2010). Warwick *et al.* (2003) conducted a study in three schools in England to investigate the use of writing frames to encourage learners to develop and express their procedural understanding in science classrooms. Similar to the studies reported above, in their findings they report that the writing frames can be used as one means of helping to develop metacognitive processes. With such mediation tool as AWFs, learners use the language inherent in the frames to talk and by so doing, they better understand the text of the word problems they must solve.

2.4.3 Benefits of using AWFs

Using AWFs was reported in the findings of a study conducted by Rawson (1997) on working with writing frames in mathematics introduced to Devon teachers. This study found that learners were able to formulate, organise and discuss their ideas. The teachers were expected to help learners to understand how ideas are linked in writing to create a coherent whole using writing frames.

Subramaniam (2010) reports on the benefits of writing frames when used in inquiry-based lessons that they open up learners' thoughts as they focus on the objectivity of the given work. Writing frames act as translator that helps learners to focus on their scientific writing (written arguments, discussions, explanations, experiments, expositions, procedures, recounts, and reports) and they also assist teacher-intervention. The use of writing frames brought about that learners develop and express their procedural understanding (Warwick *et al.*, 2003).

According to Webb *et al.* (2008), writing frames were used to develop argumentation in two Grade 9 Science classrooms in a previously disadvantaged South African School over a period of eight weeks. The writing frames were used in the classes where there was little classroom talk as an instrument to scaffold learners' thinking process. The main aim of introducing the writing frames in such classes was to teach learners how to learn to talk, write and read science. This exercise embedded language tasks that needed explicit explanations (Webb *et al.*, 2008). Toulmin's Argumentation Programme (TAP) instrument was used to measure the levels of argumentation during the research conducted by Webb *et al.* (2008). Webb *et al.* (2008) further report that if an oral discourse during teaching is unstructured, it is not sufficient to support the learning activity.

In this study, AWFs and dialogue were used as teaching and learning techniques. Writing frames are templates that consist of starters, sentence modifiers and connectives. Accordingly, in this study, writing frames were always used with discussions and teacher modelling before the joint teacher-plus-child construction was effected as it developed the learners' oral language and thinking. Below I give more light on three concepts that form the crux of the intervention of using AWFs namely, argumentation, dialogue and discussion.

2.4.4 Argumentation in AWFs

In the field of Cognitive Science Education and Philosophy, argumentation has considerably advanced as a process that fosters critical thinking and conceptual standing in which individuals construct and critique arguments (Nussbaum, 2011). More importantly, Nussbaum (2011) contends that Toulmin has largely guided the concept of argumentation.

Argument as product and argument as process have been described as the two senses of the word argument (Nussbaum, 2011). The classroom discussion in which learners engage in dialogue to construct and critique one another's argument is called the dialectical argumentation, which is the sense of argumentation as a process. Learners need to talk and discuss the content, using the AWFs to support dialogue in order to understand and know how to solve the multiplicative word problems. Sepeng (2014a) maintains that the argumentation technique is employed to enhance maximal learner participation in mathematics classrooms and mathematical

reasoning through discussion. Sepeng further states that scaffolding and the structure to support learning are required by the discussion technique.

Ross *et al.* (2009:28) define argumentation from the Science perspective as an interaction that “involves offering and responding to claims, providing and asking for evidence or justifications, and analysing those claims to formulate a decision”. Ross *et al.* further state that the process of argumentation should increase understanding, add information, and clarify concepts, in their study where they explored the use of language frames to learn the art of argumentation in a Grade 4 class. The authors highlight language frames as effective tools that provide learners an opportunity to share their thinking as they consolidate their understanding, which the teacher uses to model to build learners’ capacity for holding meaningful discussions. Ross *et al.* (2009) note that argumentation is a necessary strategy needed in the classroom which learners need to engage in with language frames providing an effective bridging scaffold in the classroom teaching (modelling) process.

2.4.5 Dialogue in AFWs

According to Norenes and Ludvigsen (2016), communication and the articulation of learners enhance the development of conceptual understanding in Mathematics classrooms, which is either effective or does not occur at all. Norenes and Ludvigsen further argue that learners produce and coordinate mathematical understanding at the intersection between social, cultural and cognitive aspects, where the cultural aspect involves scaffolding tools for learners’ learning (Norenes & Ludvigsen, 2016). The authors further claim that an effective dialogue comprises a rationale with specific talk by learners which is enhanced by the educator in making use of different types of scaffolds. Barnes and Todd (cited by Norenes and Ludvigsen, 2016:68), claim that in collaborative dialogue, learners interact with one another’s contribution and develop their discourse by elaborating, eliciting and utilising each other’s utterances in which they find meaningfulness. During the mathematical explanations process, learners become aware of the gaps, misconceptions, errors, and contradictions in their generation of understanding which captures new and old information.

According to Mercer and Sams (2006), classroom dialogue incorporates dialectic teaching which is characterised by features such as questions that are structured so as to provoke thoughtful answers. The answers provoke further questions and are seen as the building blocks of dialogue rather than its terminal point. Furthermore, the individual teacher–learner and learner-learner exchanges are chained into coherent lines of enquiry rather than left stranded and disconnected.

The above features resonate with my belief that bringing talk through the AWFs as a tool into the classroom, better performance outcomes for the learners will be reached when they solve their word problems. Teachers have to model through the use of language constructing knowledge and AWFs to stimulate the learners to talk and engage in dialogues.

2.4.6 Discussions in AFWs

Mercer and Sams (2006) conducted a study in primary schools in South East England, where the use of language was used as a tool for reasoning and to enable the use of discussion skills that learners developed in carrying out mathematical activities. The teacher that was reported in this study encouraged learners to discuss errors and misunderstandings that were entailed in dialogue. However, the talk which took place in this study did not constitute a good, effective discussion because learners were rarely offered guidance and training in how to communicate effectively. As such, learners could not bring a well-developed capacity for reasoned dialogue to a task (Mercer & Sams, 2006). On the other hand, good dialogue inherits “reasoning words” such as what, how, if, and why, as learners are led through a discussion activity that has been initiated by the teacher (Mercer & Sams, 2006:520-521).

From a study conducted in the U.S with learners of a high school graduating class of 2011, Jaafar (2015) reports that (group) discussion in particular had a positive impact on the learners’ handling of word problems and their ability to solve them. However, in the beginning of the study, learners were reported to have difficulty in knowing whether to multiply, divide, add or subtract in given word problems. The learners’ difficulty pointed out to the necessity of both procedural abilities and conceptual understanding being necessary and essential for the learners’ success in solving word problems. In Jaafar’s study learners were given homework on single-step and multi-step processes included in multiplication, division, addition and subtraction, covered proportion and percentages concepts. Jaafar’s findings also indicated that learners who worked in groups performed better in solving their tasks, despite the fact that learners did not change their perception of the level of difficulty of the problems, even after undergoing the intervention that was carried out.

The findings also showed that familiarity, group discussions and individual interest had a positive impact on learners’ handling of word problems and their ability to solve them (Jaafar, 2015). The learners’ responses implied that their getting some of the tasks correct was probably by chance, they were still not confident of their problem-solving abilities.

In word problem solving in Grade 7 classes, effective learning can only take place when learners and teachers or learners amongst themselves talk or communicate. The communication during

the interaction involves language which needs to be read, comprehended and applied in the solutions of solving word problems. Communication comes in the form of argumentation, dialogue and discussions. The use of AWFs captures reading the language, and the talk which leads to learners' word problem-solving in the Grade 7 mathematics classrooms.

2.5 Chapter summary

This chapter provided a review of literature drawn from research results of various authors locally and globally, on issues of word problem-solving, language in mathematics as well as argumentative writing frames. Word problem-solving enlightened issues of what word problems are as well as how word problems are solved. Issues of language gave insight on language as it is used in South African Grade 7 classrooms, the significance of language in Grade 7 classrooms and difficulties that learners experience with language when solving word problems. Argumentative writing frames illuminated the definition of AWFs and how they work, their benefits, dialogue, argumentation and discussion in AWFs. Chapter Three discusses the theoretical framework that underpins the research study.

CHAPTER 3

THEORETICAL-CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter is presented in four sections. In section 3.2, I articulate the philosophical orientation of the study. In Section 3.3, I discuss the theoretical perspectives that align with the selected orientations and these will provide analytical tools that I worked with to analyse data. The analytical tools are discussed in depth in section 3.4. Suffice it to point out that the analytic tools have emerged from the selected theoretical framework. The chapter concludes with section 3.5 which is a summary of the chapter.

3.2 Philosophical orientation

There are several paradigms or worldviews that determine how people's beliefs, assumptions, principles, ideas or laws maybe be understood. These worldviews are crucial because of their influence on how research may be conducted and how evidence from research may be considered as well as the relative importance of the evidence (Creswell, 2014; Okeke & Van Wyk, 2015). A paradigm is the way we look at the world (Mertens, 2015:8). More importantly, research paradigms are philosophical lenses or bases that researchers use to align the choices of their methodology to use and research questions to address. The concept of paradigms was initiated by the philosopher Thomas Kuhn in the *The Structure of Scientific Revolutions* in 1962 (Okeke & Van Wyk, 2015:21). Each one of these philosophies postulates and focuses the theory to be used in the study that has been followed. For instance, there is the Afrocentricity philosophy, Positivism philosophy, Interpretivism philosophy, Critical paradigm, Pragmatic philosophy, to mention a few. However, in this study, I will discuss the "old" Positivism, the Interpretivism as well as the Pragmatic paradigm. Each of these three orientations will be elaborated on further under three philosophical themes or concepts, namely, Ontology, Axiology and Epistemology.

3.2.1 Positivism as research paradigm

Okeke and Van Wyk (2015) consider the positivist paradigm as the oldest of the major paradigms. It has come to be known as the hard science because of its origin in the scientific world. Positivism is grounded by the belief of studying the social world in the same way as the natural world and providing an explanation of casual nature (Mertens, 2015).

Positivism is a paradigm that uses the scientific method (Cohen *et al.*, 2018; Mertens, 2015) from which it measures and understands the behaviour that is observed from the experimentation (Okeke & Van Wyk, 2015) for it to be considered meaningful. A study that is underpinned by the

positivist paradigm is subjected to an assumption that the world has laws that govern it, and as such, the phenomena in the world are observable, measurable, predictable, and stable, and can be understood through scientific research. Aligning positivism with quantitative approach only is misguided (Cohen *et al.*, 2018). On an interesting note, Johnson and Christensen (2017:422) refer to positivism as “a term used by qualitative researchers to refer to what might be better labelled “scientism,” which is the belief that all true knowledge must be based on science...” In addition to the above terms, Creswell (2014) calls the positivism research paradigm, the scientific method, science research, post-positivist research and post-positivism. A study that is subjected to a positivist research paradigm is based on testing a theory, which relates to variables that are measured in numbers and analysed with statistical procedures (Okeke & Van Wyk, 2015). I used the positivist paradigm world view because I wanted to understand the nature of the learners’ problem-solving abilities and their performance in relation to word problems. The learners’ word problem-solving abilities and performance was tracked prior to a sequence of intervention lessons as well as after the intervention was carried out. Based on Social Sciences (Cohen *et al.*, 2018), the positivist paradigm comes from an empiricist tradition that was established by Auguste Comte (1798-1857), who was the founder of Sociology (Okeke & Van Wyk, 2015).

3.2.2 Interpretivism as research paradigm

The interpretive research paradigm is termed constructivist (constructivism world view) (Creswell, 2014), qualitative, naturalistic, post-positivist or post-modern perspective because it is based on the formation of words and reporting of detailed views from the respondents or study subjects (Okeke & Van Wyk, 2015). I used the constructivism/interpretivist world view because I wanted to explore and understand how the Grade 7 learners made their utterances and interactions using AWFs in the context of word problem-solving (Okeke & Van Wyk, 2015). I wanted to explore how the Grade 7 learners constructed their understanding of multiplicative word problem-solving in particular, made their interpretations when solving the word problems, and made meaning of their solutions in their classrooms with the researcher as a mediator (see 1.3). The constructivism paradigm is built on the basis that reality is socially constructed by active participants of a research and the researcher is expected to understand the social world (Merriam, 2002) from the lived experiences of those who have lived it (Greig *et al.*, 2007; Mertens, 2015).

The essence that Merriam (2002) puts forth is actually the constructed meaning about their (participants’) world and their experiences; that is, how do people (research participants) make sense of their experiences. The meaning of the phenomenon is mediated by the researcher as the instrument and presentation of the results in a descriptive manner (Merriam, 2002).

3.2.3 Pragmatism as research paradigm

The pragmatic paradigm is of the worldview that stems out of actions, situations and consequences used by some researchers as opposed to post-positivism antecedent conditions (Creswell, 2014). It has its origins in the social science research trying to establish what works and how things work; it is philosophically ideal to underpin mixed or multiple methods studies. Cherryholmes (1992) argues that pragmatism does not focus on methods, but the emphasis in this study was on the research question and the use of all approaches available to understand the problem in pragmatic or practical terms. Hence, the study is underpinned by the pragmatism research paradigm because the researcher mixed and used elements from the interpretivist paradigm and the positivist paradigm.

3.2.4 Ontology: Positivist, interpretivist and pragmatic

Ontology, often known as metaphysics, is about what knowledge is. Therefore, it is the science of being and dealing with matters of reality or existence (Okeke & Van Wyk, 2015). Ontology refers to the nature of reality or truth (Johnson & Christensen, 2017; Mertens, 2015). Ontology considers the question: "What is truth?" (Okeke & Van Wyk, 2015:60).

The positivist ontology views reality as objective, and independent of the researcher, which means that, the truth is "out there", separate from the individual who observes it. In a study, oriented by positivism, the subject who is the researcher and the object which is the phenomenon, are two separate and independent entities. Positivist researchers must measure things objectively by using an instrument such as a questionnaire (Creswell, 2014; Okeke & Van Wyk, 2015). Positivists believe in the scientific knowledge as being objective and that only the scientific knowledge is valid, certain and accurate; yet the empirical and objective data fall short when it comes to human behaviour (Mertens, 2015). In observing and understanding the human behaviour it is most difficult to have an absolute truth when testing theory, more especially within the positivism paradigm.

Interpretivists on the other hand, believe in multiple realities that exist in any given situation. The researcher must be ready to report holistically from the different perspectives of the individuals being researched. The researcher must be ready to report on his or her own perspective, including anticipating the audience who interpret the study findings from their own perspectives (Okeke & Van Wyk, 2015).

Okeke and Van Wyk (2015) imply that interpretive researchers' interest is in the use of triangulation, as they use several sources of data and they use several methods as well as instruments of data collection. Researchers in the interpretivist paradigm view reality as subjective

as they believe that it is created in the beholder's mind. Hence, in this ontology, interpretivists believe in reality that cannot be separated from the individual who observes it. Therefore, for the constructivist paradigm, researchers are of the idea that reality can only be construed by the individuals involved in the research context or situation; reality cannot simply be imprinted on individuals but is formed through interactions with others. Hence the term social constructivism. (Creswell, 2014; Mertens, 2015; Okeke & Van Wyk, 2015).

Pragmatism is not committed to one system of philosophy or reality, but inquirers draw liberally from both quantitative and qualitative approaches when engaging in their research (Creswell, 2014). Truth is what works at that particular time. Therefore, mixed or multiple methods researchers use both the quantitative and qualitative data in order to provide the best understanding of the phenomenon under investigation. The pragmatists assert that there is a single reality and that each individual has his/her own unique interpretation of reality (Mertens, 2015).

Ontologically this study was fit for the pragmatic philosophy. I will be reporting on the learners' multiple realities from different perspectives on the reality that the learners construed in the word problem solving context. The learners created the reality of engaging in talk (dialogue, argumentation and discussion) in the classroom, and word problem solving abilities were formed through interactions with the teacher (researcher) in the learners' social environment (classroom). Learners were also subjected to learners' focus groups (pre- and post-intervention). The truth could not be separated from the learners because they created the meaning through the lived experiences as they were subjected to the intervention. This is in opposition to the positivists who embrace the truth as independent of the participant and the pragmatists who do not commit to any truth. From the Positivism paradigm as a researcher I measured the learners' word problem-solving abilities and performances objectively by using the pre- and post-test instrument (Creswell, 2014; Mertens, 2015; Okeke & Van Wyk, 2015).

3.2.5 Axiology: Positivism, interpretivism and pragmatism

Axiology in a study talks to issues of values, value judgements, norms, and ethics. Axiology is the nature of ethical behaviour (Mertens, 2015). In a study that is orientated by a positivist axiology, observable facts that are distinct from personal ideas and values are projected. Statements about values are completely omitted from written reports that use impersonal views, report the facts, and argue from the evidence gathered in the study (Okeke & Van Wyk, 2015).

In the issue of values, value judgements and ethics in the interpretivist research paradigm, qualitative researchers admit that the nature of the study is value-laden. Hence, they believe and

claim that a researcher gives meaning to whatever phenomenon he/she is researching, in a partial, subjective and biased way. The idea of measurement is seen as fallible and prone to error and bias and therefore calls for the advocacy of multiple measures and observations in order to achieve credibility in the study (Okeke & Van Wyk, 2015). In fact, constructivist researchers actively report their own values and biases as well as the nature of the value of information gathered from the field in their own language, personal and first person (Okeke & Van Wyk, 2015).

The pragmatist axiology posits that researchers have a freedom of choice in choosing the methods, techniques and procedures of research that best satisfy their needs and purposes as far as their research work is concerned. Because pragmatists do not see the world as an absolute unity, they look to many approaches for collecting and analysing data rather than sticking to one approach, whether quantitative or qualitative (Creswell 2014). Pragmatists are influenced by the researcher's values and politics on the gained knowledge pursuit of the desired ends (Mertens, 2015).

I profess the pragmatism axiology because it talks to issues of values, value judgements, norms, and ethics of the learners and researcher. As a researcher, pragmatism gives me freedom to choose the methods, techniques and procedures of research that best satisfy the needs and purposes of my research work. I found the issues of combined theories of caring and social justice within the constructivism approach humane and ideal for relations. Being humane enhances respectful ways of interaction between the participants (learners) and myself as the researcher (Mertens, 2015).

3.2.6 Epistemology: Positivism, interpretivism and pragmatism

Epistemology is defined as the science of truth reality to how a researcher comes to know and the reliability of the claims constituted in the knowledge (Okeke & Van Wyk, 2015). Epistemology tends to consider the question: "What is knowledge?" (Okeke & Van Wyk, 2015: 60). It is the reality and truth of knowledge as well as the relation between knower and would-be-known (Mertens, 2015:11).

In a positivist world view the researcher maintains a distant and independent position from that being researched in an attempt to control bias by selecting a representative sample and maintaining an objective assessment (Okeke & Van Wyk, 2015).

Interpretivist researchers interact with and observe the participants involved in the study for a considerable length of time while minimising the distance between them (researchers) and those being researched (Okeke & Van Wyk, 2015). Researchers in the interpretivism research paradigm are of the school of thought that the knowledge they build reflects their particular experience,

history, goals, and culture, to mention but a few. The interpretations are assembled in a logical, explicit and narrative manner in the constructivism paradigm because of the personal, interactive medium of collecting data between the researcher and the participants. Interpretivist researchers closely monitor the learners' construction of their experiences within a close proximity as they interact and observe them. Hence an explicit logical narrative is reported with specific quote where needed. A study that is aligned with the interpretivist orientation is based on beliefs and purposes that do not accept the view of a stable, coherent uniform world. The study embraces meaning as situated in a particular context or perspective, since different people have different perspectives, contexts and interpretations (Okeke & Van Wyk, 2015). Interpretivists understand what participants are thinking and feeling, in both verbal and non-verbal modes. A German sociologist, Max Weber (1864-1920), and the German philosopher, Wilhem Dilthey (1833-1911), began the interpretive social science as a counter movement arising partly as a reaction to the dominant traditional positivist assumption (Mertens, 2015; Okeke & Van Wyk, 2015).

Pragmatists use pluralistic approaches to construct and derive knowledge about their research problems. For the pragmatist researchers to look at the what, they look at the purpose for mixing, the rationale for the reasons why the data need to be mixed. The pragmatists view relations as appropriate as deemed fit by the researcher in that particular study in any research under way (Mertens, 2015). Pragmatists' view of reality is that you are free to believe anything that you want, as it furthers some lines of action and resists others (Morgan, 2007). Morgan concurs, though, that pragmatists do believe that all knowledge of the world is based on experience, which is social knowledge.

Aspects from the Interpretive/constructivism research paradigm as well as the positivism research paradigm underpin this study because I draw concepts and ideas from it. Subsequently, the pragmatism's view epistemologically frames this study. In my study, the aspects of learners constructing knowledge, meaning from different perspectives (researchers and participants), and values attached to the study findings and participants' utterances require an interpretivist approach. Moreover, the knowledge of the world is based on the learners' experiences, which is social knowledge as viewed by pragmatists (Morgan, 2007).

Conversely, the experimental use of instruments such as a pre-test, the use of variables that are measured in numbers and analysed with statistical procedures and aspects, require that I draw from the positivist approach. However, most of the data collected are explained in narrative form rather than in statistical referential; hence the study is underpinned by the interpretivist paradigm orientation. Learners' experiences on the contexts of exploring the use of AWFs in a case of Grade 7 learners' (multiplicative) word problem-solving were the phenomena under investigation.

3.3 Theoretical perspective

The worldview underpinning the study is grounded in the pragmatism paradigm. I will draw from theories of the constructivism paradigm. However, I will not use theories from the positivism paradigm, but I will use the statistical component of it. The researcher discusses the rationale for using the constructivist philosophy, Vygotskian Socio-cultural theory. According to Grant and Osanloo (2014:13), a theoretical framework is a "blueprint which provides a structure on which to define the study methodologically, epistemologically, philosophically and analytically." On the other hand, "a conceptual framework is the understanding of the researcher as to how the proposed study will be explored, which is the logic of how the concepts are connected" (Grant & Osanloo, 2014:16).

3.3.1 Constructivist theory

The constructivist philosophy underpins the view that learners are expected to discuss Mathematics with their peers and their teachers in Mathematics classrooms (see 1.3). This theory views learning as an effective social interacting process that learners and teachers undergo. Furthermore, it requires the learner to collaborate with the adult at the Zone of Proximal Development (ZPD) to accomplish a task. Learners' understanding of their own world as they make meaning is rooted in the socio-cultural contexts and social interaction that embrace communication (Mertens, 2015), which emanates from Vygotsky's perspective. In the teaching and learning interaction, new knowledge is constructed to rethink ideas, to argue, evaluate, share and examine the new knowledge. Learners also understand the conceptual underpinnings of Mathematics as they become better problem solvers through active discussion with their educator (see 1.1). As such, this study sought to investigate the correlation between learners' word problem-solving abilities, their academic performances and the use of AWFs to support dialogue (talk) in the teaching and learning of word problems. The knowledge construction and social interactions are aimed at exploring the benefits of the nature and extent of effects of using AWFs.

3.3.2 Vygotsky's socio-cultural constructivist theory

This study was particularly underpinned by Vygotskian social-cultural constructivist perspective. Social constructivist perspective is a variant of constructivism that was grounded in the research of Piaget, Vygotsky, Gestalt psychologists, Bartlett, and Brenner as well as the philosophy of John Dewey. These theorists aver that learners have to be active in constructing their own knowledge and social interactions were enhanced as they were important to knowledge construction (Woolfolk, 2007). Moreover, social constructivism is grounded in Vygotsky's socio-cultural inclination towards learning as motivated by Peled-Elhanan and Blum-Kulka (2006) and Dobber and van Oers (2015). These authors place instructive dialogue at the core of successful meaningful engagement of learners in teaching and learning. They also highlight observations of inquiry practices in different schools for Developmental Education that were observed in countries such as the Netherlands. In addition, Vygotsky's socio-cultural theory underpins the construction of meaning from participants' utterances (talk). In a word problem-solving mathematics classroom, the notions of ZPD, social interaction and mediation enhance the participants' utterances. Central to Vygotsky's theory with the notion of Zone of Proximal Development is his belief that a learner's immediate potential for cognitive growth is limited on the lower end by that which he can accomplish with the help of a more knowledgeable peer, tutor or teacher (see 1.3).

In actual fact, through social interaction with more knowledgeable peers and adults, learners develop higher mental functions such as logic, language, problem-solving skills, reasoning, memory schemas as well as morals (Doolittle, 1997). It is actually through language, which is Vygotsky's cultural tool that learners are able to internalise thoughts that originated from others such as teacher or other learners (Greig *et al.*, 2007) in a word problem-solving classroom as they engage in the talk. Ultimately, the learner ends up being able to execute given problems independently, which he could not do without the collaboration before. Literature states that learners show better cognitive development (Greig *et al.*, 2007), when they work with a teacher or more able learners. This becomes evident in their performance showing better results. Against this background, the ZPD is an ideal notion that is based on cooperative learning, which is learning in small-groups instruction for learners to solve problems (Doolittle, 1997). Harland (2003) perceives Vygotsky's theory from a child psychologist's perspective, where it provides a strong argument that learning and development differ and that learning not only leads to development, but that learning creates the ZPD. However, Wertsch and Tulviste (1992) emphasise that the ZPD should be tied more closely to the level of potential development of the learner than to the actual development for the organisation of instructions.

Wertsch and Tulviste further argue that the actual potential levels of development correspond with interpsychological and intrapsychological functions, which they term intermental and intramental respectively. Teachers should be mindful of these functions (1992:549).

3.4 Analytical tools: Conceptual framework

I articulated the analytic tools that emerged from Vygotsky's socio-cultural constructivist theory. In this research, I used analytic tools from Vygotsky's socio-cultural theory to construct meaning from participants' utterances (talk). By way of example, the notions of ZPD, social interaction and mediation were used. From the Constructivism perspective, learners are expected to discuss Mathematics with their teachers or peers in Mathematics classrooms as an effective social interacting process. On the other hand, in the core of the ZPD is that a more capable peer or teacher is needed to help learners who are viewed as less competent participants to operate at a higher level than they could on their own, and become independently proficient with teachers scaffolding their learning (Chaiklin, 2003; Wass & Golding, 2014).

3.4.1 The Zone of Proximal Development (ZPD)

According to Vygotsky (1978:38), the ZPD is "...the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult or in a collaboration with more capable peer". Vygotsky refers to ZPD as the functions that are developing and maturing, which are still in the embryonic state. The functions mentioned above are termed the "buds" or "flowers" of the developmental process. ZPD is notably evident by the collaboration produced in the interaction between the learner and more knowledgeable other learners or teacher. The learners are in the process of developing towards maturity in their learning endeavour which is mediated by language (Murphy, Scantlebury & Milne, 2015). As mentioned earlier, the language embedded in the word problems need the teacher to mediate the learners' understanding. Hence, the researcher used the AWFs as a tool to mediate the understanding of the syntax so that learners could better solve the word problems. I also mediated their word problem-solving abilities by modelling how multiplicative word problems in particular were computed or solved. According to Van de Walle, Karp and Bay-Williams (2013), the ZPD is a symbolic space as compared to a physical space that is used during knowledge impartation between learners and teachers who are more knowledgeable than learners. In addition, Landsberg, Krüger and Swart (2016) define the ZPD as a representation of the learners' actual independent developmental levels, where the teacher serves to guide them as they encounter learning challenges beyond their present level of mastery (Jacobs, Vakalisa & Gawe, 2016).

Hence, the ZPD is a continuum of observations that learners start doing tasks they are not able to do and need a mentor or teacher to assist in doing them (Landsberg *et al.*, 2016; Reed & Walker, 2015).

The sequence of observations of learners' developmental levels as they moved from being less accomplished to becoming more knowledgeable better problem-solving solvers were video-taped. These learners collaborated with the researcher/teacher (adult) at the ZPD to accomplish a task (Brenner, 1998). In the ZPD, there is learning and teaching of new understanding in situations where dialogue has produced inadequate understanding (Miller, 2011). The zone of proximal development analytic tool embraces language, teacher modelling and more knowledgeable learners displaying a better task in its core. Hence, the ZPD was used as one of the lenses of the AWFs intervention.

3.4.2 Social interaction

During learning and teaching in a Mathematics classroom context of word problem solving, the interaction of the learners and the teacher in particular is core. Van de Walle *et al.* (2013) define social interaction as one vital essence for mediation. They further argue that the learners' nature of the community is created by the social and historical culture of the members of the classroom instead of being affected by the culture of the teacher. Jacobs *et al.* (2016) argue that Vygotsky's social nature is/has to be present before human beings can learn. Vygotsky's social development theory robes in interaction of interpersonal (social), cultural-historical and individual factors that incorporate relationships and social interactions between the teacher and the learners and among the learners as peers, all impacting on teaching and learning developments (Jacobs *et al.*, 2016). Woolfolk (2007) defines social interaction as cognitive developmental influences that create our cognitive structures and thinking processes which were the origin of higher mental processes such as problem-solving (Jacobs *et al.*, 2016). In social interaction, learners bring and construct their own understanding and meaning as they engage with the knowledge and the teacher (Jacobs *et al.*, 2016). As a result of the above, learners eventually develop effective mental strategies or processes which are called Higher Mental Function by Vygotsky (Jacobs *et al.*, 2016). The learners and the teacher in the ZPD need a situation of interaction or exchange between them, as presupposed by the Law of Socio-genesis; hence, the structure of social interaction is necessary for people to communicate (Jacobs *et al.*, 2016).

In addition, Miller (2011:89) argues that "...social interaction presupposes generalisation and the development of verbal meaning..." The Grade 7 learners had to orally (verbally) talk during argumentation, dialogues and discussions platforms created by the teacher while trying to understand their experiences of word problem-solving in the classroom setting created by the teacher. Learners also displayed their verbal meaning during the learners' focus group interviews that were conducted by the researcher. The social interaction analytic tool lensed the pre- and post-intervention learners' focus group interviews.

3.4.3 Mediation

Van de Walle *et al.* (2013:20) define mediation as follows:

the means of exchanging semiotics between the learners and the teachers as well as among the learners, which can be referred to as the use of language, and other ways of conveying the cultural practices such as action visuals, diagrams, etc. the socio-cultural theory brings forth a concept of semiotic mediation which is a vehicle by which beliefs, attitudes and goals of individuals are affected and get affected by the practices of institutions and socio-cultural practices.

In Mathematics, semiotics includes mathematical symbols which can be developed. Vygotsky (1978) emphasises that dialogue and language play a vital role in mediated cognitive growth, while viewing learning as a social process. In addition, Vygotsky contends that language provides learners with supplementary tools in solving tasks and to plan solutions to problems before executing them (Vygotsky, 1978). Furthermore, Miller (2011) defines mediation as an action that is acquired through an intervention of another person as compared to being originated by the actor. Moreover, Jacobs *et al.* (2016) state that mediation, when viewed from the psychological tool perspective, is perceived as an internal process in which attention, memory and concept formation as mental functions are of importance. Woolfolk (2008) argues that, mediation is crucial for all higher-order mental processes such as problem-solving and reasoning by using psychological tools such as symbols, signs as well as language. Mediation is the use of signs as means to regulate, control and master learners' internal psychological functions (Miller, 2011). In addition, the process of using signs can also be used as means of self-control or self-regulation of mental processes in mediation (Miller, 2011). The form of action to be taken in the process of teaching and learning is determined by mediation.

Vygotsky raised the concepts of dialogue and language as crucial tools or elements in the mediation process. Howe and Abedin (2013) regard dialogue as the main component for effective pedagogy in the western context.

Howe and Abedin further describe dialogue as comprising answer, argumentation, communication, dialogic conversation, dialogue, discourse, discussion, feedback, ground rules, interaction, language, oracy, question, reciprocal, recitation, speaking and listening, talking, and turn taking (Howe & Abedin, 2013:325). Miller (2011) defines dialogue as an exchange of meanings and understandings between two people or parties. Much was elaborated on language in the literature section. However, thinking, developed reasoning, and cultural activities such as reading and writing, are promoted by language (which is one of Vygotsky's main tools) when learners solve problems by talking (Jacobs *et al.*, 2016). In the core of mediation are the units of dialogue, language, mathematics symbols and problem-solving (computations) amongst other units that the researcher will use to analyse the data collected.

In the exchange of meanings and understandings (dialogue) (Miller, 2011) of word problem-solving between the learners and the teacher, lies argumentation and discussions, amongst other components that the researcher will use as analytic units. According to Ross *et al.* (2009), argumentation is offering and responding to claims, providing and asking for evidence or justification as well as analysing those claims made in order to formulate a decision, made in science in particular. Discussion on the other hand is a teacher-learner interaction that is characterised by a proposal, justification and reconciliation of competing perspectives (Howe & Abedin, 2013). In addition, learning in the Mathematics educational culture involves argumentation that is grounded in sociocultural, socio-constructivist, and interactional perspectives. Accordingly, argumentation is a teaching aim and major feature in the notion of "learning to argue" in a sophisticated everyday Mathematics instructional class and this makes learning Mathematics argumentative learning (see 1.3).

Fostering argumentation in word problem-solving through teacher modelling and group discussion is enhanced by language frames (see 2.4.4). Hence the argumentative (writing) frames were used during the intervention process as a mediating tool for learners to engage in the talk. In the talk (argumentation and discussion) the writing frames were solely used as argumentative frames, hence the researcher used AWFs referring to the writing frames. Writing frames are templates that consist of starters, sentence modifiers and connectives. These tools offer children a structure for communicating what they want to say, by asking children to select and think about what they have learnt by re-ordering information and demonstrating their understanding, rather than just copying out text (see 2.4.2).

Vygotsky's analytic tools are interwoven, intertwined and comprise the teacher and the learners. The two parties meet at the ZPD which by nature manifests a social interaction during the teaching and learning process.

The teacher mediates the learning using the intervention tool, which in this case is the use of AWFs in Grade 7 word problem-solving. The mediation analytic tool will lens the word problem-solving abilities through the learners' pre-and post-test.

3.5 Chapter summary

Chapter three outlined the philosophical orientation of the study, the theoretical perspective, and the analytic tools which covered the conceptual framework were used as variables to frame and analyse data within the contexts of the study investigation. The following chapter focuses on the discussion of the research methodology, research design and data collection techniques. In brief, all the methodological tools are outlined in that chapter.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter focuses on the discussion of the research design and methodology and data collection techniques. In brief, all the methodological tools are outlined in this chapter. Furthermore, it elucidates the mixed method research approach that adopted the interpretive mixed-method case study. The researcher used a two-phase approach in order to collect data. I used the quantitative data in the first phase. I analysed the results, and then used the results to plan (or built on to) the second, qualitative phase, sampling strategies, purposive sampling and convenience sampling. The instrumentation pre- and post-test, pre- and post-intervention learners' focus group interviews conducted were explored as well as the use of visual data collection (video recordings). Thereafter, the data analysis techniques were explained. Issues of sampling, validity and reliability were considered, and the instruments used for this study are described, explained and motivated. The notion of ethical research is discussed, and the ethical stance taken in this study is described.

4.2 Research methodology

Methodology is a plan of action or a strategy that links methods, techniques or procedures that one proposes to use to achieve one's desired choice of outcomes and their usage (Creswell, 2003). In addition, methodology concerns issues of how researchers find out about the phenomenon, the approaches used, and justification of the principles used to underpin the study (Cohen *et al.*, 2018). Cohen *et al.* (2018) further add that methodology concerns the kind of research approach, the type of study conducted, sampling, instrumentation, as well as issues of validity. Methodology is the identification, the study and justification of research methods used by researchers (Johnson & Christensen, 2017).

4.2.1 Quantitative approach

Quantitative designs originated in Psychology discipline around the late 19th throughout the 20th century underpinned by the post-positivist paradigm (Creswell, 2014). Furthermore, quantitative designs include true experimental research which is moulded by fewer experiments such as the casual-comparative experiments, correlational designs, etc. This kind of approach is also characterised by true experiment research involving experiments with variables and treatments such as surveys and quasi-experiments (Creswell, 2014).

A quantitative research as defined by Johnson and Christensen (2017) is characterised by the collection of numerical data and follows casual explanations and predictions, identifying general scientific laws as well as informing national policy, amongst other things. The survey design is characterised by numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. On the other hand, the experimental research design is about determining if treatment influences an outcome of the experiment (Creswell, 2014).

4.2.2 Qualitative approach

Conversely, the qualitative approach originated from Anthropology, Sociology, the humanities, and evaluation (Creswell, 2014). A pure qualitative research relies on the collection of mostly non-numerical data such as words and pictures (Johnson & Christensen, 2017). This approach follows subjective descriptions, emphatic understanding and explorations of understanding participants' experiences in their social settings. Accordingly, qualitative approach is identified by grounded theory and research strategies of ethnography which captures the essence of participatory action research such as narrative research, phenomenological research, case studies, etc. (Creswell, 2014). The grounded theory originated from sociology and the researcher presents the interaction processes grounded in the views of the participants (Creswell, 2014).

4.2.3 Mixed-methods approach

The pragmatism research paradigm underpinned this study because I mixed and used elements from the interpretivist paradigm and the positivist paradigm (Creswell, 2014). Hence, I reported on the learners' multiple realities that learners encountered in word problem solving context. The mixed-method approach brings forth the integration of qualitative and quantitative research and data in a research study (Cohen *et al.*, 2018; Creswell, 2014; Johnson & Christensen, 2017). The dimensions of mixing could be at one or more of the stages of research which are the data collection, methodology, analysis, and interpretation. Mixed-method builds in itself the concept of triangulation as a design by means of convergence across qualitative and quantitative method (Creswell, 2014). Triangulation is a process that facilitates interpretive validity, establishes data trustworthiness and reduces the risk of systematic bias (Maree, 2007). In fact, triangulation deals with involvement of multiple methods and multiple data sources to strengthen the interpretations and conclusions of a research (Mertens, 2015). A better understanding of a problem (learners' experiences of talk) was aligned with my research under investigation as is crucial to parties that will positively benefit from the study. Hence combining the quantitative approach and the qualitative approach (Cohen *et al.*, 2018) was a necessity for this study under way.

The above authors argue that the mixed-method research brings comprehensiveness and completeness of understanding of the phenomena under investigation as compared to either one of the two approaches. Triangulating the quantitative and qualitative approaches reduces the weaknesses and biases of giving subjective and partial meanings in the qualitative approach as well as issues of objectivity of assessment in the quantitative approach.

Within the mixed-methods approach, three primary models based on social sciences were identified: the convergent parallel mixed methods, explanatory sequential mixed methods as well as the exploratory sequential mixed methods (Cohen *et al.*, 2018; Creswell, 2014). Within the convergent parallel mixed method, the researcher collects data at almost the same time and merges the quantitative and qualitative data in order to provide a comprehensive analysis of the research problem. In contrast, the exploratory sequential mixed-method considers a sequential pattern of conducting a quantitative research, analyses the results and then builds on the results to explain them in more detail with qualitative research. Researchers using the exploratory sequential mixed method start with the qualitative research phase and explore the views of participants; analyse, and build into a second, quantitative phase (Creswell, 2014).

In this study, the researcher followed an interpretive mixed-method case study which also followed an explanatory and sequential process. Therefore, the researcher used the two-phase approach in order to collect the quantitative data in the first phase, analysed the results, and then used the results to plan (or build on to) the second, qualitative phase (see 1.4). In other words, the qualitative data helped in explaining in more detail the initial quantitative results. More importantly, the mixed methods provided a more complete understanding of a research problem than either approach alone. Creswell (2014) underscores that the mixed methods approach strengthens the understanding of the research question, and the combination of qualitative and quantitative database overcomes the limitations of the single method approach. In ethnography, which comes from Anthropology and Sociology, the researcher pursues shared patterns of behaviour, language, and actions of an intact cultural group in a natural setting over a prolonged period of time. Case studies structure research in many fields where the researcher develops an in-depth analysis of a case, often a programme, event, activity, process, or one or more individuals (Creswell, 2014). According to Sepeng (2014b), the mixed-method design maintains the strength of both research designs, having advantages that complement the weaknesses of the other, making it a stronger research design.

4.3 Research design

A research design can be explained as a plan that is drawn up for organising the research and making it practicable in order for research questions to be answered; it also warrants evidence (Cohen *et al.*, 2018). A research design refers to a type of inquiry within a quantitative, qualitative, or mixed method approach which is also called a strategy of inquiry that provides specific direction or procedures used in that research design (Creswell, 2014). On the contrary, McMillan and Schumacher (2010) define a research design as a general plan in terms of how the research was set up, what happened to the subjects, and what methods of data collection were used. The above definition qualified the research methodology sub-topic to be crucial because of the idea of integration as one dataset was used to check the accuracy of the other dataset (Creswell, 2014).

This study explores a bounded case study of two groups, both in Grade 7 (two different schools) in order to explore and establish if the use of AWFs to enhance talk in the experimental group was effective as they engaged in word problem-solving. The case study inquiry illuminated the learners' understanding and views of how the learning discourse unfolded (through the interviews) during the intervention period. The six-months long (in-depth over time) investigation which was characterised by interactions of communication (dialogue) took place in the learners' classes (real-life context of one setting) (Cohen *et al.*, 2018). The unit of analysis was the process of solving multiplicative word problems.

A case study enquiry or design denotes an investigation that takes place in its real-life context, hence the study at hand was conducted in the learners' classrooms which was a specific phenomenon (Cohen *et al.*, 2018). A case study explores the in-depth process, reports on the real-life investigation and unfolds the interactions of activities and relationships between learners and the researcher/teacher (Cohen *et al.*, 2018). A case study, with its multiple meanings, can be defined as a unit of analysis, a research method which could be positivist, interpretive or critical in its bounded system (Greig *et al.*, 2007; Maree, 2007; Merriam, 2002; Sargeant & Harcourt, 2012). Maree (2007) further argues that a case study describes a systemic inquiry that aims to describe and explain an event with related events within a phenomenon of the researcher's point of interest. Hanley-Maxwell and Bottge (2006) clarify further by saying that the phenomenon is bound by time and place in a case study. The case study enquiry described by Hanley-Maxwell and Bottge (2006) was characterised by participants' observation, interviews and conversation, documents and field trip notes, accounts, notes and memos as methods of data collection. Similarly, Johnson and Christensen (2017:50) echo that a case study addresses "exploratory, descriptive, and explanatory, phenomenology which focuses on individuals' experience of some phenomenon..."

Johnson and Christensen (2017) further delineate a case study as a research that is simple, providing an account that is detailed and an analysis of the dynamics and characteristics present in one study or more. In addition to what has been mentioned above, a case study should give light to the historical background (Mertens, 2015) of the case or phenomenon at hand. In addition to what has been mentioned above, Greig *et al.* (2007) state that in the variety of data collection methods in a case study, standardised assessments and rating scales are also employed. Greig *et al.* (2007) further state that as much as a case study is more qualitative, it frequently includes traditional or classic quantitative approaches, when dealing with learners in particular. It was for this reason that the researcher, in trying to unearth deeper understandings of the phenomenon, subjected the experimental and comparison groups to a pre-test to form a base or background of the rest of the data processes that followed through.

In a scenario like this study where learners were powerless and voiceless because they lacked confidence in what they might have wanted to say, and because of their background and context, a case study was ideal (Maree, 2007). These learners came from a location where the use of language by learners was problematic. I used the descriptive type of case study (Cohen *et al.*, 2018) because I wanted to provide a narrative account of how the argumentative writing frames were applied to help Grade 7 learners to engage in the talk in the mathematics classroom. Letting learners participate in the talk helped them to better solve the word problems. In this study I focused mainly on one experimental group that was subjected to an intervention. The comparison group was a representative or typical case of such classrooms in the South African context; hence it followed a single-case design (Cohen *et al.*, 2018). I followed an intrinsic process (which denotes the essential significance inherent to the kind of research) in understanding how learners solved their word problems in the pre- and post-intervention exercises. An instrumental case study sampling was undertaken in order to gain an understanding of whether the use of AWFs could engage or improve talk within the learners in a word problem-solving context. The sampling technique was also to explore the effects of using AWFs as a mediating tool to improve learners' word problem-solving abilities (Mertens, 2015). Johnson and Christensen (2017) explain a single-case study as one that captures the intrinsic design, which is the researcher's interest in understanding a specific case. The process was also sequential as the data collection process ran consequently with one stage affecting the subsequent stage.

The data collection process started with a pre-test, pre-intervention learners' focus group interview, intervention, post-test, post-intervention learners' focus group interview, where the subsequent stage built on the previous stage. This case study used both quantitative and qualitative methods, data collection strategies, statistical, and qualitative analysis tools (Cohen *et al.*, 2018).

In this study, learners' pre- and post-test, learners' pre- and post-intervention focus group interviews, conversations (the use of AWFs during the intervention), and documents (learners' exercise books) were used to collect data. As a participant-observer I incorporated video shots of six lessons by a colleague in the class where I intervened by means of AWFs; the colleague was also a researcher in his own capacity (post-doc fellow) in mathematics education.

The setting of the study under way is interpretive which is also called naturalistic setting with enquiries such as a case study that I used in this study. The researcher used the interpretive mixed-method case study. The reason for using the interpretive approach was that I wanted to gain considerable meaning from and understanding of the learners' voices and opinions in how they solve word problems in a Grade 7 context of multiplicative word problems in particular (Hanley-Maxwell & Bottge, 2006). The study also used the pre-test–intervention–post-test (PIP) design emanated from a quasi-experimental design that crafted the non-equivalent (pre-test and post-test) control-group design. The researcher purposefully selected an experimental group and a control group, which were subjected to both a pre-test and a post-test, with the experimental group receiving the treatment in the form of an intervention. The intervention used AWFs to involve learners in the talk (argumentation and discussions) during the teaching and learning process at learner-level (Creswell, 2014).

Table 4-1: A non-equivalent comparison-group design (adapted from Johnson & Christensen, 2017:357)

	Pre-test measure	Treatment	Post-test measure
Experimental Group	O_1	X_1	O_2
Comparison Group	O_1		O_2

Note: The dashed lines indicate non-random assignment to the comparison groups

Learners forming the experimental group and comparison group were not randomly assigned to the groups, hence they were subjected to a quasi-experimental design. I as the researcher studied the effect of the intervention to which the experimental group was subjected (Mertens, 2015).

4.4 Researcher site

The research worked with two schools within Rekopantswe Area Office in the Montshiwa Township in Mahikeng (Mmabatho), Ngaka Modiri Molema District in the North-West Province to conduct the study. The participating schools were in the vicinity of the researcher's place of study, which made their access easier for the researcher.

4.5 Participants

The study involved Grade 7 learners from two primary schools in Ngaka Modiri Molema District around the Montshiwa Township in the North-West Province. Both experimental group and a control group were used as a convenience sample. A purposive sampling was used to select one Grade 7 class from each of the two primary schools. Purposefully sampling the two schools was on the basis of convenience (Hanley-Maxwell & Bottge, 2006) as they were at a convenient place and accessible for me; I could drive to the schools and back in between my lecturing periods. The rationale for using purposeful sampling was to obtain detailed information from Mathematics participants in order to maximise the range of specific information that was obtained from the learners. According to Creswell (2014), participants are purposefully selected in order to best help the researcher understand the problem and the research question(s). Results obtained from a purposeful sampling cannot be generalised as a non-random sampling technique (Johnson & Christensen, 2017).

The study used a mixed method sampling as both a non-probability quantitative approach to sampling and a purposive qualitative approach were used (McMillan & Schumacher, 2010). In the study, the stratified purposive sampling was used as one type of non-probability sampling method in order to establish the individuals and groups to be studied while in pursuit of understanding all the aspects of the research topic. Purposefully, I wanted learners from schools with the same academic and social background (both in a location) who could have more or less the same exposure academically. They were monitored by the same District Education Manager and with the same treatment of the curriculum. I wanted learners' groups that were both in Grade 7 classrooms. Johnson and Christensen (2017) call a purposeful sampling a judgemental sampling because the researcher solicits persons with specific characteristics to partake in the study. In the case of this study, one school was closely tracked throughout (Cohen *et al.*, 2018) the intervention period as the experimental group while the other as a comparison group. I believed that the two tracked groups followed a homogeneous sampling as they shared similar characteristics, coming from the same location; hence they had the same contextual background experience which was ideal for comparison (Cohen *et al.*, 2018; Johnson & Christensen, 2017; Mertens, 2015). Furthermore, stratified sampling allowed the quantitative approach of stratifying the population, followed by purposive selection of eleven learners from the experimental group studied intensively through focus group interviews.

4.5.1 Reasons for selecting purposeful sampling of Grade 7 learners

Exploring the responses of learners in word problem-solving in Grade 7 classes was brought about by the fact that this is the first class in the senior (secondary) band of classes (Grades 7-9) in the curriculum of South Africa. Hence, it projects how ready the learners are in their abilities to move from the algorithm thinking to a relational thinking which becomes more intense as the learners progress to Grade 8 in secondary schools. Learners in the InterSen phase (Intermediate phase - Grades 4-6 and Grade 7 classes) learn word problems in the classroom where teachers practically scaffold the learning process through modelling and mediating the learning which leads to a conceptual shift. In Grade 7 learners should show competency in solving word problems and show readiness to move from the conceptual shift, let go of specific numbers and move towards an abstract shift which is characterised by more reasoning entailed in the algebraic shift that includes word problems. Myers, Jun, Brownell and Gagnon (2015) argue that secondary school learners need foundation skills in mathematical reasoning and number knowledge and fluency as cognitively demanding skills, procedures and knowledge in order to solve mathematical problems that include word problems. Once grade 7 learners lack these demanding cognitive skills and knowledge, the low performance in the Grade(s) ahead will drop more. Learners undergo a transition from intermediate phase (Grade 6) to the first class of the senior phase (Grade 7). Hence, in my study, the intervention was meant to bring about and implement instructional mediation that would help learners to acquire a foundation of more knowledge and skills in understanding and ability to solve word problems. Moreover, the instructional mediation could bring about the correct computation with a clear understanding of what was asked from the learners.

4.6 Data collection strategies

Data collection in this case study was done through social interaction with the participants (use of AWFs), field studies (intervention - test, learners' exercise books), participant-observation (visual data - video recordings) and interviews (learners' focus groups) amongst other strategies (Maree, 2007) which is underpinned by Vygotsky's socio-constructivism theory. Data collection in this interpretive mixed method approach allowed both quantitative and qualitative collecting techniques to provide the best understanding of the research question (Creswell, 2002). In this study, the qualitative data helped in explaining the initial quantitative results in more detail. Moreover, the mixed methods provided a more complete understanding of a research problem than either approach alone would. Creswell (2014) asserts that the mixed methods approach strengthens the understanding of the research question and that the combination of qualitative and quantitative datasets overcomes the limitations of the other approach. The data collection

engages rigorous quantitative sampling in the first phase and purposeful sampling in the second, qualitative phase (Creswell, 2014).

The qualitative data were subsequently collected from individuals who participated in the quantitative data collection process and built directly on the quantitative results. The researcher used the qualitative data, which was a follow-up from the quantitative results, to make meaning of the quantitative data. The quantitative results informed the sampling procedure as well as being used to point out how to plan the types of qualitative questions to ask the participants in the second phase (see 1.4). In addition, data collection involved gathering of both numeric (e.g. on statistical instruments) as well as textual information (e.g. from interviews) so that the final database represented both quantitative and qualitative information. The data collection instruments discussed in the next sub-section were used to address and answer the main research question as well as the secondary questions by using the same techniques discussed earlier.

4.6.1 Field study: Pre-and post-test

During the field study or trips I taught both the experimental and comparison groups of learners' mathematics concepts based on word problem-solving which led to their writing the post-test. Documents in the form of exercise books for the experimental group were also used by learners during the intervention period. The post-test came after the learners had been administered a pre-test and an intervention of using AWFs to help them better solve word problems. Below is how the pre- and post-test were administered:

4.6.1.1 Pre-test

The pre-test was a quantitative experimental set-up where participants were engaged before an intervention (see 1.4). In addition, the pre-test was administered to learners in both the experimental and the control groups (Creswell, 2014). Accordingly, the pre-test was used to understand the nature of the learners' performance and problem-solving abilities in relation to multiplicative word problems prior to a sequence of intervention lessons. The pre-test, which was exactly the same as the post-test, consisted of seven tasks that were administered to all Grade 7 learners in the two schools in Rekopantswe Area Office at Montshiwa Township. Covered in the pre-test were mostly multiplicative word problems that covered concepts such as area, percentages and ratio. Question 1 (1.1 – 1.3) with three sub-questions covered word problems on sense-making in Mathematics. Question 2 (2.1 – 2.4) focused solely on multiplicative word problems. In this study, the pre-test and the post-test were administered within a week, depending

on the availability of time in the two different schools and also because the researcher was facilitating the writing of the test in both schools.

The pre-test was administered in January 2017 (on 24 January for the experimental group and control group) and the post-test was administered in June 2017 (on 07 June for the control group and 09 June for the experimental group). The pre-test was marked and analysed for purposes of informing the learners' focus group interview questions. The pre- and post-test items were categorised as follows:

Question 1: This covered questions 1.1 – 1.3. Question 1 entailed *Real mathematical word problems without real meaning* (PWRM). PWRM used real-life numerical data without real meaning that did not ask illogical questions (Sepeng, 2014b). In this section, the word problems required learners to use common sense to get the answers.

Question 2: Question 2 covered questions 2.1 - 2.4. Question 2 covered *Realistic (real-world) problems* (RP). RP attended to realistic considerations (Sepeng, 2014b). These realistic real-world problems had textual representations of information from everyday settings (Aksoy, Bayazit & Dönmez, 2015:828). In this section, the word problems required learners to work out the answers.

The rationale for using the pre-test was to understand the learners' problem-solving skills and abilities better when solving multiplicative word problems. Furthermore, the item analyses of learners' written work provided proof of the ability (or inability) to make sense of word problem-solving and realistic considerations (or lack thereof). The results of the pre-test assisted the researcher to develop the items of the learners' focus group interviews schedule.

As a teacher–researcher I have been involved with Grade 7 mathematics (content), either teaching it or moderating it as a Mathematics Head of Department in a number of schools for more than a decade. For content validity of the test, I covered the appropriate content (Mertens, 2015) with the assistance of the two Mathematics teachers at the two schools. There was also one Mathematics HOD who was teaching Grade 7 Mathematics when I went for the pilot-testing of the test in 2016; one Mathematics HOD as well as the Inter-Sen (Grades 4-7) Mathematics subject advisor in the Rekopantswe Area. I also used the Grade 7 Policy document, textbooks that the two schools were using, as well as the Departmental workbooks at those schools, which were the same.

4.6.1.2 Post-test

A post-test is a quantitative experimental set up where participants are engaged after an intervention (see 1.4). The researcher administered the post-test, which was exactly the same as the pre-test, in order to establish if there was any change in the dependent variable(s) conditions (Okeke & Van Wyk, 2015). Eventually, all the learners in experimental and the comparison groups were subjected to the quantitative post-test. In essence, the post-test as compared to the pre-test results helped the researcher to measure the effectiveness of using AWFs in the case of Grade 7 classrooms' word problem-solving and how it influenced the learners' academic performance.

In all the test items, learners had to answer the word problem questions in two categories. Firstly, learners had to give or compute the *solution* on the left-hand side. Secondly, learners had to explain in writing as to *how I arrived at the answer* on the right-hand side of the answer page. In answering the second part, learners were expected to say what they did in order to arrive at the *solution* they gave under the solution part. The kind of word problems that were used were adapted from the syllabus that was followed by the two schools through their Learning Programmes and Work Schedules. The syllabus and topics covered by the two schools were as the Department of education paced syllabus. As stated in literature, learners had difficulties with *Real mathematical word problems without real meaning*. I included this kind of word problems to explore how learners solve such questions which elicit sense making in the talk. Below is the discussion of the pre- and post- test tasks:

4.6.1.3 The seven pre- (post-) test items

Table 4-2: Outline of seven pre- (post-) test items

Test item (TI) 1 (questions 1.1)	
Problem	<i>There are five birds on a tree. If one is shot down by a hunter, how many birds are left?</i>
Description	This test item was a real-world word problem that used real-life numerical data without real meaning and did not ask a logical question. In Mathematics classrooms learners would be expected to use numbers that were given with probably an operation sign that learners had been taught such as, +, -, x and ÷ signs. This kind of question needed more thinking from the learners, situationally. Most learners subtracted to find the solution. Situationally, all the birds would fly away because of the noise that was produced during the shooting of the one bird.

Test item 2 (questions 1.2)	
Problem	<i>A farmer keeps 5 pigs, 25 cows and 130 goats. How old is he?</i>
Description	This was another PWRM question. Realistically speaking, no farmer's age is calculated or determined by the amount of livestock or any material possession (s) he has. Hence learners were expected to give an age number that would be in the range of a person who was grown up and be in a position to have acquired livestock of this amount. Such a person would be above the age number of a minor.
Test item 3 (questions 1.3)	
Problem	<i>Mr Smith the butcher had 26 kg of meat in his shop and orders 10 kg more. How much meat does he have now?</i>
Description	This kind of word problem is Realistic (real-world) problems (RP) oriented (see 4.6.1.1). These realistic real-world problems had textual representations of information from everyday settings (Aksoy et al., 2015: 828). Computationally, learners were expected to use the given numbers with some thinking. The question also expected learners to qualify their answers. Firstly, if no meat was sold between the time of ordering the meat and its arrival, the addition sign could be used ($26\text{kg} + 10\text{kg} = 36\text{kg}$). However, if all the meat was sold while waiting for the order, only 10 kg of meat would be left ($0\text{kg} + 10\text{kg} = 10\text{kg}$). On another note, any answer between 36kg and 10kg would be correct, if a part of the 26kg was sold. Marks were awarded for a correct computation, for the justification as well as the explanation of how they arrived at the answer.
Test item 4 (questions 2.1)	
Problem	<i>Tshego has 6 toy cars. Each car is missing a wheel. Tshego puts his cars in a box. How many wheels are in the box?</i>
Description	This was a multi-step RP word problem. Solving abilities were displayed when learners had to remember that a car had four wheels. Missing a wheel meant that they had to subtract one wheel from four wheels of a car ($4 - 1 = 3$). The next step would be to find the total number of wheels in the box. This will mean that learners have to multiply the remaining three wheels by the number of cars ($3 \times 6 = 18$ wheels).
Test item 5 (questions 2.2)	
Problem	<i>Mr Tladi can fit 4 desks along the long side of his classroom and 3 desks along the short side. Mrs Khunou has a longer classroom. She can fit 2 more desks along the long side of her classroom. How many desks can Mrs Khunou put to fill in the whole classroom?</i>
Description	This was also a multi-step realistic real-world problem. The area of the classroom was to be calculated. Mr Tladi's classroom was the basis from which to work Mrs Khunou's classroom area. Two more desks along the long side (length), meant that they added 2 to Mr Tladi's classroom length ($4 + 2 = 6$ desks). This gave a new length with the initial width/ breadth of Mr Tladi's classroom, which was 3 desks. Finding the area meant multiplying the length by the width ($6 \text{ desks} \times 3 \text{ desks} = 18 \text{ desks}$).

Test item 6 (questions 2.3)	
Problem	<i>Container A is 67 % full and has a capacity of 25 litres. Container B is 72 % full and has a capacity of 20 litres. Which has more liquid in it?</i>
Description	TI 6 was a multi-step RP on percentages. Learners had to first convert the percentages to fractions ($67\% = \frac{67}{100}$; $72\% = \frac{72}{100}$). They also had to multiply the fractions by the capacity of each container before they could compare which container had more liquid (Container A: $\frac{67}{100} \times \frac{25}{1} = 16.75$ litres; Container B: $\frac{72}{100} \times \frac{20}{1} = 14.40$ litres). From this computation, it was evident that container A contained more than container B by 2.35 litres ($16.75 - 14.40 = 2.35$ litres).
Test item 7 (questions 2.4)	
Problem	<i>A profit of R 99 360 was made at a music concert. It was later shared between the Nelson's Children Charity and Thandolwethu Crèche. If Nelson Children Charity got twice as much as Thandolwethu Crèche, how much did each group receive?</i>
Description	TI 7 was a RP question based on ratio. Learners were expected to remember how ratio questions are computed. In order to get the correct ratio, they had to understand what is meant by twice as much as (one part is 1 and the other is 2 x 1). The denominator of the ratio fractions then was (1 + 2 = 3). For Nelson's Children Charity: $\frac{2}{3} \times \frac{R\ 99\ 360}{1} = R\ 66\ 240$. For Thandolwethu Crèche: $R\ 99\ 360 - R\ 66\ 240 = R\ 33\ 120$.

4.6.2 Interviews: Pre-intervention learners' focus group interview and post-intervention learners' focus group interview

Interviews in the form of pre-intervention learners' focus group interviews and post-intervention learners' focus group interviews were conducted by the researcher. An interview is a conversation that allows the researcher to see the world from the learners' point of view. The researcher asks the participants (learner) questions about ideas, opinions, and views (amongst other things) to collect data (Maree, 2007). Interviews make it easy for the interviewer (researcher or someone working for the researcher) to probe for clarity or additional information from the interviewee (the research participant), either face-to-face or telephonically (Johnson & Christensen, 2017). A focus group on the other hand is a group that is kept on focus on a topic being discussed. The group, which could be learners, teachers, etc., share in detail what they think and feel about the topic (Johnson & Christensen, 2017). I used the learners' focus group in order to obtain information about interests, experiences on how they solved word problems and how they interpreted the data that I had obtained from their pre-test and post-test (quantitative results).

I also wanted to find out how learners talked about the interventions, from the post- intervention learners' focus group in particular, hence I got an impression about the intervention which I submitted for further research. The focus group interviews were more dominated by the learners' points of view on word problem-solving issues (Mertens, 2015).

4.6.2.1 Pre-intervention learners' focus group interview

Focus groups are qualitatively purposefully sampled small groups of eight to twelve individuals that are interviewed instead of each person individually (Johnson & Christensen, 2017; McMillan & Schumacher, 2010). The researcher employed the focus group interviews to understand the learners' pre-test responses better. A qualitative face-to-face learners' focus group interview (with experimental group only) was conducted immediately after administering the pre-test. I used the focus group interview because I believed it was going to yield a widened range of responses (Maree, 2007). An interview schedule (see appendix G) was used with a purposive sample of eleven learners drawn from the one class that was the experimental group. The interview was semi-structured (Maree, 2007) because I had predetermined questions in which I also engaged a bit of probing and clarity of answers from the learners. The interview was audio-recorded with consent given by parents and the learners involved.

4.6.2.2 Post-intervention learners' focus group interview

The researcher carried out qualitative learners' post-intervention focus group interview with the same eleven learners who participated in the pre-intervention focus group interview. An interview guide that was almost the same as the pre-intervention focus group was used (see appendix H). More importantly, the post-intervention interview was done in order to explore the nature, effect and implications of the pedagogic practice of the study as well as learners' perceptions about the intervention.

4.6.3 Social interaction: The intervention

Social interaction in this study came in the form of an intervention. During the intervention, learners were taught multiplicative word problems and sense-making word problems. The multiplicative word problems was the primary focus of the study, whereas the sense-making set of word problems questions were mainly used to probe the talk during the intervention and were used as an introduction of the talk in the classroom. Argumentative writing frames were used to mediate the teaching of word problem-solving. This was enhanced by the argumentation and discussion processes which emanate from dialogue; as echoed by Vygotsky, that interaction, mediation, and learners' utterances are enhanced by language. Hence, the process of how the

intervention unfolded is explained below, together with the major analytic framework that was used during the social interaction, argumentation, discussions (dialogue).

In this study, an intervention was carried out by the researcher as a participant observer, which followed the introduction of AWFs in the case of Grade 7 classrooms' word problem-solving and how it influenced the learners' academic performance. The intervention, in the form of teaching Grade 7 learners the use of AWFs was prepared, planned and implemented in the experimental group by the researcher in the learners' normal classroom setting. The intervention was carried out in two academic terms (January till June 2017). The rationale for carrying out the intervention was to explore the benefits of using AWFs in the case of Grade 7 classrooms' multiplicative word problem-solving in particular and how it influenced the learners' academic performance. In addition, the intervention strategy was also used to explore how learners solved multiplicative word problems (problem-solving abilities). The intervention was implemented in the experimental group with the aim of assisting learners, not only to identify problem situations that were problematic from a realistic point of view, but also to consider the (in) appropriateness of applying mathematical operations directly as their solutions. As a result, this strategy engaged the learners in discussions of solution methods with the researcher as a teacher modelling effective strategy. The joint teacher-plus-child argumentation was effected in developing the learners' oral language and thinking and argumentation skills. The progression of the intervention period was video recorded.

In this study, AWFs and dialogue (argumentations and discussions) were the teaching and learning techniques which were used during the intervention. There were ten AWFs that were used in this intervention. They consisted of starters, sentence modifiers and connectives templates which offered children a structure for communicating what they wanted to say. Learners had to select and think about what they had learnt by re-ordering information and demonstrating their understanding. This enhanced *talk* among the learners as they learned to argue to reach a meaningful decision enhanced by teacher modelling (see 1.2 & 1.3).

The implementation of the intervention was employed concurrently with the analyses of the classroom interactions. This enabled the researcher to understand how learners solved problems and the nature of the *talks*/discussions and argumentations in the classrooms as well as to analyse written work using AWFs in the teaching and learning of word problem-solving. During the intervention implementation, the researcher simultaneously taught the one class that was the experimental group and the comparison group. Therefore, the researcher introduced AWFs and dialogue. The researcher further explored how learners solved the multiplicative word problems in particular as teaching and learning progressed.

4.6.3.1 AWFs to support dialogue and written problem-solving during the intervention

The researcher adapted ten writing frames from Seidlitz Education (2010) that were developed by the researcher to suit the context of the learners where the intervention was carried out. The researcher decided on frames that she felt would mediate learners' understanding of the word problem-solving. The frames became starters learners used to frame their argumentations and discussions. I felt that ten frames would be a manageable number in the given time of teaching multiplicative word problems as they were not taught every day.

The ten writing frames were: *The problem gives the following information.....; The problem requires me to find.....; I already know that.....so that/ because.....; The steps/strategies I took in solving this problem were.....; This did not work, so.....; Another strategy I could use to solve this problem would be to.....; I think the answer is.....because.....; To check if my answer is correct, I.....; The easiest/most difficult part of this topic/today's lesson was.....; One thing I learned in this topic that I did not know before, was.....* (Ross et al., 2009). An example of sense-making question was, "There are 26 sheep and 10 goats on a ship. How old is the captain?" (Verschaffel, et al., 2010). However, such questions were not included in the list of frames because they only used to help the teacher to probe talk from the learners. The following topics and concepts were taught by the researcher and only 6 video shots were recorded; *Ratio; Financial Context (Budgets); Financial Context (discounts); Financial Context (interest and loans); simplifying fractions*. Christou and Philippou (1998) viewed multiplicative concepts as *rate, compare, and Cartesian-product and rectangular-area* problems.

As the researcher, I taught both the experimental and the control groups the same concepts in the same week around about the same days. The time slots were dependent on the time tables of the two schools and the Mathematics periods for that particular class as both schools had more than one Grade 7 class. Sometimes the two classes were taught on the same day, sometimes there was a difference of one day or so. The concepts covered had word problems in them and were aligned with the schools' work schedules for term one and term two. I aligned with the schools' work schedules because of the agreement that I would not upset the progression of the schools' planning (work schedules). During the lessons, I taught the learners the contents of the topics. In short, my lessons were some kind of an extension of what the subject teachers had taught as I only came in when it was time for the word problems components in those topics. However, in a few cases I would teach even before the word problems started, when the teacher(s) would be away sick or attending a one-day workshop or some other emergencies that cropped up. All the contact sessions were one hour long for both groups.

In both groups I taught the word problems to help them read these word problems in a traditional way that I had used in my previous years of teaching mathematics word problems, and expected the learners to give answers. However, in the experimental group, when they responded I would introduce one or two frames that I had taught them on how to frame their answers before introducing the frames officially. Argumentative writing frames were gradually introduced to the learners as starters, as connectors as well as to argue why their answers were correct or wrong, with the teacher using the frames to mediate the learners' understanding of the word problems. In problems such as, *The problem gives the following information.....*, learners actually listed what was provided in the word problem. In this particular frame, *I already know that.....so that/ because.....*, learners actually related to what they had learnt in the topic/concept from the time it was introduced and taught as a fundamental without the word problem, and built on it in solving the word problem. Teaching and learning in the form of discussions and argumentations progressed as one group (whole class) during the introductory part of the frames. With time, learners were grouped into fours or in pairs where four was not possible.

I delayed to give learners the written frames worksheet because I did not want the paper to be a distractor before they got used to the frames used to help them frame what they wanted to say. Hence, using frames without reading them carried on until the learners became somehow at ease responding to questions that were asked with an anticipated answer that would require a frame to be used, e.g. a question such as "What information does the problem give?" Such a question would channel the learners to use the frame, *The problem gives the following information.....*. In actual fact, the written/typed AWFs were issued to learners on the 3rd May when the concept on fractions was taught. The typed AWFs helped the learners to see the whole collection of ten AWFs, and their proper spelling, and I could use them by reading for those who were still not comfortable and confident to answer. For all the concepts taught before learners were issued with the written frames, their usage was oral; responses and argumentations were verbal.

After the learners received their AWFs papers, oral/verbal responses in the form of discussions and argumentations carried on. Learners were however, at this stage assigned different frames that they were supposed to use and write down in their exercise books for a word problem-solving question for the whole class. Once all the groups had answered the word problem using their given frame, the whole class would answer the same question orally, each group presenting answers as per their argumentative frame. The teachers helped in probing the learners to argue, justify their claims, etc.

Eventually the groups worked more as smaller groups with the teacher moving around, helping the groups to answer the questions and argue their points amongst themselves using the AWFs. After the allocated times to the groups, the teacher would engage the learners as a class for more

clarity where needed and more discussions and argumentations before moving to the next question(s). Concepts where argumentative writing frames were used were, *percentages*; *multiplication of decimals* as well as *Area of 2DS*. It should be noted though that the main use of the AWFs was to help the learners understand the questions, to be able to discuss and argue their points as a mediating tool, so that learners could compute correct answers. It was not necessary for the learners to learn how to write the frames, but writing them was to show that they can frame their *talk*. As such, mostly they argued verbally/orally, and not in writing per se. Confidence is essential for learners to learn Mathematics and be motivated to reason quantitatively about public and political issues, to understand concepts behind algorithms. The algorithms are underlying within mathematical concepts such as in the meaning of whole numbers, fractions and percentages (Frankenstein, 2010).

I must say though that some planned lessons could not take place because of issues such as very rainy days when the schools decided to dismiss learners early before the Mathematics periods could take place. Other days were when schools were having sports days (competitions) as well as emergency school meetings. However, what was reported in this study, was what did take place.

4.6.3.2 Schedule of visits to the experimental group (intervention)

The following table presents an intervention schedule of how the researcher worked with the experimental group (Grade 7A):

Table 4-3: Intervention schedule – Experimental group (Grade 7A)

Date	Activity
19 January 2017	• I introduced my study to the learners. • I explained the ethical issues such as consent and assent to the learners. • Consent/Assent forms were issued to learners by the researcher (for parents and the learners).
24 January 2017	• Consent/assent forms were collected back by the researcher • A pre-test was administered by the researcher (All learners brought back the forms)

31 January 2017	- Learners were issued with stationery that was used for the intervention (72 pages exercise book, a mathematical instrument set and a pen), by the researcher. - First lesson on <i>rate</i> and <i>ratio</i> was taught by the researcher.
01 February 2017	- Consent forms for the learners who took part in the learners focus group interviews were issued out. - Lesson 2: <i>Ratio</i> word problems. - AWFs were gradually introduced by the researcher, who helped the learners to frame their answers.
03 February 2017	The researcher conducted the learners' pre-intervention focus group interview (11 learners).
06 February 2017	Lesson 3: It was a continuation of the <i>rate</i> concept.
10 February 2017	- Lesson 4: <i>Rate</i> word problems. - The first video shot was captured. - The use of AWFs by the researcher carried on, helping learners to stem their <i>talk</i>. - The researcher allowed some discussions, justification of answers as teaching and learning progressed.
17 February 2017	- Lesson 5: A financial concept (profit, loss, and discount) word problem was taught. - The second video shot was captured.
20 February 2017	Lesson 6: A financial concept (loans and interest) word problem was taught.
24 February 2017	I bounced at the school because of heavy rain, learners were dismissed early to go back home.
02 March 2017	Lesson 7: I assisted the class teacher (team teaching) on the concept of <i>angles</i>.
26 April 2017	Lesson 8: Team teaching on <i>add common fractions with different denominators</i> – simplify (<i>HCF</i>).
03 May 2017	- Lesson 9: Concept on <i>fractions</i> word problems. - I introduced the AWFs formally. I issued each learner with a <i>typed copy</i> of the ten frames. They pasted their copies in their exercise books. - Together with the learners, we read all the frames so that they could get the correct pronunciations. I further made some illustrations of their answers on using the AWFs. - Learners used the copies to frame their discussions and argumentations. They could read the frames on their own to frame what they wanted to say. - A third video shot was captured.

10 May 2017	• Lesson 10: The concept of <i>percentages</i> on word problems was taught. • Use of AWFs by learners to engage in the <i>talk</i>. • Video shot four was captured.
24 May 2017	• Lesson 11: The lesson was on <i>multiplication of decimals</i> word problems. • Use of AWFs. • Video five was captured.
07 June 2017	• Lesson 12: The lesson was on the area of 2D shapes word problems. • Use of AWFs. • Video shot number six was captured (last one).
09 June 2017	• The post-test was administered by the researcher.
13 June 2017	• The researcher conducted the learners' post –intervention focus group interview with the 11 learners.
16 June 2017	• I visited the school to exit formally. I had a brief talk with the learners, thanking them to partake in my study. I had a session with all the teachers of the school during break time where we shared refreshments together. • However, I have not stopped visiting the school; whenever the teacher needs some assistance on certain concepts of her choice I go there to help. I also do team teaching whenever I get time in her current Grade 7 class.

4.6.3.3 Schedule of visits to the comparison group

Below is the schedule of my visits to the comparison group during my study (Grade 7 A). The school timetable was scheduled according to day 1, day 2... until day 5. This was different from the experimental group which used the days of the week (Monday, Tuesday...until Friday).

Table 4-4: Schedule of visits – Comparison group (Grade 7A)

Date	Activity
19 January 2017	• The school introduced me to the learners (Grade 7 A) classroom. I visited them when they were still in Grade 6 trying to set an entry to the school, preparing for 2017. • I introduced my study to the learners. • I explained the ethical issues such as consent and assent to the learners. • Consent/assent forms were issued to learners by the researcher.
24 January 2017	• I collected back the signed forms. • The pre-test was administered to the learners by the researcher.

25 January 2017	- Learners were issued with stationery. - Lesson 1: I taught the concept of <i>ratio</i> (word problems).
31 January 2017	Lesson 2: The <i>rate</i> concept on word problems was taught by the researcher.
06 February 2017	I bounced at the school. The school had an internal activity, so learners were not available for a class session.
09 February 2017	Lesson 3: The introduction of <i>financial context</i> (loss, profit, buying and selling) concept was taught.
16 February 2017	Lesson 4: <i>Financial context</i> (profit, loss and discounts) word problems were taught.
20 February 2017	Lesson 5: <i>Loan</i> and <i>interest</i> in financial context word problems were taught.
13 March 2017	Lesson 6: I helped in teaching <i>construction of circles</i>. This was team teaching with the Mathematics teacher.
02 May 2017	Lesson 7: I taught solving of <i>fractions</i> word problems.
25 April 2017	Lesson 8: I taught word problems on <i>comparing addition and multiplication of fractions</i>.
02 May 2017	Lesson 9: I taught more on solving <i>fractions</i> word problems.
07 June 2017	Lesson 10: The concept of <i>area for 2D shapes</i> word problems was taught.
09 June 2017	The learners wrote the post-test that was administered by the researcher.
13 June 2017	- I visited the school for an exit session, where I thanked the learners, the Mathematics teacher and the School management. - I am still in contact with the Mathematics teacher for help where she indicates a need for assistance. I still visit the school for team teaching where possible.

4.6.3.4 How I entered the research environments (with the learners)

After the reception by the experimental school's principal, I was introduced to the HOD by the principal for the InterSen phase who introduced me to the Grade 7 Mathematics teacher. She took me with and introduced me to the Grade 7A class from the two classes which the school decided to give me to work with. They mentioned my name and the fact that I was coming from the university of which the learners knew as it was not that far from the schools. The same procedure happened at the comparison school and I was also given Grade 7A out of four classes.

On the first day at each of the two schools, experimental school and comparison school, I discussed with the Mathematics teachers issues of the class timetables, Mathematics work schedules, and how and when I could come for classes. I was given a copy of the timetable and the work schedule by each of the teachers (schools). Luckily, with the paced schedule, both

schools were more or less teaching the same topics or concepts at around about the same times. This made things easier for me as I prepared lessons on one concept at the same time for both schools. It was a matter of differences in hours in teaching the same concept or at most two days, depending on the timetables as to when the Grade 7 mathematics slots were scheduled. In both schools, learners were taught by their Mathematics teachers in the beginning of almost all the concepts and I would teach where the word problems started. Sometimes I visited the schools when I was free at work during their time slots. I would help the Mathematics teachers in collaborative teaching more especially in concepts that were a bit challenging to the subject teachers as per their requests. Sometimes, I would help them by marking their learners' Mathematics class exercise books and workbooks.

On my first day alone with the classes, in trying to create a relaxed mood with the learners, I asked them to introduce themselves, and I further introduced myself. I explained why I was at their schools and the importance of my research (topic). I explained what the process of my stay would entail as I explained what I was requesting them to do. I also explained the duration of my stay with them and explained my research stance with both groups. I explained issues of signing consent forms by parents or guardians as well as by them giving assent to be part of my study (Sargeant & Harcourt, 2012), as mentioned under the informed consent section. I then issued the consent/assent forms and also the intervention mathematics exercise books, a set of mathematical instruments for each learner, a pen and a pencil. The next day we met, I collected the signed forms. The rest of the field work process progressed as mentioned earlier.

4.6.4 Participants observations: Visual data: Video recordings and Documents (Learners' exercise books)

4.6.4.1 Video recordings

In this study, observations were also part of data collection strategies; however, in a form of observing video recordings that were captured during the lessons' progressions. Video recordings are said to overcome the partialness of the observer's view and the tendency of recording the frequently occurring events (Cohen *et al.*, 2018). Video recordings offer the unfiltered observational record of natural human behaviour in real time. Because videos can be watched more than once, they have the capacity for completeness and comprehensiveness of material for the researcher to better interpret the data (Cohen *et al.*, 2018).

The saying "a picture is worth one thousand words" in collecting observational data which is called *visual data collection* is indeed true (Johnson & Christensen, 2017:245). Observation is an everyday activity which is a systemic process to record the behaviour patterns of participants and

their occurrences in gathering data (Maree, 2007). The above author further contends that visual data which includes videos, photographs, and drawing, is the richest method of collecting data because these are concrete data (Mertens, 2015).

As a participant-observer, I observed the lessons without taking formal notes but using an observation schedule form as I was carrying out the intervention. Hence, video shots were captured by a colleague who was also a researcher himself, being a post-doc in the mathematics education department. I used the captured video lessons to observe the learners' reflection on the intervention as it unfolded and analysed the videos. This kind of observation recording is known as the running records because the focus of the recording was more than just the actions; it also captured the situations, which all enabled a comprehensive description in the context of a classroom where it occurred (Maree, 2007). Learners' work was also captured while they used their exercise books in class using the AWFs. Maree (2007) contends that observation is recording the behavioural patterns of participants (learners) and occurrences in a systematic process without questioning them. I observed the recordings in order to gain more insight and understanding (Maree, 2007) of the learners' *talk*, interactions through dialogue as well as their responses to word problem-solving as far as their abilities to solve them. I watched the recordings over and over in order to capture what was recorded and observed. I also cross-checked with the video shooter here and there, *member checking* for trustworthiness.

Each video with learners' utterances was transcribed into coding forms - indicators/themes (argumentation, discussion) paced through pre-intervention, intervention and post-intervention (Bowman, 1994). The main means of observation was by video recording learners' *talk* or utterances (Bowman, 1994). An observation schedule was used by the researcher that captured the essence of how the intervention progressed, under the given units of observation (see Table 4-5 below):

Table 4-5: Observation schedule of the video data (discussion) (Bowman, 1994; Doolittle, 1997; Howe & Abedin, 2013; Miller, 2011)

DISCUSSION						
	Pre-intervention	During Intervention			Post-intervention	
	1	2	3	4	5	6
1. Zone of Proximal Development (ZPD)						
• Teacher modelling-						
• Learners becoming knowledgeable						
• Learners' competency in word-problem solving abilities						
2. Mediation						
• Making claims						
• Construction of ideas (learners)						
• Learn to argue (using AWFs)						
3. Social interaction						
• Learners' utterances (talk)						
• Learners engaging with teacher						
• Engage with peers (learners)						

Table 4-6: Observation schedule of the video data (argumentation) (Bowman, 1994; Doolittle, 1997; Howe & Abedin, 2013; Miller, 2011)

ARGUMENTATION						
	Pre-intervention	During Intervention			Post-intervention	
	1	2	3	4	5	6
1. Zone of Proximal Development (ZPD)						
• Teacher modelling-						
• Learners becoming knowledgeable						
• learners' competency in word-problem solving abilities						
2. Mediation						
• Making claims						
• Construction of ideas (learners)						
• Learn to argue (using AWFs)						
3. Social interaction						
• Learners' utterances (talk)						
• Learners engaging with teacher						
• Engage with peers (learners)						

4.6.4.2 Definitions of aspects of the observed video data

As a study underpinned by Vygotsky's constructivism theory, the ZPD, mediation and social interactions were used as theoretical lenses or units of observation in the observations of the *talk* through *discussions* and *argumentations*. As mentioned earlier, the ZPD is a continuum of observations that learners start doing tasks they were not able to do (see 3.4.1), with a more capable peer or teacher to operate at a higher level in cooperating teacher scaffolding in their learning (see 3.4).

In the teaching and learning process, which includes amongst other things, interaction, new knowledge is constructed to rethink ideas, to argue, share and understand the conceptual

underpinnings of Mathematics as learners become better problem solvers (see 3.3.1). Instructive dialogue (*talk*) is placed at the core of successful and meaningful engagement in teaching and learning (see 3.3.2). Social interaction is necessary for people to communicate (see 3.4.2) and *the development of verbal meaning* (see 3.4.2). Van de Walle *et al.* (2013) define mediation as the *use of language* which is perceived as an internal process in which attention, memory and concept formation, as mental functions, are of importance (see 3.4.3). The concepts mentioned above are for all higher-order mental processes such as problem-solving and reasoning as symbols, signs as well as language (see 3.4.3). Fostering argumentation in word problem-solving through teacher modelling and group discussion is enhanced by language frames (see 3.4.3).

Entailed in the theoretical lenses are observed aspects of *teacher modelling*, *learners becoming knowledgeable*, *learners' competency in word-problem solving abilities* under the ZPD that the researcher used to give insight into the visual observations. Under mediation were aspects of *making claims*, *construction of ideas (learners)*, *learn to argue (using AWFs)*. Social interaction was discussed under *learners' utterances (talk)*, *learners engaging with teacher* and well as *engaging with peers (learners)*.

The visual observation aspect of *teacher modelling* meant the exercise of the researcher/ teacher demonstrating, either orally or written, how a word problem was solved. It also meant the teacher demonstrating how to use the AWFs to frame an answer in the way the learners were expected to respond. The aspect of *learners becoming knowledgeable* meant the learners' attempts to either work out the given questions or to participate in the *talk* (discussions). *Learners' competency in word-problem solving abilities* meant the evidence of learners solving word problems more confidently, either on the board, exercise books, verbally as well as discussing answers with the teacher or with peers. In most instances, learners would raise their hands to answer questions which was an obvious indicator of wanting to participate in the teaching and learning activities/progress. On a few occasions, the teacher would point at other learners whose hands were not raised up to get their views. Most of them responded (incorrectly but also correctly) more especially towards the end of the intervention.

In mediation, *making claims* meant learners' *talk* as the first step of argumentation and discussion in giving answers to word problem-solving questions asked. *Construction of ideas (by learners)* meant learners' *talk* where they would show that they had added some information or knowledge based on the question asked. This happened when they further added on the first responses.

The aspect *learn to argue (using AWFs)* by learners was evident when learners started to justify their answers after making claims of their solutions. Under social interaction, *learners' utterances (talk)* meant learners' responses, whether using the AWFs as *frames* to understand the word

problem or responding to how the computation of the solution went about. The aspect of *learners engaging with teacher* meant instances where learners would raise up their hands and participate in the discussion or argumentation processes. Learners would respond orally, volunteer to answer a question and give or demonstrate the solution on the chalkboard, or orally demonstrate to peers how the AWFs could be used to frame learners' answers. *Engage with peers (learners)* was when learners were in their groups answering questions or responding to other learners' questions or learners' claims of their answers.

However, the use of video cameras might cause reactivity amongst the participants that the observer might not be aware of. Due to the exposure to the video camera participants' behaviour might change by way of behaving in a socially desirable or deliberately acceptable way (Cohen *et al.*, 2018). Learners in the experimental group were somehow fascinated by the video shots, hence, some learners kept on looking at the direction of the video in the first shot. The video provided a fine-grained multimodal record and collection of naturally occurring data (Jewitt, 2012). Watching videos takes time (Jewitt, 2012); subsequently it took the researcher quite some time to analyse the visual data.

4.6.4.3 Learners' exercise books

The researcher issued exercise books to all the experimental group learners and the comparison group learners before the intervention started. All the learners' exercise books from the experimental group were collected during and after the intervention period. From the learners' exercise books, I checked if they were actually writing the given classwork and/or homework. I also checked the learners' problem-solving abilities. Towards the end, I asked learners to write a few of the AWFs and respond to them as they worked out the answers. These AWFs activities were a guide to the learners in understanding what was given in the questions, what they had to find out, as well in solving the problem(s). This was done in order to check the progress on learners' written work by using the AWFs in solving the word problems. Data collected through the exercise books and the video recordings during the implementation of the intervention by the researcher were later analysed. Table 4-7 below presents how the data collection tools matched the research questions.

Table 4-7: Matching data collection tools to the research questions

Data collection tool	Research question
Pre-test	• What was the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?
Learners' focus group interviews	• What was the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?
AWFs to support dialogue and written problem-solving intervention	• In relation to the literature and theory, what was implemented across the series of lessons? How did learners' talk in argumentation change across the implemented lessons?
Document (exercise books) and video analyses	• In relation to the literature and theory, what was implemented across the series of lessons? How did learners' talk in argumentation change across the implemented lessons?
Post-test	• What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post-intervention lessons?
Post-intervention learners' focus group interviews	• What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post-intervention lessons? • What were the implications for the pedagogic practice of these findings? • What were the nature and effects of the intervention?

4.7 Data analysis

During data analysis within the case study at hand, I constantly compared the data of the experimental group with the comparison group using Vygotsky's variables (ZPD, mediation and interaction). Comparing the two groups led to coding the categorisation of the data, conceptualisation and assessment of the similarities and differences of the two groups in comparison (Maree, 2007). The data analysis approach under the case study design should allow the researcher to use a holistic description and search for themes shedding light on the case (Johnson & Christensen, 2017). During the data analysis process, both the quantitative and the qualitative datasets were analysed separately (Creswell, 2014). Thereafter, the quantitative results were used to plan the qualitative follow-up. Data collected through multiple sources that included pre- and post-tests, learners' focus group interviews, documents (exercise books) and video recordings used both qualitative and quantitative data analysis methods to provide a better understanding of the case study phenomenon of interest as the results were interpreted together (Creswell, 2014; McMillan & Schumacher, 2010).

Different data sources of information were examined from the sources and used to build a coherent converging justification for themes. Data analysis was conducted during and after data collection processes.

4.7.1 Units of analysis

The unit of analysis refers to the major entity that is being analysed in a study. For instance, a unit of analysis in a study could be individuals, groups, artefacts (books, photos, newspapers), or utterances. It is important to understand that the unit of analysis is not the same as the unit of observation. Data can be analysed in various ways. Essentially, the unit of analysis is the “who” or the “what” that is to be analysed in the study (Miller, 2011; Van de Walle *et al.*, 2013).

Vygotsky (1962:4) defines a unit of analysis as a “...*product of analysis which, unlike elements, retains all the basic properties of the whole and which cannot be further divided without losing meaning.*” I discussed Vygotsky’s theory notions of the ZPD, social interaction and mediation for the units of observation in this chapter.

According to Van de Walle *et al.* (2013), the analytic notions of mediation occur through interactions that produce *words, learners’ constructions of ideas* and *solutions to problems*, which create the foundation to the learning of learners, which in this case was the participants’ utterances (*talk*) (Reed & Walker, 2015).

Vygotsky’s social interaction as a developmental action takes place through the analysis unit of *speech and action*, which is taken over by the learner and internalised (Jacobs *et al.*, 2016; Vygotsky, 1978). The analytic unit of verbal thought is found in the internal aspect of the word, which is in the ‘*ord*’ *meaning*, from the internal aspect of speech (Miller, 2011; Van de Walle *et al.*, 2013). Vygotsky describes the *word meaning* analytic unit as a unit for both thought and social interchange (Vygotsky, 1962). The unit of analysis for this particular study was *the process of solving multiplicative word problems* using the argumentation and discussions analytic framework.

4.7.2 Qualitative data analysis

According to Creswell (2014), qualitative data analysis intends to make sense out of the text and image data that involved segmenting and taking apart the data. This proceeded concurrently with the data collection and the write-up of findings that developed in a linear, hierarchical approach of six steps. Qualitative analysis is also defined as a relatively systematic process of coding, categorising, and interpreting data to provide explanations of a single phenomenon of interest (McMillan & Schumacher, 2010).

In the study, inductive analysis was used in order to synthesise and make meaning from the data, starting with specific data on the attainment of the test marks and ending with categories and patterns.

Data gathered through learners' focus group interviews and implementation of the intervention by the researcher using video camera were transcribed. For this study, the learners' focus-group interview data were analysed using semantic analysis. For the learners' focus group interviews I used questions that were asked to analyse the data. Therefore, thematic analysis was useful because it provided the descriptive presentation of qualitative data. For the visual data (observations), I used the observable indicators/units of observation, argumentation and discussions which were tracked through pre-intervention, intervention as well as post-intervention. In addition, the researcher used Creswell's (2014:247) steps as follows:

- Step 1: Organised and prepared the data for analysis. This involved transcribing interviews, optically scanning material, typing up field notes, cataloguing all of the visual material, and sorting and arranging the data into different types depending on the sources of information.
- Step 2: Read or looked at all the data. This second step provided a general sense of the information and an opportunity to reflect on its overall meaning. What general ideas were participants communicating? What was the tone of the ideas? What was the impression of the overall depth, credibility, and use of the information? Sometimes qualitative researchers write notes in margins of transcripts or start recording general thoughts about the data at this stage. For visual data, a sketchbook of ideas took shape.
- Step 3: Started coding all of the data. Coding was the process of organising the data by bracketing chunks (or text or image segments) and writing a word representing a category in the margins. It involved taking text data or pictures gathered during data collection, segmenting sentences (or paragraphs) or images into categories and labelling those categories with a term; often a term based in the actual language of the participant (called an *in vivo* term).
- Step 4: Used the coding process to generate a description of the setting or learners, as well as categories or themes for analysis.
- Step 5: Advanced how the description and themes were represented in the qualitative narrative.
- Step 6: A final step in data analysis involved making an interpretation in qualitative research of the findings or results.

In coding the learners' focus group interviews, I got a sense of the whole interview, and transcribed both sessions. I read all the transcriptions carefully and jotted down some ideas as

they came to mind as I read. Each interview session was answered and analysed per the questions asked of its substance of the information underlying the meaning. I wrote thoughts alongside the margin of the prescribed data. Extracts of learners' talk were provided as examples under each interview question asked. The researcher arranged the observation (visual data) topics into columns, arrayed levels, pre-intervention, during intervention as well as post-intervention. I assembled the data material belonging to each category in one place and performed the analysis. I recorded the existing data (Creswell, 2014; Tesch, 1990).

4.7.2.1 Documents (learners' exercise books) and video recordings

All the learners' exercise books from the experimental group were collected during and after the intervention period, for analysis of the written work the AWFs. Data analysis in this phase involved the qualitative approach. The exercise books analysis was done concurrently with the intervention implementation. The analysis was done in order to understand if there was any improvement in the proficiency of the learners in solving the multiplicative word problems. The video-recorded lessons were for the analysis of the progress of the intervention implementation on how learners solved the multiplicative word problems and the nature of argumentation or discussion in the classrooms. The researcher used social cultural tools to track the talk in the argumentation and discussions. These tools, mediation and social interaction, included the ZPD and were observable indicators in analysing the video data. The solving abilities were used to analyse the documents (exercise books).

4.7.3 Quantitative data analysis

The quantitative data collected were coded and statistical analysis was used. Descriptive statistics were used to present the data; the frequency (f) distribution of scores, percentages and tabular formats were used (see 1.4). According to (Creswell, 2002), descriptive statistics help the researcher to describe responses to each question in the datasets and determine the distribution and trend of the data. On the other hand, McMillan and Schumacher (2010) describe descriptive statistics as summary statistics that are used to summarise, organise and reduce large numbers of observations.

The test was written first, marked and analysed, and the feedback on the performance informed the interviews. The test marks were first converted to percentages to find out how many learners attained marks 40% and above. A 40% mark qualified a learner to progress to the next grade (DBE, 2011). From the scripts, the problems and errors manifested were identified.

The test results gathered from the learners' test responses were coded into the following categories:

- (a) Situationally Appropriate (SA): All instances where learners interpreted the context(s) of the problem statement appropriately.
- (b) Situationally partially Appropriate (SPC): All the cases where learners partially interpreted the contexts or partially appropriate but lacked enough supporting argument.
- (c) Situationally Inappropriate (SI): These were the cases where learners misinterpreted the problem statement and/or ignored the situation or context(s) of the problem.
- (d) Mathematically Accurate (MA): Those cases that were mathematically correct.
- (e) Partially Correct (PC): All responses that were mathematically partially correct.
- (f) Incorrect Responses (IR): All cases that were mathematically inaccurate.
- (g) No response (NR): Instances where a problem was not solved or attempted (see 1.4).

Codes used for analysing the question 1 test items were Codes a, b and c, whereas Codes d, e, f and g were used to frame Question 2 test items. The same learners' test responses coding categories were used to mark the test items respectively. On recommendation of a qualified statistical consultant, the pre-test and the post-test generated data were subjected to the Statistical Package for the Social Sciences® (SPSS' IBM®) software using the Wilcoxon Signed Rank Test, the Mann-Whitney test and Wilcoxon rank-sum test as well as the Pearson's Chi-Square Test to produce the statistical results (Field, 2013). Accordingly, the Wilcoxon Signed-Rank Test was used to compare a paired set of scores from the same learners, which were the pre-test and the post-test of the experimental group learners as well as of the comparison group learners (Field, 2013; Imam, Usman & Chiawa, 2014; Mehta & Patel, 2012). The Wilcoxon Signed-Rank Test makes use of the paired samples and here gave statistical significance of the t-tests in comparing the means of the pre-test and post-test as variables that were measured (Field, 2013; Wagner, 2017). The experimental group took a pre-test and then an identical post-test was administered after the intervention using AWFs. The results were given at a statistically significance level of 0.05 (Wagner, 2017). The Wilcoxon Signed Rank Test, the Mann-Whitney test and Wilcoxon rank-sum test on the other hand were used to compare the two groups (comparison and experimental) on their performances based on the pre-test and the post-test during the intervention period, as different participants (Field, 2013). The Pearson's Chi-Square Test was used to determine the relationship between the pre- and post-test performances of the experimental group as well as of the comparison group (Field, 2013; Wanger, 2017). The association was declared statistically significant for any p-value of equal to or less than 0.05 (Field, 2013). The descriptive statistics calculated for observations and measures at the pre-test

or post-test stage of experimental designs consisted of means, medians, minimum scores and maximum scores (Creswell, 2014).

4.8 Ethical concerns

Every research is guided by a set of principles that were developed to help researchers in conducting ethical studies (Johnson & Christensen, 2017). Research where data are collected from people and about people subjected the study to requirements for ethical considerations in order to make any argument of the study (Creswell, 2014). On the contrary, Bogdan and Biklen (2007) define ethics in research as principles that a particular group accept at a particular time, right or wrong. They further argue that official guidelines of ethics in a research were to ensure that informants enter research projects voluntarily, understanding the nature of the study and the obligations that are involved. Informants are not to be exposed to risks that are greater than the gains they might derive. According to Okeke and Van Wyk (2015), ethics gate-keepers “understood how to protect the interests of those who were ready and willing to take part in research”. Ethical issues need to be addressed in relation to the different phases of the inquiry including issues prior to conducting the study; beginning a study; during data collection and data analysis; and in reporting, sharing, and storing the data (Creswell, 2014). In this study, the ethical considerations the researcher followed covered the informed consent and minors as research participants.

4.8.1 Institutional ethical issues

(a) Prior to conducting the study

I submitted my proposal for an Institutional Review Board (IRB) (Mertens, 2015) which was approved by the NWU. I identified and went through local approvals; found gatekeepers or key personnel to help. Permission was requested from the Department of Education and the schools to carry out the research at the participating primary schools. I selected sites that did not raise power issues with the researcher. I requested permission from the principals of the two schools within Rekopantswe Area Office at the Montshiwa Township in Mahikeng (Mmabatho), Ngaka Modiri Molema District in the North-West Province to conduct the research study to work with one class of Grade 7 Mathematics learners in each school to be part of the study.

(b) Beginning the study

I contacted participants and informed them of the general purpose of the study. I explained to the participants that they did not have to sign any forms other than the consent forms for participation.

I obtained appropriate consent from parents, as well as assent from the learners. I built trust and conveyed the extent of anticipated disruption in gaining access.

(c) Collecting the data

I was aware of possible withdrawal of research participants; subsequently I put into place waiting list provisions for experimental and comparison groups. I discussed the purpose of the study with participants and how data were to be used. I avoided sharing personal impressions; I avoided disclosing sensitive information. I involved participants as collaborators. I stuck to questions stated in an interview protocol with probes where necessary.

(d) Analysing the data

I reported multiple perspectives. I reported contrary findings. I assigned fictitious names or aliases and developed composite profiles of participants.

(e) Reporting, sharing and storing the data

I reported honestly, so that individuals could not be identified. I used unbiased language appropriate for audiences of the research. I shared results with other researchers and considered website distribution in the form of articles. There was storage of data and materials for five years (APA, 2015). I refrained from using the same material for more than one publication. I gave credit for ownership to researchers, participants, and advisers (Bogdan & Biklen, 2007; Creswell, 2002).

4.8.2 Informed consent and minors as research participants

Ethical principles allow a participant to give consent to partake in a research study, given the research information is competent and legally free (Johnson & Christensen, 2017). Informed consent protects and respects the right of self-determination and safeguards the responsibility on the participant should anything go wrong (Cohen *et al.*, 2018). However, working with minors (below age 18) like in this research study, required the learners to give assent to partake in my study. Learners' parents or guardians gave consent for their children. I wrote letters to the learners' parents/ guardians to ask for their consent to use their children in my study. It is known ethically that parents have legal authority to give or not give permission for their children under the age of 18 to become research participants (Mertens, 2015). Asking for learners' assent, I read the contents and conditions of my research study and issues of willingness, confidentiality and anonymity which are guiding principles in the ethical review process. The parents and the learners were informed that they had the rights to withdraw from the research at any point in time (Greig *et al.*, 2007). Taking visual images of children is also subject to consent and assent to be given

by parents/guardians and the learners; otherwise it is considered as discrimination (Cohen, *et al.*, 2018).

Identification, anonymisation and obscuring of the participants (learners) is ethical and part of legal protection regulations on data protection (Cohen *et al.*, 2018). Images may be anonymized by eye blocking, voice modification, using pseudonyms, showing the back of the person, showing only the non-identifying features such as hands, etc.

4.8.3 Ethics in data analysis

I adhered to the data analysis ethical considerations by analysing the data instead of judging, not falsifying and not making up data. The researcher did not breach the ethical requirements of confidentiality and anonymity. The researcher gave sufficient voice to the participants, more especially in the qualitative data (Cohen *et al.*, 2018).

4.9 Researcher's role

According to Creswell (2014), the researcher's role necessitated the identification of assumptions, values and biases as the primary data collection instrument at the onset of the study. During data collection, the researcher was an assessor, a marker and analyser of the data collected from the test and an interviewer during the learners' focus groups interviews. The researcher was a participant observer during the implementation of the intervention of AWFs in word problem-solving.

Also, my role was to prepare and structure the learners' focus group interviews schedule and facilitate the interviews. I analysed and triangulated the data (Maree, 2007). I was the *research instrument* in the data gathering process, as echoed by Maree (2007). As a research instrument, I observed the captured video lessons as well as wrote everything that was written from the video observations (Mertens, 2015). I was a social person and professional with a genuine purpose of understanding how the social world looks from the learners' perspective (Mertens, 2015).

Being in the Education Department and having taught Mathematics for more than 12 years had shaped my personal experiences in working closely with learners in multilingual Mathematics classrooms. Because of this previous experience, where learners had been struggling in solving word problems, I suggested the use of AWFs to support word problem-solving (teaching and learning) in Grade 7 learners and better their academic performances in multiplicative word problems.

4.9.1 Researcher bias

On issues of researcher bias, I made every effort to ensure objectivity. These biases could have shaped the way I viewed and understood the data I collected and the way I interpreted my experiences. As a researcher I adhered to reflexivity, where I consciously engaged in critical self-reflection about my potential biases as a researcher evolving interpretations (Johnson & Christensen, 2017). Hence, I refrained from selective observations, but all lessons that were meant to be video recorded were captured and they were all observed and reported on.

4.10 Reliability and validity

Validity is defined as the extent to which interpretations of data are warranted by the evidence used in addition to the theories used (Cohen *et al.*, 2018). Everything that was reported to have taken place in this study actually happened. I reported the description of events, learners' behaviours and the classroom settings accurately, hence adhered to *descriptive validity* (Johnson & Christensen, 2017). The meanings attached to learners' experiences and viewpoints were portrayed accurately in the research report, hence adhered to the *interpretive (emic) validity*. Moreover, the degree to which the theoretical perspective was explained and developed fits the data and is therefore defensible and credible to qualify for the *theoretical validity* (Johnson & Christensen, 2017).

In adhering to the validity expectations and virtue, this thesis employed accepted definitions and constructions of concepts, which abides with the *construct validity*. It also ensured that the findings and interpretations of the results derived at were transparent; hence *internal validity* was adhered to. The clarification of theory and domains from which generalization was made, made this study to be *external validity* accepted. I used multiple sources and evidence to address the research questions, hence making the study *concurrent validated*. I tried, as much as I was the participant-researcher, not to be prejudiced and biased by not being selective when reporting on this investigation; as such I adhered to *avoidance of bias* expectations. As a researcher, I was consistent with internal issues, hence adhering to *reliability* expectations (Cohen *et al.*, 2018). I engaged multiple data collection strategies such as test, intervention, focus group interviews, affording trustworthiness of the study under investigation. Triangulating the approaches, methodology, data, instruments as well as perspectives ensured the study to be *convergent validated* and also resulted in a good practice of trustworthiness (Johnson & Christensen, 2017; Maree, 2007). I used the Wilcoxon Signed Rank Test and the Pearson Chi-Square Test because of the small samples that these tests cater for. Using the small sample, I reported the exact significance of the output without rounding it off (Field, 2013).

As tests that are used in conjunction with small samples, they are known as non-parametric tests (Imam *et al.*, 2014). According to Mohajan (2017), there is no error of measurement as long as the observations are the true scores; then the hypothesis of the tests is proposed in terms of true scores.

4.10.1 Content validity (pre-and post-test)

The contents of the pre- and post-tests covered multiplicative word problem concepts that were taught during the intervention period. These concepts were adapted from the schools' work schedules and Department of Education Curriculum for term one and term two. The test was checked against the Curriculum and I also checked with the District Subject Advisor for Mathematics in the area (following Maree, 2007). The test was piloted with a Grade 7 group in 2016. After the pilot study was completed, the test was modified to correct possible flaws in the measurement procedure. The numbering of the questions, which had been 1.1 - 1.7 was changed to numbers 1.1- 1.3 and 2.1 – 2.4. Numbers 2.3 and 2.4 were swapped around after considering the difficulty levels. This was per the views of the Head of Department of the school, the Mathematics Subject Advisor and me as the researcher.

4.11 Chapter summary

Chapter four has outlined the research methodology of the study, the quantitative, qualitative and mixed methods as well as the research design. The research site, participants, and data collection strategies were discussed in detail. The chapter also discussed issues of data analysis, qualitative and quantitative treatments, ethical issues, researcher's role as well as reliability and validity issues. Chapter five presents findings from the quantitative phase and the qualitative data collected from the study, where the data analysis process will be demonstrated and discussed to enhance presentation of meanings and recommendations.

CHAPTER 5

DATA ANALYSIS

5.1 Introduction

This chapter presents the findings on the quantitative and qualitative data that were generated in this study in answering the research questions, using the methodology and research instruments described in Chapters three and four respectively. The quantitative data generated from pre-test and the post-test administered in both experimental (n=42) and comparison (n=35) groups are discussed. Accordingly, the quantitative data were subjected to the Statistical Package for the Social Sciences® (SPSS® IBM®) software applying the Wilcoxon Signed Rank Test and the Pearson Chi-Square test to produce the statistical results (see 4.10). The qualitative data presented in this chapter were generated from the focus group interviews with at most eleven learners sampled from the experimental group; the video recordings and learners' written work. The qualitative data followed a thematic analysis by using a systematic process of coding. The structure of this chapter followed the research design of this study and therefore it begins by outlining the pre-tests' results; pre-intervention focus group interview data; followed by results of the data analysed from the video recordings; finally it discusses the post-tests' results as well as post-intervention learners' focus group interview data. The chapter then concludes by giving an overview of statistical analyses in order to demonstrate the impact (or lack thereof) of the intervention strategies. The results of the study could not be generalized because of the small sample used for the experimental and comparison groups as well as the non-random sampling technique used.

5.2 Quantitative results: Pre-tests

As noted earlier, this quantitative pre-test consisted of seven test items (TIs). The test required learners to solve the TIs and then immediately explain and describe how they arrived at their proposed or final answers (see 2.2.2.14). The TIs were divided into two question categories: Question 1 (Items 1.1-1.3) measured learners' abilities to make sense of the situation (or context) of the problem statement; and Question 2 (Items 2.1-2.4) measured learners' problem-solving abilities (i.e., mathematical or computational correctness of the item). In doing so, the codes as adapted by Sepeng (2010:63) from Verschaffel *et al.* (1994), were used to analyse learners' written work, and were framed by constructivist and socio-cultural theories (see 2.2.2.13 & 3.2).

These were as follows:

- (f) *Situationally Appropriate (SA)*: All instances where learners interpreted the context(s) of the problem statement appropriately.
- (g) *Situationally partially Correct (SPC)*: All the cases where learners partially interpreted the contexts or partially answered appropriately but lacked enough supporting argument.
- (h) *Situationally Inappropriate: (SI)*: These were the cases where learners misinterpreted the problem statement and/or ignored the situation or context(s) of the problem.
- (i) *Mathematically Accurate (MA)*: Those cases that were mathematically correct.
- (j) *Partially Correct (PC)*: All responses that were mathematically partially correct.
- (k) *Incorrect Responses (IR)*: All cases that were mathematically incorrect.
- (l) *No response (NR)*: Instances where a problem was not solved or attempted.

Following from the above codes used for analysing the test items, Codes a, b and c were used to frame Question 1 items, whereas Codes d, e, f and g were used to frame Question 2 items. Tables with frequencies and percentages means, medians, minimum scores and maximum scores were used to analyse the results. In all the categories, the two groups were compared across and within each group.

5.2.1 Sense-making in word problem-solving: Pre test

This section discusses the first three items on issues of sense-making when the comparison and experimental learners solved word problems in the pre-tests, using the SA, SI and SPC codes.

5.2.1.1 Item 1.1 pre-test results

Table 5-1 below shows the results of the pre-tests in frequencies and percentages in tables formations. In Table 5-1, we notice that on the left-hand side is the comparison group (n=35) and on the right-hand side is the experimental group (n=42). Both groups in the situational appropriateness schema obtained responses that were situationally accurate (SA) and situationally inappropriate (SI). The data further show that majority of the learners (at least 94%) in both groups could not interpret the problem statement correctly. As a result, learners produced solutions that were primarily influenced by the mechanical way of solving the Mathematics problem without considering the reality of the problem statement.

Table 5-1: Pre-test results of item 1.1 of both comparison and experimental groups

Tabulation of Item 1.1 (Comparison pre-)				Tabulation of Item 1.1 (Experimental pre-)			
Item 1.1	Freq.	Percent	Cum.	Item 1.1	Freq.	Percent	Cum.
SA	2	5.71	5.71	SA	1	2.38	2.38
SI	33	94.29	100.00	SI	41	97.62	100.00
Total	35	100.00		Total	42	100.00	

5.2.1.2 Item 1.2 pre-test results

Table 5-2 below shows the results of the learners' performances with regard to item 1.2. The data show that majority of the learners in both groups demonstrated a tendency to ignore the reality embedded within the problem statement when solving test item 1.2. In actual fact, the experimental group's (SI = 80.95%) ability to consider reality when solving this item was worse than that of the comparison group (SI = 71.43%). In other words, both groups struggled to make sense of the context in the problem statement. However, comparatively speaking, the experimental group produced more situationally appropriate responses, approximately 4.76% better than the comparison group for this item.

Table 5-2: Pre-test results of item 1.2 of both comparison and experimental group

Tabulation of Item 1.2 (Comparison pre-)				Tabulation of Item 1.2 (Experimental pre-)			
Item 1.2	Freq.	Percent	Cum.	Item 1.2	Freq.	Percent	Cum.
NONE	2	5.71	5.71				
SA	5	14.29	20.00	SA	8	19.05	19.05
SI	25	71.43	91.43	SI	34	80.95	100.00
SPC	3	8.57	100.00				
Total	35	100.00		Total	42	100.00	

5.2.1.3 Item 1.3 pre-test results

The data illustrated by Table 5-3 below show that quite a high number of learners in both the comparison and experimental groups interpreted the word problem statement situationally partially correctly and considered reality partially which lacked supporting argument though when answering item 1.3. As a result, at least 94% produced situationally appropriate responses. In actual fact, both groups produced almost the same results.

Table 5-3: Pre-test results of item 1.3 of both comparison and experimental groups

Tabulation of Item 1.3 (Comparison pre-)				Tabulation of Item 1.3 (Experimental pre-)			
Item 1.3	Freq.	Percent	Cum.	Item 1.3	Freq.	Percent	Cum.
SI	2	5.71	5.71	SI	2	4.76	4.76
SPC	33	94.29	100.00	SPC	40	95.24	100.00
Total	35	100.00		Total	42	100.00	

5.2.2 Using the mathematical tools to solve word problems

In this section, the results of learners' responses were analysed on the base of how they worked out their tasks, which was their abilities to solve the multiplicative word problems. The discussion will only focus on items 4-7, questions 2.1-2.4. The schema codes that were used were *Mathematically Accurate* (MA): *Partially Correct* (PC), *Incorrect Responses* (IR): *No response* (NR).

5.2.2.1 Item 2.1 pre-test results

Notice in Table 5-4 below that learners from both the comparison and experimental groups attempted to solve item 2.1. Evidently, the data demonstrate that learners in the comparison group produced MA=8.57% and the experimental group MA=21.47%. We notice that learners in both groups struggled to solve the problem correctly. However, the experimental group produced more (12.86%) better MA than the comparison group. We further note that both groups had learners who produced partially correct responses that were at the same percentage range with the comparison group (54.29%) and in the experimental group (54.76%).

Table 5-4: Pre-test results of item 2.1 of both comparison and experimental groups

Tabulation of Item 2.1 (Comparison pre-)				Tabulation of Item 2.1 (Experimental pre-)			
Item 2.1	Freq.	Percent	Cum.	Item 2.1	Freq.	Percent	Cum.
IR	12	34.29	34.29	IR	10	23.81	23.81
MA	3	8.57	42.86	MA	9	21.43	45.24
NR	1	2.86	45.71	NR	23	54.76	100.00
PC	19	54.29	100.00	PC			
Total	35	100.00		Total	42	100.00	

5.2.2.2 Item 2.2 pre-test results

We notice in Table 5-5 below that learners from both the comparison and the experimental groups attempted to solve item 2.2. Evidently, the data demonstrate that learners in both groups showed a tendency of producing responses that were partially correct. This implies that learners had some idea of solving the problems but were not completely accurate. Therefore, the comparison group obtained 48.57% while the experiment group obtained a much higher (71.43%) of the PC responses. We further note that the experimental group obtained 2.38% of the responses that were mathematically correct, as compared to the comparison group that did not obtain any mathematically correct responses.

Table 5-5: Pre-test results of item 2.2 of both comparison and experimental groups

Tabulation of Item 2.2 (Comparison pre-)				Tabulation of Item 2.2 (Experimental pre-)			
Item 2.2	Freq.	Percent	Cum.	Item 2.2	Freq.	Percent	Cum.
IR	18	51.43	51.43	IR	11	26.19	26.19
PC	17	48.57	100.00	MA	1	2.38	28.57
				PC	30	71.43	100.00
Total	35	100.00		Total	42	100.00	

5.2.2.3 Item 2.3 pre-test results

The data in Table 5-6 below display that learners in the comparison group demonstrated difficulties in the abilities to solve this item (68.57%) as compared to the experimental group that obtained 35.71% of incorrect responses which were 32.86%. In addition, 5.71% of the comparison group responses indicate that learners did not attempt to answer the item. We further note that the experimental group had 64.29% of learners who produced partially correct responses which was 38.58% more than the comparison group (25.71%).

Table 5-6: Pre-test results of item 2.3 of both comparison and experimental groups

Tabulation of Item 2.3 (Comparison pre-)				Tabulation of Item 2.3 (Experimental pre-)			
Item 2.3	Freq.	Percent	Cum.	Item 2.3	Freq.	Percent	Cum.
IR	24	68.57	68.57	IR	15	35.71	35.71
NR	2	5.71	74.29	PC	27	64.29	100.00
PC	9	25.71	100.00				
Total	35	100.00		Total	42	100.00	

5.2.2.4 Item 2.4 pre-test results

Table 5-7 below shows that learners in the comparison group produced partially correct responses that were only 2.86% as compared to the experimental group that produced 69.05%, which was very high; 66.19% higher comparatively speaking. The experimental group's partially correct ability to solve this item was crowned by 2.38% of MA responses of learners, which was not produced by the comparison group. A very inferential number of learners (97.14%) in the comparison group obtained incorrect responses when attempting to solve item 2.4, as compared to the experimental group that was low with 68.57%.

Table 5-7: Pre-test results of item 2.4 of both comparison and experimental groups

Tabulation of Item 2.4 (Comparison pre-)				Tabulation of Item 2.4 (Experimental pre-)			
Item 2.4	Freq.	Percent	Cum.	Item 2.4	Freq.	Percent	Cum.
IR	34	97.17	97.14	IR	12	28.57	26.19
PC	1	2.86	100.00	MA	1	2.38	28.57
				PC	29	69.05	100.00
Total	35	100.00		Total	42	100.00	

5.2.3 Sense-making and using the mathematical tools to solve multiplicative word problems: Pre-test

This section compares the situationally and mathematically appropriateness within each group for tasks in questions 1.1-1.3. It compares the relationship between the sense-making or reality consideration and the mathematical ability to solve the word problems.

5.2.3.1 Comparison group

(m) Item 1.1 pre-test results

In Table 5-8 below, data show that learners in the comparison group had a tendency of solving sense-making word problems in mechanical ways. In the comparison group, learners in item 1.1 produced more responses in which were mathematically accurate (94.29%) as compared to the high responses of situationally inappropriate responses (94.29%). The 94.29% of learners' responses in the comparison group who obtained situationally inappropriate responses seemed to have been closely associated with learners who gave incorrect responses (2.86%).

Table 5-8: Pre-test results of item 1.1 of comparison group: Sense-making and using the mathematical tools

Tabulation of Item 1.1 (Comparison pre-)				Tabulation of Item 1.1 (Comparison pre-)			
Item 2.4	Freq.	Percent	Cum.	Item 2.4	Freq.	Percent	Cum.
SA	2	5.71	5.71	IR	1.1	2.86	2.86
SI	33	94.29	100.00	MA	33	94.29	97.14
				PC	1	2.86	100.00
Total	35	100.00		Total	35	100.00	

(n) Item 1.2 pre-test results

The data illustrated in Table 5-9 indicate responses of learners in the comparison group that were SA (14.29%) that could be associated with learners' responses that were MA (25.71%). It seemed that the more the learners' responses in the comparison group were situationally inappropriate, the more learners produced incorrect responses (71.43%) which was coupled with responses produced from learners who were partially correct (34.29%). The results of the comparison group imply the absence of or little sense-making if associated with lack of mathematically solving abilities in task item 1.2.

Table 5-9: Pre-test results of item 1.2 of comparison group: Sense-making and using the mathematical tools

Tabulation of Item 1.2 (Comparison pre-)				Tabulation of Item 1.2 (Comparison pre-)			
Item 1.2	Freq.	Percent	Cum.	Item 1.2	Freq.	Percent	Cum.
NONE	2	5.71	5.71	IR	12	34.29	34.29
SA	5	14.29	20.00	MA	9	25.71	34.29
SI	25	71.43	91.43	NR	2	5.71	65.71
SPC	3	8.57	100.00	PC	12	34.29	100.00
Total	35	100.00		Total	35	100.00	

(o) Item 1.3 pre-test results

The data in Table 5-10 below depict the majority of learners' responses of the comparison group that produced partially appropriate (94.29%) and also a very high response of learners that were computationally correct (85.71%). In fact, the results of the comparison group imply that learners solved the word problem with some reality consideration, which was however lacking in supporting arguments.

Table 5-10: Pre-test results of item 1.3 of comparison group: Sense-making and using the mathematical tools

Tabulation of Item 1.3 (Comparison pre-)				Tabulation of Item 1.3 (Comparison pre-)			
Item 1.3	Freq.	Percent	Cum.	Item 1.3	Freq.	Percent	Cum.
SI	2	5.71	5.71	IR	2	5.71	5.71
SPC	33	94.29	100.00	MA	30	85.71	91.43
				PC	3	8.57	100.00
Total	35	100.00		Total	35	100.00	

5.2.3.2 Experimental group

(p) Item 1.1 pre-test results

Table 5-11 below shows that learners in the experimental group produced more responses that could not take reality into consideration (97.62%), who seemed to be associated with high responses from learners that were computationally accurate (80.95%). The data from the experimental group implied that learners were more mechanical than sense-making. Situationally appropriate in the experimental group for item 1.1 was as low as 2.38%, and we also notice very low learners' responses for incorrect problem-solving abilities (7.14%).

Table 5-11: Pre-test results of item 1.1 of experimental group: Sense-making and using the mathematical tools

Tabulation of Item 1.1 (Experimental pre-)				Tabulation of Item 1.1 (Experimental pre-)			
Item 1.1	Freq.	Percent	Cum.	Item 1.1	Freq.	Percent	Cum.
SA	1	2.38	2.38	IR	3	7.14	7.14
SI	41	97.62	100.00	MA	34	80.95	88.10
				PC	5	11.90	100.00
Total	42	100.00		Total	42	100.00	

(q) Item 1.2 pre-test results

In item 1.2, more learners in the experimental group produced situationally inappropriate responses (80.95%), and there were (28.57%) responses that were mathematically accurate in addition to learners' responses that were partially correct (38.10%). Responses of learners in the experimental group who considered reality were 19.05% and those responses from learners who could not solve item 1.2 were 33.33%.

Table 5-12: Pre-test results of item 1.2 of experimental group: Sense-making and using the mathematical tools

Tabulation of Item 1.2 (Experimental pre-)				Tabulation of Item 1.2 (Experimental pre-)			
Item 1.2	Freq.	Percent	Cum.	Item 1.2	Freq.	Percent	Cum.
SA	8	19.05	19.05	IR	14	33.33	33.33
SI	34	80.95	100.00	MA	12	28.57	61.90
				PC	16	38.10	100.00
Total	42	100.00		Total	42	100.00	

(r) Item 1.3 pre-test results

The results given in Table 5-13 below show a high percentage of learners' responses in the experimental group that were situationally partially correct (SPC) (95.24%) in item 1.3 and the majority of learners who produced MA (90.48%) responses. The results show that learners partially included reality considerations in understanding the item that needed more supporting argument but solved it correctly. The group obtained SI=4.76% and IR=7.14%.

Table 5-13: Pre-test results of item 1.3 of experimental group: Sense-making and using the mathematical tools

Tabulation of Item 1.3 (Experimental pre-)				Tabulation of Item 1.3 (Experimental pre-)			
Item 1.3	Freq.	Percent	Cum.	Item 1.3	Freq.	Percent	Cum.
SA	2	4.76	4.76	IR	3	7.14	7.14
SPC	40	95.24	100.00	MA	38	90.48	97.62
				PC	1	2.38	100.00
Total	42	100.00		Total	42	100.00	

The above quantitative results were meant to answer the following research question:

5.2.3.2.1 What was the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?

With regard to research question 1: the nature of the learners' academic achievement was better demonstrated by the learners' abilities to make sense of the situation (or context) as well as the learners' problem-solving abilities (i.e. mathematical or computational correctness.) The data show that the majority of the learners in both groups could not interpret the problem statement correctly. The learners' abilities to make sense of the situation revealed that the comparison group, for items 1.1 and 1.2 obtained situationally incorrect responses of 94.29% and 71.43% respectively and in item 1.3 obtained 94.29% responses of situationally partially correct responses. On the other hand, the experimental group for items 1.1 and 1.2, obtained 97.62% and 80.95% respectively and 95.24% for the SPC responses. Comparatively speaking, the comparison group showed a better performance compared to the experimental group. Learners' problem-solving abilities which were demonstrated through mathematical or computational correctness also depicted difficulties that led to low learners' academic performance. The comparison group obtained 8.57% while the experimental group obtained 21.43% of mathematically accurate responses for item 2.1. The comparison group obtained 48.57%, 25.71% and 2.86% of partially correct responses for items 2.2 – 2.4 respectively, while the experimental group obtained 71.43%, 64.29% and 69.05% PC responses for items 2.2 – 2.4 respectively. The experimental group showed a better tendency of producing responses that were partially correct as compared to the comparison group. Prior to the intervention, learners' argumentation was not explored as far as word problem solving in relation to (multiplicative) word problem-solving, in particular.

Table 5-14 below shows some examples of how learners responded to item 1. The examples display how learners used their abilities of sense-making and using the mathematical tools in showing their problem solving abilities. The MA marking code was relevant because with proper justification of the computed response, the learners were correct.

Table 5-14: Examples of learners' responses to problem-solving task 1.1

Learners' Responses/Answers		Situationally Accurate (SA)	Mathematically Accurate (MA)						
1	1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left? <table><tr><th>SOLUTION</th><th>HOW I ARRIVED AT THE ANSWER</th></tr><tr><td>$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$</td><td>I subtracted one into five .</td></tr><tr><td>NR</td><td>0/</td></tr></table>	SOLUTION	HOW I ARRIVED AT THE ANSWER	$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$	I subtracted one into five .	NR	0/	Situationally, the response lacks the exercise of reality.	The learner showed a lack of understanding the question and knowledge of operations that, it is a smaller number that is subtracted from a bigger number.
SOLUTION	HOW I ARRIVED AT THE ANSWER								
$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$	I subtracted one into five .								
NR	0/								
2	1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left? <table><tr><th>SOLUTION</th><th>HOW I ARRIVED AT THE ANSWER</th></tr><tr><td>$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$</td><td>I subtracted to get the answer correct. 4 birds are left.</td></tr><tr><td>MA</td><td>3/</td></tr></table>	SOLUTION	HOW I ARRIVED AT THE ANSWER	$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$	I subtracted to get the answer correct. 4 birds are left.	MA	3/	Situationally, it lacked the insight of reality.	This is a mathematically correct computation, with the use of the subtraction operation.
SOLUTION	HOW I ARRIVED AT THE ANSWER								
$\begin{array}{r} 5 \\ -1 \\ \hline = 4 \end{array}$	I subtracted to get the answer correct. 4 birds are left.								
MA	3/								
3	1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left? <table><tr><th>SOLUTION</th><th>HOW I ARRIVED AT THE ANSWER</th></tr><tr><td>$5 - 1 = 4 \text{ or } 0$ Because the will fly away</td><td>I subtracted</td></tr><tr><td>MA</td><td>3/</td></tr></table>	SOLUTION	HOW I ARRIVED AT THE ANSWER	$5 - 1 = 4 \text{ or } 0$ Because the will fly away	I subtracted	MA	3/	The learner showed the use of common sense. After the computation, the learner also reasoned to say, the birds flew away. However, the reason for flying away is not stated.	It was mathematically accurate.
SOLUTION	HOW I ARRIVED AT THE ANSWER								
$5 - 1 = 4 \text{ or } 0$ Because the will fly away	I subtracted								
MA	3/								

4

1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left?

SOLUTION	HOW I ARRIVED AT THE ANSWER
No bird is left left	I said that if birds hear a bullet they won't just stand still they will run away. ✓
* MA	3/

The learner just used straight reasoning to say the birds will fly. In addition, he stated the reason of flying, to "...if birds hear a bullet they won't just stand still they will run away."

The learner did not see the need of computing anything but only used common sense.

5

1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left?

SOLUTION	HOW I ARRIVED AT THE ANSWER
The are not left , I just used my because when you shot mind to think one bird the other then I got The ones will fly away ✓ answer	
* MA SA	3/

The learner used a situational reasoning to say the birds will fly away when using his mind.

No computation was done by the learner but only the use of common sense.

As seen in Table 5-14 above, the learners' responses number 1, shows an example of over 90% percent of learners who could not demonstrate sense-making when responding to the question. Another point of concern was finding learners in Grade 7 who had difficulties in placing numbers for a subtraction computation. Response 2 show a case of learners who can compute correctly but lack the insight of reality situationally. Responses 3-5 demonstrated more insight of reality in the given context.

5.3 Qualitative results: Learners' pre-intervention focus group interview

The researcher carried out a pre-intervention focus group interview with the experimental group as a way of triangulating the learners' pre-test data. A focus group was used with a purposive sample of eleven learners (see 4.6.2.1) in order to make sense of the nature of learners' problem-solving abilities and the reasons for answering the test items the way they did. The researcher asks the learners questions about ideas, opinions, views amongst other things to collect considerable meaning and understanding of the learners' data face-to-face (see 4.3 & 4.6.2). The pre-intervention interview guide consisted of seven items. The interview session was tape recorded and data were transcribed. The following were learners' responses to the seven items.

5.3.1 Interview item 1: What did you do in order to solve the word problems in the test?

Learners' word problem-solving abilities were being explored in this interview item (see 2.2.2.14). The following extract displayed the learners' responses to this interview item. In solving the pre-test questions, learners responded by stating that they divided all the numbers to get the age of the farmer for word-problem-solving task (TI) 2. However, other learners did not write answers (see extract 5.1). The responses showed that learners experienced difficulties in solving the tasks given, showing lack of sense-making, when a number of learners added the number of pigs and cows (see response for Learner 8), in particular (Greer, 1997).

Extract 5.1

L6 (Learner 6): We had to divide all the numbers and see the years of the farmer.

L8 (Learner 8): I have added 5 pigs and 25 cows.

R (Researcher): What do you think, if someone has got something, say for instance, you have pets at home; you have five cats, you have ten dogs and you have 20 chickens?

To get your age, do we have to divide or do we have to add that livestock that you have?

How do you get the age of the person having some livestock or some pets or something.

How do we get the age of a person?

R: So how do you count the age of a person if that person is just attaching that thing to him? How do you know the age of a person? Can you actually know the age of a person when you are given the livestock or some pets?

L2 (Learner 2): I didn't write the age of the farmer.

R: You didn't write the age of the farmer? What did you write?

About 10% of the learners actually left blank spaces where they were expected to write solutions and that showed that they had forgotten how to work out those word problems. In concepts such as ratio, almost all the learners used wrong computations. In responding to the multiplicative word problems solving tasks, learners had to show the competency of being able to question their decisions on their response (see 2.2.3).

Argumentative writing frames were used to mediate the teaching of word problem-solving where learners' utterances were enhanced by language. As much as the researcher taught a few word problems that portrayed a scenario of "window-dressing" because of the "hidden curriculum" (see 2.2.3), these were instances where an illogical answer was asked, with irrelevant questions or irrelevant data. Learners solved mathematical problems by using the numbers given in the *story* in a phenomenon of "suspension of sense-making" when doing school arithmetic (see 2.2.2.11). Learners attached an operation such as addition instead of realising that the question was somehow nonsensical in what was asked. However, the word problems used in the most frequently used textbooks were found to be somehow the reasons for the lack of use of everyday-life knowledge as textual factors relating to the stereotypical nature of "suspension of sense-making" (see 2.2.2.13). This comes as a curriculum gap in the type of word problems that learners are taught at schools.

5.3.2 Interview item 2: What problems did you encounter in solving the word problems in the test?

Solving multiplicative word problems is regarded as difficult when compared to the other operations such as addition, subtraction, etc. Learners are expected to monitor their thinking and how they apply learned strategies, such as the concept of '*ratio*' (see 2.2.2.14). In responding to the problems learners encountered in solving the word problem, they articulated in extract 5.2 that they did not know what to do when task 7 talks about Nelson Mandela Charity having "*twice as much as*" Thandolwethu. Other responses were, "*dividing R99 360 twice by two; divide the amount by two because there were two groups and then double Nelson Mandela's Charity as well as divide it by two, divide it again and take one half and add it to Nelson's Charity*".

Extract 5.2

L2: My problem was in 2.4 when they said, “Nelson Charity got as twice as much as Thandolwethu, I didn’t know how to do the sum, I had to go to the scribbler and search for the correct answer and the sum”.

R: So, I don’t get your problem, what was your problem? Is it that you didn’t work it out on the paper or you didn’t know how to work it out?

L2: I didn’t know the sum to work out.

L8: We divided.

R: You divided, what did you divide?

L3 (Learner3): We divided R99 360 twice, by two.

R: By two? Why by two? Yes...

L1 (Learner 1): I divided into two because they are two groups and then I take the answer that I divided and then I divided into one again and then I doubled Nelson’s Charity.

*R: **Twice as much as this one.** But if you divide it by two now they are going to be equal.*

L7 (Learner 7): Into two again, so that that half you can add it into the other one.

Learners in this instance showed the lack of exposure to conceptual ideas requiring a full range of arithmetic skill as compared to exposure to algorithm only because they did not know whether to multiply or divide in this given ratio word problems (see 2.2.2.9). Quite a number of learners did not know how to solve the word problem, a majority of learners divided by two, and less than half of the learners divided by two and divided again. It could also be that some learners experienced organisational deficiencies, which were characterised by learners who had difficulty in selecting and using the appropriate strategy to get solutions. Hence such learners only mastered one particular strategy such as division in particular and then would apply it to all problems even when the strategy is not called for (see 2.2.2.10). Almost three quarters of the learners rushed into solving the word problems without carefully reading and understanding what was required of the word problem (see 2.2.2.6). One could not negate the possibility of teachers’ inadequate (or lack of) explanations of the complex words in the word problem that could help the learners understand as well as the procedures to be carried out (see 2.2.2.6). Sepeng and Madzorera (2014) attribute the lack of mediating the understanding of unfamiliar words in mathematical word problems by teachers as emanating from the culture of the classroom. Furthermore, the lack of mediation also affected the learners’ previous mathematical experience, with more focus on memorisation of steps in solving word problems.

More than half the number of learners had difficulty to transform the problem text to form a mental model or a cognitive representation of the problem corresponding to the problem elements and

their relationships when working out the word problem such as the *area of a 2 D shape* in TI 5. They could not use concrete external representations such as pictures to facilitate the process of constructing the solution. Learners continuously explore ineffectual paths when solving word problems, even if they may not lead toward a solution (see 2.2.2.1).

A few of the learners who were unsuccessful in solving word problems tended to focus on the surface features of the problems, where the use of the “keyword”, for example, “times” did not cue the operation of multiplication. Hence, it was difficult for the learners to transfer their learning to a wide range of structurally similar problems (see 2.2.2.10) such as in TI 7 (question 2.4), where the question said: *Nelson’s Charity got as twice as much as Thandolwethu*. In this case the question needed a teacher- mediated instruction that would explain that the word “times” implies multiplication. However, division that made use of *ratio* concept is the correct operation to solve the particular word problem correctly. Learners’ errors on mathematical word problems such as in test item 2.4 were mainly owing to problem misrepresentation of identifying the correct operation that they needed to use; that is regardless of the computational knowledge and computational skill applied thereafter (see 2.2.2.14). Sepeng and Sigola (2013) (see 2.2.2.8) argue that most learners commit errors because of lack of strategies to a solution, whereby they apply rules without understanding the basic concepts in solving word problems, as opposed to being weak.

5.3.3 Interview item 3: What influenced you to solve the word problems the way you did when you took the test?

Similar to a study conducted by Zhang *et al.* (2011), learners seem to lack multiplicative reasoning which is one of the factors that influence learners to apply the (in)correct strategy when they solve word problems. As much as 50% of the learners better interpreted the word problem-solving, enhancing better understanding by obtaining more than 34% in the post-test which was a pass. I was also noted that the other 50% of the learners failed the test. Hence, such indicated that with more time on modelling the multiplicative word problems, learners would show great improvement (see Table 5-34). As such, learners stated that what influenced them to solve the TIs the way they did, as per extract 5.3, *was just doing it for the sake of the teacher to mark; just to finish and submit; did not know the correct answers as well as did not understand what the question required them to do*. As a result, learners seemed to lack understanding of the concepts asked.

Extract 5.3

*R: But **what made you to keep on writing wrong answers even when you knew that eish, this question, I don't know, it's wrong.** What made you to carry on writing them? That's the question.*

L3: So that the teacher can mark, that the teacher should mark your script.

R: So you are doing it for the teacher to mark? Okay.

L8: I must do it for the time, the time your period is over, I must be through with the test, I will be finished with the question paper.

*R: Finished with the question paper? **But when the answers were wrong, why did you write these wrong answers? What made you to write these wrong answers?** Yes.*

L9 (Learner 9): What made me to write these answers is that I wanted to finish.

R: You wanted to just finish, in short to say, I have answered every page?

L1: I answered and I did not get the questions right because time was not enough.

R: There was not enough time?

During the intervention period, learners were encouraged to ask questions where they could not understand or had missed certain aspects of the taught concepts (lessons). Very few of the learners asked any questions. Literature states that learners' attitudes towards Mathematics, time spent on homework, learners' anxiety, cognitive ability as well as reading ability were highlighted as other factors that registered as posing positive and negative effects on learners' Mathematics achievement (see 2.3.4).

5.3.4 Interview item 4: What problem-solving techniques did you use every time when you struggled to solve word problems correctly?

Learners explained the solving strategies they applied in solving their tasks (see 2.2.2.8). In solving the test tasks, learners left some questions unanswered; skipped the questions; they worked out answers in their scribbles. Other learners re-read the questions for better understanding as well as asked for assistance and clarity from the teacher for better understanding (see extract 5.4). As earlier mentioned, this was a pre-intervention interview, hence, nothing much was done by the researcher in teaching the learners with regard to these word problems; they could only refer to their past learning experiences.

Extract 5.4

L10 (Learner 10): I wrote the wrong answers because I didn't know the right answers and even when I try I was scared to ask.

R: Okay, you had to write, because you had to write the answers and you were scared to ask.

L3: I was not understanding.

R: You did not understand? But you still wrote it even though you did not understand.

L2: I was writing the wrong answers because in my head I felt that it was the right answers.

L2: I skipped to the other question.

L5: (Learner 5): I will go to the scribbler and then I will do, through that number I will have to read well and then I will tell the teacher that this question I don't understand, and the teacher then explain it to you?

Possibilities that often make learners to just write wrong answers, claim that they did not understand, are somehow related to lack of language comprehension strategies that would effectively improve in solving of word problems (see 2.2.2.10) & 2.3.4. Another possible reason that makes learners apply wrong "rote" algorithms that eventually increase the low academic performances in Mathematics is the use of previously learned knowledge and strategies regardless of whether the problems are similar or not to what they learned (see 2.2.2.10).

5.3.5 Interview item 5: What do you think you need to do as learners in order to solve word problems successfully?

Learners need to, amongst other things, plan a strategy, comprehend the text, retrieve some of the answers from memory in order to solve problems successfully (see 2.2.2.2). Learners realised that for them to be successful in solving word problems, they needed to listen carefully during teaching and learning; be given homework; ask someone at home or the teacher if they did not understand as well as get extra Mathematics classes/remedial as per extract 5.5.

Extract 5.5

L5: You need to listen carefully.

R: What, when?

L5: When a teacher teaches you how to solve a problem.

R: You need to listen carefully when the teacher solves a problem. Yes.

L8: You need to focus in class and every day when you get home you have to study.

R: When you get home you have to study, yes.

L6: You have to ask if you don't understand.

R: Okay!

L4: You will have to listen carefully and focus in the class then if you don't understand after school you must go to the teacher that teaches you maths and you have to ask him about word problems.

R: Okay

L5: When the teacher gives you word problems you have to focus and test yourself that did you get it or not.

R: Did you?

L5: Did you get it or not?

R: Did you get it or not, okay.

L7: You must focus.

L8: You will have to get in the extra classes of Maths.

L3: You will have to practise and you will have to ask somebody at home.

R: Okay, you have to ask somebody at home. Do you still have some more to say?

L7: You have to study at home.

During the intervention, learners were requested to finish off work that was not finished in class and also given homework on some days. About a quarter of the class of learners could not finish the work and a few could not even do the homework. Because of time constraints, the researcher would go over the corrections and then moved on to that day's work. It was observed during teaching and learning that just below half the class could not listen attentively. Now and then, these learners were asked to keep quiet. The inattentiveness was also observed during my first visits when I was introduced to the learners and working on the ethical issues such as issuing and collecting the consent letters for the learners and parents. In short, learners confirmed that they really needed to focus, study, do homework, as well as ask someone to help where needed, in order for a better performance gain in their word problem solving.

5.3.6 Interview item 6: What suggestions can you make to your teacher in terms of the use of context for setting and teaching word problem items?

Learners' response to this question on the use of context for setting and teaching word problems was combined with interview question 7 below on language difficulty, hence see the discussion below interview question 7.

5.3.7 Interview item 7: What suggestions do you make to your teacher in terms of language difficulty as they set and teach word problem items?

Learners' responses to interview items 6 and 7 were given interchangeably at the same time slot (see extract 5.8). Factors of English language in Mathematics classroom were better argued by Sepeng (2010) (see 2.3.5.1). Learners in this study felt that the Mathematics teachers teaching word problem-solving should explain in English and code-switch to the learners' home-language, which was Setswana in this particular instance.

Learners claimed that some of their classmates did not understand English language. Simple English should also be used in explaining the questions, whether written in books or other sources. Learners felt that several teachers struggled to pronounce and explain some words in the textbooks that are used in the classrooms. Hence, they suggested that Mathematics dictionaries should be used to enhance better understanding of concepts. Learners further raised the importance of notes given by the teacher and suggested that all learners should copy those notes and examples and read the notes.

Extract 5.6

L2: Yes Mam. If he teaches Maths, and he teaches you English. There are some other learners that do not understand English well. The teachers need to explain the same things in Setswana again.

R: So you want the teachers to code switch to teach in English and then change to the mother language? So that's what he says, let's hear what the others are saying. What can you say to the teachers, what should they do?

L4: They must explain to you in simple English that you can understand but not the books' English because sometimes they do not understand the English that is written in the books.

R: So the teacher must simplify in a language that you can understand?

L4: In an easy way.

R: In an easy way. Yes, what else can the teachers do?

L1: The teachers might have to explain to the learners in English and after that they must explain in Setswana because the other learners do not know English properly.

R: Okay, but Setswana is not in the question paper, only English is here.

L6: They have to translate.

R: Try to simplify it?

All: Yes Mam.

L5: Mam, sometimes there are difficult words in the book even teachers cannot pronounce them well or explain them well but you have to look them in the dictionary to know those words.

R: Okay. So, in short here, together, you and the teachers need to identify these words that you don't understand?

L7: We as learners, for the words that we don't understand, we need to buy maths dictionaries so that we can understand the words.

L8: When the teachers write the notes, you don't have to close the books, you have to open the books, you have to read the notes, do the examples and you have to do your classwork for your own.

L1: You need to read it and understand it.

Solving word problems require the learners to know mathematics language; it requires learners to “be able to read words and also to interpret grammatical constructions representing mathematical relations (such as twice the size of), even if they are more unusual in colloquial language” (see 2.3.6). If learners are not helped, they develop an attitude to hate Mathematics if they do not come right with the pragmatics of the mathematics language (see 2.3.6). For this reason, I had to mediate learners’ understanding, and model how to solve word problems/questions correctly. However, there are underlying factors that could cause learners not to perform as they have been taught, such as past experiences, maternal education, household income, quality of schools and teachers, lower expectations for minority learners, educational policies, and leadership (see 2.2.1.1; 2.2.1.3; 2.2.2.10 & 2.3.3).

5.4 Qualitative results: The intervention (video and learners’ exercise books)

The Language of Learning and Teaching in this school was English. Hence, during the intervention, all lessons were conducted in English as per the School Policy. There were a number of multiplicative word problems such as ‘*Ratio; Financial Context (Budgets); Financial Context (discounts); Financial Context (interest and loans); simplifying fractions*’ (see 2.2.2.14), that were taught and learned during the intervention period (see Table 5-15). However, the following tables give more insight into what happened during the teaching and learning of six lessons in six videos that were captured or recorded for this study in the two academic terms which comprised the duration of the intervention. The following themes or units of observation emerged from the analysis: mathematical argumentation and mathematical discussion. The argumentations and discussions were carried out using three levels before the intervention (using AWFs), during the intervention as well as post-intervention in the experimental group (see Tables 5-16 & 5-17).

In another study conducted by Livingstone (2012:3), the use of a new resource (ICT) was said ***to have brought about evidence of improvement in the learners' achievement as compared*** to not using it in the educational outcomes of the curriculum. The focus of the mentioned study was on British schools. Other resources mentioned to have been used were interactive whiteboards and educational computer games. It was further reported in Livingstone's study that in an analysis done by the Programme for International Student Assessment (PISA) survey found that learners who sometimes used computers or the Internet at school performed better than those who never used them. In this study, learners' exercise books were used as supporting resources to further identify the effect and nature of the intervention (if any) impacting on the learners' academic performances. Table 5-15 below gives an outline of the concepts taught during the video recordings, stating the dates as well as the word problem questions.

5.4.1 Video recorded lessons during the intervention period

Table 5-15: Video concepts recorded

Video	Date	Concept	Problem-solving Question(s)
1	10 February 2017	Rate	(i) Autumn started and over a period of four hours, 120 leaves fell from a tree. At this rate, how many leaves fell in one hour? (ii) Zaheeda scored nine goals in five netball matches. At this rate, about how many goals did she score in each game? (iii) Climbing up a mountain, Richard ascended 120 metres every hour. At this rate, how many metres will he ascend in four hours? (Grade 7 Mathematics in English Book 1 Term 1 & 2: p.17). (iv) Cape Town is 1 200 kilometres from Johannesburg. A taxi takes 15 hours to make the trip. - How fast does it travel? - How fast is it supposed to travel to get back in 10 hours?
2	17 February 2017	Financial contexts; profit and loss	(i) You are buying sweets for 45c each and selling them for 65c each. I made a profit/ loss of ___ (amount) per sweet. (ii) You are buying pencils for R2, 00 and selling them for R2, 40 each to your friends. You managed to sell 40 pencils. I made a profit of ___ (amount).
3	03 May 2017	Solving problems with fractions, mixed and whole numbers	(iii) You have a dozen eggs. (iv) You give $\frac{1}{3}$ of the eggs to your neighbour. You keep $\frac{2}{3}$ for yourself. How many eggs do you have? (v) You use $\frac{3}{4}$ of the $\frac{2}{3}$ of the eggs to make chocolate cakes. (vi) What fraction of a dozen eggs will you use for the cakes? (vii) How many eggs will you use? (viii) How many eggs will you have left over?
4	10 May 2017	Percentages	(ix) Bucket X is 80 % full of juice and has a capacity of 250 litres. Bucket Y is 72 % full and has a capacity of 300 litres. Which bucket has more juice?

			(x) Katlego did a survey on hair colour. These were his findings. In a group of 60 people he found that 12 people had black hair, 15 people had brown hair, 21 people had ginger hair and the rest had green hair. (xi) How many people had green hair? (xii) Calculate the percentage of the people for each hair colour.
5	24 May 2017	Multiplication of Decimals	(xiii) Mr Jacobs the fisherman calculated the price he would receive for one crate of fish. The crate contained 49,005 kg of fish. He charged the restaurant R12, 50 per kilogram. Calculate how much he received for his fish. (no.6) (xiv) Mr Scullard needed 2, 36 m of fabric to make one suit. How much fabric did he need to make 15 suits? (no.7)
6	07 June 2017	Geometry: Area (2Ds)	(xv) Mpho can fit 3 tables along the long side of his room and 2 tables along the short side. Kelebogile has a longer room. She can fit 2 more tables along the long side of her room. How many tables can Kelebogile put to fill in the whole room?

5.4.2 Video data observation schedule

Table 5-16 and 5-17 below demonstrate the visual observation schedules outlined for the six lessons recorded for the units of observation *discussion* and *argumentation*. The schedules also indicate the theoretical notions underpinned by Vygotsky. The numbers 1 to 6 in Tables 5-16 and 5-17 below denote the actual number of video shots that were captured during the intervention period. The ticks in the blocks mean that that concept actually took place during that period of intervention under the indicated video shot.

Table 5-16: Observation schedule of the video data – (Discussion) (Bowman, 1994; Doolittle, 1997; Howe & Abedin, 2013; Miller, 2011)

DISCUSSION						
	Pre-intervention	During Intervention			Post-intervention	
	1	2	3	4	5	6
1. Zone of Proximal Development (ZPD)						
• Teacher modelling-	√	√	√	√	√	√
• Learners becoming knowledgeable			√	√	√	√
• Learners' competency in word-problem solving abilities					√	√
2. Mediation						
• Making claims		√	√	√	√	√
• Construction of ideas (learners)		√	√	√	√	√
• Learn to argue (using AWFs)				√	√	√
3. Social interaction						
• Learners' utterances (talk)		√	√	√	√	√
• Learners engaging with teacher		√	√	√	√	√
• Engage with peers (learners)				√	√	√

Table 5-17: Observation schedule of the video data – (argumentation) (Bowman, 1994; Doolittle, 1997; Howe & Abedin, 2013; Miller, 2011)

ARGUMENTATION						
	Pre-intervention	During Intervention			Post-intervention	
	1	2	3	4	5	6
4. Zone of Proximal Development (ZPD)						
• Teacher modelling-	√	√	√	√	√	√
• Learners becoming knowledgeable			√	√	√	√
• learners' competency in word-problem solving abilities					√	√
5. Mediation						
• Making claims		√	√	√	√	√
• Construction of ideas (learners)		√	√	√	√	√
• Learn to argue (using AWFs)				√	√	√
6. Social interaction						
• Learners' utterances (talk)	√	√	√	√	√	√
• Learners engaging with teacher	√	√	√	√	√	√
• Engage with peers (learners)			√	√	√	

5.4.3 Video data analysis

Table 5-18 below illustrates a detailed descriptive analysis of the visual observation. The table narrates how learners solved word problems under the units of observation (discussion and argumentation) tracked through pre-, during and post-intervention.

Table 5-18 intends giving answers to the following research questions:

2. ***In relation to the literature and theory, what was implemented across series of lessons?***
3. ***How did learners' talk in argumentation change across the implemented lessons?***
4. ***What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post - intervention lessons?***

Table 5-18: Narrative description/ interpretation/ discussion based on the observation schedule - (discussion and argumentation)

During the intervention period, I taught word problem solving once, and sometimes twice, in a week in the two schools. I extended the same concepts (multiplicative) that the subject teacher taught as outlined in section 5.4, paragraph 1 as well as in Table 5-15. The six lessons recorded in Table 5-15 outlined the units of observation *discussion* and *argumentation*. The AWFs were used to mediate the learning during intervention. In analysing the progression of how the learners responded to the treatment necessitated that I include all three stages (pre- during and post-intervention so that a complete picture would be projected. I started teaching the concepts without an obvious inclusion of the AWFs. However, in the way I was probing the learners to talk, engage in the discussions and argumentations, I used the AWFs to help them start and stem their talk. I observed and noted down the way learners were responding to the intervention. Recorded in the table below is what unfolded during the intervention period.

A. DISCUSSION	Pre-Intervention	During Intervention	Post-Intervention
1. Zone of Proximal Development (ZPD) - Teacher modelling - Learners becoming knowledgeable - learners' competency in word-problem solving abilities	Learners had difficulty in understanding mathematical contents and concepts that were inherited in the English language (LoLT) (see 2.3.3). This made learners to have difficulties in responding and expressing themselves freely to say what they wanted to say in engaging in the discussions, in the LoLT. That implied learners' lack of exposure to comprehension strategies to effectively improve in solving of word problems (see 2.3.4). The zone of proximal development was used in response to a suggestion of the need for an explicated instructional scaffolding practices (see 2.3.4). Hence the teacher had to model through ZPD on how to respond to questions asked and let the learners attempt responding.	The teacher modelled understanding of the word problems through discussion as learners' manifested difficulties embedded in the concept usage. The teacher would read the question with the learners and ask them what information was given as well as what information was needed to be found. After the discussions of what the word problem gives as information and what needed to be done, learners started becoming knowledgeable. The word problems 'provided' a context through which learners practice the algorithms and apply the formulas (see 2.2.1.2).	During teacher modelling, learners used AWFs as starters or stems, hence they participated in the discussions of how to understand the given text, (such as in video 6). Vygotsky's analytic tool of language was brought about by dialogue that was internalised by the learners to bear action that made thoughts and speeches (see 3.4.3). In this instance, learners became more knowledgeable in understanding the language in the text and hence they discussed their answers with the teacher and amongst themselves in their groups of fours. In video 5, learners were participating more as they were engaged in the

	The syntax and vocabulary were the point of difficulty for learners in understanding the text of the word problems. This made the learners' progress and process of becoming knowledgeable slow (see 2.2.2.5). Learners' abilities in solving word problems (see 2.2.2) was a problem as calculation tasks were embedded in text. Another difficulty was creating mental representations which was an ongoing process (see 2.2.2.1), by applying reasoning processes (Lemke <i>et al.</i>, 2004). Word problem solving abilities needed learners to use more meaningful strategies to solve those type of mathematical word problems, which they lacked then (see 2.2).	The learners' competency in word-problem solving abilities was slowly utilising cognitive effort to overcome the gap between the current reasoning abilities that were mentioned before mental processes (Kennewell, 2001; Woolfolk, 2007).	discussions in their groups even in the absence of the teacher. In displaying understanding in the nature of the problems, learners were able to plan a method or strategy and executed the plan (see 2.2.2.6). This implies that learners were overcoming the lack of understanding of the mathematical concept involved (see 2.2.2.6). As learners became competent in word-problem solving abilities, they were able to explain how a multiplication computation is carried out as an example (See 2.2.2.7).
2. Mediation • Making claims • Construction of ideas (learners) • Learn to argue (using AWFs)	The lack of comprehension in the word problem text within the learners which led to confusion, hence they were not able to make claims of their answers (see 2.2.2.6). It was the natural language and mathematical language that posed problems for learners' successful learning of Mathematics, in their construction of ideas (see 2.3.3). Hence the teacher mediated by using AWFs for better understanding.	Learners' difficulties emanating from unfamiliar vocabulary or computational abilities (see 2.2.2.5) improved as learners started to make claims of their solutions, mediated by the teacher.	Learners used the AWFs as a language mediator to enable them express themselves better in making their claims of solutions during teaching and learning. They were able to frame their talks. Learners showed more reasoning skills and logic in their construction on ideas as they were justifying their computations in video 5, on the concept of Area on the question based on Kelebogile's room (see Table 5-1). Learners explained with ease the 5 tables "... we added $3 + 2 = 5$, because the question says, they were 2

	The teacher used the AWFs to mediate the understanding of the text which was presented in English language. This helps learners to identify the missing information from the question, made a plan and solved the word problems to get the solutions (2.2.2.1).		<i>more on the long side when compared to Mpho's room...</i>" Learners were able to remember the formula for area, substituted correctly and eventually gave the correct answers: (5 tables x 2 = 10 tables).
3. Social interaction - Learners' utterances (talk) - Learners engaging with teacher - Engage with peers (learners)	There was less <i>talk</i> as far as the lesson discussions were concerned. Learners were not raising up their hands to respond to questions to give solutions of the word problems. They were not interacting with the teacher. Instead, they used the time to talk to their group members/ peers other than to discuss the work given. The interaction was characterised by delays in groups to start on the work assigned to them.	Learners started to socially interact with the teacher and their groups' members. In their utterances, it was implied that aspects of attention, memory and language were developed as learners uttered their solutions (see 2.2.2.2). Learners were fascinated and distracted by the video in the classroom.	Learners started to <i>talk</i> more during the discussions of the questions. They were fluently interacting with each other in their small groups as well as when the whole answer was outlined on the chalkboard as a class.
B. ARGUMENTATION	Pre-Intervention	During Intervention	Post-Intervention
1. Zone of Proximal Development (ZPD) - Teacher modelling - Learners becoming knowledgeable - learners' competency in word-problem solving abilities	Learners could not place numbers correctly when subtracting to find profit for number i.e. 45c - 65c, instead of the other way around (video 2). The teacher as a more knowledgeable person in the ZPD had to model (see 2.2.2.13) the correct arrangement of numbers.	The ZPD was necessary for the learners to learn or be reminded of how, <i>fractions are multiplied by a whole number</i> as they were still not able to give correct solutions, assisted by the teacher (see 4.7.1).	Learners displayed elements of competency in word-problem solving. In video 5 (area), learners were seen reading the problems on their own in their groups of 3 or 4, without much push from the teacher who was facilitating the groups.

		The teacher modelled solving word problems based on concepts such as the meaning of whole numbers, fractions and percentages in helping learners in becoming knowledgeable (see 2.2.2.4).	They were actually using their hands to model a room with so many desks, argued, discussed, re-read the question in a more relaxed mood. Most learners demonstrated improved word problem solving abilities in computing basic facts, completing all the necessary steps in questions asked (see 2.2.2.2).
2. Mediation • Making claims • Construction of ideas (learners) • Learn to argue (using AWFs)	Learners missed the essence and art needed from them to make a claim, provide suitable evidence to justify it and logically defend it until a meaningful decision. Learners lacked communication and the academic language and syntax which are required in the in constructing ideas and the art of argumentation (see 2.4.4).	Learners started to use language in re-wording of the word problems in making claims of the answers and constructing their ideas (see 2.2.2.2). The AWFs comprised of language was aiding in the argumentation process, by also offering a counterclaim on evidence provided and interacted with their peers using academic (mathematical) language. Learners also argued well to say in 80/100 x 250 litres, we multiply 80 by 250 because in multiplication of fractions, you multiply the numerator by numerator and the denominator by denominator.	Finally learners were able to read a question, and use the argumentative frames to find out information based on the word problem questions. Learners were able to use the AWFs in framing their argumentation such as, <i>The problem gives the following information...; the problem requires me to find...; I already know that.....so that/ because...; the steps/ strategy I took in solving this problem were...; etc.</i> Language frames provide an effective scaffold for bridging the divide between teacher modelling and group discussion" (see 3.4.3).
3. Social interaction • Learners' utterances (talk) • Learners engaging with teacher	The low level of fluency hindered learners to engage effectively in mathematical activities in the	The teacher mediated argumentation with the use of the AWFs. The language offered augmentative communication, oral speech that was	Most of the learners were actively involved in the cognitive thinking process and reasoning in making their answers realised in the process. In video 6 (Area),

Engage with peers (learners)	classrooms within the social interaction space (see 2.3.3).	used by learners to express ideas, thoughts and feelings (see 2.3.3) during social interaction. Through interactions, learners started to produce words, constructions of ideas and solutions to word problems.	the actual concept was not given to learners, but they were asked to think what the topic/ concept was... (see 2.2.1.1) When asked why they answered that way, they responded by saying “...it talks about sides; (long and short), which shows it is a rectangle and covering the room with tables...” This demonstrates the Vygotskian social-cultural constructivist view of learning as an effective social interacting process between learners and teachers where learners had to be active in constructing their own knowledge, accomplished with the help of a more knowledgeable peer, tutor or teacher (see 3.3.2).
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The discussion below responds to research question 2: ***In relation to the literature and theory, what was implemented across series of lessons?***

In relation to the literature, issues of English language as a LoLT and its influence on the learning of teaching of word problem-solving were given more insight of how it went about. The mathematics language issues, which covered learners' problem-solving abilities, applying correct procedure, understanding mathematical concepts as well as sense-making in word problem-solving were explained. In relation to theory, as mentioned earlier that the study is underpinned by Vygotsky's constructivism theory, notions that were developed as theoretical lenses were drawn from the constructivism theory, namely ZPD, mediation and social interactions. Across the series of lessons, the notions mentioned were discussed under discussions and argumentations which were the two vehicles for *talk* (dialogue) during the intervention.

In answering question 3: ***How did learners' talk in argumentation change across the implemented lessons?***

The learners' talk during the period of the intervention was reported as it developed from pre-intervention, during intervention as well as post-intervention. Talk amongst learners was facilitated through discussions and argumentations. Learners before the intervention started were not fully participating during teaching and learning. Hence, they did not respond to questions asked. As the intervention progressed learners started to participate during discussions that were conducted by the researcher in class. The use of AWFs helped learners to frame their talk on what they wanted to say.

Research question 4: ***What was the nature of the learners' performance and argumentation in relation to multiplicative word problems in post - intervention lessons?***

AWFs as a language mediator enabled them to express themselves better in making their claims of solutions during teaching and learning. They started to use language in re-wording of the word problems given in making sense of what was written. In this way, learners created some internal representations of networks of ideas. Through argumentations conducted, learners eventually were able to justify their claims.

5.5 Quantitative results: Post-test

The post-test, which was exactly the same as the pre-test, was administered by the researcher to the comparison and experimental groups in order to establish if there was any change in the dependant variable(s) conditions (see 4.6.1). The post-test results were compared to the pre-test results on how learners solved multiplicative word problems (problem-solving abilities). In essence, the post-test as compared to the post-test results sought to help the researcher to measure the effectiveness of using the AWFs as an intervention tool in multiplicative word problem-solving. The following tables present the data on learners' responses to each of the seven test items. The coding that was used for the post-test was similar to the one used for the pre-test, with major themes situationally and mathematically orientated. The post-test responses were analysed in comparison with the pre-test responses in mind.

5.5.1 Sense-making in word problem-solving: Post-test

This section discusses the first three test items on issues of sense-making when the comparison group and the experimental group learners solved word problems in the post-test, using the SA, SI and SPC codes.

5.5.1.1 Item 1.1 post-test results

Table 5-19 below shows that learners in both the comparison (88.57%) and the experimental groups (95.24%) still produced high responses of situationally inappropriate responses for item 1, with the experimental group worse by 6.67%. This was lower than the responses in the pre-test. Learners in both groups who obtained SA responses in the post-test slightly improved by (5.71%) and (2.38%) respectively as compared to the pre-test. Learners still displayed difficulties in taking reality into consideration when solving item 1.

Table 5-19: Post-test results of item 1.1 of both comparison and experimental groups

Tabulation of Item 1.1 (Comparison post-)				Tabulation of Item 1.1 (Experimental post-)			
Item 1.1	Freq.	Percent	Cum.	Item 1.1	Freq.	Percent	Cum.
SA	4	11.43	11.43	SA	2	4.76	4.76
SI	31	88.57	100.00	SI	40	95.24	100.00
Total	35	100.00		Total	42	100.00	

5.5.1.2 Item 1.2 post-test results

The data in Table 5-20 below indicate that learners improved inferentially for the comparison group (SA=51.43%) and for the experimental group (54.74%), as compared to the pre-test at 14.29% and 19.05% respectively. Situationally incorrect responses dropped for both groups, the comparison group from 71.43% to 45.71% and the experimental group from 80.95% to 40.48%. In fact, learners demonstrated some abilities of sense-making in the post-test results with the improvements recorded with the experimental group showing better improvement. However, the experimental group produced more responses that were situationally accurate than the comparison group by 3.33%. Furthermore, the experimental group had a smaller percentage of learners who gave situationally incorrect responses as compared to the comparison group. This shows a better performance of the experimental group over the comparison group. The attempt of the experimental group learners to give correct responses was further noted when their SPC responses were greater than the comparison group by 1.9%. For item 1.2, the intervention favoured the experimental group in the abilities of sense-making in the situational context.

Table 5-20: Post-test results of item 1.2 of both comparison and experimental groups

Tabulation of Item 1.2 (Comparison post-)				Tabulation of Item 1.2 (Experimental post-)			
Item 1.2	Freq.	Percent	Cum.	Item 1.2	Freq.	Percent	Cum.
SA	18	51.43	51.43	SA	23	54.76	54.76
SI	16	45.71	97.14	SI	17	40.48	95.24
SPC	1	2.86	100.00	SPC	2	4.76	100.00
Total	35	100.00		Total	42	100.00	

5.5.1.3 Item 1.3 post-test results

The data presented in Table 5-21 below indicate the responses of learners who still struggled with taking reality into consideration, with the experimental group obtaining slightly lower than the comparison group by 2.38% for situationally inappropriate responses. We also noticed that the experimental group obtained 2.38% of the situationally accurate responses more than the comparison group, which did not obtain any responses of learners with situationally appropriate responses. The data results imply that the intervention favoured the experimental group over the comparison group.

Table 5-21: Post-test results of item 1.3 of both comparison and experimental groups

Tabulation of Item 1.3 (Comparison post-)				Tabulation of Item 1.3 (Experimental post-)			
Item 1.3	Freq.	Percent	Cum.	Item 1.3	Freq.	Percent	Cum.
SI	5	14.29	14.29	SA	1	2.38	2.38
SPC	30	85.71	100.00	SI	7	16.67	19.05
	35	100.00		SPC	34	80.95	100.00
Total	5	14.29	14.29	Total	42	100.00	

5.5.2 Mathematical suitability of performances: Pre- & Post-test; Overall performances with figures: Pre- and post-test of each group

In this section, the frequencies and percentages were used in the tabulation format. The SPSS Wilcoxon Signed Test Statistics Strata using the Mann-Whitney t-test was used, which is a non-parametric test to compare the two sets of test scores if there was any difference in the performance of the learners as far as word problem-solving was concerned. Two samples of the learners' tests were matched or paired with each pre-test having a corresponding post-test for the same learners' tests. This test also projects the minimum, maximum as well as the mean and median of the scores.

5.5.2.1 Performance of the comparison and experimental groups

Tables 5-22 and 5-23 display the results analysis of the comparison group and the experimental group that were analysed using the Wilcoxon Strata statistical technique. The results were presented in tabular formats. Summary statistics, as stratified by study group, are given as minimum, maximum, mean, and median. Tables 5-22 and 5-23 below (representing the results of both the comparison group and experimental group) presents the summary statistics for both pre- and post-testing results.

I notice that the comparison group had a pre-test minimum mark of three marks out of 40, which increased to six marks in the post-test. The experimental group had a minimum mark of zero increasing to four marks in the post-test. Moreover, the minimum marks increased from 17 to 31 marks and 16 to 32 marks respectively.

It can be seen that the experimental group had higher post-total scores than the Comparison group (Experimental groups' median = 15.50 versus Comparison group's median = 13.00). The distributions of the marks in the pre-testing conditions between the two study arms had equal medians of eight. The data in Tables 5-22 and 5-23 indicate the experimental group obtained a higher post-mean of 16.78571 over the comparison group that obtained a post-mean of 14.91429. The results suggest that the intervention seemed to have favoured the experimental group in the performance of the two groups.

Table 5-22: Comparison group's overall performance of the pre-and post-test scores

Variable	Min	Max	Mean	Median
pre-item 1.1	1	3	2.857143	3
pre-item 1.2	0	2	0.9142857	1
pre-item 1.3	0	2	1.857143	2
pre-item 2.1	0	5	1.771429	1
pre-item 2.2	0	6	1.228571	0
pre-item 2.3	0	2	0.3142857	0
pre-item 2.4	0	0	0	0
PRE- TOTAL	3	17	8.942857	8
post-item 1.1	0	3	2.8	3
post-item 1.2	0	2	1.371429	2
post-item1.3	0	2	1.714286	3
post-item 2.1	0	5	3.085714	2
post-item 2.2	0	6	2.114286	2
post-item 2.3	0	8	2.371429	1
post-item 2.4	0	8	1.457143	1
POST- TOTAL	6	34	14.91429	13

Table 5-23: Experimental group's overall performance of the pre-and post-test scores

Variable	Min	Max	Mean	Median
pre-item 1.1	0	3	2.595238	3
pre-item 1.2	0	2	1.261905	2
pre-item 1.3	0	2	1.809524	2
pre-item 2.1	0	5	1.952381	2
pre-item 2.2	0	5	0.5238095	0
pre-item 2.3	0	1	0.2380952	0
pre-item 2.4	0	1	0.0238095	0
PRE- TOTAL	0	16	8.404762	8
post-item 1.1	0	3	2.761905	3
post-item 1.2	0	2	1.166667	1
post-item1.3	0	2	1.714286	2
post-item 2.1	0	5	2.47619	1
post-item 2.2	0	8	2.52381	2.5
post-item 2.3	0	9	2.47619	1
post-item 2.4	0	9	3.47619	2.5
POST- TOTAL	4	32	16.78571	15.5

5.5.2.2 Comparisons of the comparison group and the experimental group's pre- and post-test performances

The Wilcoxon signed rank sum test and the non-parametric version of a paired samples t-test, were used to compare the pairs of data sets from the same learners which were the pre-test and the post-test within the same group (see 4.7.3). The results were declared statistically significant of any p -value that was found to be less than 0.05. The Comparison group's pre-and post-tests results within each group are discussed below:

(s) Comparison group: pre- and post-test results

Table 5-24 indicates that test items 1.1 through 1.3 had no statistically significant differences between the pre-test and the post-test as the p values were 0.9642; 0.0510 and 0.4631 respectively. That implies that learners in the comparison group performed the same way in these three test items. However, there were statistically significant differences between the pre- and post-testing conditions for items 2.1 through 2.4 with p -values of 0.004; 0.0198; 0.001 and 0.001 respectively. The statistically significant difference between the pre-total and the post-tests total had a p -value of 0.001 as well as 0.0198, in favour of the post-total. The higher scores were observed in the post-testing conditions. The results analysis showed that the comparison group performed better in the post-test in test items 2.1, 2.2, 2.3 and 2.4, and in the overall performance.

Table 5-24: Comparisons of pre- and post-test results within the comparison group

Study Group	Pre-Test	Post-Test	Z-score	p -value	Comment
Comparison	Item 1.1	Item 1.1	0.0450	0.9642	insignificant difference
	Item 1.2	Item 1.2	-1.9520	0.0510	insignificant difference
	Item 1.3	Item 1.3	0.7340	0.4631	insignificant difference
	Item 2.1	Item 2.1	-3.5600	0.0004 ^a	favoured post-test condition
	Item 2.2	Item 2.2	-2.3300	0.0198 ^a	favoured post-test condition
	Item 2.3	Item 2.3	-4.0420	0.0001 ^a	favoured post-test condition
	Item 2.4	Item 2.4	-4.5870	<0.0001 ^a	favoured post-test condition
	Pre-Total	Post-Total	-4.7000	<0.0001 ^a	favoured post-test condition

^a Statistically significant at 5%-error level ($p < 0.05$)

(t) Experimental group pre- and post-test results

I note that similar observations were made within the experimental group, as presented by Table 5-25 below, since no statistically significant differences were observed for test items 1.1 through 2.1 as their p values were 0.5002; 0.5606; 0.3300 and 0.3233, respectively. However statistically significant differences were observed between pre- and post-testing conditions for items 2.2 to 2.4 at p values (0.0001) in all three items. The p value of the pre-total and the post-total was (0.0001), with the highest scores or marks being in the post-testing condition. Therefore, this results analysis showed that the experimental group demonstrated mathematical solving abilities in the post-test to solve the multiplicative word problems for tasks 2.2, 2.3 and 2.4. In the overall performance, there was a statistically significant difference of 0.001, showing that there was improved performance. Every statistically significant difference between the pre- test and the post-test was denoted by (^a). This meant that the p value was equal to or less than 0.05. The performance of the experimental group in items 2.2, 2.3, 2.4 and the overall performance imply that the intervention had a positive influence on the group in favour of the post-test.

Table 5-25: Comparisons of pre- and post-test results within the experimental group

Study Group	Pre-Test	Post-Test	Z-score	p-value	Comment
Experimental	Item 1.1	Item 1.1	-0.6740	0.5002	insignificant difference
	Item 1.2	Item 1.2	0.5820	0.5606	insignificant difference
	Item 1.3	Item 1.3	0.9740	0.3300	insignificant difference
	Item 2.1	Item 2.1	-0.9880	0.3233	insignificant difference
	Item 2.2	Item 2.2	-4.4970	<0.0001 ^a	favoured post-test condition
	Item 2.3	Item 2.3	-4.3170	<0.0001 ^a	favoured post-test condition
	Item 2.4	Item 2.4	-5.2290	<0.0001 ^a	favoured post-test condition
	Pre-Total	Post-Total	-5.3180	<0.0001 ^a	favoured post-test condition

^a Statistically significant at 5%-error level ($p < 0.05$)

5.5.3 Sense-making and using the mathematical tools to solve multiplicative word problems: Post-test

In comparing the variables within a group, the Pearson's Chi-square test of association was used to determine whether there was an association between the categorical variables which are the pre-tests and the post-tests within each group.

This statistical test uses contingency tables known as cross-tables or crosstabs or two-way tables, where data are classified according to rows and columns. The association was declared statistically significant for any p-value of less than 0.05.

5.5.3.1 Comparison group

(u) Item 1.1 post-test results

I observe from Table 5-26 below that situationally, learners' SA responses increased, showing that they were using their sense-making abilities to view wor(l)d reality from two responses (33.33%) to four responses (66.67%). Situationally, SI learners' 31 responses (48.44%) were comparatively lower to their 33 pre-test responses (51.56%). Evidently, this shows that learners were regressing in their ability to solve problems. Therefore, the results show that there was no association between the sense-making and the mathematical abilities to solve the word problems.

Table 5-26: Post-test results of item 1.1 of comparison group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.1	Post-test	Pre-test	Total	Item 1.1	Post-test	Pre-test	Total
SA	4	2	6	IR	2	1	3
	66.67	33.33	100.00		66.67	33.33	100.00
SI	31	33	64	MA	11	9	20
	48.44	51.56	100.00		48.44	51.56	100.00
				PC	2	1	3
					66.67	33.33	100.00
Total	35	35	70	Total	35	35	70
	50.00	50.00	100.00		50.00	50.00	100.00
$\chi^2 (1) = 0.7292$		Pr= 0.393		$\chi^2 (2) = 0.7292$		Pr = 0.694	

I further observe from Table 5-26 above that the Pearson's Chi-square of (1) = 0.7292, p -value (0.393) was bigger than the p -value of 0.05. Hence, there was no inferential difference between pre- and post-tests ($p = 0.393$). Therefore, the proportions of respondents in the levels of Item 1.1 were not significantly different in the pre- and post-testing. Mathematically, the Pearson's Chi-square (2) = 0.7292 ($p = 0.694$) showed no statistically significant difference between the pre-test and the post-test for the comparison group.

(v) Item 1.2 post-test results

Table 5-27 shows that there was a slight increase in SA responses in the post-test with a frequency of 18 (78.26%) when compared to the pre-test 5 (21.74%). Furthermore, there was also a slight increase in the MA 11 (55.00%) as compared to its pre-test 9 (45.00%). With the SI decreasing from 25 (60.98%) to 16 (39.02%) and the IR responses also decreasing from 12 (60.00%) to 8 (40.00%), a bit of association is viewed. These results imply that there was a marginal relationship between the sense-making and problem-solving abilities in this task.

Table 5-27: Post-test results of item 1.2 of comparison group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.2	Post-test	Pre-test	Total	Item 1.2	Post-test	Pre-test	Total
NONE	0	2	2	IR	8	12	20
	0.00	100.00	100.00		40.00	60.00	100.00
SA	18	5	23	MA	11	9	20
	78.26	21.74	100.00		55.00	45.00	100.00
SI	16	25	41	NR	1	2	3
	39.02	60.98	100.00		33.33	66.67	100.00
SPC	1	3	4	PC	15	12	27
	25.00	75.00	100.00		55.56	44.00	100.00
Total	35	35	70	Total	35	35	70
	50.00	50.00	100.00		50.00	50.00	100.00
$\chi^2 (3) = 12.3234$		Pr = 0.06		$\chi^2 (3) = 1.6667$		Pr = 0.644	

Comparing the situational appropriateness within the comparison pre- and post-test results from Table 5-27 above, ($p=0.006$) implies that there was a statistically significant difference between pre- and post-tests ($p = 0.006$). The proportions of respondents in the levels of Item 1.2 had a situationally statistically significant difference in the pre- and post-testing. In problem solving abilities, statistically, there was no significant difference between pre- and post-tests ($p = 0.644$).

(w) Item 1.3 post-test results

The comparison group results in Table 5-28 show that learners regressed in the ability to make sense; SPC decreased from 33 (52.38%) to 30 (47.62%) and SI increased from 2 (28.57%) to 5 (71.43%). They also regressed in their MA responses from 30 (50.85%) to 29 (49.15%). This implies that somehow there was a similar pattern of association between situational and mathematical considerations in this task as they both decreased in their performances.

Table 5-28: Post-test results of item 1.3 of comparison group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.3	Post-test	Pre-test	Total	Item 1.3	Post-test	Pre-test	Total
SI	5	2	7	IR	3	2	5
	71.43	28.57	100.00		60.00	40.00	100.00
SPC	30	33	70	MA	29	30	59
	47.62	52.38	100.00		49.15	50.85	100.00
				PC	3	3	6
					50.00	50.00	100.00
Total	35	35	70	Total	35	35	70
	50.00	50.00	100.00		50.00	50.00	100.00
$\chi^2 (1) = 1.4286$		Pr = 0.232		$\chi^2 (2) = 0.2169$		Pr = 0.897	

Situationally, within the group there was no statistically significant difference between pre- and post-tests ($p = 0.232$). Therefore, the proportions of respondents in the levels of Item 3 were not inferentially different in the pre- and post-testing. Mathematically, there was no statistically significant difference between pre- and post-tests ($p = 0.897$).

5.5.3.2 Experimental group

(x) Item 1.1 post-test results

The results analysis for the experimental group is shown in Table 5-29 below. I notice that there was a slight improvement on learners who obtained situationally incorrect response when learners' responses dropped from 41 (50.62%) to 40 (49.38%) and increased situationally accurate from 1 (33.33%) to 2 (66.67%) compared within the group. On the contrary, mathematically, they experienced a MA decrease from 34 (50.75%) to 33 (49.25%). However, the experimental group increased their partially correct responses from 5 (38.46%) to 8 (61.54%) and the incorrect responses decreased from 3 (75.00%) to 1 (25.00%).

This shows some relationship in the sense that when learners started to use realistic consideration abilities even the performance increased in the MA and PC. The data seemed to imply that the intervention had some influence on the experimental group learners' abilities to take real life into consideration as well as on the abilities of word-problem solving in test item 1.1.

Table 5-29: Post-test results of item 1.1 of experimental group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.1	Post-test	Pre-test	Total	Item 1.1	Post-test	Pre-test	Total
SA	2	1	3	IR	1	3	4
	66.67	33.33	100.00		25.00	75.00	100.00
SI	40	41	81	MA	33	34	67
	49.38	50.62	100.00		49.25	50.75	100.00
				PC	8	5	13
					61.54	38.46	100.00
Total	42	42	84	Total	42	42	84
	50.00	50.00	100.00		50.00	50.00	100.00
$\chi^2 (1) = 0.3457$		Pr = 0.557		$\chi^2 (2) = 1.7072$		Pr = 0.426	

Situationally, within the group, there was no statistically significant difference between pre- and post-tests ($p = 0.557$). Mathematically, there was no statistically significant difference between pre- and post-tests ($p = 0.426$). Therefore, the proportions of respondents in the levels of Item 1.1 were not inferentially different in the pre- and post-testing.

(y) Item 1.2 post-test results

Table 5-30 shows that the experimental group drastically increased SA responses from 8 (25.81%) to 23 (74.19%) comparatively speaking, SPC from 0 (00.00%) to 2 (100.00%) and decreased the SI from 34 (66.67%) to 17 (33.33%). Evidently, there was also an improvement in their problem-solving abilities, MA increased from 12 (41.38%) to 17 (58.62%), and there was a marginal decrease in the IR from 14 (51.85%) to 13 (48.15%). Therefore, these results depict that the more learners gained sense-making abilities, the more their problem-solving abilities improved. It seemed the intervention had a great influence in improving the learners' performance on issues of sense-making abilities and abilities to solve word problems.

Table 5-30: Post-test results of item 1.2 of experimental group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.2	Post-test	Pre-test	Total	Item 1.2	Post-test	Pre-test	Total
SA	74.19	25.81	100.00	IR	13	14	27
	17	34	51		48.15	51.85	100.00
SI	33.33	66.67	100.00	MA	17	12	29
	2	0	2		58.62	41.38	100.00
SPC	100.00	0.00	100.00	PC	12	16	28
	42	42	84		42.86	57.14	100.00
Total	50.00	50.00	100.00	Total	42	42	84
	74.19	25.81	100.00		50.00	50.00	100.00
$\chi^2 (1) = 14.9247$		Pr = 0.001		$\chi^2 (2) = 1.4705$		Pr = 0.479	

Within the group, Table 5-30 above indicates that situationally, there was a statistically significant difference between pre- and post-tests ($p=0.001$) in favour of the post-test. Therefore, considering the proportions of respondents in the levels of item 1.2, situationally there was a statistically significant difference in the pre- and post-testing. This implies that the sense-making abilities were greatly improved during the intervention. Mathematically, there was no statistically significant difference between pre- and post-tests ($p = 0.479$). The sense-making abilities in the experimental group seemed to imply that the intervention had an influence on the group in item 1.2.

(z) Item 1.3 post-test results

The experimental group in test item 1.3 experienced some regression in the learners' responses SI, 2 (22.22%) in the pre-test to 7 (77.78%) in the post-test; SPC from 40 (54.05%) to 34 (45.95%) respectively, with only 0 (00.00%) to 1 (100.00%) increase in the SA as shown in Table 5-31 below. Mathematically, learners' problem-solving abilities regressed from 38 (53.52%) to 33 (46.48%); their IR did not change at 3 (50.00%) before and after. However, their PC increased from 1 (14.29%) to 6 (85.71%). The results indicated that there was an association in the decrease of sense-making and a decrease in problem-solving in this task. The major increase in the partially correct responses of the learners implies some kind of influence made by the intervention on the experimental group.

Table 5-31: Post-test results of item 1.3 of experimental group: Sense-making and using the mathematical tools

Testing				Testing			
Item 1.3	Post-test	Pre-test	Total	Item 1.3	Post-test	Pre-test	Total
SA	1	0	1	IR	3	3	6
	100.00	0.00	100.00		50.00	50.00	100.00
SI	7	2	9	MA	33	38	71
	77.78	22.22	100.00		46.48	53.52	100.00
SPC	34	40	74	PC	6	1	7
	45.95	54.05	100.00		85.71	14.29	100.00
Total	42	42	84	Total	42	42	84
	50.00	50.00	100.00		50.00	50.00	100.00
$\chi^2 (1) = 4.2643$		Pr = 0.119		$\chi^2 (2) = 3.9235$		Pr = 0.141	

Table 5-31 above shows that, situationally, there was no statistically significant difference between pre- and post-tests ($p = 0.119$). The results show that there was no statistically significant difference between pre- and post-tests ($p = 0.141$). The learners' responses imply that the intervention could not produce statistically significant change in the learners' performances on this item; this was probably due to its small sample.

5.5.4 Statistical comparison between the comparison and experimental groups

A Wilcoxon signed-ranked test was used to determine the variables (items 1.1 – 2.4) and to compare the paired set of scores from the same learners in the pre- and post-tests of the two groups per each test item to see if there was any statistically significant difference between them. Furthermore, a two-sample Wilcoxon rank-sum (Mann-Whitney) test was used to determine the performance relationships between the two groups (comparison and experimental) based on the pre-test and the post-test.

As noted in Table 5-32 below, the results emanated from the analysis on the performance of the learners in their respective groups both in the pre- and post-tests. Each item was compared between the two groups both in the pre-test and in the post-test to determine the group performance against each other. The results depict that in the pre-test on the left hand side, there was no statistically significant difference between the performance of the learners in the comparison group and experimental group in items 1.1, 1.2, 1.3, 2.1, 2.3 and 2.4, as all the p-values were ($p \geq 0.05$), $p=0.2065$; 0.0787 ; 0.8978 ; 0.5567 ; 0.5909 and 0.3613 respectively.

But for item 5, the p value was 0.0138, implying that, there was a statistically significant difference in the pre-test performance in favour of the comparison group. This means that the performance of the experimental group was a bit lower than the comparison group in this item. The Wilcoxon rank-sum pre-total by group was recorded at $p=0.8210$. Therefore, this depicts that overall, there was no statistically significant difference between the experimental group and the comparison group. This meant that the overall performance of the experimental group in the pre-tests was not different from the performance of the comparison group in the pre-test.

I noted that on the right-hand side that the post-test results are shown, a similar pattern to the pre-test performances for test items 1.3-2.3, $p=0.5982$; 0.3100; 0.7387; 0.1068; 0.5030 and 0.6537 respectively is revealed, as all these p-values were ($p \geq 0.05$). Evidently, this shows that there was no statistically significant difference between the performance of the experimental post-test items and the comparison post-test performance in the six items. However, I note that in item 2.4, the p value was 0.0100 in favour of the experimental group. This depicts that the experimental group had a higher performance than the comparison group in item 2.4. The rank-sum post-total by group recorded the $p= 0.2960$. Statistically, this implies that in the post-test results, the performance of the experimental group was improved to match the performance of the comparison group.

Table 5-32: Statistical comparison of the comparison and experimental groups: Pre- and post-test

Test Item	Pre-test	Post-test
	Comparison vs. Experimental	Comparison vs. Experimental
1.1	Prob = 0.2065	Prob = 0.5982
1.2	Prob = 0.0787	Prob = 0.3100
1.3	Prob = 0.8978	Prob = 0.7387
2.1	Prob = 0.5567	Prob = 0.1068
2.2	Prob = 0.0138	Prob = 0.5030
2.3	Prob = 0.5909	Prob = 0.6537
2.4	Prob = 0.3613	Prob = 0.0100
Grand-Totals:	Prob = 0.8210	Prob = 0.2960

Subsequently, one can conclude firstly, that the experimental group performed better in item 2.2 as the group in the pre-test performed lower than the comparison group and similarly, in the post-test, their performance was not different. Secondly, the experimental group performed higher again in item 2.4 than the comparison group in the post-test.

In the pre-test for item 2.4, there was no statistically significant difference in the performances of the two groups, yet in the post-test, there was a statistically significant difference as the experimental group performed significantly better than the comparison group. This means that the intervention might have had a positive influence on the experimental group for item 2.2 and item 2.4 the small sample might have had some influence on the seemingly marginal influence of the intervention.

5.5.5 Overall summary of the learners' performance in the pre- and post-tests for the comparison group (as required by the Department of Basic Education)

Table 5-33 shows the performance of the comparison group on the pre-test results and post-test results. In this analysis, we compared the comparison's group pre-test results and the post-test results. From Table 5-33 on the left-hand side, 91% (32) of the learners obtained marks in the range 0-15. This range constitutes levels (1-2) in the South African protocol assessment system. A learner who obtains these levels is deemed to have failed and so may not progress to the next grade. The results also indicate that 9% (3) of the learners obtained 16 out of a total of 40 marks. This means that only 9% (3) of the learners obtained level 3 or higher (3-7). Accordingly, learners who obtained these levels are deemed to have passed and are eligible to progress to the next grade (DBE, 2011).

Analysis of the post-test for the comparison group on the right-hand side of Table 5-33 shows that 66% (23) of the learners obtained level 1-2 and 34% (12) obtained levels 3-7. The results of the post-test indicate that 34% of the learners passed the post-test. All in all, the results indicate that the number of learners who obtained levels 3-7 increased by 25% from 9% in the pre-test to 34% in the post-test.

Table 5-33: Overall performance of the comparison group

Comparison Group			
Pre-test		Post-test	
0-15 marks out of 40 (0-39%) Level 1-2	16 marks upwards (40-100%) Level 3 -7	(0-15) marks out of 40	(16 upwards) marks
91%	9%	66%	34%
32	3	23	12

5.5.6 Overall summary of the learners' performance in the pre- and post-tests for the experimental group (as required by the Department of Basic Education)

Table 5-34 below shows the performance of the experimental group on the pre-test results and post-test results. On the left-hand side, the table shows that 98% (41) of the learners obtained marks in the range 0-15 constituting levels (1-2). Therefore, the results imply that the learners had failed and so may not progress to the next grade. The results also indicate that only 2% (1) of the learners obtained 16 out of a total of 40 marks. This means that only 2% (1) of the learners obtained level 3 or higher (3-7). The results depict that only this one learner who obtained in this range passed and was eligible to progress to the next grade.

The post-test analysis for the experimental group on the right-hand side of Table 5-34 shows that 50% (21) of the learners obtained level 1-2 and another 50% (21) obtained levels 3-7. The results of the post-test indicate that half (50%) of the class passed the post-test. Overall, the results indicate that the number of learners who obtained levels 3-7 increased inferentially by 48% from 2% in the pre-test to 50% in the post-test. The data presented seemed to suggest that the intervention had a great influence on the performance of the experimental group in favour of the post-test results.

Table 5-34: Overall performance of the experimental group

Experimental Group			
Pre-test		Post-test	
(0-39) marks	(40-100) marks	(0-39) marks	(40-100) marks
0-15 marks out of 40	16 marks upwards		
98%	2%	50%	50%

5.5.7 Summative analysis focusing on Tables 5-33 (comparison group) and 5-34 (experimental group)

We notice that in the pre-test there were more learners (98%) in the experimental group who obtained levels 1-2 than in the comparison group (91%). However, we notice that there was a higher increase in the number of learners who obtained level 3-7 in the experimental group (48%) than in the comparison group (25%) in the post-test. This shows that both groups experienced increase in the number of learners who obtained level 3-7, with the higher increase in the experimental group by 23%. Evidently so, the results imply that the intervention had a positive influence on the experimental group.

5.5.8 Conclusions drawn from the comparison and experimental groups' results

Table 5-35 below shows the summary of the discussed statistical and inferential results of the experimental group and the comparison group with their discovered conclusions that were based on the outcome of the results. The summary displays the summaries where the two groups were compared in their pre-test and post-test performances. Furthermore, each group's performances were compared within, focusing on the pre- and post-tests.

Table 5-35: Summary of the findings on the means of the comparison and the experimental groups based on the hypothesis used

Hypothesis	Finding(s) or conclusion (s)
7. Comparison of overall performance: mean of pre-comparison = mean of pre-experiment	- According to the Wilcoxon rank-sum (Mann-Whitney) test, the mean of the comparison group was 8.9428 and the mean of the Experimental group was 8.4047 as shown in Tables 5-22 and 5-23. This gave the difference between the mean of the comparison and the mean of the experimental group 0.5380, hence that placed the comparison group as better performing than the experimental group. - The experimental groups' median = 8 versus comparison group's median = 8.
8. Comparison of overall performance: mean of post-comparison = mean of post-experiment	- The mean of the comparison group was 14.9152 and the experimental group 16.78571 and the difference 1.8704, see Tables 5.21 a) and b). - The experimental group's median = 15.50 versus comparison group median = 13.00 and the difference was 2.50. - The experimental group had a higher mean and median after the intervention.
9. Statistical comparison: pre-test comparison = mean of pre-test experiment	In the pre-test of Table 5-32 on the left-hand side, there was no statistical significance between the performance of the learners in the comparison group and experimental group in items 1.1, 1.2, 1.3, 2.1, 2.3 and 2.4 as all the p-values were $p \geq 0.05$, $p = 0.2065$; 0.0787; 0.8978; 0.5567; 0.5909 and 0.3613 respectively. But for item 2.2, the p-value was 0.0138, implying that there was a statistically significant difference in the pre-test performance in favour of the comparison group.
10. Statistical comparison: 'post-test comparison = post-test experiment'	Since in the post-test performances for items 1.1 to 2.3, $p = 0.5982$; 0.3100; 0.7387; 0.1068; 0.5030 and 0.6537 respectively, all these p-values were $p \geq 0.05$, as shown in Table 5-32. This shows that there was no statistically significant difference between the performance of the comparison post-test items and the experimental post-test performance in the six items. In the post-test, as shown in Table 5-32, the rank-sum post-total by group recorded the $p = 0.2960$, in item 2.4, the p-value was 0.0100 which was in favour of the experimental group.

The quantitative data results presented above sought to respond to the research question below:

5.5.9 What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post - intervention lessons?

The findings of the quantitative data gave more insight into the learners' performance aspect in relation to multiplicative word problems in the post-intervention part of research question 4. In the post-intervention, the post-test mean of the comparison group (14.9152) was lower than that of the experimental group (16.78571). The medians were 13 and 15.50 respectively. The experimental group was favoured by the intervention of AWFs in this regard. Statistically, the post-test results depicted p-values that were $p \geq 0.05$ for items 1.1 -2.3 when comparing the comparison group to the experimental group. However, in item 2.4, there was a statistically significant difference where p-value was 0.0100, in favour of the experimental group.

5.6 Qualitative findings: Experimental learners' post-intervention focus group interview

The post-intervention experimental learners' focus group interview was carried out with the same eleven learners who underwent the pre-intervention focus group interview. This focus group interview was carried out in order to explore the nature, effect and implications of the pedagogic practice of this study as well as learners' perceptions about the intervention. The interview guide consisted of six main question items, which had sub-questions related to the main question. The following is a report of the learners' responses as per the interview schedule items asked.

5.6.1 Interview item 1

- 11. How did you solve word problems before this innovation?*
- 12. What is the same in your approach to solving questions from the pre-test?*
- 13. What is different in your approach to solving the questions from the pre-test?*
- 14. How was it different from your previous approach?*

For learners to solve multiplicative word problems with decimal fractions in particular correctly, they needed to change their problem-solving strategies and their computational skills as well as their operation sign (Kishimoto, 2000). Learners had to consider reality and had the ability of sense-making for real wor(l)d problems (see 2.2.2.11; 2.2.2.13 & Sepeng & Webb, 2012: 5) Interview item 1 consisted of four closely related questions that sought to explore the learners' word problem-solving abilities and how or/and what was the same or different in solving tasks in the post-test when comparing it to the pre-test. Extract 5.7 entails the learners' responses.

For test item 2.3 on percentages, learners reported that they converted the percentages given into fractions and multiplied the converted fraction by the capacity for each container over 1, which

was a different response and problem-solving from the pre-test (extract 5.7). Learners had to understand concepts behind algorithms that underlie the mathematical concepts such as in the meaning of whole numbers, fractions and percentages as presented by this interview item (see 2.2.2.4).

Extract 5.7

R: Okay! That's what you did, let's hear from him.

L: I first converted the percentages into fractions

R: Yes

L: Then I multiplied

R: Okay! You converted the percentages to fractions

L: Yes

R: Let's take for container (A) what fraction did you get for container (A)? The percentage

L: 67% over 100

R: So, it's 67 over 100 and what did you do with that?

L: I multiplied by 25 litres over 1

R: You multiplied by 25 litres over 1?

L: Yes

R: Get the capacity of container (A)

L: (A)

R: And you do the same for container (B)?

L: Yes

R: Yes and then from there you got how much capacity was in each and then you compared which one had more. I think this later one this last one was the correct method of doing it. Okay!

In this multistep array kind of multiplicative word problem, learners had to formulate a plan and work out a procedure of how to get to the solution rather than simply applying an overlearned operation. Learners had to apply more than one operation to work out this task (see 2.2.2.14). I recognised when learners demonstrated understanding of the concept (percentages), hence they engaged the correct procedure in changing a percentage into a fraction. Learners also changed the strategy by using the correct computational operation (multiplication sign) to work out the answer (Kishimoto, 2000).

I could see that learners in the experimental group became independently proficient in becoming better problem-solvers after the researcher had scaffolded their learning with the use of AWFs

within the zone of proximal development during the intervention (see 3.4). Learners were seen to be socially interacting with the more knowledgeable peers and the teacher, in developing higher mental functions such problem-solving skills, reasoning as well as memory schemas (see 3.3.2). The improvement of the experimental group learners in the abilities to solve the word problems implied a positive influence of the intervention on the group.

5.6.2 Interview item 2

15. What problems did you encounter when you solved word problems in the test this time?

16. Did you encounter the same problems?

Extract 5.8 below gives an ideal answer for most learners on the problems encountered in the post-test and whether if they experienced the same problem as in the pre-test. Learners responded by saying that they did not experience problems because they had seen the questions before, so, it was easy for them this time. As discussed earlier that the post-test was the same as the pre-test (see 5.5), learners were correct to say they had seen such question before. However, the time that lapsed between the pre-and post-test could have made some learners to forget the questions asked.

Extract 5.8

R: Was it the same problems or the problems were less or they were more this time, did you encounter the same problems with the same questions? Let me start with you.

L: No. This one was better.

R: Oh! This one was better because now you've eh ... you said what the reason is why is it better?

L: Because we have met these questions ...

R: You've met these questions before... okay, yes.

L: This time, this time, it was easy.

R: Hmm!

L: Because these questions at the pre-test; they did not change.

R: Hmm!

L: We wrote the same thing and we started a focus group and we sorted out our problems with this question papers.

R: Okay! Let me ask then during the teaching. Between the pre-test and the post-test, did we learn something about these word problems in class?

L: Yes ma'am, we did.

It is noted that learners' responses to the post-test questions showed improvement on the performance as compared to their pre-test (see 5.5.5). Quite a number of them, 50% (21 learners) obtained levels 3-7, meaning that half the class passed the post-test by getting correct answers as compared to the initial 2% in the pre-test. About half the number of learners produced correct answers in the test, such as higher performances on the MA of test item 1.2 and 1.3 amongst other improved performances. In using the post-test that was the same as the pre-test, I meant to establish whether there was any change in the performance of the learners after I administered the intervention (see 4.6.1). It was noted from the learners' responses that, solving the word problems was easy in the post-test and their performance that there was some improvement. The use of AWFs as an intervention technique seemed to have had a positive influence in the learners' abilities in word problem-solving.

5.6.3 Interview item 3

17. What influenced you to solve the word problems in the actual test the way you did in the test now?

Learners were influenced by the knowledge and fact that they were solving these problems for the second time. Hence, they claimed it was easy. Most of the learners underscored that the use of AWFs helped them to solve the test items better this time around. Learners displayed that they had acquired problem-solving skills through the AWFs mediation by the teacher-researcher (see 3.4.3).

Extract 5.9

R: What influenced you to solve the word problems the way you did during the writing of the test now? In short what helped you ... What is it that you think was the reason that made you to solve the problems better this time around when you compare it with the pre-test? If you solved problems better this time, what made that possible? Yes, dear.

L: Because of ... we wrote this last time, so it makes us know the answer easily.

R: Okay! Yes dear.

L: The frames helped us.

R: The frames helped you?

L: Chorus: Yes

R: Okay! Yes, I am going to come back to that.

L: It was different because last time we had talked about this question papers so we learn from our mistakes.

R: You learnt from your mistakes? Yes dear.

L: Me, also the frames have helped me when I solved these problems.

R: Okay! So, Didintle said the frames also helped her to solve these problems this time around.

Learners claimed that the frames helped them. It was during discussions and argumentation within the intervention period when learners learnt about the argumentative writing frames (see 5.4.2). Learners used these AWFs as modifiers, starters, connectives to frame their *talk* during the discussions and argumentations (see 2.4.2). Learners' prior knowledge was activated by the use of the AWFs, hence they remembered the steps they used to calculate their answers in expressing the procedural understanding (see 2.4.3). The learners' understanding of their own world as they made meaning that was rooted in the socio-cultural contexts and social interaction embraced the communication during the intervention (see 3.3.1). Hence, learners felt that the frames helped them to solve the word problems in a better way than before the intervention. Some learners understood the conceptual underpinnings of word problem solving in Mathematics as they became better problem solvers (see 3.3.1). Through the use of AWFs, learners learned to talk. The more learners talked, the more they comprehended the word problems. Learners learnt to re-order their questions as they expressed their understanding of what was needed out of the questions. Hence their performance changed drastically, for the better. The intervention seemed to have had a great influence on bringing *talk* into this Grade 7 mathematics classroom. The intervention seemed to have brought about more understanding of the word problems to the experimental group as they interacted with the researcher/teacher during the scaffolding activity of word problem-solving through the AWFs.

5.6.4 Interview item 4

18. Were the strategies you used similar to or different from the ones you used when writing the test before?

19. How were they similar or different?

In responding to the strategies used, and whether they were similar or different in post-test items, learners stated that some of the strategies were similar and others were different. The change of the strategies in about half the class was evident in the increase shown in their performance in the post-test. Learners showed that by changing strategies in answering the questions, they implied that they comprehended the questions better (see 2.2.2.2).

The elaboration of how or which were similar or different was lacking, except for the issue of the birds in item 1.1. For the latter problem, in the pre-test, some learners subtracted and in the post-test one learner used his mind to reason that the rest of the birds flew away. Learners produced

responses that made sense for the strategies that they used, implying that they gave informed decisions based on their experiences as echoed by Xin *et al.*, (2005) (see 2.2.2.10), however, the situation asked, was problematically not mapped to any operation.

Extract 5.10

*R: My question 4. **Were the strategies you used similar to or different from the ones you used when you were writing the test before?** The methods that you used to solve the problems now or the strategies were they similar or different from the time that you solved the test during the pre-test? Let's hear from you!*

L: Some were similar.

R: Some were similar?

L: And some were not similar.

L: Last time I minus the number of the birds and this time I just used my mind.

R: Okay! He says, last time he just used the numbers; he subtracted the smaller one from the bigger one to get the answer and this time around he says he just used his mind so he used his common sense.

L: Sense

R: Okay! Can you share with us what was your answer this time around, what did you say?

L: I said because when you shoot one bird down.

R: Hmm...

L: Then the others will fly away.

R: Okay!

L: So, the answer is none of the birds are left.

For item 1.1, at least one learner indicated that he used his mind (common sense) to respond to the number of birds that were left after shooting down one, instead of subtracting which was done in the pre-test. The learner further argued that no birds were left as all the birds flew away (extract 5.10). Learners showed the ability to make sense of real wor(l)d problems (Sepeng & Webb, 2012) implying that they worked out their responses with reality in mind (see extract 5.10) (see 2.2.2.6; Sepeng & Webb, 2012). As mentioned earlier on (see 5.5.3.2) that the experimental group learners' response increased on matters of sense-making abilities, learners attested to that in their response in extract 5.10 above.

The lack of use of everyday-life knowledge as textual factors relating to the stereotypical nature of the most frequently used textbook problems seems to have a negative impact in the learners' educational experiences. However, the intervention seemed to have brought about some abilities

of taking real life into consideration when learners responded to the word problems during this intervention.

5.6.5 Interview item 5

20. *After your participation in the intervention, what do you think you need in order to succeed in solving word problems?*

In order for the learners to succeed in word-problem solving, they felt they or anyone needed to use the AWFs to enhance better understanding of word problems questions given in particular. Learners emphasised that when they answer questions, they need to frame their answers using the AWFs. More importantly, learners need to ask teachers when they do not understand. They need to use their scribblers, study at home as well as write neatly and clearly.

Extract 5.11

*R: Okay! So, now the question is based there; **after your participation in the intervention. What do you think one needs in order to be successful in word problems, in order for anyone to be successful or for you or for anyone to be successful?***

L: They need the argumentative frames so that they can be successful in word solving problems

R: So that they can succeed ... they can be successful in?

L: Word ...

R: Word solving problems?

L: Yes

R: Okay! So, you think we do need the ...

L: The frames.

R: The frames; what do you say?

L: They also need frames to work their word problem-solving, when the teacher is teaching; they need to use their frames. When you give them the paper/worksheet of word solving problem then they need to use their argumentative frame to get their answers correctly.

R: Okay! So, if they get some word problems they need to use the frames so that they understand the word problems better?

L: We must not sit around if you don't understand what the teacher is saying you must always ask.

R: Using you mind?

- L: And using a scribbler.*
- L: Concentration.*
- L: Writing neatly and eligible.*
- L: Writing homeworks always.*
- L: Given yourself time and studying.*

Learners demonstrated that they were active participants creating their own meaning of what was taught and as such they were engaged in the interaction processes grounded in the views of the participants (see 4.2.2). Learners implied that the use of AWFs effectively mediated the use of language embedded in the word problem texts and bring about supplementary tools in solving tasks (see 3.4.3 & 4.6.4.2). The AWFs provided leads, clues, cues and insights into the questions as well as 'prompts' for learners to communicate and enhanced learners' understanding of the word problems (see 2.4.1). I noticed that learners were able to make claims of their answers, that they further justified, framing their talk with AWFs (see 2.4.4). Learners were seen producing argumentation that was fostered by critical thinking and conceptual standing in which they had constructed as per their understanding and critique arguments (see 5.4.3). The intervention seemed that it had an influence on the learners' learning, thinking as well as performance, hence learners averred that it could be used by other learners and teachers in Mathematics classrooms.

5.6.6 Interview item 6

21. What suggestions can you make to the teachers in terms of:

- a. The context of the word problem questions?

In terms of the context of the word problem questions, learners said that teachers should set the scene by availing resources that learners can use and giving them notes to study at home. In addition, learners gave their understanding of how a wrong problem should look like; "words and numbers". This resonates with (García, Jiménez & Hess, 2006) who assert when describing a word problem as a function of semantic structure, that is change, combine, compare, and equalise.

Extract 5.12

*R: So now, **what suggestions can you make to the teachers in terms of A) the context of word problem questions?***

L: Teachers must make copies for their children to know if they do something in class

R: Hmm!

L: There will be a kid that did not understand and it's shy to ask a question.

R: Okay!

L: They should give the learners notes so that they can study at home.

L: We always expect numbers.

R: You always expect numbers should it be all numbers or words and numbers or ...?

L: Words and numbers.

L: When we solve the word problem-solving, they must always underline what is important and then you must work it out.

L: At word solving problems, we expect statements.

I noticed that learners were cognisant of the fact that word problems have significant background information of the problem which is presented as text rather than as mathematical notation (see 2.2.1.1 particularly Boonen *et al.* (2013). As learners read through the word problems, they realised that they needed to be competent in word problems calculation tasks as they carried descriptions and mathematical operations that are embedded in the word problems. All the above brought about the learners' suggestions for teachers to make copies for learners as well as their expectations of numbers more than words, as numbers are perceived to be easier and more straightforward for the learners. Hence, it seemed that the intervention brought about some realisation to the learners that, the teachers' scaffolding is needed somehow.

(aa) Language difficulty of the word problem questions?

In terms of the language difficulty, learners suggested that teachers should not always speak English because they (learners) claimed that they were not in that level of English, as echoed by language difficulties embedded in a study conducted by Sepeng (see 2.3.5.1).

Extract 5.13

*R: Maybe, let me ask this other question: **In terms of language difficulty of the word problem questions, what can you say about the language or the difficulty of the word problems?** The teacher gives you a word problem; what can you say about the difficulty in the language or anything?*

L: Teachers must not use English always because of ... some learners don't understand English.

R: So in short, in the word problems do you expect teachers to write in English and then also write in another language?

L: No ma'am

R: Okay! How then? Explain!

L: When they explain ...

R: Oh when they are explaining?

L: Yes ma'am.

L: We expect teachers not to write hard English because we didn't ... we are not in that level of that English.

*R: And maybe before I carry on to say what I want to say. Going back to the writing frames I know now that you don't have your exercise books with you, which is good. **Can you share with me some of the writing frames that you can still remember even if it's not the exact words, but what are the writing frames what were they all about?** Let's share them. You can pick any just say what you remember, one ...*

L: To get the answer I ...

L: This did not work; so...

R: This did not work. So...? Let's think of some more.

L: I use this method because ...

L: I think this is ... Because ...

L: This answer is...

L: The question requires me to find a ...problem

Learners' responses demonstrated speech and actions that had been internalised within Vygotsky's notion of social interaction (see 3.4.1 & 3.4.3). In this last extract (5.13), the teacher-researcher wanted to hear from learners as they claimed that the AWFs helped them to determine if they remembered frames that helped them. Learners were able to share a few of the frames. The governing body of the experimental group (school) decided on English language as the Language of Learning and Teaching, drawn up from the language policy which stipulates possibilities of the LoLT of schools (see 2.3.2).

Issues of the mother-tongue and English at the same time in enhancing learners' conceptual understanding in mathematics have been dealt with by a number of authors (see 3.3.3). Learners demonstrated some social interaction aspects as they displayed development of *verbal meaning* through the AWFs (see 3.4.2).

Essien (2018) (see 2.3.3) contends that in the teaching and learning of Mathematics, the use of multiple languages could be an ideal strategy to mediate teaching and learning and could enable learners to have access to Mathematics materials and questions in their home language and English simultaneously. Code-switching seemed ideal for the experimental group as its location was in a township, where learners came from diverse backgrounds, with some learners having innate language barriers (see 2.3.3, particularly Adler, 1998; Schäfer, 2010). As mentioned earlier, AWFs apply language; using them (AWFs) to let learners *talk* gave them confidence to express themselves in other avenues. It seems that the intervention had an influence on learners to talk about other views that concerned what could influence their learning and teaching which is the language of instruction in class. Language was perceived as the means by which learners learn to organise experiences and thoughts that shape learning through cognitive, affective as well as social issues (see 2.3.1, particularly DBE, 2010).

The above discussions sought to explore the following research objective:

5. To explore the implications for the pedagogic practice of these findings

After learners had been exposed to the use of AWFs, half the number of learners (50%) in the experimental group were able to better solve word problems. The comparison group which was not exposed to the AWFs had 34% of learners obtaining a pass mark of 40% as per the department of education requirement. They used correct operations and correct computations. This implies that learners better interpreted the word problem-solving, enhancing better understanding. Learners developed abilities of sense-making and awareness of realistic context in word problem-solving. As much as learners raised concerns of English language difficulties as a LoLT, they demonstrated better performance during discussions and argumentations when they started to voice their utterances. All the above-mentioned aspects seemed to point to the fact that pedagogical practice favoured the use of AWFs in the mathematical classrooms.

5.7 Summary of quantitative and qualitative results

Table 5-36: Summary of quantitative and qualitative results

	QUANTITATIVE	QUALITATIVE
Pre-test (Comparison and Experimental Groups): (problem-solving abilities)	- The distributions of the marks in the pre-testing conditions between the two study arms had equal medians of eight. - The comparison group had (mean= 8.9428) and the experimental group (mean= 8.4047). - The comparison group had a minimum mark of 3 and maximum 17 while the experimental group had a minimum of zero and a maximum of 16.	- There was no difference between the median performance of the comparison and the experimental groups. - Learners in the comparison group performed slightly higher mean difference (0.5380) as compared to the experimental group, as well as the minimum and maximum marks.
Post-test (Comparison and Experimental Groups): (problem-solving abilities)	- The experimental group had marginally higher post-total scores than the comparison group: (Experimental groups' median = 15.50 versus comparison group's median = 13.00) - The comparison had (mean=14.9142) and the Experimental (mean= 16.7857). - The comparison group had a minimum mark of 6 and maximum 34 while the experimental group had a minimum of 4 and a maximum of 32.	- The experimental group had marginally higher post-total scores than the comparison group, when the means and medians were compared. - The mean scores were higher in the experimental group by (1.8714).
Pre-test compared to post-test of each group: (Problem-solving abilities)	- The comparison group performed better in the post-test in tasks 2.1, 2.2, 2.4, and in the overall performance. The experimental group showed improved performance for tasks 2.2, 2.3 and 7 and in the overall performance. - Since the p-values were smaller than Alpha (0.05) this implied that there was a statistically significant difference in favour of the experimental group performance.	- There were statistically significant differences between the pre- and post-testing conditions for items 2.1 through 2.4 and totals. - There were statistically significant differences between the pre- and post-testing conditions for items 2.2 through 2.4 and totals.

Pre- and Post-tests Performances (Comparison group and Experimental group)	• In item 2.2, the comparison group (n=35) performed better than the experimental group with $p=0.0138$). However, in the post-test, $p=0.5030$ for both groups implied that there was no statistically significant difference between the performance of the comparison post-test items and the experimental post-test performance. It is evident from the fact that the experimental group performed better than the comparison group as it covered the gap of the statistically significant difference. • In task 7 (item 2.4), there was no difference in the problem-solving abilities of both the comparison and experimental groups in the pre-test ($p=0.3613$). However, after the post-test the p value was 0.0100 in favour of the experimental group, since Alpha (0.05) was higher when compared to the p-value of 0.0100	• The experimental group improved in the performance after the post-test. • The experimental group had a better performance compared to the comparison group.
Learners' Pre-intervention focus group interview		• Learners confessed that they did not know how to solve certain tasks. • They used given numbers to work out their solutions without thinking if it made sense. • They used wrong operations without thinking. • They wanted explanation to be done in their home Language (Setswana) as well.

Intervention (video, exercise books) (bb) Mathematical discussion (cc) Mathematical argumentation		• Learners started by a “shut down” during discussion. • They started engaging in dialogue and discussions in their groups and with the teacher as they engaged in solving the word problems. • They were seen boundary-crossing with the teacher; they explained how a task was solved to the class on the chalk board. • Teacher mediated teaching by using the AWFs. • Learners started framing their sentences using the AWFs. • Used AWFs when discussing and writing in the exercise books to understand the word problems and completing the frames.
Post-test (Problem-solving and sense-making)	• The Pearson's Chi-square test of association was used to determine whether there was an association between the categorical variables which are the pre-tests and the post-tests within each group. The comparison group, for test item 1.1 - 1.3 had p-values 0.393; 0.006 and 0.232) respectively, which implied that, there was no statistically significant difference between pre-post-tests. • The experimental group, for test items 1.1 – 1.3 obtained ($p=0.557$); ($p=0.001$) and ($p=0.119$) respectively. This showed that for item 1.2 there was a statistically significant difference between pre- and post-tests ($p=0.001$). This implies that the sense-making abilities were greatly improved during the intervention.	• Learners demonstrated sense-making in their responses to the task, such as “<i>no birds were left....they all flew away.</i>” • Correct operations and correct procedures were used. Even if the tasks were not 100% completed but they were more partially correct than incorrect. • However, learners forgot about what they were taught in class, because they got some concepts wrong in the post-test although they were taught in class by the teacher-researcher.

Learners' post-intervention focus group interview

- Learners could make their claims and justified their arguments of how they reached their answers.
- They reported that they changed their computations in the post-test in order to get correct or at least partially correct responses.
- Learners recommended amongst other things that teachers should use simple understandable language; learners should concentrate during teaching and learning, do their homework and ask where they did not understand.
- The use of AWFs in understanding and framing their answer during word problem-solving was emphasised by learners. They felt that any learner who wanted to succeed in solving word problems should have and use them (AWFs).

Below is a summary to respond to research objective 6: ***To understand the nature and impact of the intervention.***

The intervention where the AWFs were used to bring talk in the case of Grade 7 Mathematics classrooms during the study seemed to have brought about some benefits in the teaching of word problem-solving. The experimental group was favoured by the intervention when learners performed better than the comparison group in computational abilities (post-test, item 2.4). Learners in the experimental group developed attributes of talk in the classroom during discussions and argumentations. With the ZPD that was scaffolded by the researcher, learners used AWFs to frame their talk as well as to justify their claims.

5.8 Chapter summary

The results from the data analysis of the research instruments used in this study were generated from the pre-test and the post-test. These included learners' pre-intervention focus group (experimental); intervention (videos and exercise books); Post-test as well as the Learners' post-intervention focus group. The data were analysed and were subjected to SPSS software (Wilcoxon Signed Test and the Chi-Square) to produce the statistical results analysis of results captured from the pre-tests and the post-tests from both the comparison and the experimental group. The findings suggested that there were no statistically significant differences between the performances of the two groups either when their pre-test and post-test were compared across or within a group. However, the statistical descriptive results in comparing the pre-test for the two groups with their post-test results, a higher performance increase in the number of learners who passed in the level 3-7 range was recorded in the post-tests, in favour of the experimental group. Furthermore, analysis of results from the learners' pre and post-intervention focus group interviews implied that there was a great improvement in favour of the post-intervention interview.

After the intervention strategy, the experimental group's sense-making abilities appeared to improve. In actual fact, post-test data showed that learners displayed a tendency to consider reality of the situation in a problem statement when solving multiplicative word problems. Their problem-solving abilities and level of mathematical reasoning improved. It was also noted that there was improvement in aspects such as engagement in a dialogue, voicing a claim and justifying arguments. The learners also improved in expressions in the Language of Learning and Teaching (LoLT) which helped in the learners' *talk* in the Mathematics classroom, with the use of AWFs as an intervention mediating learning tool. As a result, aspects such as engagement in a dialogue (argumentation/discussion), putting a claim and justifying arguments and better/improved expressions in the LoLT seemed to benefit the learners' meaning-making abilities.

These results imply the effectiveness of the implementation of the AWFs strategy, which was used to mediate teaching and learning in the experimental group during the intervention, to a certain degree. In the next chapter, the results presented in this study will be discussed, giving an overview of both the qualitative and quantitative data while responding to the research questions and research aims as framed by both literature used in and theory underpinning this study.

CHAPTER 6:

DISCUSSION OF THE RESULTS

6.1 Introduction

Chapter five presented an in-depth analysis of the results that were attained from the quantitative and qualitative data presented with reference to the research aims and questions outlined in Chapter one of this study. This chapter presents findings coming from the discussion and interpretation in view of the aims and questions. Furthermore, the findings were presented descriptively and statistically in regard to the pre- and post-test, learners' focus group interviews, and intervention comprising document analysis (learners' exercise books) and video recordings as well as the use of AWFs. The context of theoretical underpinnings presented in Chapters two and three of this study was used to interrogate the data and analyse the results to come to findings in attempting to answer the research questions.

6.2 The Quantitative results

As discussed earlier, quantitative data were generated from the pre-test and the post-test of the comparison group as well as the experimental group. The data were analysed and were subjected to the SPSS® software (using the Wilcoxon Signed Test, the Mann-Whitney test and Wilcoxon rank-sum test and the Pearson Chi-Square Test) to produce the tabulated statistical results in Chapter five (see 4.7.3 & 5.5). Below is the discussion of the statistical results and the practical implications.

6.2.1 Pre- and post-tests

Bonotto (2013) and Sepeng (2013a) argue that the inclusion of word problem-solving in schools, amongst other reasons, is to probe, instil and practise the use of sense-making and word problem-solving abilities (see 2.2.2.1 & 2.2.2.13). The pre-test in particular was used to understand the nature of the learners' performances and problem-solving abilities better in relation to multiplicative word problems, in particular before and after the post-test and the sequence of intervention lessons. This was also a means of analysing and assessing the learners' abilities or inabilities to make sense of the word problem-solving and realistic considerations - or lack thereof. The post-test in particular helped the researcher to measure the influence of using the AWFs tool in a case of mathematical word problem-solving in a classroom of Grade 7 learners.

6.2.1.1 Sense-making and realistic considerations

Sense-making and realistic considerations were probed from learners in question 1 (items 1.1 - 1.3) of the test. The three items were said to be situational because in the learners' responses, the situational aspect of these responses to show realistic consideration was considered. However, most

learners had difficulties in displaying sense-making. The results for situational test item 1.1 suggest that both the comparison and experimental groups initially had almost the same abilities of sense-making, with each group obtaining situationally accurate responses (SA=33.33%). In the post-test, both groups obtained SA responses of 66.67%. When compared, the experimental group demonstrated the same abilities of sense-making as the comparison group. Statistically the p-value for item 1.1 for the comparison group was 0.393 and for the experimental group 0.557 when comparing each group's performance from pre-test and post-test.

This further denoted that the performance of the two groups was almost the same. In test item 1.2 in the sense that learners initially added all the numbers that were given in that task item, some multiplied in order to get the "*age of the farmer*"; this showed that learners did not take reality into consideration. Most learners showed constraints in the use of sense-making. Hence, the majority of them gave a numeric response instead of questioning if the response was a realistic response (see 2.2.2.11, particularly Verschaffel *et al.*, 2010). In test item 1.2, the results showed that the two groups performed almost the same in the pre-test. In contrast, in the post-test, the experimental group displayed better abilities of reality consideration. The comparison group obtained more learners' responses that were situationally incorrect (SI) by 5.69% as compared to the experimental group. Statistically, the p-value for the comparison group was 0.006 and the experimental p-value was 0.001. The results denoted progress in the learners' abilities of sense-making in favour of the post-test. It was noted as well that both the experimental group and the comparison group improved and performed better in item 1.2 in the post-test. For test item 1.3, situationally, the comparison group could not produce any learners' responses that were situationally accurate even in the post-test. The experimental group learners' responses on the other hand produced situationally accurate responses in the post-test which they did not have in the pre-test. This shows that the experimental group had a higher performance in the post-test. The experimental group was favoured by the intervention in sense-making. Significantly, the comparison group had $p = 0.0232$ while the experimental group had $p = 0.119$. The results denote that the groups' performances were similar even at the post-test level. The impact of the intervention seemed to be low and could not produce a significant difference in the experimental group.

6.2.1.2 Word problem-solving abilities

Question 2 (test items 2.1 - 2.4) displayed mathematical items, meaning that, the question items required learners to display their problem-solving abilities. In the pre-test, learners could not use the correct operations, or correct methods of computation. However, in the post-test, learners improved in their computational skills, with the experimental group giving better results. It was a case of word problem-solving task 2.2 (item 2.2): *Mrs Khunou's classroom; Length = 2 more desks (4 +2) = 6 desks; Length × breadth; learners had to compute '6 desks × 3 = 18 desks'* instead of the given response of "4+2+3=9 desks". A similar study was carried out by Van Dooren, Chen and Verschaffel (2011). In solving for a flask item, learners solved the problem wrongly by using a wrong operation such as an addition (3.5 cm + 20 cm) instead of a multiplication.

As discussed earlier, the learners' abilities to solve the word problems (multiplicative) were coded with, *Mathematically Accurate (MA)*, *Partially Correct (PC)*, *Incorrect Responses (IR)* and *No response (NR)* (see 5.2). It was noted that in the first test item (1.1) learners in the two groups started with basically high problem-solving abilities in the pre-test as they had their highest learners' responses in mathematically accurate (MA) responses with very low in partially correct and lowest in incorrect responses. However, the experimental group increased their partially correct responses from 5 (38.46%) to 8 (61.54%) and the incorrect responses decreased from 3 (75.00%) to 1 (25.00%). This showed an improved performance on the experimental group (see 5.5.3.2). In item 1.2 the experimental group obtained an increase in the MA responses from 12 (41.38%) in the pre-test to 17 (58.62%) in the post-test, implying better problem-solving abilities. The comparison group was sitting at 55.00% MA responses in item 1.2 in the post-test. In item task 1.3 both groups had MA as their lowest responses from learners, meaning that solving that word problem was a challenge. Interestingly though, the experimental group had a hike in their PC learners' responses, from 1 (14.29%) to 6 (85.71%) while the comparison group had a stagnant 50% in both the pre- and post-test.

In item 2.1, both groups showed that almost a third of each group lacked problem solving abilities as shown by their IR comparison=34.29% and experimental 23.81%. However, the rest of the responses showed that they had some knowledge but also lacked some problem-solving skills as they had responses obtained of more than 50% in both groups. In item 2.2, the comparison group lacked the abilities more than the experimental group as not a single response was MA, and the IR were more than 50%. The experimental group had about a third (26.19%) who could not get the accurate or at least partially correct responses. On the contrary, task 2.3 exposed both groups to lack skills of solving word problems; there was not a single MA response in both groups.

However, the experimental group solved task 2.3 better with 64.29% of learners' responses produced as compared to the comparison group's 25.71% in addition to 5.71% responses of the NR. The comparison group was much exposed in item 2.4, with IR responses 97.14% against the experimental group's 28.57%. Generally speaking, learners experienced more problems in the pre-test than in the post-test as shown above. However, using the statistical results discussions will map any improvements in cases where they were noted as evidence of any improvement that occurred.

6.2.1.3 The nature of the learners' performance (comparison vs. experimental)

The results analysed earlier indicated that in the pre-test, both the comparison and the experimental groups started with the same median of eight. In the post-test, the median for the comparison group was 13 and that of the experimental group was 15.5. Furthermore, the experimental group started with a mean of 8.4047 in the pre-test, while the comparison group started with a mean of 8.9428. In the post test, the mean of the comparison group was 14.9142 and that of the experimental group was 16.7857. This implies that the experimental group had a higher performance. Hence, it was evident that the intervention had a positive influence on the experimental group. It was noted that in the pre-test, the comparison group had a lowest mark of one out of 40 while the experimental started with a zero mark. The highest marks were 17 and 16 respectively. In the post-test, the lowest marks were six and four while the maximum marks were 34 and 32 respectively. This illustrates that the performance of the learners was quite low as the average was within levels 1-2 in the South African protocol assessment system. Levels 1-2 are equated to 0-39%. A learner who obtains these levels is deemed to have failed and therefore may not progress to the next grade. Levels 3 -7 are equated to 40-100% and learners in that range are deemed to have passed and may progress to the next grade. While both groups experienced an increase in the number of learners who increased their performance, the higher increase in the experimental group might be associated with the use of AWFs. This implies that the intervention might have had a positive influence on the experimental group. Learners who obtained these levels are deemed to have passed and are eligible to progress to the next grade (see 5.5.4 particularly DBE, 2011: 16).

As noted from the results analysis indicated earlier in the seven mathematically oriented tasks, the performance of the learners in solving the multiplicative word problems was not that much different between the comparison group and the experimental group. However, we noted that, in Table 5-32, in item 2.2, the comparison group performed better than the experimental group with a p-value of $p=0.0138$ as compared to the experimental group's $p=0.5030$. However, after the post-test, the experimental group had a higher performance as it managed to perform the same way as the comparison group that earlier had a significant difference from the experimental group's performance, making the results not to be different any more at $p(0.5030)$.

Secondly, in task 7 (item 2.4), there was no difference in the problem-solving abilities of both the comparison and experimental groups in the pre-test ($p=0.3613$). However, after the post-test results, the experimental group had a higher performance ($p=0.0100$) that implied that learners in the experimental group acquired better abilities of solving the multiplicative word problems better than the comparison group after the intervention. Therefore, these results imply that the intervention had an influence on the experimental group.

Table 5-24 indicated that the comparison group, when compared within, pre-test against the post-test, started on a better performance on items 2.1, 2.2, 2.3, and 2.4 with statistical significance $p \leq 0.05$. This made it a better performing group as compared to the experimental group (Table 5-25) that only obtained significant differences in only items 2.2, 2.3 and 2.4. After the AWFs intervention, the comparison group obtained ($p=0.0001$) and the experimental group obtained ($p=0.0001$). Overall, the experimental group showed a better improvement by performing the same as the comparison group after starting at a lower performance. As a result, there was a significant difference in both groups after the implementation of the AWFs intervention, more in favour of the experimental group.

6.3 The qualitative results

Qualitative data were collected through pre-intervention learners' focus group interviews and post-intervention learners' focus group interviews involving eleven learners from the experimental group. Another set of data was collected through videos and learners' exercise books during the intervention period with the experimental group.

6.3.1 Pre- and post-intervention learners' focus group interviews

As noted earlier, these focus group interviews were carried out with eleven learners from the experimental group to understand the learners' pre-test and post-test responses better as far as their word problem-solving abilities were concerned. The interviews were also conducted in order to investigate the nature of learners' problem-solving abilities and the reasons for their answering the test items the way they did. The post-intervention interview was meant to evaluate the nature, influence and implications of the pedagogic practice of this study as well as learners' perceptions about the intervention.

6.3.1.1 Learners' problem-solving abilities prior to intervention

Learners' responses for this interview for test item 1 depicted lack and suspension of sense-making and lacked the element of realistic consideration. In item 1.2 (extract 5.1), when learners had to give the age of the farmer, logic says the age of a person is not determined by any possession you have, such as livestock.

You cannot then get the age of a person by adding up the numbers, dividing them or multiplying the numbers given. The test item, *A farmer keeps 5 pigs, 25 cows and 130 goats. How old is he?* Learners' responses such as $130+25+5=160$ years; $130 \times 5 = 650$ years, etc., were not realistic answers in as far as the lifespan of a human being who happens to be a farmer could be. An ideal answer would be any number which could be suitable age for a grownup adult who would have accumulated money to buy and take care of the livestock as a farmer. A similar study was conducted by Greer (1997:293) in pursuit of teaching and learning of word problems used within the culture of Mathematics education in looking into the "suspension of sense-making", using the word problem *There are 125 sheep and 5 dogs in a flock. How old is the shepherd?* Another study was carried out by Frankenstein (2010), where the author used an illustration of pencils and the learners were asked to find out, how old they were (their ages) (see 2.2.2.3).

For test item 2.4 (extract 5.2), learners could not answer that question correctly on the basis of not knowing what to do or just using wrong algorithms to answer the question. Selecting and using the appropriate strategy (see 2.2.2.10) as well as not knowing whether to use multiplication or division in ratio (see 2.2.2.9) was a problem to learners. Learners could have not understood the question asked. Misunderstanding could have led to misinterpretation and hence resulted in lack of computational knowledge and computational skill (see 2.2.2.14).

For test item 2.1, *Tshego has 6 toy cars. Each car is missing a wheel. Tshego put his cars in a box. How many wheels are in the box?* Most learners managed to get the correct calculation: subtract 1 wheel from 4 wheels for each and multiply the 3 wheels by 6 cars to get 18 wheels. However, there were those who just multiplied 4 wheels by 6 cars to get 24 wheels without taking into cognizance of the fact that *each* car was missing a wheel. A very small percentage subtracted 1 wheel from the 24 wheels, missing out on the words *each car*.

In some instances, learners left blank spaces, skipping some of the questions (extract 5.4). The lack of mediation of unfamiliar words and strategies in most cases as argued by Sepeng and Madzorera (2014) (see 5.6) in this instance was evident. Difficulties experienced by learners in word problem-solving that lead to wrong answers do indeed aggravate the low academic performances in Mathematics.

6.3.1.2 Learners' problem-solving abilities post-intervention

Some learners' responses for test item 2.3, (see extract 5.7) showed that they remembered that converting 67% to a fraction is $67/100$. They also argued well to say in $67/100 \times 25$ litres, we multiply 67 by 25 litres because in multiplication of fractions, you multiply the numerator by numerator over denominator by denominator.

In this instance, learners demonstrated some memory schema, showing higher mental functions (see 3.3.2) as they applied more than one step and operation (see 2.2.2.14).

For extract 5.10, which was a question on the number of birds left when one was shot down, learners said they gave answers such as *none of the birds are left; fly away...* They argued that the sound will frighten the rest of the birds; hence, they will fly away, as compared to the pre-test where they just subtracted 1 from 5 to get 4 birds. In this instance, the learners' responses showed the ability to respond with reality in mind, making sense of real world (see 2.2.2.6 & 5.6). On the word problem test item 7, *A profit of R 99 360 was made at a music concert. It was later shared between the Nelson Mandela's Children Charity and Thandolwethu Crèche. If Nelson Mandela's Children Charity got twice as much as Thandolwethu Crèche, how much did each group receive?* Learners in this case realised that the question was on ratio. Hence, they managed to get the total of the two partitions $1+2=3$; *take each part, divide by 3 then multiply by the amount to be shared; R 99 360.*

After the use of AWFs intervention, more learners developed and applied correct problem-solving skills through social interaction. The scaffolding provided by teachers through the zone of proximal development enhanced learners to apply their abilities of solving questions with reality and sense-making. Learners applied reasoning skills as they interacted with their peers and the mediation of exercises by their teachers (see 2.2.2.14; 3.3.2 & 3.4).

6.3.1.3 Problem-solving strategies or techniques used by learners when solving word problems (pre- and post-intervention)

In the pre-test responses, learners admitted to have used the following strategies:

- *"I was writing the wrong answers because in my head I felt that it was the right answers."*
- *"I will go to the scribbler and then I will do, through that number."*
- *"I will have to read well."*
- *"I will tell the teacher that this question I don't understand and the teacher then explain it to you?"* (See extract 5.4).

Learners depicted some signs of not knowing the answers, and not being sure of what they were writing in the pre-intervention learners' focus group interview. In responding to the interview question *Were the strategies you used similar or different from the ones you used when writing the test before? How were they similar or different?* In the post-test, learners used problem-solving strategies that were different from the ones they used in the pre-test. Most of the strategies used in the post-test were correct where they had answered wrongly in the pre-test (extract 5.10). Evidently, this was an indication that they had learnt something during the intervention teaching and learning sessions.

6.3.1.4 Learners' suggestions to mathematics teachers in terms of context

Learners felt that teachers should provide material such as hardcopies and give them notes. They (learners) took the responsibility to study at home as some could be shy to ask the teacher to repeat what they missed in understanding during teaching and learning. Another issue was that the word problems should be mixed with numbers so that it is words and numbers. This implies that learners wanted to understand the meaning of words underlying mathematical concepts such as in the meaning of whole numbers, as echoed by Frankenstein (see 2.2.2.4).

6.3.1.5 Learners' suggestions to mathematics teachers in terms of language

The learners raised the issue of language as a challenge to say that some did not follow through if the teaching and learning was purely in the English language. Planas (2014) carried out a similar study and asserted that mathematical difficulties and obstacles reported emanate from the use of bilingualism in the learning and teaching of Mathematics (see 2.3.5.2). In this study, learners felt that teachers should code-switch to their mother language. They pleaded that teachers should not use difficult terms or language in their teaching. This is similar to a study that was carried out by Sepeng (2013b) where he found out that *learners preferred both LoLT (English) and home language (isiXhosa) in mathematical word problem-solving,...* (see extract 5.13) (see 2.3.5.1).

6.3.2 Video recordings and documents (exercise books)

The intervention in this study was meant to explore the benefits of using AWFs as a tool in a case of Grade 7 classrooms' word problem-solving and how it influenced the learners' academic performance, carried out in the experimental group only. The video recordings and the learners' exercise books were used as a vehicle in the experimental group to actualise the assistance of learners not only to identify problem situations that were problematic from a realistic point of view, but also to consider the (in) appropriateness of applying mathematical operations directly as their solutions during the intervention period. This strategy engaged the learners in discussions of solution methods with the researcher as a teacher modelling effective strategies. The learners' word problem-solving abilities of multiplicative word problems were also explored in the process. The units of observation (*discussions* and *argumentations*) were used to track the *talk* using Vygotsky's notions; the zone of proximal development, mediation and social interaction.

6.3.2.1 Mathematical discussions

As discussed earlier, entailed in the theoretical lenses were observed aspects of; *teacher modelling*, *learners becoming knowledgeable*, *learners' competency in word-problem solving abilities* under the ZPD that the researcher used to give insight into the visual observations. Learners' reasoning skills needed some mediating from the more knowledgeable teacher (see 1.3, particularly Doolittle, 1997; Harland, 2003 & Wertsch & Tulviste, 1992). This was because they struggled to make-sense out of the word problems, such as ...*if Richard climbed 120 metres in 1 hour, then in 4 hours it has to be more, hence a multiplication sign had to be used,*' instead of a division that learners used. Mathematical language was a problem to the learners as they seem not to relate *income* to money, *percentages* with 100. Research indicates that mediation is crucial for all higher-order mental processes such as problem-solving and reasoning by using psychological tools, such as symbols, signs as well as language (see 3.5.2, particularly Woolfolk, 2008). Furthermore, primary school learners struggle to connect classroom Mathematics with their daily activities outside Mathematics classrooms (Kunene & Sepeng, 2017). Through the ZPD, learners demonstrated competency in word-problem solving abilities. Most learners worked out the given questions on the board, exercise books or participated in the *talk* (discussions).

Mediation aspects of *making claims* by learners, *construction of ideas (learners)*, *learning to argue (using AWFs)* were also explored by the teachers together with the learners, and became evident. However, when learners were asked questions at the beginning, no one wanted to respond. As the intervention time progressed, they started showing signs of "thinking" as they started responding to questions, whether the answers were correct or incorrect, but at least they were saying something. Yet they started by showing signs of a "shut down" mentally when it came to thinking about anything they were asked, such as when they were asked *what information is given in the word problem?* Most learners started to justify their answers after making claims of their solutions. Learners would show that they had added some information or knowledge based on the question asked, in constructing ideas. The teacher-researcher continued to mediate learners' learning with the use of AWFs; learners were more engaged in thinking and expressing their thoughts, such as when they used critical thinking to work out the task on *area of Kelebogile's room*. Furthermore, they explained that the task modelled a *rectangle* and explained how to get Kelebogile's longer side of the room with tables, etc.

Social interaction was discussed under *learners' utterances (talk)*, *learners engaging with teacher* and well as *engaging with peers (learners)*. With learners struggling to engage in the discussions that were initiated by the teacher-researcher, it was evident that they needed more engagement to enhance the *talk* in the classroom. According to Venkat (2013) (see 1.2), teachers should engage learners during the process of teaching and learning in order to understand the rules of solving problems to get to the correct answers.

Moreover, learners could not cooperate effectively at first, even during the initial stages of the intervention. They were making unnecessary noise and were not responsive to simple basic questions such as asking them to list the four basic operations. This finding is similar to a study conducted by Kennewell (2001) (see 5.4.2), where learners were unable to cooperate effectively. However, towards the end of the intervention, after the teacher-researcher had engaged learners in the use of AWFs, learners' attitude changed for the better. Learners responded by using the AWFs as *frames* in their utterances to understand the word problem or respond to the computation of the solution. Learners raised their hands to answer questions, which was an obvious indicator of participation. In their groups, learners answered questions or responded to other learners' (peers) questions or learners' claims.

6.3.2.2 Mathematical argumentation

The performance of learners in word problem solving indicated that the ZPD was necessary for the learners to learn or be reminded of how, *fractions are multiplied by a whole number*. More importantly, learners acquired skills on how fractions are multiplied, and this should be done correctly to make them learn and develop effective strategies where the learners started doing tasks they were not able to do and needed a teacher to assist in doing them (see 3.4.1).

Learners still showed signs of forgetfulness as they still used wrong operations and signs. When working out given problems such as *getting a fraction of a whole*, they used a *division operation*. In doing so, they were showing insufficient understanding of the problem conditions. Furthermore, learners would not remember what is contained in a *dozen*. They said "10" instead of "12". The above examples were similar to a study carried out by Radatz (1980) where the learners, in addition to the above, also manifested errors owing to lack of command of oral calculation rules, and incorrect use of the four basic operations. Towards the end of the intervention, learners improved in their word problem solving abilities. This improvement was evident in computing basic facts, completing all the necessary steps in the questions asked. As such, (see 2.1, particularly Ross *et al.*, 2009) language frames can be effective as templates that are effective in developing learners' thinking and writing skills. However, the teacher modelling of these effective tools is required to hold meaningful discussions.

Eventually, learners were the ones leading the argumentations and illustrations of how certain word problems were solved on the board during mediation. Learners used *language*, enhanced by instilling the AWFs which helped them frame their *talk*. At first, learners struggled to display the essence and art needed from them to make a claim, provide suitable evidence to justify it and logically defend it until a meaningful decision has been reached. Similarly, Van de Walle *et al.* (2013) and Reed and Walker's (2015) (see 4.7) studies corroborates these findings.

Learners eventually became free and confident to argue their points such as “using the *multiplication* operation for *Mr Scullard* to find out the *total amount of material for sewing 4 suits...*” Ross *et al.*'s (2009) study (see 2.4.4) resonates with these findings.

With the use of AWFs, learners were able to read the word problem questions with understanding. They used the argumentative frames to find out information based on the word problem questions. They were able to communicate their claims, and they constructed their ideas of concepts. Learners were able to use AWFs to frame their argumentations.

Learners were cooperative, willingly participating in class discussions on concepts taught during social interaction. Learners could state their arguments in showing understanding of the word problems being solved. Similarly, these findings resonate with Mercer and Sams (2006) study (see 2.4.5 and 2.4.6) conducted in South England where language was used as a tool to enable the use of discussion skills that learners develop in carrying out mathematical activities. Through the social interactions, learners started to produce words, constructions of ideas and solutions to word problems. During the intervention, the teacher enhanced learners' utterances with the use of AWFs. The language in AWFs offered augmentative communication, oral speech that was used by learners to express ideas, thoughts and feelings. Most learners were actively involved in the cognitive thinking process and in reasoning their answers.

6.4 Summary of quantitative and qualitative results

The influence of using the AWF to support dialogue and written problem-solving techniques has been positively noted in bringing talk in the classroom and solving word-problems in the teaching and learning of Mathematics (Nussbaum, 2011; Ross, Fisher & Frey, 2009; Sepeng, 2014a; Venkat, 2013; Webb, Williams & Meiring, 2008) (see 1.2; 1.3 & 2.4.4).

6.4.1 The use of AWFs (Intervention)

The introduction of AWFs as a strategy to support dialogue and written word problems worked and brought about an increase in the classroom discussions and argumentations as there was little classroom *talk* prior to the intervention. The strategy became an instrument to scaffold learners' thinking processes in writing using the frames and reading word problems with understanding (see 1.2 & 1.3, particularly Webb *et al.*, 2008).

6.4.2 Discussion in the classroom

Learners were engaged in processes that involved the integration of a number of cognitive processes such as attention, memory, and language when solving their word problems. This also involved metacognitive processes such as self-questioning, self-monitoring and self-evaluation as they used the AWFs tool or technique.

This further enhanced comprehending the text, representing the nature of the problem correctly, planning a strategy, executing the plan, and verifying the solution, in addition to retrieving an answer from memory (see 2.2.2.2, particularly Jitendra *et al.*, 2015).

6.4.3 Argumentation (talk) in the classroom

During the teaching process in the duration of the intervention, learners made their claims, provided evidence to justify them logically and reached meaningful decisions by using the AWFs. Using the AWFs enhanced learners' participation and mathematical reasoning, as they argued (Krummheuer, 2007; Sepeng, 2014b). A similar study echoed these findings that viewed the AWFs as a framework that scaffolds argumentation because it changes beliefs in propositions through reason and evidence (see 1.2 & 1.3, particularly Nussbaum, 2011). The argumentation brought about, among other things, collaborative dialogue where learners interacted with one another's contributions and the teacher, as well as developed their discourse by elaborating, eliciting and utilising each other's utterances in which meaningfulness was ascribed (see 1.2, particularly Barnes & Todd cited by Norenes & Ludvigsen, 2016:3).

Furthermore, the classroom dialogue incorporated dialectic teaching that was characterised by the following features:

- Questions or test items together with the AWFs were structured so as to provoke thoughtful answers.
- Answers provoked further questions and were seen as the building blocks of dialogue rather than its terminal point.
- Individual teacher-learner and learner-learner dialogues or discussion exchanges were chained into coherent lines of enquiry rather than left stranded and disconnected (see 2.4.6, particularly Mercer & Sams, 2006).

6.4.4 Solving multiplicative word problems

Solving multiplicative word problems begins with issues such as word problem-solving as a process involving numbers and cognitive processes. The computational errors that were of concern that arose in order to manifest incorrectly solved word problems decreased significantly, which were more evident when solving multistep word problem items (see 2.2.2.14, particularly Agostino, *et al.*, 2010). There was a decline in learners applying wrong "rote" algorithm, hence increasing the low academic performances in learners' mathematics performances (see 2.2.2.10, particularly Huang, 2004). The low reading ability (see 2.3.5.4, particularly Reikerås, 2009) improved gradually, showing positive influence on the learners' academic performances in the post-test in particular after undergoing the AWFs intervention.

It was noted that learners gained confidence as an essential ingredient to learn Mathematics and became motivated to reason quantitatively about understanding concepts behind algorithms underlying mathematical concepts such as in the meaning of whole numbers, fractions and percentages (see 2.2.2.4, particularly Frankenstein, 2010).

6.5 Answering the research questions

The study, as mentioned earlier, sought to answer the following main research question:

What are the nature and extent of influence of using argumentative writing frames to support dialogue and written problem-solving (teaching and learning) techniques on grade 7 learners' academic achievement in multiplicative word problems?

In responding to the above question, the following sub-questions, which emanated from the research question and the aims of the study, were answered below.

6.5.1 What is the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?

6.5.1.1 Nature of learners' performance pre-intervention

The nature of the learners' performances in relation to multiplicative word problems before the sequence of intervention lessons was better accounted for by the quantitative results of the study that were illustrated in Table 5-32 in item task 5, where the comparison group performed better than the experimental group with a $p = 0.0138$. In task 7 (item 2.4), there was no difference in the problem-solving abilities of both the comparison and experimental groups in the pre-test ($p = 0.3613$). Both the comparison and the experimental groups started with the same mean. As noted earlier, according to the DBE, learners are said to have underperformed when they attained marks that are lower than level 3 (less than 40%) in Mathematics (DBE, 2011). In the pre-test, the comparison group had a lowest mark of 1 out of 40 while the experimental group started with a 0 mark. The highest marks were 17 and 16 respectively. The comparison group started on a better performance on items 2.1, 2.2, 2.3 and 2.4 with statistically significant difference $p \leq 0.05$. This made the comparison group to start the intervention as a better performing group compared to the experimental group that obtained a significant difference ($p \leq 0.05$) only in items 2.2, 2.3 and 2.4.

6.5.1.2 Argumentation prior to the intervention

The qualitative results obtained from the learners' post-intervention focus group made it explicit about the nature of the learners' argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons. More importantly, learners' low level of fluency prevented them from engaging effectively in the mathematical activities in the classrooms during the argumentation process within the social interaction space. The learners seemed to struggle to express themselves to say what they wanted to say in responding and engaging in the discussions in the LoLT (which was English) when it came to mathematical discussions. Learners were not participating in the *talk* as far as the lessons discussions were concerned. They lacked argumentation skills, such as the academic language and syntax; the essence and art needed from them to make a claim, provide suitable evidence to justify it and logically defend it until a meaningful decision was reached. Furthermore, learners felt that their Mathematics teacher should explain in English and also code-switch to the learners' home-language, more especially the word problem-solving. To make things worse, they claimed that some teachers struggled to pronounce and explain some words in the textbooks that were used in the classrooms, which was a language concern.

6.5.2 In relation to the literature and theory, what was implemented across series of lessons? How did learners' talk in argumentation change across the implemented lessons?

The qualitative data results analysed in the previous chapter gave what was implemented across the series of lessons and how the argumentation changed across the implemented lessons. The data were gleaned from the videos recorded and it was evident in the learners' exercise books by using the AWFs during the intervention period.

6.5.2.1 In relation to the literature what was implemented across the series of lessons?

Word problem-solving requires the teacher to use word problems as vehicles to teach learners to model (see 5.3, particularly Zhang *et al.*, 2013) problems in Mathematics which also form part of the South African Mathematics curriculum (see 2.2.2.1, particularly Sepeng & Sigola, 2013). The teaching and learning of word problems came as a learners' experiential process (see 2.2.1.2, particularly Wenger, 19902) that involved cognitive processes such as language (see 2.3.5.2, particularly Planas, 2014) that they used in expressing themselves and memory (Jitendra, Griffin, McGoey, Gardill, Bhat & Riley, 1998) of the multiplication table when they had to multiply numbers to find the area of a rectangle.

Learners were led to understand the key elements in the problem situations, working through the technique or strategies or model to reach the mathematical answer (see 2.2.2.11, particularly

Verschaffel *et al.*, 2010) using the AWFs, such as *what information was given, what did the problem require the learners to do...?*

The misinterpretation of word problems that caused learners to commit errors and hence, adopting a short –cut strategy (see 2.2.2.6, particularly Agostino *et al.*, 2010) was minimised, by probing learners to explain how they got their answers for given solutions. Solving of one-step and multi-step multiplicative word problems (see 2.2.2.14, particularly Agostino *et al.*, 2010; Zhang *et al.*, 2011) were modelled on the board and learners worked them out in their exercise books. Learners' conceptual knowledge and multiplicative or quantitative reasoning were enhanced, such as realising that a numerator and a denominator have multiplicative relationships as compared to having an additive relationship (Zhang *et al.*, 2011). The introduction and implementation of the AWFs to support dialogue and written work was done while enhancing argumentation and the teacher scaffolding teaching in the experimental group (see 1.2 & 1.3, particularly Webb *et al.*, 2008). Dialogue, which comprises word problem-solving *talks* by learners on the articulation of conceptual understanding during teaching and learning, scaffolded by the teacher with the use of AWFs, was enabled and carried out.

6.5.2.2 In relation to theory what was implemented across the series of lessons?

As far as theory is concerned during the implementation of the AWFs technique in the duration of the intervention, most of the activities were underpinned by theory. As a study that was framed by the pragmatic research paradigm (see 3.2.4, particularly Creswell, 2014), the researcher drew from the quantitative approach when working out the answers to those word problem-solving tasks on the concepts taught and learnt. A qualitative approach was also explored when learners had to elaborate and explain how they reached the answers. As a study that was underpinned by the constructivism philosophy, learners collaborated with their teacher at the zone of proximal development to accomplish the given word problems solving tasks in the classroom, enabling learners to be better solvers (see 1.3 & 3.4.1, particularly Brenner, 1998; Hart, 1999; Vygotsky, 1978).

More importantly, learners learned to build their understanding of their experiences of solving word problems and as such empowered themselves to be in control of their learning through involvement and critical thinking (see 3.4.2, particularly Jacobs *et al.*, 2016). Moreover, social learning as one of the analytic tools made it possible for learners to construct their own understanding and meaning as they engaged with the teacher in order to develop effective mental strategies or processes to solve word problems.

Framing this study was also the concept of mediation. Mediation of the lessons was done through the use of AWFs during the intervention that yielded psychological tools such as memory (when learners remembered facts such as the multiplication timetables) and concept formation (learning and knowing concepts such as *rate*).

Through the use of the AWFs, dialogue enhanced the conversation between learners and the teacher as well as between the learners themselves, face-to-face and taking turns in exchanging of meanings and understanding (see 3.4.3, particularly Miller, 2011). The notion of argumentation was enhanced, which offered claims, justifications and logically defending them until meaningful decisions were reached, while maximising learner participation and mathematical reasoning.

6.5.2.3 How did the learners' *talk* in argumentation change across the implemented lessons?

During the implementation of the AWFs tool and strategy, the learners' *talk* in argumentation changed for the better. Argumentation in this study was an oral discourse that was supported by the argumentative writing frames (see 1.2 & 1.3, particularly Webb *et al.*, 2008) and mediated by the teacher-researcher to the experimental group. The experimental group was one class that had little *talk* when it came to constructive Mathematics word problem-solving oriented group. Essentially, the teacher-researcher used the AWFs to scaffold the teaching and learning process in the experimental group to teach the multiplicative word problem solving. In addition, some writing templates of the AWFs were used to help frame the learners' *talk* and argued their points from there as well as writing the templates in their exercise books in answering the tasks given. In this study, argumentation was aimed at instilling abilities of being able to make a claim, provide suitable evidence to justify it as well as defending the claim in a more logical way (see 2.4.4, particularly Ross *et al.*, 2009 & see 1.2 & 1.3, particularly Webb *et al.*, 2008). Language was one major essence of the art of argumentation that capacitated communication within the learners (see 2.1, particularly Ross *et al.*, 2009).

Eventually, learners were able to respond to counter-arguments made by their classmates and made their own elaborations of how they understood a given task, which is termed dialectic argument by Nussbaum (2011). Accordingly, this notion was also underpinned by the notion which puts argumentation at its centre because it brings in the notion of reason and evidence, promoting modelling and model-based reasoning (see 2.4.4, particularly Nussbaum, 2011). Learners learnt and expressed the art of argument during the Mathematics instructional class, hence learning Mathematics entailed *argumentative* learning (see 1.3, particularly Krummheuer, 2007).

6.5.3 What is the nature of the learners' performance and argumentation in relation to multiplicative word problems post-intervention lessons?

6.5.3.1 Nature of learners' performance post-intervention

The quantitative results of the study generated from the post-test illustrated the following results on the nature of the learners' performance in relation to multiplicative word problems post-intervention lessons: In the post-test the experimental group had a higher performance, with a mean of 15.5 over the comparison group with 13. In task 7 (item 2.4) after the implementation of the AWFs intervention,

the experimental group had a higher performance ($p=0.0001$) than the comparison group. In the pre-test, there was no statistically significant difference in the problem-solving abilities of both the comparison and experimental groups in the pre-test ($p=0.3613$). However, in the post-test total the experimental group showed a better improvement than the comparison group ($p=0.0001$) after starting at a lower performance (see 6.2.1.3). The intervention seemed to have favoured the experimental group as per the above argument.

6.5.3.2 Nature of learners' argumentation post-intervention

The qualitative results obtained from the learners' post-intervention focus group made it explicit that learners felt a positive impact of the use of the AWFs, as they suggested that every learner who is taught word problem-solving should have the frames to help to structure the argumentation *talk* and enhanced understanding of the task that needed to be solved. During the intervention and during the focus group interview, learners could argue their claims as well as justify their argumentation or claims until a solution was reached. Moreover, learners' sense-making abilities improved after the intervention. They could not make sense out of the fact that the age of a farmer could not be 160 years as that number of years was not realistic in the lifespan of a human being who also happened to grow up and be a farmer.

6.5.4 What are the implications for the pedagogic practice of these findings?

The qualitative results from the learners' post-intervention focus group interview responses brought forth the positive influence of the pedagogical practice of this study's findings. Learners confirmed that the use of AWFs during the word problem-solving was a positive aid. The AWFs enabled learners to reason, think, and perform better after the intervention in their interview responses and in the post-test administered. In addition, learners admitted to have learnt from their mistakes, after the intervention had acted as a mediating tool for their success. The learners claimed that all learners needed the AWFs when the teacher taught word problem-solving so that they ...*understand* word problems *better*. Learners were able to change their computational strategies and used correct operations and correct steps of algorithm when answering their questions in about half the class.

This was evident in the increase shown in their performance in the post-test. By changing strategies in answering the questions, the learners implied that they comprehended the questions better (see 2.2.2.2).

6.5.5 What are the nature and influence of the intervention?

The qualitative data results analysis obtained from the learners' post-intervention focus group interview responses outlined the following influences of the intervention:

- The intervention brought in *talk* in the experimental classroom.

- Learners gained the abilities to argue, make some claims and justify their claims until they reached a consensus.
- Learners developed abilities of sense-making and awareness of realistic issues.
- They started realising the use of more correct operations with more understanding of the word problem-solving tasks.
- They made the correct, or at least partially correct, computations and responses.
- Learners were able to identify their problems in solving word problems; hence, they changed their strategies or techniques when answering the word problem tasks.

Learners' utterances, understanding of the problem text and construction of internal representations in the mathematical word problem-solving classrooms are of utmost importance. Underpinned by Vygotsky, learners' experiences have to be shared and scaffolded by the teacher or researcher through the zone of proximal development, social interaction and well as mediation. I introduced the argumentative writing frames in the Grade 7 classrooms with the intention of achieving discussion and argumentation. The use of AWFs brought about *talk* in the grade 7 classrooms. In this way, learners started to understand word problem-solving, developed abilities of sense-making in situational context. All these above-mentioned influences of *talk* brought about a better performance from the Grade 7 learners in mathematical word problem-solving. The use of AWFs in Grade 7 Mathematics classrooms to help learners in word problem-solving seemed to have yielded some positive influence on the learners' performance, sense-making and bringing *talk* into the classrooms.

6.6 Chapter summary

The results discussed in this chapter were centred on both the quantitative and qualitative data produced in this study. Both the inferential and descriptive statistical analyses were used to determine the pre-and post-tests, learners' pre- and post-intervention focus group interviews responses as well as the use of AWFs to support dialogue intervention technique. Essentially, the findings were explored within the literature and theoretical underpinnings presented in Chapters two and three.

Quantitative data suggest that the use of AWFs to support dialogue was very effective on the experimental group as it performed better than the comparison group, gaining a greater pass rate in the post-test administered. Furthermore, learners manifested positive word problem-solving abilities and meaning making in the experimental group when working out responses of their post-test. The statistical analysis of Wilcoxon – Mann-Whitney test depicted statistical significance, in which the experimental group ($n=42$), *obtained a bigger median of 15.50 in the post-test from a median = 8*, higher than the comparison ($n=35$), which ended with mean=13. The experimental group's performance in the post-test in test item 7 was higher ($p=0.0100$) as compared to the comparison group ($p=0.3613$). In task 5, the experimental group had a higher performance as it managed to

perform the same as the comparison group that earlier had a significant difference over the experimental group performance.

The qualitative data discussed generated from the interviews, video shoots and learners' exercise books gathered during the AWFs intervention implemented indicated that the use of AWFs technique improved the learners' *talk* in the experimental classroom. From evidence captured through the videos and exercise books, learners solved tasks better (on the chalkboard) towards the end of the intervention as they put forth their claims, justifying them and explaining to the rest of the class as to how they reached their answers. From the post-intervention interview, learners confirmed that the use of AWFs was helpful to them in the sense that they performed better in the post-test as compared to the pre-test in solving their word problems. Hence, learners suggested that if any learner wanted to succeed in word problem-solving, the use of AWFs should be the focal mediating tool, as it helped them performing better in their post-test.

Vygotskian social-cultural constructivist theory views learning as an effective social interacting process between learners and teachers; learners have to be active in constructing their own knowledge, accomplished with the help of a more knowledgeable peer, tutor or teacher (see 3.3.2). Accordingly, this was facilitated by AWFs because they probed the learners' thinking as well as guided them on identifying what information was given in each question or problem task given. The following chapter presents the conclusion and recommendations drawn from this study.

CHAPTER 7

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS OF THE STUDY

7.1 Introduction

This chapter presents the conclusions from the results and findings according to the data that were collected, analysed and presented. Recommendations of strategies to remedy the investigated problem are presented, based on the findings. The limitations of the study as a whole are presented, which could be from any aspect of the actual research actualisation. Furthermore, the intervention of AWFs used in this research seem to suggest that the teachers' educational practices, created conducive teaching and learning platforms in the teaching and learning of Mathematics word problems, and multiplicative word problems in the Grade 7 classroom in particular.

7.2 Rationale and design

The learners' low academic performance problems in Grade 7 Mathematics in word problem solving in particular were associated with several factors. These factors included issues of learners' computational abilities, intelligence and memory, sense-making (taking real wor(l)d into consideration), language of teaching and learning, language of mathematics (discipline), and the absence of *talk* in the mathematics classrooms (see 1.2; 2.2.2.10; 2.2.2.11; 2.3.5; 2.3.6; DBE, 2013; Sepeng, 2014b; Steele, 2002; Venkat, 2013).

In instances where *talk* was used successfully, it appeared to enhance coherence on teachers' teaching in that it enabled effective teaching that assisted learners to understand what was taught (see 1.1 - Venkat & Askew, 2016). The success of *talk* which was facilitated by the use of AWFs seemed to be made possible by the teaching and learning interaction new knowledge, which was constructed to rethink ideas, to argue, evaluate, share, examine, as well as learners' understanding the conceptual underpinnings of Mathematics as learners became better problem solvers (see 1.1 - Hart, 1999; Brenner, 1998). The use of AWFs activated learners' prior knowledge which learners needed to demonstrate in their word problem solving experiences. As a result, learners were seen using correct computational operations when answering questions. The AWFs provided leads, clues, cues and insights into the questions as well as prompts for learners to communicate, and enhanced learners' understanding of the word problems. AWFs provided modifiers, starters, and connectives for learners to frame their *talk* during discussions and argumentation as tracked in the intervention period. Eventually, learners were seen improving in their academic performance, particularly after the intervention of AWFs.

Therefore, it was against this background that the study sought to investigate the use of AWFs in a case of Grade 7 classrooms' word problem-solving and how it would influence Grade 7 learners'

academic performance. Furthermore, the potential significance of this research, which appeared to have been achieved, was to improve the teachers' educational practices, and create conducive spaces in the teaching and learning of multiplicative word problems in Mathematics classrooms dominated by second language learning.

This research study adopted the interpretive mixed-method case study, underpinned by Vygotsky's constructivist perspective. I used a two-phase approach in order to collect data. Firstly, I used the quantitative data and the results to plan (or build on to) the second, qualitative phase which gave more clarity into the study underway. A pre-test – intervention – post-test (PIP) design was also used in the study. The pre-test explored better understanding of the Grade 7 learners' problem-solving skills and abilities when solving multiplicative word problems. More importantly, the pre-test provided the learners' ability (or inability) to make sense of word problem-solving and realistic considerations as well as understanding the nature of the learners' performances in relation to multiplicative word problems prior to a sequence of intervention lessons. The follow-up learners' focus group interview with eleven learners was aimed at investigating the nature of the learners' problem-solving abilities and the reasons for answering the word problem-solving test tasks the way they did. It was also conducted to better understand the learners' pre-test responses and give more clarity on issues that were explored quantitatively.

Learners in the experimental group were exposed to the use of AWFs intervention that supported *talk* in the teaching and learning of multiplicative word problems. In addition, a video was shot and exercise books were used in exploring the benefits of using AWFs, discovering how learners solved multiplicative word problems in particular, as well as engaging learners in discussions and argumentation of the solution methods as the teacher modelled strategies. Moreover, oral language, thinking and argumentation skills were developed through teacher/learner as well as learner/learner argumentation. The intervention took two academic terms (six months). A post-test was given to establish if there was any change in the dependent variable(s) conditions, and, compared to the pre-test results, how learners solved multiplicative word problems (problem-solving abilities). The post-test further helped the researcher to measure the effectiveness of using AWFs in a case of Grade 7 classrooms' word problem-solving was administered to the comparison and experimental groups.

Lastly, a learners' post-intervention focus group interview was carried out with eleven learners (in the experimental group) in order to explore the nature, effects and implications of the pedagogic practice of this study as well as learners' perceptions about the intervention.

7.3 Primary findings

The previous chapter discussed that the main finding of this study was that, in the experimental group where the use of AWFs technique was implemented during the intervention, the level of 'talk' (discussion and argumentation) was achieved. As a result, the learners' academic performance

improved significantly in the experimental group after the intervention as compared to the pre-test performance as well as compared to the comparison group.

The quantitative data seemed to suggest that there was an improvement in the learners' abilities to solve multiplicative word problems in terms of the experimental group in particular for item 5 and 7 respectively. The experimental group learners' improved levels of sense-making abilities were evident. Learners could generate correct computations, and they used correct operation signs in solving the word problems. Learners from the experimental group also showed signs of better understanding of the multiplicative concepts on word problem-solving. Learners started to use correct computational algorithms when answering their word problems.

The qualitative data seemed to suggest that learners were able to use AWFs to frame their talk during discussions and argumentation as they expressed themselves during teaching and learning. Learners from the experimental group also showed signs of better understanding of the multiplicative concepts on word problem-solving. They were engaged in discussions with the teacher-researcher and demonstrated how certain concepts on multiplicative word problem-solving should be worked out to get the mathematically accurate responses. In doing so, most learners successfully expressed their arguments better with the aid of AWFs, which framed their *talk* in justifying and defending their problem-solving approaches as well as answers to multiplicative word problems.

This study used the sub-questions below emanating from the main research question, to give direction and impetus to the study.

1. *What was the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons?*

The learners' performance prior to the sequence of intervention lessons was noted in the nature of results produced from the pre-test taken by the experimental group and the comparison group. From the seven test items, the experimental group started with a lowest mark of 0 out of 40 while the comparison group had 1 out of 40 marks. The highest marks obtained by the learners were 16 and 17 respectively. The pre-test mean was 8.404762 for the experimental group and 8.942857 for the comparison group.

Statistically, the experimental group had significant difference ($p \leq 0.05$) for items 2.2, 2.3 and 2.4, while the comparison group obtained significant difference in items 2.1, 2.2, 2.3 and 2.4. The experimental group started at a lower performance than the comparison group's performance.

The nature of argumentation before the intervention revealed that learners were not engaging in discussions and argumentations that were facilitated by the researcher-teacher. In the 10% of response from the learners, I realised that the learners were struggling to express themselves in the LoLT, in saying what they wanted to say when responding to the questions. The essence of making

claims, justifying them to reach a decision that was meaningful, was almost not evident at all. This sub-question seemed to imply that an intervention to let learners talk in class during teaching and learning was necessary.

2. In relation to the literature and theory, what was implemented across series of lessons?

In relation to literature, issues of word problem solving where learners had to demonstrate their abilities of word problem-solving were explored. Learners experienced word problems that were word-oriented and had to solve them. Issues of taking real-life into consideration when solving word problems were also explored. I also gave insight into issues of language in Mathematics classrooms, as LoLT and experienced by learners. In relation to theory, Vygotsky's theory was used to underpin the study. Within the constructivism theory where learners give their utterances and construct their own knowledge were notions of the zone of proximal development, mediations and social interaction. With the learners showing difficulties in demonstrating competent abilities in solving word problems, sense-making and lack of talk, the need to intervene and scaffold learning was essential. Hence AWFs were ideal in such a situation.

3. How did learners' 'talk' in argumentation change across the implemented lessons?

I noted that learners' abilities to express themselves in class was a challenge, seemingly because of lack of exposure to talk during Mathematics lessons in classrooms in the beginning of the intervention. The argumentation art of making a claim of their answers, justifying the answers as well as coming to a meaning decision was lacking in the learners in the beginning of the intervention. However, with more scaffolding carried out by myself as the researcher using AWFs, learners learned to start talking using the AWFs to frame their talk, argue their points and justify their claims. The frames seemed to enhance the learners' understanding of the word problems as they would give more correct answers. It was evident that learners in this Mathematics class needed some kind of intervention that would engage them in the talk.

4. *What was the nature of the learners' performance and argumentation in relation to multiplicative word problems post - intervention lessons?*

The nature of learners' performance in the post-intervention space manifested improved performance. The experimental group obtained an improved lowest mark of 16 out of 40 marks, highest mark of 32, and a mean of 16.78571 in the post-test. The comparison group on the other hand obtained 17.34 and 14.91429 respectively. In the seven test items, the experimental group had a higher performance in item 2.4 ($p=0.0001$) than the comparison group. In the post-test total the experimental group showed a better improvement than the comparison group ($p=0.0001$) after starting at a lower performance with no significant difference. The experimental group also performed well with statistically significant difference of ($p=0.0001$) in items 2.2 and 2.3 as compared to its pre-test. This implies that the intervention might have had an influence on the experimental group with regard to that performance.

5. *What were the implications for the pedagogic practice of these findings?*

Pedagogically, learners attested to some influence that might have been a result of the use of AWFs. Learners mentioned that the use of AWFs helped them to solve the word problems better in the post-test after the intervention. I also observed that learners talked more freely in class about their views on how the word problems were to be solved, suggesting strategies that could be used.

6. *What were the nature and influence of the intervention?*

The intervention brought talk into this Grade 7 Mathematics classroom. The art of learners' argumentation during discussions was enhanced. Learners demonstrated developed abilities of sense-making and taking real life into considerations. Learners were seen using correct problem-solving strategies which demonstrated better abilities of word problem-solving. The use of AWFs seemed to have had a positive influence in the increase of the experimental learners' performance in the post-test.

The learners' academic performances were recorded before and after the intervention. The nature of discussion and argumentation were tracked throughout (before, during and after) the implementation intervention strategy. The implications, nature and effects of the intervention were measured against the success (or lack thereof) of *talk*, which appeared to be beneficial to learners' understanding how they can solve word problems better, in most instances.

7.4 Limitations of the study

This study used a small sample of the population of learners in the district it was carried out, and as a result, its findings are not necessarily meant to be generalised in cases where the context of schools may be different. In actual fact, what the study did was to demonstrate, using empirical evidence, the benefits (or lack thereof) of using the chosen strategy (AWFs) in an attempt to understand why learners perform the way they do under traditional pedagogies in mathematics classrooms.

7.5 Implications for teacher practice and development

The intervention of this study targeted a limited number of learners in the Montshiwa township schools and, as noted in the previous section, the findings should not be generalised. Nonetheless, the findings of the study pointed to a strong suggestion of using the AWFs in Mathematics classrooms when any topic related to solving multiplicative word problems is taught. In doing so, there exists a likelihood of improved *talk* during the lessons, which may result in better academic performances by learners in word problems generally. The talk will facilitate argumentation and discussions in the Mathematics classrooms. Furthermore, issues of sense-making and taking real life into considerations likely to be improve. Abilities of word problem solving are very likely to be enhanced, as learners start to comprehend the problems better and improve their (learners') reasoning skills. Both the quantitative and qualitative data analysed appeared to suggest that the intervention promoted more *talk* (discussion and argumentation) in the teaching and learning of multiplicative word problems in particular and positively influenced learners' performance in problem-solving abilities and abilities of sense-making. In addition, Mathematics teachers may be equipped with an alternative pedagogy to employ when dealing with story problems in Mathematics curricula, which may improve how word problems are dealt with in the classroom. More importantly, this study gives teachers sufficient insight and understanding into the benefits of using AWFs to support in a case of Grade 7 classrooms' word problem-solving across all the major four operations, more especially the multiplicative word problem-solving in Mathematics classrooms.

7.6 Recommendations for future research

- This study has shown that issues of *talk*, (*discussion* and *argumentation*), *word problem solving* and *sense-making* are of utmost importance in the teaching and learning of multiplicative word problems in Mathematics classrooms. The reflection from the implementation of the intervention suggests that the use of AWFs yields some positive benefits in the academic performance of a participating group. It is on this basis that a study that investigates the nature of impact that AWFs will have on all types of word problems can be undertaken.

- In addition to this, the nature of impact of the use of second language on learners' academic performances in word problems should be studied within the contexts of using *English* as the primary language for learning and teaching in the majority of South African schools.

7.7 Final analysis

This study sought to explore the effects of using AWFs in a case of learners in Grade 7 classrooms' word problem-solving and how it influenced Grade 7 learners' academic performances. It has seemed to be evident in this study from the data interrogated and presented that the use of AWFs had some influence on the learners' academic performance in multiplicative word problem-solving in particular. Learners' abilities of word problem-solving, abilities of sense-making, *talk* that encompassed the art of argumentation and discussion, pointed to the possible influence of the use of argumentative writing frames that were used in this study as an intervention technique. The information, suggestions and recommendations emanating from this study should benefit future researchers, learners, teachers and the DBE by enhancing the present capacity of learners in word problem-solving in Mathematics classrooms as far as improving *talk*, sense-making and awareness and consideration of reality.

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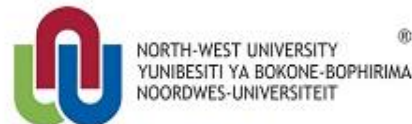
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ADDENDA

APPENDIX A



NORTH-WEST UNIVERSITY
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ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by the Human Resource Research Ethics Committee (HRREC) on 23/03/2017, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: Using argumentative writing frames to support dialogue and written problem-solving in multiplicative word problems: A case of Grade 7 learners in Montshiwa Township Schools.																												
Project Leader/Supervisor:	Prof P Sepeng																											
Student:	NAT Kunene																											
Ethics number:	<table border="1"> <tr> <td>N</td> <td>W</td> <td>U</td> <td>-</td> <td>0</td> <td>0</td> <td>4</td> <td>0</td> <td>2</td> <td>-</td> <td>1</td> <td>7</td> <td>-</td> <td>A</td> <td>9</td> </tr> <tr> <td colspan="3">Institution</td> <td colspan="3">Project Number</td> <td colspan="3">Year</td> <td colspan="3">Status</td> </tr> </table> Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation	N	W	U	-	0	0	4	0	2	-	1	7	-	A	9	Institution			Project Number			Year			Status		
N	W	U	-	0	0	4	0	2	-	1	7	-	A	9														
Institution			Project Number			Year			Status																			
Application Type:	Doctoral																											
Commencement date:	2017-03-15																											
Expiry date:	2020-03-15																											
Risk:	N/A																											

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HRREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HRREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The project leader (principal investigator) must report in the prescribed format to the NWU-IRERC via HRREC:
 - annually (or as otherwise requested) on the progress of the project, and upon completion of the project
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
 - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the HRREC. Would there be deviation from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via HRREC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-IRERC and HRREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the project;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the HRREC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.
- HRREC can be contacted for further information via Estie.Emtsohi@nwu.ac.za or 018 289 2873.

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or HRREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA
Du Plessis

Digitally signed by
Prof LA Du Plessis
Date: 2017.04.10
12:19:12 +02'00'

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

APPENDIX B

H C Sieberhagen

SATI no 1001489

hettiesieb@gmail.com

Translator and Editor

082 3359846

018 264 2309

CERTIFICATE OF LANGUAGE EDITING

ISSUED ON 26 MARCH 2019

This is to certify that I have edited the language of the thesis

**A CASE STUDY OF SELECTED GRADE 7 LEARNERS
USING ARGUMENTATIVE FRAMES
FOR SOLVING WORD PROBLEMS**

by

Nothile Abrijard Tivelele Kunene

submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

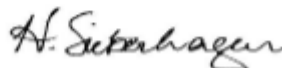
in the Faculty of Education

at the **NORTH WEST UNIVERSITY**

Mafikeng Campus

SUPERVISOR: Professor Hercules Nieuwoudt

The responsibility to effect the recommended changes remains with the student.



H C Sieberhagen

SATI no 1001489

26 March 2019



271 Editing

Tel: 082 879 5799

E-mail: 271editing@gmail.com

To whom it may concern

This letter is to confirm that Ms Nothile Kunene submitted her PhD dissertation to me for bibliographic control, as well as for the technical formatting of the document according to the prerequisites of the North-West University. I hereby confirm that the final reference list and in-text citations meet the requirements of the NWU Harvard style, which differs in some aspects to the general Harvard style of referencing. To consult or query the style, please visit: <http://library.nwu.ac.za/sites/library.nwu.ac.za/files/files/documents/quoting-sources.pdf>

Regards

A handwritten signature in black ink, appearing to read 'Kirchner van Deventer'. The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Kirchner van Deventer

9 April 2019

APPENDIX C

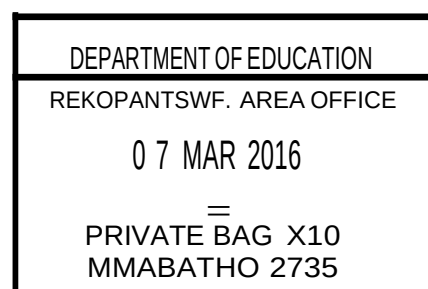
P. O. Box 22269

Middelburg

1050

07 March 2016

Department of Education
Rekopantswe Area Office
Corner Thelesho and Modiri Molema Road
Montshioa
2737



Attention: The Area Office Manager

SUBJECT : REQUEST FOR PERMISSION TO CONDUCT A RESEARCH IN
SELECTED SCHOOLS WITHIN REKOPANTSWF AREA OFFICE.

Dear Dr. E. Mammen

My name is Nothile A. T. Kunene, a PhD (Mathematics Education) student at North-West University (NWU) at Mahikeng Campus. The proposed research broadly involves issues of dialogue and argumentative writing frames in the teaching and learning of mathematics word problems in grade 7 classrooms. The proposed research project will be conducted under the supervision of Professor Percy Sepeng (North-West University, Mahikeng Campus).

It is therefore against this background that I humbly request your permission to access the selected schools where I will request a sample of both grade 7 mathematics teachers and learners to participate in the project.

I have also provided a snapshot of the research proposal in the subsequent pages. My study will not interfere with the smooth running of teaching and learning in any way. Furthermore, participation will be purely voluntary. If you require any further information, please do not hesitate to contact me on contact number: 081 434 3747 or 072 170 2994; email address: nothilekunene@gmail.com

Thank you for your time and consideration in this matter.

Yours sincerely,

Kunene Nothile A. T.

*Approved:
provided that the
① better bring proper identification
② Teaching and Learning is
not compromised
Dr E. Mammen*

Title: Dialogue and Argumentative Writing Frames: Issues of Grade 7 learners' academic achievement in multilingual classroom settings *in a case of word-problem solving*".

The purpose of this study is to:

- ✓ To investigate better how teachers teach word problems. (Issues of teaching)
- ✓ To understand how learners learn word problems.
- ✓ To explore the types of errors that learners make.
- ✓ To determine the Grade 7 learners' problem-solving and sense-making abilities when solving word problems.
- ✓ Understand learners' attitudes when solving word problems
- ✓ To investigate the effects of dialogue and argumentative writing frames on English second languages learners' academic achievement in word problems.

How the participants will contribute to the study:

- a) The learners will write pre-test drawn up by the researcher. They will also undergo a focus group focus interview, and finally, write a post-intervention test.
- b) The grade 7 mathematics teachers will be involved in filling in a questionnaire, face to face interview by the researcher and will be observed during their teaching and learning. The teachers will attend workshops on using: Dialogue and argumentative frames" as an intervention to teach word problem solving in mathematics.
- c) The whole process will last for this academic year (2016).

Ethical considerations:

- a) I will let the participants know that participation is voluntary and withdrawal without reprisal is accepted. I will honour the participants' privacy. Participants are welcome to ask questions.
- b) Unless otherwise agreed to, the informants' identities will be protected so that the information I collect does not embarrass or in other ways harm them.
- c) I will treat the informants with respect and seek their cooperation in the research.
- d) In negotiating permission to do the study, I shall make it clear to those with whom negotiate what the terms of the agreement are, and I shall abide by that contract I will tell the truth when I write up and report findings.

APPENDIX D

P.O. Box 22269

Middelburg

1050

19 January 2017

Diphetogo Primary School

P. O. Box 3104

Mmabatho

2735

The Principal: Mr T. Phejana

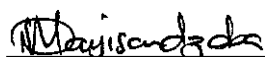
REQUEST FOR PERMISSION TO CONDUCT A RESEARCH AT DIPHETOGO
PRIMARY SCHOOL

Dear Sir

My name is Nothile A. T. Kunene, a PhD in Education (Mathematics Education) student at North-West University (NWU) at Mahikeng Campus. The proposed research broadly involves issues of dialogue and argumentative writing frames in the teaching and learning of mathematics word problems in grade 7 classrooms. The proposed research will be conducted under the supervision of Professor Percy Sepeng (North-West University, Mahikeng Campus).

It is therefore against this background that I humbly request your permission to access your school where I also request one grade 7 class of learners to participate in the project. I have also provided a snapshot with of the research proposal in the subsequent pages. My study will not interfere with the smooth running of teaching and learning. Furthermore, participation will be purely voluntary. If you require any further information, please do not hesitate to contact me on contact number: 081 434 3747 or 072 170 2994/018 389 2408; email address: nothilekunene@gmail.com.

Yours sincerely,



Kunene Nothile A. T. Mrs

Title: Using Argumentative Writing Frames to support dialogue and written problem-solving in multiplicative word problems: A case of a Grade 7 learners in Montshiwa township school.

The purpose of this study is to:

- ✓ To understand the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons.
- ✓ To understand in relation to literature and theory what was implemented across the series of lessons and how has learners' talk in argumentation changed across the implemented lessons.
- ✓ To investigate the nature of the learners' performance and argumentation in relation to multiplicative word problems post- intervention lessons.
- ✓ To explore the implications for the pedagogic practice of these findings.
- ✓ To understand the nature and effects of the intervention.

How the participants will contribute to the study (School A):

- a) The learners will write pre- and post-test drawn up by the researcher. They will also undergo a pre- and post-learners' focus group interviews.
- b) The researcher will draw and implement the intervention on "using Argumentative Writing Frames to support dialogue and written problem-solving in multiplicative word problems" to teach word problem solving in mathematics.
- c) The whole process will last for *not more than 6 months (2017) I 2 Academic Terms*

Ethical considerations:

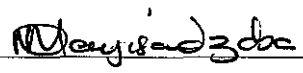
- a) I will let the participants know that participation is voluntary and withdrawal without reprisal is accepted. I will honour the participants' privacy.
 - b) Unless otherwise agreed to, the informants' identities will be protected so that the information I collect does not embarrass or in other ways harm them.
 - c) I will treat the informants with respect and seek their cooperation in the research.
 - d) In negotiating permission to do the study, I shall make it clear to those with whom negotiate what the terms of the agreement are, and I shall abide by that contract. I will tell the truth when I write up and report findings.
-

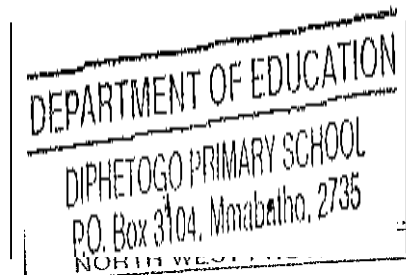
CONSENT: Your signature below will indicate that you have agreed to participate as a research subject and that have read and understand the information provided above:

Signature of Principal

 Date: 11/01/17

Signature of Researcher

 Date 19/01/17



19 JAN 2017

APPENDIX E

P. O. Box 22269
Middelburg
1050
19 January 2017

The Connie Minchin Primary School
Private Bag X2030
Mmabatho

2735

The Principal: Mr P. Itumeleng
REQUEST FOR PERMISSION TO CONDUCT A RESEARCH AT THE CONNIE
MINCHIN PRIMARY SCHOOL

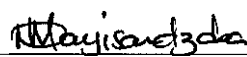
Dear Sir

My name is Nothile A. T. Kunene, a PhD in Education (Mathematics Education) student at North-West University (NWU) at Mahikeng Campus. The proposed research broadly involves issues of dialogue and argumentative writing frames in the teaching and learning of mathematics word problems in grade 7 classrooms. The proposed research will be conducted under the supervision of Professor Percy Sepeng (North-West University, Mahikeng Campus).

It is therefore against this background that I humbly request your permission to access your school where I also request one grade 7 class of learners to participate in the project.

I have also provided a snapshot with of the research proposal in the subsequent pages. My study will not interfere with the smooth running of teaching and learning. Furthermore, participation will be purely voluntary. If you require any further information, please do not hesitate to contact me on contact number: 081 434 3747 or 072170 2994/018 389 2408; email address: nothilekunene@gmail.com.

Yours sincerely,



Kunene Nothile A. T. Mrs
NWU

Title: Using Argumentative Writing Frames to support dialogue and written problem-solving in multiplicative word problems: A case of a Grade 7 learners in Montshiwa township school.

The purpose of this study is to:

- ✓ To understand the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons.
- ✓ To understand in relation to literature and theory what was implemented across the series of lessons and how has learners' talk in argumentation changed across the implemented lessons.
- ✓ To investigate the nature of the learners' performance and argumentation in relation to multiplicative word problems post- intervention lessons.
- ✓ To explore the implications for the pedagogic practice of these findings.
- ✓ To understand the nature and effects of the intervention.

How the participants will contribute to the study (School B):

- a) The learners will write pre- and post-test drawn up by the researcher.
- b) The researcher will teach the learners word problem solving in mathematics.
- c) The whole process will last for *not more than 6 months (2017) or 2 Academic Terms*

Ethical considerations:

- a) I will let the participants know that participation is voluntary and withdrawal without reprisal is accepted. I will honour the participants' privacy.
- b) Unless otherwise agreed to, the informants' identities will be protected so that the information I collect does not embarrass or in other ways harm them.
- c) I will treat the informants with respect and seek their cooperation in the research.
- d) In negotiating permission to do the study, I shall make it clear to those with whom negotiate what the terms of the agreement are, and I shall abide by that contract. I will tell the truth when I write up and report findings.

CONSENT: Your signature below will indicate that you have agreed to participate as a research subject and that have read and understand the information provided above:

Signature of Principal



Date: 19/01/2017

Signature of Researcher



Date 19/01/2017

THE CONNIE
MINCHIN
PRIMARY
SCHOOL
MODIRI
MOLEMA
ROAD
Private Bag X
2030,Mmabatho,273

5
TEL:(018)392 2423
FAX:(018)384 j-948

DATE..19/01/2017

APPENDIX F

GRADE 7 PRE-TEST: MULTIPLICATIVE WORD PROBLEMS

Date: _____

(Please provide the following information about you by completing spaces below)

Name of Learner: _____

Name of School: _____

Grade: _____

Age of Learner: _____

Home Language: _____

Gender: _____

Ethnicity: _____

Instructions:

Answer ALL questions given below using a pen in the answer sheets given to you. Show ALL your workings and explain in written words where necessary.

QUESTION 1

1.1 There are five birds on a tree. If one is shot down by a hunter, how many birds are left?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

1.2 A farmer keeps 5 pigs, 25 cows and 130 goats. How old is he?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

1.3 Mr. Smith the butcher had 26 kg of meat in his shop and orders 10 kg more. How much meat does he have now?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

QUESTION 2

2.1 Tshego has 6 toy cars. Each car is missing a wheel. Tshego put his cars in a box. How many wheels are in the box?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.2 Mr Tladi can fit 4 desks along the long side of his classroom and 3 desks along the short side. Mrs Khunou has a longer classroom. She can fit 2 more desks along the

long side of her classroom. How many desks can Mrs Khunou put to fill in the whole classroom?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.3 Container A is 67 % full and has a capacity of 25 litres. Container B is 72 % full and has a capacity of 20 litres. Which has more liquid in it?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.4 A profit of R 99 360 was made at a music concert. It was later shared between the Nelson's Children Charity and Thandolwethu Crèche. If Nelson Children Charity got twice as much as Thandolwethu Crèche, how much did each group receive?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

END

APPENDIX G

GRADE 7 POST-TEST: MULTIPLICATIVE WORD PROBLEMS

Date: _____

(Please provide the following information about you by completing spaces below)

Name of Learner: _____

Name of School: _____

Grade: _____

Age of Learner: _____

Home Language: _____

Gender: _____

Ethnicity: _____

Instructions:

Answer ALL questions given below using a pen in the answer sheets given to you. Show ALL your workings and explain in written words where necessary.

QUESTION 1

1.4 There are five birds on a tree. If one is shot down by a hunter, how many birds are left?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

1.5 A farmer keeps 5 pigs, 25 cows and 130 goats. How old is he?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

1.6 Mr. Smith the butcher had 26 kg of meat in his shop and orders 10 kg more. How much meat does he have now?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

QUESTION 2

2.5 Tshego has 6 toy cars. Each car is missing a wheel. Tshego put his cars in a box. How many wheels are in the box?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.6 Mr Tladi can fit 4 desks along the long side of his classroom and 3 desks along the short side. Mrs Khunou has a longer classroom. She can fit 2 more desks along the

long side of her classroom. How many desks can Mrs Khunou put to fill in the whole classroom?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.7 Container A is 67 % full and has a capacity of 25 litres. Container B is 72 % full and has a capacity of 20 litres. Which has more liquid in it?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

2.8 A profit of R 99 360 was made at a music concert. It was later shared between the Nelson's Children Charity and Thandolwethu Crèche. If Nelson Children Charity got twice as much as Thandolwethu Crèche, how much did each group receive?

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>

APPENDIX H

GRADE 7 PRE-TEST: MULTIPLICATIVE WORD PROBLEMS **MEMORANDUM**

Date: _____

40 marks

(Please provide the following information about you by completing spaces below)

Name of Learner: **MEMORANDUM**

Name of School: _____

Grade: _____

Age of Learner: _____

Home Language: _____

Gender: _____

Ethnicity: _____

Instructions:

Answer ALL questions given below using a pen in the answer sheets given to you. Show ALL your workings and explain in written words where necessary.

QUESTION 1

1.7 There are five birds on a tree. If one is shot down by a hunter, how many birds are left?

(3)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>
❖ No birds will be left on the tree ✓	➤ I used common sense to think logic. ✓
As the remaining four will be frightened and	
fly away. ✓	

1.8 A farmer keeps 5 pigs, 25 cows and 130 goats. How old is he?

(2)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>
The age of the farmer is not related to the	➤ I used common sense. ✓
number of animals he has. ✓ OR	
I do not know his age. ✓	

1.9 Mr. Smith the butcher had 26 kg of meat in his shop and orders 10 kg more. How much meat does he have now?

(3)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>
❖ Mr. Smith might have $26 + 10 = 36$ kg ✓	➤ I used common sense to think logic. ✓
of meat if the ordered 10 kg arrived before	
the 26 kg was sold. ✓ (OR)	
❖ If any amount of the 26kg was sold ✓	
Then it could be any amount of meat up to 1	
10 kg which was what was ordered. ✓	

QUESTION 2

2.9 Tshego has 6 toy cars. Each car is missing a wheel. Tshego put his cars in a box. How many wheels are in the box? (5)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>
❖ $4 - 1 = 3 \text{ wheels}$ in each car. (✓)	➤ Knowing that a car has 4 wheels and 1 is missing; ➤ I subtracted 1 wheel from each car. (✓) ➤ Was left with 3 wheels for 1 car.
❖ $6 \text{ cars} \times 3 \text{ wheels} = 18 \text{ wheels}$ (✓)	➤ Multiplied the given 6 cars by 3 wheels, to get the total number of wheels in the box for all the toy cars (✓)

2.10 Mr Tladi can fit 4 desks along the long side of his classroom and 3 desks along the short side. Mrs Khunou has a longer classroom. She can fit 2 more desks along the long side of her classroom. How many desks can Mrs Khunou put to fill in the whole classroom? (8)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u>
❖ Mr Tladi's classroom: ❖ Length = 4 desks ❖ Breadth = 3 desks (✓)	➤ Used the information for Mr Tladi's classroom to get Mrs Khunou's classroom information; of the "length"
❖ Mrs Khunou's classroom ❖ Length = 2 more desks (4 + 2) ✓ = 6 desks (✓)	➤ Added 2 desks on Mr Tladi's length as Mrs Khunou's is more by 2 desks. (✓)
❖ Length $\times$ breadth (✓) = 6 desks $\times$ 3 desks (✓) = 18 desks (✓)	➤ Calculated "area" of Mrs Khunou's classroom (because the question needs the number of desks to fill up the classroom). ➤ Used a rectangle formula as a classroom is rectangular in shape (length and breadth). ➤ Multiplied the two dimensions to get the area. ➤ Used "desks" as arbitrary units used for measurement. (✓)

2.11 Container A is 67 % full and has a capacity of 25 litres. Container B is 72 % full and has a capacity of 20 litres. Which has more liquid in it? (10)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u> (√) (√)
Container A: $\frac{67}{100} \times \frac{25}{1}$ (√)	➤ Firstly I calculated the capacity of container A. ➤ Converted the percentage (67 %) into a fraction ➤ Multiplied the fraction by the capacity (25 litres) of the container.
$= \frac{1675}{100}$ litres (√)	➤ Multiplied numerators over product odd denominators.
$= 16.75$ litres (√)	➤ Divided numerator by denominator to get the decimal fraction.
Container B: $\frac{72}{100} \times \frac{20}{1}$ (√)	➤ Calculated the capacity of container B. ➤ Converted the percentage (72 %) into a fraction ➤ Multiplied the fraction by the capacity (20 litres) of the container. ➤ Divided numerator by denominator to get the decimal fraction.
$= \frac{1440}{100}$ litres (√)	➤ Both answers were in litres, which was a common measurement for both amounts.
$= 14.40$ litres (√)	➤ This made it easy to compare like terms.
$16.75 - 14.40 = 2.35$ litres (√)	➤ Subtracted the smaller from the bigger capacity to find the difference between the two containers.
➤ Therefore container A is more than container B by 2.35 litres. (√)	➤ Compared the two containers and gave the difference to prove the difference in the containers

2.12 A profit of R 99 360 was made at a music concert. It was later shared between the Nelson's Children Charity and Thandolwethu Crèche. If Nelson Children Charity got twice as much as Thandolwethu Crèche, how much did each group receive? (9)

<u>SOLUTION</u>	<u>HOW I ARRIVED AT THE ANSWER</u> (√) (√)
❖ $2 + 1 = 3$ (√)	➤ As a ratio; I added 2 and 1 (as twice as much as 1) is 2, in order to get 3 (total ratio).
❖ Nelson Children Charity $= \frac{2}{3} \times \frac{R\ 99\ 360}{1}$ (√)	➤ Nelson Children Charity is 2, thus make it a ratio fraction: $\frac{2}{3}$ of the total profit (R 99 360). ➤ Multiplied the ratio by the total profit to get the share of Mandela Children Charity.
$= \frac{2}{1} \times \frac{33\ 120}{1}$ (√)	➤ Divided R99 360 by 3. ➤ Multiplied numerators over denominators product .
$= \frac{66\ 240}{1}$ (√)	➤ Got products of numerators and denominators
$= R\ 66\ 240$ (√)	➤ Simplified the improper fraction to get amount for Mandela Children Charity share.
❖ Thandolwethu Crèche: $R\ 99\ 360 - R\ 66\ 240$ (√) $= R\ 33\ 120$ (√)	➤ Subtracted Mandela Children Charity share from the total amount to get the share for Thandolwethu Crèche.

END

APPENDIX I

PRE-INTERVENTION LEARNERS' FOCUS GROUP INTERVIEW GUIDE

1. What did you do in order to solve the word problems in the test?
2. What problems did you encounter in solving the word problems in the test?
3. What influenced you to solve the word problems the way you did when you took the test?
4. What problem solving techniques did you use every time when you struggled to solve word problems correctly?
5. What do you think you need to do as learners in order to solve word problems successfully?
6. What suggestions can you make to your teacher in terms of the use of context for setting and teaching word problem items?
7. What suggestions do you make to your teacher in terms of language difficulty as they set and teach word problem items?

APPENDIX J

POST-INTERVENTION LEARNERS' FOCUS GROUP INTERVIEW-GUIDE

You have been exposed to an innovation called Argumentative Writing Frames to support Dialogue Strategy of Learning how to solve multiplicative word problems. From what you understand of this strategy, kindly respond to the following questions:

1.
 - a) How did you solve word problems before this innovation?
 - b) What is the same in your approach to solving questions from the pre-test?
 - c) What is different in your approach to solving the questions from the pre-test?
 - d) How was it different from your previous approach?
2.
 - a) What problems did you encounter when you solved word problems in the test this time?
 - b) Did you encounter the same problems?
3. What influenced you to solve the word problems in the actual test the way you did in the test now?
4.
 - a) Were the strategies you used similar or different from the ones you used when writing the test before?
 - b) How were they similar or different?
5. After your participation in the intervention, what do you think you need in order to succeed in solving in word problems?
6. What suggestions can you make to the teachers in terms of :
 - a) The context of the word problem questions?
 - b) Language difficulty of the word problem questions?

APPENDIX K

MATHEMATICS ARGUMENTATIVE WRITING FRAMES

2017

KUNENE N.T.

- 1. The problem gives the following information.....**
- 2. The problem requires me to find.....**
- 3. I already know that.....so that/ because.....**
- 4. The steps/ strategy I took in solving this problem were.....**
- 5. This did not work, so.....**
- 6. Another strategy I could use to solve this problem would be to.....**
- 7. I think the answer is.....because.....**
- 8. To check if my answer is correct, I.....**
- 9. The easiest/ most difficult part of this topic/ today's lesson was.....**
- 10. One thing I learned in this topic that I did not know before, was.....**

APPENDIX L

CONSENT FOR MINORS TO PARTICIPATE IN A RESEACH STUDY (SCHOOL A & B)

Title: Using Argumentative Writing Frames to support dialogue and written problem-solving in multiplicative word problems: A case of Grade 7 learners in Montshiwa township school.

Purpose of the study: The purpose of this study is to:

- ✓ To understand the nature of the learners' performance and argumentation in relation to multiplicative word problems prior to a sequence of intervention lessons.
- ✓ To understand in relation to literature and theory what was implemented across the series of lessons and how has learners' talk in argumentation changed across the implemented lessons.
- ✓ To investigate the nature of the learners' performance and argumentation in relation to multiplicative word problems post - intervention lessons.
- ✓ To explore the implications for the pedagogic practice of these findings.
- ✓ To understand the nature and effects of the intervention.

How the participants will contribute to the study:

- a) The learners will write pre- and post-test drawn up by the researcher. They will also undergo a pre- and post-learners' focus group interviews.
- b) The researcher will draw and implement the intervention on "using Argumentative Writing Frames to support dialogue and written problem-solving in multiplicative word problems" to teach word problem solving in mathematics.
- c) The whole process will last for not more than 6 months (2017) / 2 Academic Terms

Ethical considerations:

- a) I will let the participants know that participation is voluntary and withdrawal without reprisal is accepted. I will honour the participants' privacy. Participants are welcome to ask questions.
- b) Unless otherwise agreed to, the informants' identities will be protected so that the information I collect does not embarrass or in other ways harm them.

- c) I will treat the informants with respect and seek their cooperation in the research.
 - d) In negotiating permission to do the study, I shall make it clear to those with whom I negotiate what the terms of the agreement are, and I shall abide by that contract. I will tell the truth when I write up and report findings.
-

If you require any further information, please do not hesitate to contact me (Kunene N. A. T.) on contact number: 081 434 3747. Thank you for your time and consideration in this matter.

CONSENT: Your signature below will indicate that you have agreed to allow your child to volunteer as a research subject and that you have read and understand the information provided above:

Signature of Legal Parent/Guardian _____ Date: _____

Signature of Researcher _____ Date: _____

LEARNER ASSENT: Your signature below indicate that you agree to volunteer as a research subject and that you have read and understood the information provided above:

Signature of Learner: _____ Date: _____

APPENDIX M

LEARNERS CONSENT FORM FOR VIDEOTAPE RECORD OF MATHEMATICS CLASSES

Researcher: Kunene N. A. T.

If you as a learner / as parent or guardian for your child, are happy to be videotaped, please sign below.

I am happy to be videotaped/ for my child to be videotaped during lesson observations as well as professional development sessions in school and in cluster groups as part of the research.

Parent/ guardian	Learner
Name:	
Signed	
Date	

WHAT WILL THE RESEARCHERS DO?

The Researcher (with the help of the Research Assistance) will videotape you as the Researcher teaches during the intervention time in your class in your school. The purpose of videotape records of teaching is that it will assist with obtaining an accurate record of the observations made.

It is difficult to guarantee anonymity in video recordings. The video recording in your class will be focused on the researcher (teaching) and on you as the learners interacting with the researcher/ teacher. In all instances, the camera person will, as far as is possible, avoid focusing on the faces of participants.

HOW WILL THE VIDEOTAPE INFORMATION BE USED

The videotapes will be used to capture data that will inform the researcher about issues to study on argumentation and its implementation with classroom. It is important to note that all video data obtained will be given careful consideration in relation to clarity that no prejudice or harm will follow from sharing of this data.

LEARNER'S RIGHTS: You may withdraw your permission to be videotaped at any time during the research.

APPENDIX N

LEARNERS CONSENT FORM FOR AUDIOTAPED FOCUS GROUP INTERVIEWS

Researcher: Kunene N. A. T.

If you as a learner / as parent or guardian for your child, are happy to be audiotaped, please sign below.

I am happy to be audiotaped/ for my child to be audiotaped during lesson observations as well as professional development sessions in school as part of the research.

Parent/ guardian

Learner

Name:

Signed

Date

WHAT WILL THE RESEARCHERS DO?

The researcher would like to audiotape the Focus Group interview with you. The purpose of the audio tape is that it provides an accurate record of the interviews. The researchers will listen to the tape and transcribe useful sections. The researchers will use the information from the interviews to inform professional development and write research papers.

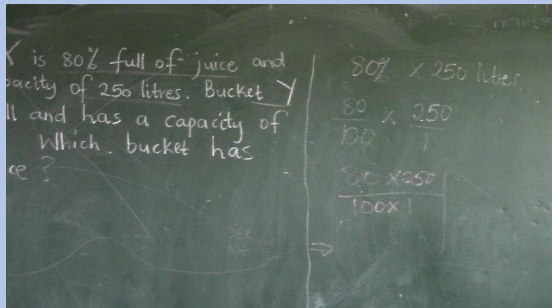
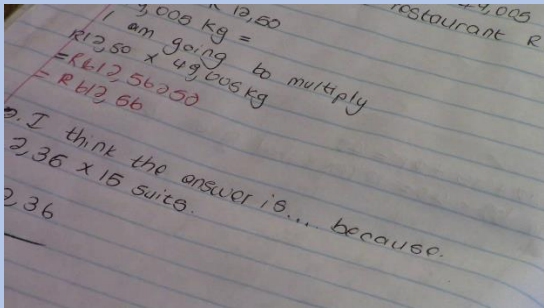
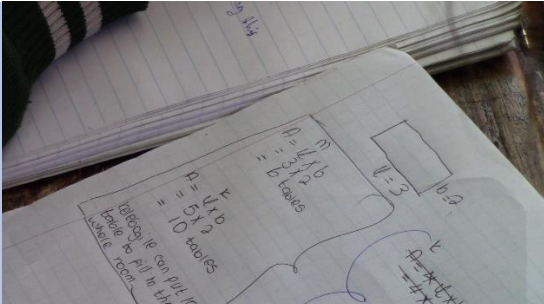
LEARNER'S RIGHTS

You can withdraw your consent at any point in the research.

APPENDIX O: VIDEO SNAPSHOTS

The appendix below displays pictorials that were captured during the intervention of the scenes that took place in the classrooms corresponding to Table 5.16 above. The video screenshot give more visual clarity as evidence of the arguments discussed in the different multiplicative word problems.

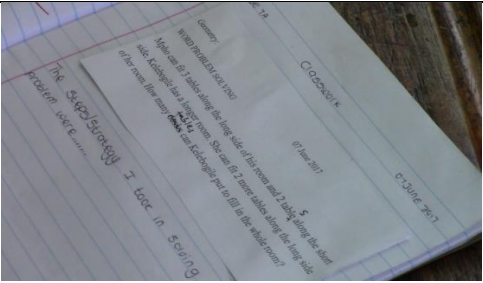
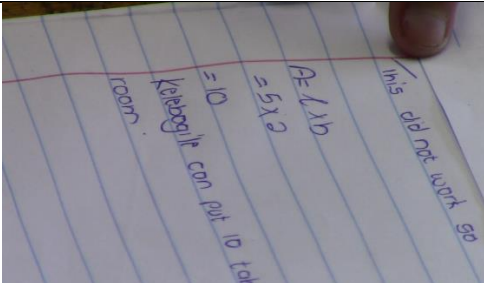
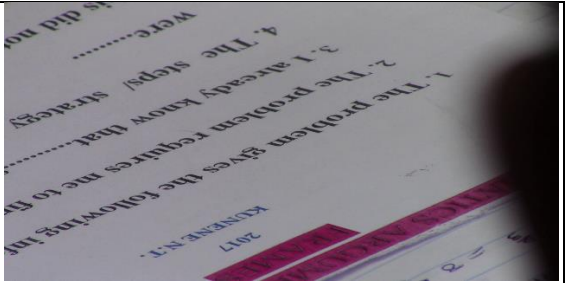
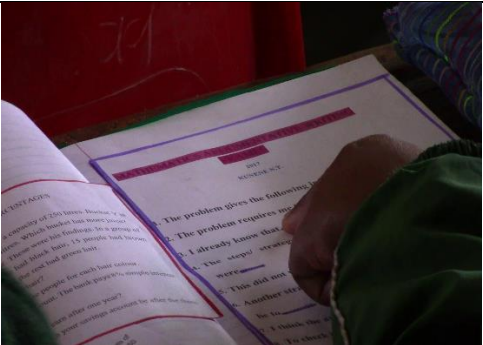
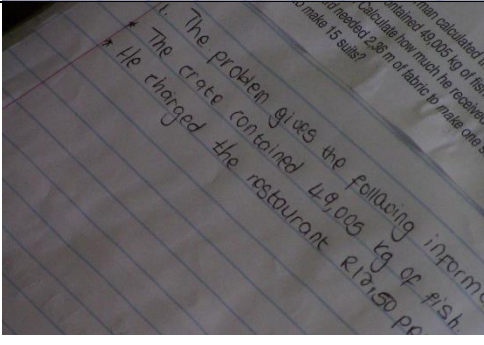
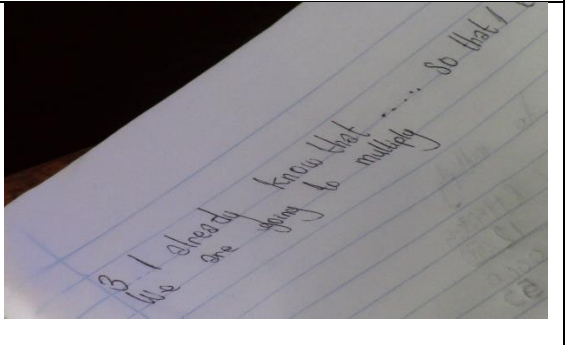
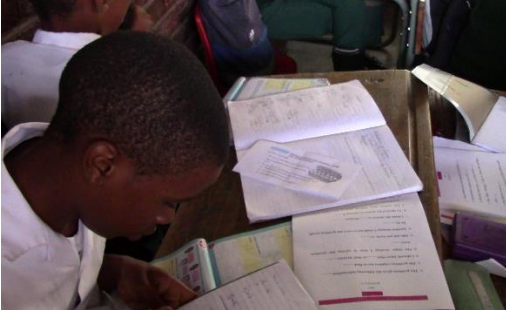
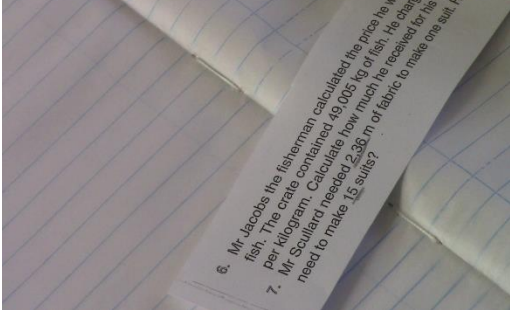
Level	Before the intervention (AWF): Learners hardly ‘talk’ in the discussions.	During the Intervention (AWF): Rate, example- <i>divide 120 by 4.</i>	After the intervention (using AWF): Discussions in their groups even in the absence of the teacher.
Mathematical discussion	 Figure 1	 Figure 2	 Figure 3

Level	Before the intervention (AWF): Lacks the essence and art needed to make a claim provide justification...	During the Intervention (AWF): Teacher mediated argumentation with the use of the AWF.	After the intervention (using AWF): Students argued that the operation to be used for Mr Scullard was “multiplication” and “...because... (They justified their claims).
Mathematical argumentation	 Figure 4	 Figure 5	 Figure 6
Level	Before the intervention (AWF): Lack of logic when it came to the operation they used, which was <i>multiplication</i> instead of <i>division</i> .	During the Intervention (AWF):	After the intervention (using AWF): More reasoning skills and logic in their justification of the ‘area of a rectangle’ concept
Mathematical reasoning	 Figure 7		 Figure 8

Level		Before the intervention (AWF): Could not place numbers correctly when subtracting.	During the Intervention (AWF):	After the intervention (using AWF): Learners were seen boundary-crossing with the teacher.
Problem-solving		 Figure 9		 Figure 10
		 Figure 11		 Figure 12
Level		Before the intervention (AWF): Learners were seen to experience a 'shut down' mentally.	During the Intervention (AWF)	After the intervention (using AWF): Teacher engaged learners in using the AWF to think... were actively involved.
Mathematical thinking				

Level	Before the intervention (AWF): Learners' response was "... <u>1.8 goals</u> ." indicated the exclusion of reality and common sense.	During the Intervention (AWF): Idea of mathematical modelling was slowly being realised.	After the intervention (using AWF): Learners were seen reading the problems on their own in their groups of 3 or 4s, teacher facilitates one.
Sense making	 Figure 13	 Figure 14	 Figure 15

APPENDIX P: EXAMPLES OF DOCUMENTS: LEARNERS' EXERCISE BOOKS

i.		ii.		iii.	
iv.		v.		vi.	
vii.		viii.		ix.	

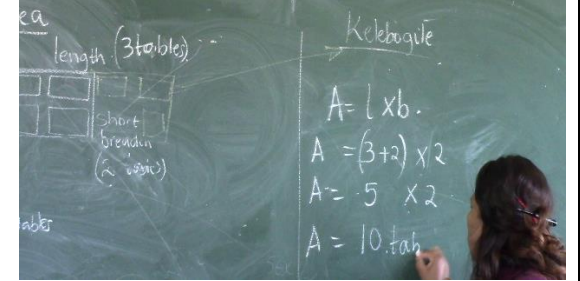


x.

xi.



xii.



xiii.

xiv.

