# AN EXPLORATION OF A VISUALIZATION INTERVENTION IN A GRADE 7 MATHEMATICS CLASSROOM IN THE PINETOWN DISTRICT

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# DEDICATION

This dissertation is dedicated to the Almighty God, the giver of wisdom, knowledge and understanding.

And

To my lovely husband, Prof. Babatunde Bakare, for your encouragement and support and my lovely children, Daniel and David, for your constant prayers.

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To my friends and spiritual family, I say thank you for your love and support.

## DECLARATIONS

I, Onozare Mercy Bakare, declare that

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As the candidate's Supervisor, I agree to the submission of this thesis.

**Prof Vimolan Mudaly** [redacted]

Signed.................... [redacted].

# ABSTRACT

With the growing research on visualization in mathematics, it is important to understand how visualization intervention strategies impact learners' solving and success of mathematical word problems. This study focused on exploring a visualization intervention in a grade 7 mathematics classroom in the Pinetown District of KwaZulu-Natal. The methods used by learners and their effectiveness in solving word problems were investigated as this formed the basis of this study. Their understanding of the methods and strategies chosen was revealed through an interview, leading to a visual intervention on how they (learners) can become better visualizers. Boonen, Van der Schoot, Van Wesel, De Vries, and Jolles, (2013, p. 57) asserted that the difficulties learners encounter in solving word problems emancipate from lack of understanding of the problem text, identifying solution-relevant components, the relations between them, and making a complete and clear representation of the situation described in the problem. Good problem solvers ought to have a good understanding of the text and strategies required for every given problem, and for this to take place, learners are required to think visually. Visualization and its importance in mathematics or in solving mathematical word problems cannot be overstressed. It is a skill that learners ought to possess to become good problem solvers. Therefore, it is not enough for learners to possess these skills and form visual images, but they also should be able to use the skills when required and for analytical reasoning. Hence, the reason for conducting this study is for learners to be taught these skills and strategies through an intervention process and determine the effectiveness of the intervention given to them. Data was gathered using a qualitative research method. An interpretative approach was used, which helps to understand what is being understudied. Learners were given word problems to solve, and a one-on-one open-ended interview was conducted on randomly selected learners from the class. This research was conducted in the naturalistic setting of the participants; the sample was purposive and convenient.

The conclusion drawn from the investigation findings has shown that learners do not have a natural inclination to use diagrams or any visualization form before the intervention strategies were introduced. Secondly, evidence suggested that learners' strategies in completing the initial task administered were not all effective. Finally, there was a significant improvement in learner's performance, their use of visuals, and the accuracy of their methods after the intervention process.

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# CHAPTER ONE

## 1 Introduction and overview of the study

Over the years, learners have struggled with problem-solving in mathematics, which also affected their performance level in the classroom as they pictured it (word problem) as an aspect of mathematics that is difficult to understand. There is always a notable difference in learners' performance in number problems and word problems, as they found the latter more difficult to attempt. Learners often gave reasons like not knowing what to do, how to solve the questions, and not understanding the problem at hand when solving word problems in mathematics. For learners' insight into mathematical word problems to be boosted, it is important that visualizations among learners are given great attention.

For this to be achieved, visualization ought to be taught to learners by their teachers and opportunities for continuous use in the classroom should be encouraged. Presmeg, (2014, p. 7) stated that the lack of desire for learners to use visualization when solving mathematical problems results from the little attention given to visualization in the mathematics classroom. Visualization has been an aspect of mathematics that has not received much attention in the research area, which could be why much attention is not given to it in the classroom. This is supported by Presmeg, (2014, p. 1) that over the years, out of the literature out there, not many of them are focused on visualization. Hence, the need for more research in the area of visualization and, most importantly, its intervention. The more we have studies that talks about how learners can be assisted visually through intervention, how it can be promoted in the classrooms and teachers getting the necessary support needed to equip them, the more benefits and success will be recorded.

Visualization strategies are essential tools that can be used in solving mathematical word problems. It plays a big part in mathematics learning, particularly in word problems. It helps learners think and represent words using diagrams, lines, pictures, colour, graphs, and so on, leading to developed mathematical thoughts and an appropriate solution. Visualization can be termed as the ability to see, understand and represent a problem with the aim of solving it. De Koning & van der Schoot, (2013) supported the claim that when learners are able to visualize on their own, it can be an effective way to better understand problem texts. This is why this study is important as the intervention was aimed at assisting learners become better visualizers using different strategies. ***Previous research*** showed that there has been some studies on teaching intervention to help equip teachers become problem solvers with the use of visual strategies but not enough intervention has been given to helping learners become real problem solvers. Thus, teaching learners to use visual representations when solving problems could be an effective way to support word problem solving (Van Garderen & Montague, 2003).

## 1.1 Purpose of the study

The purpose of this study is to investigate how visualization intervention impacts on learners success in a mathematics classroom. With the growing research on visualization in mathematics, it is important to understand how visualization intervention strategies impact on learners solving and success of mathematical word problems. This study focused on exploring a visualization intervention in a grade 7 mathematics classroom. The methods used by learners and its effectiveness in solving word problems were investigated as this formed the basis of this study. Their understanding of the methods and strategies chosen was revealed through an interview, leading to a visual intervention on how they (learners) can become better visualizers. Boonen, Van der Schoot, Van Wesel, De Vries, and Jolles, (2013, p. 57) asserted that the difficulties learners encounter in solving word problems emancipate from lack of understanding of the problem text, identifying solution-relevant components, the relations between them, and making a complete and clear representation of the situation described in the problem. Good problem solvers ought to have a good understanding of the text and strategies required for every given problem, and for this to take place, learners are required to think visually. Visualization and its importance in mathematics or in solving mathematical word problems cannot be overstressed. It is a skill that learners ought to possess to become good problem solvers. Therefore, it is not enough for learners to possess these skills and form visual images, but they also should be able to use the skills when required and for analytical reasoning. Hence, the need for this study to be carried out, for learners to be taught these skills and strategies through an intervention process and to determine the effectiveness of the intervention given to them.

Once learners know what to look out for when confronted with mathematical word problems, choosing a visualization strategy to solve them becomes easy. When learners are able to visualize, it can be an effective way to understand better problem texts (De Koning & van der Schoot, 2013). The study conducted by Lowrie, Logan, Haris and Hegarty (2018, p. 9) affirmed that a classroom-based intervention program can improve students' spatial reasoning at scale.

From the above finding, it was evident that if proper visualization intervention is provided for learners, it may cause an improvement in the way they visualize, making them better problem solvers. This will add to the impact of visualization in mathematics learning which, according to (Mudaly 2014, p. 4), has been neglected in the past. The study carried out is of great relevance as it helped shed more light on the effectiveness of visualization intervention.

## 1.2 Significance of the study

The National Curriculum Statement (2012, p. 5) aims to produce learners who can identify, solve problems, and decision-makers that can think critically and creatively in our mathematics classroom. To achieve this in our classrooms, their visualization skills and strategies needed to be improved. This study's findings are important to impact the effectiveness of visualization intervention in solving mathematical word problems in the classroom. Also, this study's findings may help improve and increase teacher's involvement in producing visualizers in our classroom. Increased support on how teachers can be further equipped and trained for the learners' benefits may be created through this study.

## 1.3 Rationale for the study

Visualization is an essential tool in the learning and solving of word problems in a mathematics classroom. The researcher was interested in first investigating the visualization strategies that learners use in a mathematics classroom and further determined the effectiveness of their strategies in solving the problems. The researcher's focus was on improving learner's problem-solving strategies through visualization intervention in a particular context.

## 1.4 Research questions

The study focused on exploring the visualization strategies used in a grade 7 mathematics classroom. The aims and objectives of the study were used to formulate the research questions, which were:

- Firstly, to investigate the visualization strategies that grade 7 learners use in a mathematics classroom.
- Secondly, to determine the effectiveness of their strategies in solving problems.
- And thirdly, to explore how their problem-solving strategies can be improved through a visualization intervention.

The three research questions that were investigated in line with the purpose and objectives of this study were:

- What visualization strategies do grade 7 learners use in a mathematics classroom?
- How effective are their strategies in solving problems?
- How can their problem-solving strategies be improved through a visualization intervention?

## 1.5 Structure of the study

The following structure has been used to approach this study.

**Chapter one** introduced an overview of this study. It presents the study's background, the purpose of conducting the study, significance and rationale of the study. The research questions were also introduced in chapter one.

**Chapter two** reviews the literature related to this study. This chapter examined visualization, its role in problem-solving, visual thinking and intervention in mathematics. Also, problems that may hinder learners' drawing from past literature were considered and possible ways to alleviate the problems mentioned in this chapter. The role mathematics educators' play in equipping learners with the necessary skills was mentioned as findings has shown how effective it can be, if and when introduced in the classroom.

**Chapter three** presents the theoretical framework that underpins this study. Activity theory which forms the framework of the study, is discussed.

**Chapter four** is an overview of how the research study was conducted by outlining the methods and processes employed in carrying out the research with ethical considerations. The chapter started with a list of research questions and the approach taken to carry out the research study, which was a case study approach. A discussion of the paradigm used was discussed, which was interpretive and qualitative in nature. This was followed by discussions on the research design, methods and methodology, which was how data was collected, and the procedures followed.

**Chapter five** explores the analysis of the data collection and study findings. The study carried out established the type of visualization strategies used by grade 7 learners when solving word problems in mathematics. The data collection in the form of a task-based worksheet and interview outlined the effectiveness of a visualization intervention in a grade 7 mathematics classroom.

**Chapter six**, the final chapter in this research, presents the conclusion that was drawn based on the research carried out. This chapter also discusses the study results in response to the three research questions and recommendation for further studies.

# CHAPTER 2

## 2 Literature Review

A literature review is done to give readers insight into research conducted in the field that is to be researched. Findings and how it relates to the research to be conducted is looked into as well. In this chapter, the literature review related to visualization, its role and benefits, problems and intervention is discussed. It is evident that mathematics is viewed globally and not only in South Africa as a very effective tool that is needed in our everyday life. On the other hand, most learners believe that it is a difficult subject to tackle. Some have grown with the misconception that you are either born with the required skills, abilities and mathematical brain, and it cannot be learned. This has been observed in my over ten years of being a mathematics educator, thus being part of what has also added to the number of failures recorded in our mathematics classroom in South Africa.

For knowledge insight in mathematics to be boosted, as it has been seen as a universal language that ensures the expressions of thoughts by way of shapes, signs and symbols, it is of necessity that visualization among learners is enhanced. With the necessary support put in place at schools like the intervention that will be administered to learners in this study, it is envisaged to influence learner's interest in mathematics. This can only be achieved if visualization is introduced/or taught to learners by the teacher with opportunities for its continuous usage being introduced. Govender, (2016. p. 26) stated that when a teaching system is learner-driven, it brings about greater learner involvement and control, promoting meaningful classroom interaction. As facilitators of the learning process, learners should be involved and allowed to take charge of their learning as it becomes meaningful to them rather than transmitting knowledge.

They also need to have adequate knowledge of how a problem is solved, as when they are knowledgeable in this aspect, it provides them with the necessary skills needed, making visualization possible. Bansilal and Naidoo (2012) note that learners' activities should be part of an investigation that gives them an opportunity to discover the mathematical concept such that learners will have a meaningful understanding when such a concept is applied later on. This should be the case when learners are taught visualization strategies. Furthermore, Bansilal and Naidoo (2012) also remarked that visualization promotes investigation and discovery through the use of diagrams, concrete manipulatives and models. Findings have shown that not much attention has been directed to visualization and its intervention like it ought to; hence there has not been many articles as should be, addressing visualization intervention in solving mathematical word problems (Presmeg 2014, p.1). Also, Presmeg (2014, p. 1), stated that very little literature out of the many out there focused on visualization over the years, with very few research conducted in the 19th century. Towards the end of that century, there was a developed interest in the topic of visualization research in mathematics education. Presmeg (2014, p. 1), stated that only a few articles specifically addressed visualization while others did not make it (visualization) their primary focus. This shows that more research needs to be conducted in visualization and its intervention in mathematics, as there is a gap in that research aspect.

This chapter focuses on reviewing available literature on visualization, its roles, problems, and intervention relevant to this study.

## 2.1 Visualization

As stated by Sepeng (2014, p. 209), 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 and strengthen learners' ability to be good problem solvers. For this to be achieved, learners need to be equipped with visual skills that will make them better problem solvers.

Anecdotal evidence shows that learners are able to solve routine problems where all it requires is the application of a formula to arrive at an answer than solving non-routine problems, which requires them to understand the problem first, think of how to solve them and come up with an approach that will be suitable for solving the mathematical problem. Previous findings have shown that the performance rate in problem-solving has been low, be it in the form of tasks, assessments and homework. This is because learners have shown little or no interest in this aspect of mathematics, which could result from battling to understand the problem in itself or not making sense of the problem at hand. This could also be due to not understanding the words or sentences used, thereby making it difficult to represent the problem in a diagram form. Learners from the age of 11 ought to be ready for visual imagery in mathematics both cognitively and meta-cognitively, as when they are equipped with the necessary skills, they should then be able to visualize on their own. When learners are well equipped with visualization skills, Govender (2016, p. 35) noted that they acquire the correct technical terms since they are able to see the definition and experience the meaning. Therefore, educators must be knowledgeable mathematically and possess the necessary skills, attitude, and ways to pass on this knowledge to their learners. Bearing in mind also that learners’ development of conceptual knowledge in problem-solving and its implementation is dependent on teachers' understanding of the content and its delivery. In addition to this, teachers also need to empower learners to be problem solvers in this instance through visualization. Past studies have been seen as a powerful tool in mathematics education capable of helping learners in a mathematical classroom, thereby leading them to become good problem solvers. This research focuses on how visualization intervention can be used as a tool to help learners become real problem solvers.

The history of visualization in mathematics has been a long one. In a report given by Kadunz and Yerushalmy (2015, p. 463), which asserted that mathematics educators since the beginning of the 1980s are interested in the practical challenges of teaching visualization, in visualization mathematics as exhibits in school or aligned with educational psychology and are in search of theoretical frameworks. Based on the findings above, visualization has been an aspect that has been challenging for teachers and learners, but play an essential role in the solving of mathematical word problem, hence the need for educators to give proper attention to it (visualization) in the classroom. According to Arcavi (2016, p. 26), visualization is defined by separate authors as "the process, the ability, interpretation and the product of creation, use of images, diagrams in our minds, on paper or with technological tools, with the purpose of representing and communicating information, thinking about and developing previously unknown ideas and advancing understandings." Research has shown that diagrams can be a powerful tool if well used in the solving of mathematical word problems. Learners can then represent the problem diagrammatically if they understand the problem given, as it may lead them to proffer a solution to the given problem. It then shows that visualization is an aspect that cannot be trivialized in the teaching and learning of mathematics. It makes learning easier for learners and helps in the interpretation of mathematical word problems. Ho (2010, p. 2) also defined visualization as the centre of problem-solving in mathematics, as it also helps learners see and have a better understanding of a problem situation. Visualization has been an aspect that helps increase learner's mathematical understanding if it is magnified in them. Suppose learners are equipped with the necessary skills. In that case, they begin to make sense of whatever problems they are presented with within the classroom by first visualizing, which then helps and make it easier for them to solve the problem presented to them. It is worthy of note that if visualization does not come naturally to learners, the teacher's responsibility is to create an avenue that will ensure that these skills are developed in them, thus making them visualizers. Visualization and its importance in mathematics cannot be overemphasized as it is an aspect that ought to be developed in learners. Furthermore, visualization from gathered literature is extensive and is not just about pictures and diagrams. It also helps understand and put together a plan that can be used to solve a problem.

According to Muchoko, Jupri and Prabawanto (2019, p. 2), learners are used to mechanical procedures for solving problems in mathematics without making sense of it. This is due to difficulties encountered in understanding words, phrases or sentences and coming up with equations, schemes or diagrams. This is a problem that is common among learners who have passed through me over the years. Furthermore, they established that visual representations such as diagrams and schemes facilitate understanding (of fractions) and reduce difficulties learners may face when dealing with abstract concepts (Muchoko, Jupri and Prabawanto 2019, p. 2).

Small (2012, p. 21) stated that an essential component in mathematics learning is reasoning, irrespective of the learner's grade. Therefore, it is necessary to ensure that learners from an early stage are encouraged to become logical in their thoughts. He further stressed that in order for learners to be competent at reasoning and explaining, visualization has been identified as a required skill. It is a powerful tool that helps learners better understand the concept taught (Muchoko, Jupri and Prabawanto 2019, pg. 2). Also, in an important research forum, Zimmerman and Cunningham (1991) described visualization as a medium for meaningful problem-solving in algebra aside other topics.

From the statement above, it then implies that visuals can play an important role in making mathematics easily accessible and approachable for learners, which can only be possible if they, in this instance learners are introduced to it as well as encourage its usage and development in the classroom. One of the reasons why learners are not motivated to using visuals is because of the minimal attention that's been given to it in the classroom. If learners see its usefulness, they begin to value it and see it as a tool that can be used when solving mathematical word problems, leading to a better performance in mathematics.

Also, according to Kashefi, Alias, Kahar, Buhari and Othman (2015, p. 803), visualization for learners should be enhanced to boost the knowledge insight in mathematics. For this to be done, Boonen, Reed, Schoonenboom, and Jolles (2014, p. 60) stated that teachers ought to help encourage learners to use visual representations in a different but flexible and functional way. This means that learners ought to be able to use diverse kind of visual representations as well as switch between them when necessary and such representation should fit the problem and useful at helping to solve the problem at hand. Also, Cappello and Walker (2017 p. 317) had believed in visuals and visual thinking to providing opportunity and support in terms of the curriculum that will assist students to reach their academic goals. This statement shows that, when learners are equipped with the necessary visualization skills, they will be able to think about the problem so as to understand it, know how a problem can be interpreted visually, as well as the type of diagram that will be used to solve the problem which tends to help improve their performances academically. Learners can only get better at using visuals if they are encouraged to use them consistently.

Solving mathematical word problems from experience as an educator has been an aspect that learners have struggled with over the years, as it has posed to be difficult to solve. Results from years of teaching have also shown that learners tend to perform better in number problems than in word problems. This may be linked to learners not having the required skills aside from other factors to solve mathematical word problems. Presmeg (2014, p. 7) mentioned in her article that learners' unwillingness to use visualization when solving mathematical problems is a result of little attention given to the aspect of visualization in the mathematics classroom. Hence, this research focuses on learners' use of visualization and how they can be made better visualizers through proper intervention. In a simple term, word problems are problems that involve words instead of numbers; hence, it poses to be difficult for learners to solve because of either the language or the concept is difficult for learners to comprehend. Anecdotal evidence also showed that learners battle in this aspect; hence, the need to devise ways in which learners can become real problem solvers. According to Boonen, Van der Schoot, Van Wesel, De Vries, and Jolles (2013 p. 57), the difficulties encountered by learners in solving word problems emancipate from lack of understanding of the problem text, identifying solution-relevant components and the relations between them, making a complete and coherent representation of the situation described in the problem. This shows that for learners to become good problem solvers, a good understanding of the text and the strategies to be used are of great importance, hence the need for learners to become visual thinkers. Findings have also shown that metacognition is vital in learning and successful problem solving as learners engage in mathematics word problems (Jacobse & Harskamp, 2012). In driving this further, learners are required to be critical thinkers, aside from understanding the problem posed at them as well as being able to visualize.

Visualization and its importance in mathematics or solving mathematical word problems cannot be over emphasized. It is a skill that learners ought to possess to become problem solvers. It is not enough for learners to possess the skills and form visual images, but they also should be able to use the skills when required and for analytical reasoning. As noted, visual reasoning is a very important skill needed to deal with real-life situations. An essential feature of mathematical development is learning to solve non-routine word problems (Depaepe, De Corte, & Verschaffel, 2010; Jiminéz & Verschaffel, 2014; Swanson, Lussier, & Orosco, 2013). This is not only restricted to South Africa but primary school worldwide. In other words, word problems help learners develop mathematically if well equipped with the required skills, which will also promote success. Learners experience difficulties in the solving of problems, which is due to inaccurate problem comprehension (Boonen, Reed, Schoonenboom & Jolles, 2016, p. 56). Visual representations could be used to help learners overcome these challenges or problems if the teacher gives adequate instructions. Once learners are well informed and know what to look out for when confronted with mathematical word problems, it becomes easier for them to know which visualization strategy will be required. Moreover, when learners can visualize, it can be an effective way to understand better problem texts (De Koning & van der Schoot, 2013).

Research shows (Boonen, Reed, Schoonenboom and Jolles (2016, p. 60)) that there have been limited studies on teaching intervention to help equip teachers to become problem solvers and competent with the use of visual strategies. Also, not enough intervention has been given to helping learners become real problem solvers, so this intervention study will throw more light on learners' performance in mathematical word problems. Thus, teaching learners to use visual representations when solving problems could be an effective way to support word problem solving (Van Garderen & Montague, 2003) as mathematics is a language that is seen to be rich in visuals (Mudaly, 2010, p. 36). This also corroborates Presmeg (1985, 1986a, 1986b) who stated that anyone, in this case, a learner that chooses to use a visual image when there are other options is known as a visualizer. Hence, if learners are taught to solve the problem by visualizing it, it becomes easy for them to choose it over other available options. An interesting quote by Macharia and Wario (1989) goes thus; "What I hear I forget, what I read I remember but what I see I understand". When learners are taught to visualize, it stays with them and thus helps them understand the concept better. With visual intervention strategies, learners can be equipped with the necessary skills that will make them have a better understanding of mathematical concepts. From research carried out by Lowrie, Logan, Haris and Hegarty (2018, p. 9), the study affirmed that a classroom-based intervention program tends to improve students' spatial reasoning at scale. The above finding shows that if proper visualization intervention is provided for learners, it may cause an improvement in the way they visualize and make them better problem solvers. Presmeg (2014, p.7), from her findings, deduced that learners lack of interest in the use of visualization in mathematics is a result of less importance given to visual aspects of mathematics in the classroom. This could be a result of educators not been keen on using it when learners are being taught. Boonen, Reed, Schoonenboom & Jolles (2016, p. 76) affirmed from the research carried out that educators choice of the use of visual representations was based on their personal preferences rather than basing it on the best fit with the word problem characteristics. Therefore, it implies that if educators focus more on introducing learners to visualization in mathematics, particularly in problem-solving, it will boost up their interest and usage. The reason is that mathematics is a subject that is complex and requires adequate prior knowledge and visual abilities to help learners develop and improve their problem-solving skills. Furthermore, many researchers have also emphasized that visualization and visual thinking are important for teaching mathematics (Horgan, 1993; Dreyfus, 1991; Bishop, 1989; Davis & Anderson, 1979) as cited by Yenilmez and Kakmaci (2015, p.191). Hence, the focus is on making learners visual thinkers and for them to be instructed on how to use visual representations.

## 2.2 Visualization and word problem solving

One of the important aspects of mathematics is the aspect of word problem solving; it involves real-life issues as well as its applications. It is then vital that strategies that will lead learners to reasonable solutions are selected. This will enable them to solve word problems in mathematics accurately, making it less difficult. Russell (2018, p. 1) stated that learners ought to know what to look out for in a question for learners to learn how to solve mathematics problems. This statement implies that learners should understand a problem first, know what is expected by either highlighting the vital information, collecting the appropriate information, knowing the procedure to use, how to apply it, identifying and using the strategy that will lead them to the correct answers.

From various researches that have been carried out in the line of visualization, it has been established that the role of visualization in mathematics cannot be overemphasized. This tells us again that visualization plays an important role in a mathematics classroom. It goes a long way to helping learners better understand concepts if well applied and achieve success in mathematics. For success in problem-solving to take place, learners should be provided with the required avenue that will expose them to applying different visualization strategies to solve mathematical word problems. Kashefi, Alias, Kahar, Buhari and Othman (2015, p. 803) stated that to boost the knowledge insight in mathematics, visualization among students must be enhanced. Learners can become successful in problem-solving if visual representations that can lay emphasis on spatial relationships can be introduced in the classroom. When learners become successful in problem-solving, they can reduce a problem to its essential in a sensible manner, which is called reduction. To achieve such concept, visualization and structuring aids are often used, such as informative figures, diagrams, tables, solution graphs or even terms. These heuristic tools are also very well suited to document in retrospect the approach adopted by the intuitive problem solvers in a comprehensible way (Liljedahl, Malaspina, Santos-Trigo & Bruder, 2016, p. 4).

It can then be said that visualization exists to better understand problem-solving as it is the ability to see, understand, and represent a problem to solve it. According to Sepeng (2014, p.103), learners need to identify the problem and find functions that link several entities in solving story problems. Visualization based on researches carried out thus far has been identified as a tool/strategy that helps learners solve mathematical word problems. Hence, this study will further look into how visualization intervention can help learners become better problem solvers in a particular context. Many studies have proven and shown the beneficial effect of visualization in problem-solving through the diagram's representative (Kashefi, Alias, Kahar, Buhari and Othman (2015, p. 805). The research carried out by Kashefi et al. (2015, p. 807) showed that from 26 studies chosen for analysis, all their findings revealed that visualization helps in the problem-solving process. This is not far from being true as it helps with understanding and guiding problem-solving methods. This is supported by Cappello and Walker (2016, p. 319), which stated that visuals could provide access to the core curriculum, promoting equity for all learners in the classroom. Relating this statement to mathematical word problems implies that visualization will encourage fairness among learners in the classroom. It can also help them have a better understanding of the concepts taught by teachers.

Sepeng and Kunene (2015, p. 103) mentioned that most learners in South African primary mathematics classrooms struggle with the idea of what constitutes a word problem in the learning, solving of tasks linked to algebra. Word problems form part of the South African mathematics curriculum and are used as a medium to teach learners how to structure problems in primary mathematics classrooms (Sepeng, 2014; Sepeng and Webb, 2012). In the process, make more vital their ability to be good problem solvers (Sepeng, 2013, 2014). Therefore, there is a need for educators in South Africa to push for more problem-solving tasks to be taught in the classroom, as this will help them acquire the necessary skills needed to be real problem solvers. A review of what solving mathematical word problems within South African classroom contexts means formed part of recent reports from studies that explored learners' abilities in solving word problems (Sepeng, 2013, 2014).

The report presented by Sepeng and Kunene (2015, p. 104) inferred that problem-solving begins when the solver reads the problem text for the solution process, leading to success as the schemas for problems are activated. In view of this, before a learner can solve a problem or represent it visually, a level of understanding should have been shown from the point where the question is read. Hoogland, Pepin Bakker, Koning and Gravemeijer, (2016. p. 30) reason that a crucial objective of mathematics education is nurturing students' ability to use mathematical knowledge and skills in solving daily life problems. Making learners become real problem solvers using visualization as a skill should form part of our strategies as educators in making them perform better.

## 2.3 Visual thinking

Visual thinking can be said to be a characteristic of mathematical practice that cuts across many subject areas and at many levels. Visual thinking is a body of methodologies that uses diagrams to represent ideas, concepts, process flows and relationships (Webspirationpro). Concepts and ideas have been seen to be generally represented by images and text and connected by lines to show association and represent the flow. Standford Encyclopedia of Philosophy (2015, p. 1) acclaimed that visual thinking is widespread in mathematical practice and has varying cognitive and epistemic purposes. Pontis (2015, p. 1) asserts that visual thinking forms an integral part of visual reasoning as it helps with the development of the necessary skills needed to use for visual logic. Visual reasoning is needful for learners to visually scrutinise information visually, enabling them to solve the problem at hand. It is a skill required of learners to acquire, and it can be learned the same way logic and critical thinking skills are learned. Visual thinking involves thinking with external visual representations that are diagrams, symbol arrays, kinematic computer images, and internal visual imagery (mental image). Both are often time combined when used and developing both is of utmost importance as it will help support students learning for solving different types of problems in mathematics. In other words, visual thinking can be combined with non-visual thinking in solving mathematical word problems. Albert Einstein, who was cited as a visual thinker, indicated that visual thinking is active, and not passive. This can then be interpreted to mean that visual thinking is an act of communication that involves the use of pictures or diagrams.

According to Matheson and Hutchinson (2014, p. 5), representing visual information in mathematics can be done using diagrams and graphic organizers. Diagrams are visual displays that use essential information in mathematical word problems. Matheson and Hutchinson (2014, p. 5-6) inferred that they are typically used to demonstrate how related information can be used to organize information and compute the answer to a problem. This can be depicted using a learner's drawing to represent the objects within a word problem. Diagrams can be pictorial (drawing of important objects within a word problem) or schematic (drawing that includes the spatial relationships between objects). The graphical organizer is a type of external visual representation that is always used in mathematics as it further improves the quality of conceptual understanding in mathematics, Matheson and Hutchinson (2014, p. 7-9). They stated further that the four types of graphic organizers that can be used in mathematics are: Semantic maps, Semantic Feature analysis, Syntactic/Semantic Feature analysis and visual displays, which is a type of graphic organizer that can be used for different purposes in mathematics. Visual display is what learners require in solving mathematical word problems, the ability to represent information using diagrams, which will aid the solving of such problem.

Cappello and Walker (2016, p. 317) asserted that visuals and visual thinking can provide opportunities and strategically scaffold curriculum to help students reach their academic goals. They (Cappello and Walker 2016, p. 318) stated further in their findings that studies showed that visual thinking strategies were ways of improving writing (Franco & Unrath, 2014; Moeller, Cutler, Fiedler, & Weier, 2013), critical thinking (Landorf, 2006; Moeller et al., 2013, Yenawine & Miller, 2014), and encouraging risk-taking (Franco & Unrath, 2014; Landorf, 2006). From these findings, it can be postulated that when learners are taught and encouraged to think visually, it develops their thought processes, making them critical thinkers.

From the research carried out in the United States of America by Boaler, Chen, Williams and Cordero, (2016, p.1) they argued that when students learn through visual approaches, mathematics changes for them, this gives them access to deep and new understandings. Available literature supports visualization skills and how it is not only a tool required by learners in South Africa alone but a skill that is required worldwide in order to be able to solve mathematical word problems and other related concepts in mathematics. For this skill to be accessible by learners, it ought to be made available to them. This can be made possible by mathematics educators if and when they introduce learners to such classroom skill. Boaler, Chen, Williams and Cordero (2016, p. 1) reasoned that good mathematics teachers use visuals, manipulative and motion to enhance students' understanding of mathematical concepts. The US national organizations for mathematics, such as the National Council for the Teaching of Mathematics (NCTM) and the Mathematical Association of America (MAA), have long recommended using multiple representations in students' learning of mathematics. Mathematics from research conducted by Boaler, Chen, Williams and Cordero (2016, p. 1) have been presented as an almost entirely numeric and symbolic subject for millions of students in US mathematics classes, with a multitude of missed opportunities to develop visual understandings. It was then stated further that students who display a preference for visual thinking are often labelled as having special educational needs in schools. As educators, much emphasis should be laid on the use of multiple representations, including symbols, diagrams/pictures, words, and models when solving word problems in mathematics in South Africa and the world at large. The Revised National Curriculum Statement for grade 7-9 in mathematics (RNCS) and Curriculum and Assessment Policy Statement (CAPS) in Mathematics (DBE, 2011, p. 5) aims at producing learners that are able to communicate effectively using visual, symbolic or language skills in various modes. Notions that arise from learners being labelled as special needs when they exhibit or prefer visual thinking strategies should be discouraged by educators with proper awareness of the role it plays in mathematics learning. Diagrams, pictures, graphs, and charts will significantly impact learners as it will give them a different perspective of how mathematics is perceived in real life. This impact can only be achieved if and only when educators are also seen as users of these classroom skills. To further ascertain this, Boaler, Chen, Williams and Cordero (2016, p. 3) stated that many research studies indicate that teachers who emphasize visual mathematics and who use well-chosen manipulative encourage higher achievement for students, not only in elementary school but middle school, high school and college. It was argued based on their findings that, if the best teachers are asked about the importance of visual representations, they will share the rich knowledge they hold, of the deep understanding that is enabled - both from teachers introducing mathematical ideas visually, and students using visuals to think and make sense of mathematics. This can only come from an experience of its usage in the classroom and reflection on how learners have been affected when they were given opportunities to use it.

The significance of visual and visual thinking in mathematics cannot be overemphasized, so educators need to embrace its usage in the classroom and teach it to their learners, starting from the lowest level. If learners are exposed to this skill early enough, it becomes easy for them to use it whenever the need arises. According to Boaler et al. (2016, p. 3), the entire volume from the Mathematical Association of America (MAA) has been devoted to encouraging visual mathematics in college. Visual mathematics has been beneficial not only to some selected few or struggling learners or so-called "visual" thinkers, nor is it only a prelude for abstract mathematics - visual mathematics is important for everyone, at all levels of mathematics (Boaler, Chen, Williams and Cordero, 2016, p. 3). This means that from the primary level to college level, visual thinking ought to be promoted and encouraged by educators. This will promote success and develop visual thinkers.

## 2.4 Role of visualization in solving word problems in mathematics

Research carried out by Huang (2015, p. 1485), established that visualization plays an important role in the solving of mathematical word problems. Various authors have published articles on the role visualization plays when used by learners to solve mathematical problems. It has also been seen to go a long way to helping learners think differently and meta-cognitively, that-is, higher-order thinking that enables understanding when engaged in learning. According to Mudaly (2014, p. 3), "In seeking to find the relationship between the visual and the mathematics, one needs to investigate further the role of visualization in the mathematization process." This is why it is necessary to find out the role visualization has played and continue to play in mathematics learning. In order for learners' understanding of mathematical concept to be enhanced, visualization in the learning and teaching of mathematics ought to be advocated for. Also, visualization encourages a higher performance in mathematical concepts as well as better understanding of the concept, as seen in the result of the intervention carried out in this study. Yilmaz and Argun (2018, p. 41), from their findings, stated that one of the advantages of visualization is its development of power for multidimensional thinking in individuals.

Furthermore, in her study, Naidoo (2012, p. 2) indicated that the master teachers made use of visual tools to assist learners in understanding abstract concepts to assist and improve mathematical, conceptual knowledge development. Going by these advantages, it is necessary to establish and outline the roles visualization plays in mathematics learning, as individuals develop the capacity for collective discussion and exchange of ideas by looking at events from different perspectives.

One of the roles of visualization, as Yilmaz and Argun (2018, p. 41-43) stated, is that it develops the power of multidimensional thinking in individuals. Secondly, it organizes knowledge as meaningful constructions and plays a significant factor in guiding the analytical development of a solution. Also, in Presmeg's (2006) visualization-related studies, cited in Yilmaz and Argun (2018, p. 43), she suggested a crucial need for research on visualization in solving mathematical problems and in learning and teaching mathematics at a different level. She stressed that analyzing visualization is important in the development of a concept. Huang (2015, p. 1485) also indicated that visualization is a critical aspect of mathematical thinking, reasoning, and understanding. In his article, he further stated that researchers have also argued that visual thinking is an alternative and powerful resource required for students to do mathematics, and solving a problem can be carried out through visualization.
Similarly, from Huang's (2015, p. 1487) finding, it was detailed that visualization allowed students to control a larger number of conditions simultaneously, while in the symbolic representation, students may only control one requirement at a time. From a teaching perspective, visualization as a meta-cognitive skill can be used to control fractions and other mathematics concepts. When learners are well equipped and sound in problem-solving skills, they develop confidence and potential to perform whatever task is set before them and even better. Hence, the need to equip them with visualization skills that will promote success in mathematics as educators. In a past article by Naidoo (2012, p. 2), she argued that when visual tools are used in solving problems in mathematics, they lead to exciting results in the teaching and learning of Mathematics. Furthermore, it was ascertained that master teachers in the research she conducted used visual tools in mathematics classrooms to make sure that the mathematics taught was easier to remember, more interesting and fun, more accessible, comprehensible, and concrete (Naidoo, 2012, p. 3).

It is also expedient to consider the roles of visualization that Ho (2010, p. 1) identified below. It is useful in the solving of word problems and will be helpful when learners apply it. Before

learners can begin to think of solving a problem in mathematics, it is important that the problem posed at them is first understood. When learners think visually, they can simplify the problem diagrammatically or in the simplest way they can, which then makes for a better understanding of the given problem. When learners better understand problems, a solution can then be proffered. Visualization is also useful in allowing for a recall of prior knowledge of a similar problem that has been solved previously, which then creates an avenue for a similar one to be solved using the same or similar approach. When learners become confident in visual skills, they are seen to use representations that they prefer. From their visual representations, an answer can be directly derived without a need for computation. It is also interesting to show learners that their answers' accuracy can be checked from the visual representation presented. Hence, it may serve as a tool to check the solution. It is paramount for educators and learners to be mindful of the role visualization play and its usage, as it will go a long way to helping them in their problem-solving process. Much emphasis has been laid on the importance of learners developing their skills in both problem-solving and visualization by The Revised National Curriculum Statement (RNCS), and Curriculum and Assessment Policy Statement (CAPS) in Mathematics (DBE, 2011, p. 12). With the attention that has been drawn to it, the experience gathered as a mathematics teacher and reports amassed from various researchers' points to the fact that visualization has not been accepted and used the way it ought to be by educators in teaching learners. Learners have also not embraced its application in the problem-solving process.
Visual representation has been seen as an essential skill; this is perceived so because higher-level math and science courses increasingly draw on visualization and spatial reasoning skills to solve problems (Zhang, Ding, Stegall, & Mo, 2012, p. 168).

It has also been more significant in learners' mathematical thinking and problem-solving experience, as pictures can provide an important tool for learning. Visualization tends to give meaning, depth, and guide to solving word problems in mathematics (Zimmerman and Cunningham, 1991). Mudaly (2010, p. 36) also stated that Mathematics is a language that is rich in visuals. This implies that it is a subject that can be communicated using diagrams, pictures, graphs, symbols, and even gesture as it indicates visual thinking. Researchers cannot overemphasize the importance of visualization and visual thinking in the teaching of mathematics. It is expected of mathematics educators to embrace this approach to ensure that learners are equipped with these skills to improve their problem-solving performance. It has been observed from experience that learners do not use visualization tools when solving mathematical word problems. Presmeg's (1985) research cited in (2014, p.16) argued that learners who can visualize in mathematics may prefer not to use it on some occasion. Hence, the need to investigate, then procure and bring in an intervention strategy with the hope of making learners become better visualizers. This intervention aims to procure solutions to difficulties that have been identified in the process of teaching and learning. Learners can then benefit from the intervention and can communicate it if used correctly, but it could also give a wrong impression in mathematics if learners misuse them. This is where the teacher's intervention comes in, to equip learners with the necessary skills that will make them become good visualizers when solving mathematical word problems. Hoogland et al. (2016, p. 25) ascertained that students perform better when they use visual or schematic elements relevant to their problem-solving process. It is assumed that visual representation should clarify problem structure by making visible all relevant information needed to solve the problem at hand, such as the numerical, spatial relations between solution-relevant elements and linguistic (Boonen et al., 2014, 2016 p. 57; Krawec, 2010, 2012).

When learners use pictures and diagrams, it helps them better understand the problem at hand, which leads to the solving process. Van Garderen and Montague (2003) also ascertained that when visual representations are used when solving word problems in mathematics, it could effectively support word problem-solving. Aside from visualization supporting learning through reasoning, thinking or remembering, it can also help develop learners. Yenilmez and Kakmaci (2015, p.191) described spatial visualization ability as a potential to change and use objects in picture form or a piece of it in mind. It can also be seen to lessen wrong interpretation. This is ascertained by Yilmaz et al. (2009), who stated that visualization process can lead to a mental transformation which then leads to a successful understanding of a concept. This view has been seen to help learners perform better in some aspects of mathematics, as visualization has the ability to make seeing and understanding a problem possible. This implies that learners who are not visualizers may battle in some aspect of mathematics. According to Yenilmez and Kakmaci (2015, p. 191), visualization also allows for a better understanding of abstract and complex mathematical subjects; it also advances learners' ability to think out of the box. With visualization, aspects that are seen as abstract or difficult becomes less difficult and real when represented using diagrams or pictures. This is why it is necessary for learners who are experiencing difficulty in mathematics to be equipped with visualization skills. Also, Yenilmez and Kakmaci (2015, p.193), based on their research findings, discovered that when visualization skills were increased in learners, their abilities and skills in mathematics increased. Through visualization, learners' thought can also be developed as it is an important skill required to learn and implement mathematics. The role of visualization in learner's thought process and in the experiences gathered in solving mathematical problems has become impressive, so learners must be equipped with skills required to become good problem solvers. This can be explored through the intervention process that will be provided in the process of carrying out this research.

According to Muchoko, Jupri and Prabawanto (2019, p.1), visualization representations such as diagrams and schemes help understand fractions and minimize difficulties learners may encounter later when they are faced with abstract concepts. This statement also establishes the role visualization will continue to play in the teaching, learning, and solving of word problems in mathematics. As mentioned in meta-analysis research carried out by Kashefi, Alias, Kahar, Buhari, Zakaria and Mirzaei (2015, p. 808), students' mathematical knowledge are boosted and established when encouraged to use diagram as a tool in problem-solving. Tanton (2016, p.32) argued further that when a diagram is drawn for a problem that has been described in words, the first step to solving it becomes evident. It is then essential that learners are equipped with visualization tools as it plays an essential role in problem-solving.

Cappello and Walker (2016, p. 317) are confident that visualization and visual thinking can give access and scaffold curriculum in a strategic way such that students will be assisted in reaching their goals academically. This implies that visually when learners are confident when solving mathematical word problems, it can lead to their success. This is also corroborated by Tanton (2016, p.7) which stated that a key component to mathematical success is the art of thinking visually. Budaloo (2015, p.38) also stated that visual imagery can be seen as a way of constructing knowledge. This knowledge construction can be attained through paper or pen diagrams, pictures, charts, gestures and other concrete objects. If learners are encouraged to visualize, it helps them become better achievers and good problem solvers. They will always picture or draw a diagram whenever they are given word problems in mathematics. Also, if learners are made aware of the role of visualization in the solving of mathematical word problems, it may create some sort of motivation in them to choosing it when solving similar problems later in future. Siew Yin (2009, p. 3) stated that as learners use visualization to solve problems, it plays different functions, which are: to understand the question, simplify the question, see connections to a related problem, cater to individual learning style, as a substitute for computation, as a tool to check the solution and to transform the problem into a mathematical form or problem that is, to understand how the elements in the problem relate to each other. When learners can represent a problem visually, it makes them understand how the elements in a problem connect. Visualization not only plays a role in problem-solving but in all aspects of mathematics which is why learners need to be equipped with these skills and probably provide intervention in the process.

Hunt and Vasquez (2014) focus was on an intervention designed to help grade six through grade eight learners as they advance in the understanding of the concept of ratio equivalence through a multiple-baseline-across-participants design. However, it is expected that the intervention that will be designed in this research should help learners develop a better understanding of visualization and better at using visualization skills and strategies, which is the focus of this research. Research has it established that when visual representation is used correctly, it can help facilitate word problem, assist in recognizing the needed solution processes and as a result adds to successful problem-solving in mathematics (Boonen et al., 2013, 2014, 2016 p. 58; Hegarty & Kozhevnikov, 1999; Van Garderen, 2006; Van Garderen & Montague, 2003).

Available literature seems to support visualization as a strategy that learners can use when thinking of the best way to solve a mathematics problem. It should be worth noting that it is not a skill that comes naturally to learners, as it ought to be taught by teachers and practised by learners before they can be confident enough to use it. Hence, the need for teachers and even In-service teachers to be provided with the necessary support, as the use of visual tools in the classroom is beneficial.

## 2.5 Problems encountered by learners in visualization

Boonen, Reed, Schoonenboom and Jolles (2016, p. 55) stated that many learners struggle when solving word problems as a result of inaccurate problem comprehension. Some learners also experience difficulty with word problems because of some learning disabilities, which can be in the form of language that is reading and comprehending a word problem. When learners cannot comprehend or understand a word problem, it becomes difficult to interpret it visually. Furthermore, this disability can take a non-verbal form where learners experience a significant discrepancy between visual-spatial and social skills (effective communication with others, active listening). Visual-spatial can be understood as a situation whereby learners lack the required skills to process and solve problems mathematically. It is a required skill needed in a mathematics classroom. Over the years, mathematics learners have shown little or no interest in visual approaches to supporting meaningful learning, which is why teachers should create an atmosphere that will encourage learners to be visualizers. Part of the problems encountered by learners is the ability to generate visual images but not able to use them for analytical reasoning. Teachers should also ensure that problems posed to learners are accurate and without errors, as well as ensure that learners know what to look for when solving mathematical word problems and perhaps how to solve the problem. Some of the problems encountered by learners can be reduced when mathematics educators instruct learners on how visual representations can be used (Boonen, Reed, Schoonenboom and Jolles 2016, p. 74). Also, some learners may find it challenging to find the important information required in the problem posed at them, which may be due to lack of comprehension and or not being able to paraphrase or summarize the question so as to be able to represent it visually. It may then be said that language can pose as a problem. However, for barriers to be avoided, emphasis should be placed on visualization (Govender, 2016, p. 35) during teaching and learning. This is why the teacher's knowledge of visual representations is essential to instructing word problem comprehension (Boonen, Reed, Schoonenboom and Jolles 2016, p. 74).

Learners sometimes can visualize by coming up with diagram representations for problems but experience difficulty in analyzing further how to come up with a correct answer. Some learners are natural visualizers, while to some, visualization does not come naturally. We also have learners who do not like to think in terms of picture, even if the problem is understood. If such learners are not taken through the visualization process, they encounter difficulties when solving mathematical problems, affecting their performance level.

Presmeg (2014, p. 17) stated that learners may be willing to use visual representations but have little training connected with the training. However, suppose educators are aware of the difficulties and strengths of learners in visual processing. In that case, for a teacher to be effective, such should be able to adapt to the need of his/her learner. This is why in the research that is to be carried out, learners will first be given the initial task sheet to solve. This will enable the researcher to identify the problematic areas and their strengths and become knowledgeable as to what and where intervention can be given. The above is buttressed by Presmeg's (1985, 1986a, 1997b) claim that if educators were aware of their learner's problem in the research she carried out, they would have helped them overcome such. When visualization in mathematics is developed in learners, it will help with their level of understanding. Visualization also tends to change learners' perception of word problems in mathematics as over the years, and from anecdotal evidence, learners battle with this aspect of mathematics. Hence, visualization can play an essential role in ensuring that they develop interest and become better at it. Kaswa (2015) concluded that when learners are exposed to visual learning aids, they possess the knowledge and conform to their skills, making them achievers. Learners become successful visualizers if and when they are allowed to use their preferred visual mode in mathematical word processing. Learners should also be encouraged to read, understand, paraphrase to highlight the important words before solving a problem and then visualize either by representing or solving diagrammatically and check.

## 2.6 Visualization intervention

Visualization, which falls under a classroom-based intervention program, has the potential of helping learner's spatial reasoning (Lowrie, Logan, Haris and Hegarty, 2018, pg. 9). According to Marita and Hord (2017, p.31), interventions are plans that are to be executed over time and monitored to determine whether learners or group of learners have shown progress towards what has been targeted. In terms of visualization and its intervention, attention should be drawn to it to enhance learners' performance in this area. Also, Interventions channelled towards helping learners improve in difficult mathematical concepts may help them achieve success in such areas and support them moving forward. When learners can interpret word problems visually, they have a better chance of achieving success. This is part of what is to be determined in this study after an intervention has been given to the learners. Also, academic interventions like the one administered in this study are defined according to Marita and Hord (2017, pg. 30) as a planned procedure used with the intention of teaching mathematics. Visual representations are the primary focus of the study as interventions relies solely on visual as a scaffold to learning. Visualization representation intervention can also be defined as any strategy dependent on visuals as the primary tool to scaffold learning (Marita and Hord, 2017, p. 36). Marita and Hord (2017, p.38), in their literature, also supported previous findings that when visual strategies are taught, it becomes beneficial to learners who are struggling. Findings in the research that is to be carried out will help shed more light on the above statement in a different study context. Also, Boonen, Reed, Schoonenboom and Jolles (2016, p. 55) stated that teachers can help reduce the problems experienced by learners by teaching in the development of visualization skills in mathematics and instructing learners on how to use visualization representation that simplifies the problem structure and visual-schematic representations. It could then be interpreted to mean that teachers play an important role in instructing learners effectively, and this can be driven by having the required mathematical knowledge and skills. Educators need to emphasize how learners are to use this strategy and how it will help them achieve success. This is buttressed by Boonen, Reed, Schoonenboom and Jolles (2016, p. 55) in their research findings that teacher's knowledge in visualization representation is of great essence to instructing word problems. Also, Aytac Kurtulus (2019, p. 181) stated that in order for mental visualization to be improved in learners, there is the need for such to be first developed in teachers who are designers of materials, teaching and learning environments. Teachers' knowledge, competency and support in visualization cannot be overemphasized as they play a significant role in its intervention as well as alleviating visualization problems.

Ho (2010, p. 3) mentioned in his article that in other to develop visualization skills in learners, educators and developers of the curriculum must take into cognizance factors that prompt learners' choice of problem-solving method and roles that visualization plays in mathematical problem-solving. It should also be noted that learners learn at different levels; interests vary likewise in readiness, which also tends to impact their performance. That being said, it is part of the educator's duty to ensure that no learner is left behind and that they are all carried along and their needs catered for. Furthermore, Marita and Hord (2017, p.38) stated that when interventions are put in place to reduce barriers experienced by learners with learning disabilities to benefit learners without learning disabilities, such intervention then provides support for all learners. In other words, visualization intervention in mathematics, when correctly put in place, can benefit all learners, irrespective of the learning challenges they may be experiencing. Success in mathematics can also be aimed at if learners are able to visualize. Therefore, educators can help learners achieve this by assisting them in acquiring visualization skills that can be in the form of visual information with opportunities given to learners to be involved in the learning process. Also, it has been documented from previous studies that visualization strategies can be beneficial to learners who are experiencing difficulty in mathematical word problems (Marita and Hord 2017, p. 37). This implies that diagrams, pictures and other visual supports can be beneficial to learners as they will help reduce the problems encountered when solving word problems in mathematics. It is part of the teacher's responsibility to help learners understand, develop the skills, and develop diagrams that will help them proffer solutions to non-routine problems and gain the confidence to solve similar problems further when confronted in the future. In their findings, Boonen, Reed, Schoonenboom and Jolles (2016, p. 60) stated that there is somewhat minimal literature on teachers' ability with visual representations and their understanding of the concept. Furthermore, their findings showed that no literature has been found that precisely addresses how teachers teach learners to construct visual representations that support word problem comprehension. It is envisaged that upon carrying out this research, the intervention that will be administered will shed more light on visualization and its intervention and how beneficial it will be for learners and the teacher's role in the entire process. Also, in the research to be carried out, interventions are planned to be carried out over time, which ought to be monitored either by an informal approach of questioning, to confirm whether progress has been made toward a targeted skill by a learner or group of learners. This is why there is a need for a post-intervention task (post-task) to be administered after the intervention period. Part of its benefits in learning mathematics is that it allows a better understanding of complex and abstract concepts which has been evident in learners who were keen on its usage. According to Yenilmez and Kakmaci (2015, p. 191), visualization enables a very abstract aspect of mathematics to become less abstract or concrete. He went further to establish that it is important for learners who are having difficulty understanding mathematical subjects. Yenilmez and Kakmaci (2015, p. 191) also stated that visualization develops the ability of dimensional thinking in individuals.

It was also reported that visual representation is somewhat discomfited for the middle-grade teachers in the US for lack of complete knowledge about its usage and interpretation (Orrill, Sexton, Lee and Gerde, 2008 cited in Boonen, et al., 2016, p. 60). This issue is not peculiar to the US alone as beginning elementary teachers also experience difficulty in visual representation as a choice in mathematics (Turner, 2008 cited in Boonen et al., 2016, p. 60). According to their findings in Germany, Dreher and Kuntze (2015) also stated that secondary school mathematics teachers do not fully understand visual representation role and usage in the learning and teaching of fractions. If teachers do not fully understand visualization role and usage in some mathematical concepts, it becomes difficult to administer any intervention correctly to their learners.

Van Dijk et al. (2003); Van Dijk et al. (2003a), cited in Boonen et al., 2016, p. 60), argued that it is of more effect for learners to be taught how to construct their own visual representation than for teachers to provide them with an approach that has already been constructed. It is beneficial for teachers to focus on how learners can make their representation rather than presenting them with an already constructed representation. For learning to be beneficial to learners, educators as facilitators of the learning process need to direct learning towards helping learners construct meaningful visual representatives that will assist in solving problems in mathematics. When learners become better at solving problems, they can use the knowledge acquired to see, understand and create a visual representation to solve the problem. Learners should be encouraged to use different visual representation and be flexible in their choice as it applies to the problem at hand; this will lead to a proffering solution. This is because learners tend to stay focused on the method or familiar way of solving problems, making it difficult to deviate or learn a new or better approach. This was evident in the classroom experience I have had with learners in the past. Learners preferred to use a method they have either learned from a past teacher or a respected adult, even if it was time-consuming than a newer approach or strategy.

Boonen, Reed, Schoonenboom and Jolles (2016, p. 61) argued further in their findings that research that will assess how teachers carry out an approach centred on the use of visual representation is required as it will help learners with word problem-solving at schools. Research has shown that when powerful visual intelligence is evident in learners, they tend to learn best by visualizing through colours and drawings. Furthermore, Yenilmez and Kakmaci (2015, p. 193) concluded that when mathematical abilities and skills are seen to increase in learners, then visualization skills are on the increase. As visualization skills become high in learners, their logical thinking skills become high and vice-versa.

Marita and Hord's (2017, p. 35) result showed an increase in overall accuracy after the intervention given to the participants. This implies that how learners are able to retain what has been learned from an intervention can also lead to success in a problem-solving task. After the intervention, learners ought to be able to transfer the knowledge acquired into solving similar problems. Yenilmaz and Kakmaci (2015, p. 199) saw the need to use visual materials during primary school education to improve learners' visual skills since most mathematical subjects are abstract in nature. Choosing materials to suit the need of the learner/s and addressing and catering for the curriculum is then dependent on the educator. Learners should also be able to communicate the benefits derived from an intervention; this will be established from their responses to the interview questions. Marita and Hord (2017, p. 37) concluded that interventions are beneficial to learners with disabilities and learners without disabilities. This research will add to the body of knowledge as the literature considered showed that a lot of research has been conducted that involved visualization, its role in mathematics and visual thinking. Nevertheless, visualization intervention has not significantly focused on mathematics learning and teaching and how effective it can be if applied.

## 2.7 Summary of the chapter

This chapter examined visualization, its role in problem-solving, visual thinking and intervention in mathematics. It is evident from all that has been discussed that learners need to be well equipped with visualization skills through teaching and facilitation for them to solve mathematical problems on their own. Also, problems that may hinder learners, drawing from past literature, were considered, and possible ways to alleviate the problems were mentioned. The role mathematics educators' play in equipping learners with the necessary skills cannot be over-emphasized as findings have shown how effective it can be if and when introduced in the classroom. Teachers' knowledge in visualization intervention is also seen to be very crucial as that is evident in how they teach and facilitate the learning process and support them at the same time. Therefore, if proper intervention is given, it is highly possible that learners will get better at being visualizers. They will be able to have the correct visual interpretation of mathematical word problems posed at them. This can help improve the success rate in mathematics. This chapter has informed not only the researcher of previous findings but also the gaps in the field. One of which will be the focus of this study; visualization intervention in a mathematics classroom.

# CHAPTER THREE

## 3. Theoretical Framework

This study explored visualization intervention in a grade 7 mathematics classroom. In the previous chapter, discussions on research findings by various researchers relevant to the study been carried out were discussed. In their research findings, Cleland and Durning (2019, p. 44) stated that a framework could be provided by theory to organize and interpret the data collected in a way that highlights attributes and patterns and produce conceptual generalizability. Theoretical framework can be said to be a lens in research findings. It is useful in the sense that whatever has been researched and concluded can be evaluated by other researchers for the purpose of being transferred and being able to apply the information acquired into other situations that might be in a different context. Also, as Cleland and Durning (2019, p. 44b) further stated, a theoretical framework can help develop an exciting and broad explanation of what is being understudied, thereby leading to an area of study that can be developed for future findings. The theoretical framework plays a vital role in research as stated above. It helps direct a researcher's focus on what is being studied, thereby throwing more light into such a study area.

This chapter is focused on the theory that underpins this research study. A discussion on the origin of the Activity theory taken from Vygotsky (1978) and its development will be discussed in this chapter. The principles of the theory will be examined and the different generations under the theory. Research that has been conducted previously using the theory will also be considered.

As earlier established, the theoretical framework helps sheds more light and develops wide explanations of the study that is to be carried out, which can be elaborated upon in future research. It also helps shed more light and elaborate on some aspects that are to be studied to produce new ideas and insight (Cleland and Durning, 2019, p. 44). Theory can then be said to aid new ways of thinking and possible direction on research that is focused on education-visualization intervention in a mathematics classroom.

The study being carried out is qualitative in nature, and Activity theory will be used as the theoretical framework. The theory is chosen for this research because an intervention is required to be carried out. Vygotsky (1978) and other researchers down history line from findings were involved in carrying out interventions, as creating challenges in a particular setting can help learners get to the next level, which is the zone of proximal development in their activity. Activity theory also helps in understanding how human activity is revealed over time based on various readings that have been gathered.

Learning is perceived as being social and participatory, not just about acquiring skills or knowledge but also about how learners relate with the skill acquired and others. It is situated in a social context, where the theory for this study has been primarily drawn from as it involves learners and the intervention given in a particular context, the classroom. Cleland and Durning (2019, p. 44) mentioned that theory helps organize and interpret data so that patterns will be generated and commonalities will also be identified for conclusions to be made. In the development and learning of mathematics, the role of Activity theory cannot be overemphasized as it provides guidance methodologically, theoretical aspects moving from the theoretical realm to offering perspectives on the realistic use of Activity theory framework in contemporary learning contexts.

## 3.1 Origin of the Activity theory

Vygotsky (1978) introduced the Activity theory in the 1920s and 1930s and was later developed by his colleague Alexei Leont'ev[8] which has been advanced through three generations of research, transforming educational research in the process. Activity theory is used in educational research as it serves as a channel through which data can be interpreted, and according to Engeström (2015, p. 63), the triangular model of an activity theory is applied often as a graphic model and channel for data analysis that is interpretive in nature. This will be used to analyze the data collected as it is interpretive in nature; it also makes obvious the context of educational processes that are being investigated. In terms of the research being carried out, the context is driven by the topic that is being explored. When research is conducted using Activity theory, it generates and employs a methodology of its own—in other words, providing guidance methodologically. Methodology is perceived as spanning a gap between theory and the data collected, which a theory should also drive; hence, the need to apply the Activity theory in this research study.

According to (Engeström, Sannino, & Virkkunen, 2014; Sannino, Engeström, & Lemos, 2016) research-based on Activity theory leads to interventions aimed at increasing expansive learning and transformative agency. Also, Activity theory is a theoretical framework that can be of use in the analysis and understanding of how human interact through the use of tools and artefacts (Hashim and Jones, 2014 p. 1).

In recent years, Activity theory has acquired a lot of popularity research-wise. This is driven home by Jonassen & Rohrer-Murphy's (1999, p. 67) assumption about Activity theory that tools serve as a mediator or changes human nature activity and tends to impact humans' mental development when incorporated.  Activity theory can be seen as considering the individual and the social and cultural context; it also aims to examine how learners interact with learning tools made available to them. In other words, how learners can use the intervention given to complete a task was looked into, and their responses to the interview conducted as this were to help find out their thoughts on the tasks and intervention.

The different generations of activity theory will be looked into and discussed in this chapter. According to Naidoo (2011, p. 59), the Activity theory framework presumes that all human actions are conciliated by artefacts and tools and cannot be separated socially from their environment. The above statement was seen as evident in the researcher's research as master's teacher used visual tools to teach mathematics. This was also evident in this research study as visualization tools like diagrams, gestures, facial expressions, and books were used as an intervention to teach learners mathematics. Activity theory also takes into consideration an entire work system (activity) to include all of its component (individual subject, objects of work and community and its rules) and how they interact (Cleland and Durning, 2019, p. 49). Also, Activity theory suggests a way of understanding human action and learning in a social and cultural context.

Engeström (1999) **first generation** of activity theory draws from Vygotsky's theory of mediation. There was no complete association between an individual in the first activity model, which is what the focus was on then, and his/her environment in an activity. The triangle shown in Figure 3.1 represents Vygotsky's way of bringing together cultural artefacts with human actions as studies during this period focused on individuals (the group of learners that participated in this study).

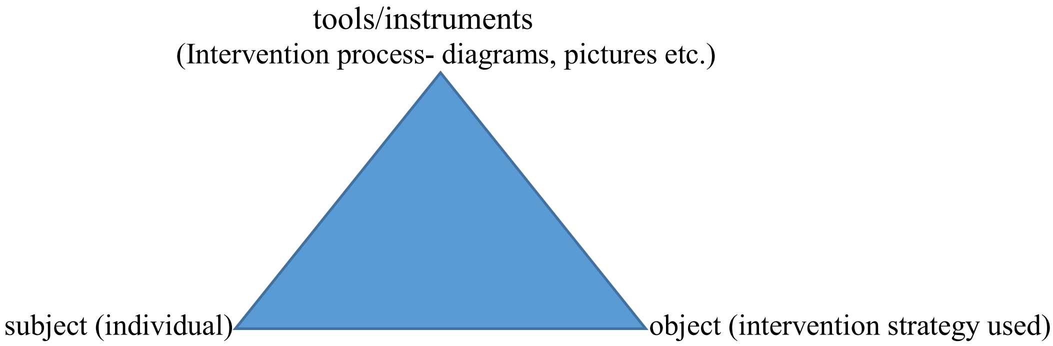



**Figure 3.1:** 1st generation activity theory by Vygotsky (Engeström, 1999)

This theory drew from Vygotsky's theory of mediation which combines artefacts with human actions. Vygotsky stated that, children learn best when they use their imaginations when engaging in learning activities, with proper development support.

WHAT IS KNOWN → ZPD → WHAT IS NOT KNOWN

Within the Zone of Proximal development, skills considered to be too difficult for a child to master on her or his own can be mastered with the guidance and encouragement from a more knowledgeable other, which can be a peer or teacher. Hence, the need for the intervention to be given by the teacher in this study.

Activity theory focuses on practice and emphasizes naturalistic study, which is why it was chosen for this research as it took place in the classroom. Hashim and Jones (2014, p. 4) asserted that Activity theory offers a holistic and contextual method of discovery that can assist qualitative and interpretive research. An Activity is made up of the behaviour that is constructed when an individual (learner) performs a task. The theory helps develop one's thought process through activities and in response to the environment. Studies tended to focus on individuals at this period; this brought about the second generation activity theory's need. The first generation limitation was that the analysis unit focus was on the individual. The second generation overcame this limitation centred on Leont'ev, where the difference between collective action and an individual action was explained.

Engeström (1999, p. 29), in the **Second generation** of Activity theory, recommends the study of artefacts as an essential and inextricable part of human functioning. He further argued that in the study of mediation, the focus ought to be on the functioning of its relationship with other parts of an activity system. For the development of activity theory to be developed, which will lead to its progress, Engeström extended the original triangular activity's representation. This allows an examination of activity systems at the immense level of the collective and the community in place of a mini level concentration on the individual representative operating with tools. Vygotsky's triangle intends to represent the social/collective elements in an activity system, which is through the inclusion of the community parts, rules and division of labour while stressing the need to analyze their actions with each other. Engeström (1999) stressed that actions that are object aligned are often clear and well detailed or indirectly distinguished by interpretation and prospect for change. Furthermore, Engeström emphasized the significance of opposition within activity systems as the main factor of change and then development.

Compared to activity theory's first and second generation, Engeström (1999) in the **third generation** sees joint practice or activity as the entity that frames what is being analyzed in a study for activity theory, not an individual activity. The third generation shows interest in the process of social transformation that includes the social world system in the analysis. Uncertainty and inconsistency are seen as the reason for change and development as stated by Engeström (1999, p. 9), and the movement and restructuring within activity systems as part of gradual development; which is not only about the subject that is amended through mediated activity, but the environment as well. Engeström's (1999) proposal of the third generation of activity theory was intended to develop conceptual devices to understand series of perspectives and channels of interacting activity systems. The third generation activity theory is what is worked with nowadays.

## 3.2 Researcher's thoughts on Activity theory as a theoretical framework.

Researchers from across the discipline have testified to the effectiveness, benefit and prospects of activity theory. They focus on different aspects of activity theory in their different study areas, which has helped them advise researchers whose desire is to use activity theory in their future studies. We see this in the work of Otrel-Cass, Andreasen and Bang (2016), who stated that Activity theory allowed them to take note of the history of standardized testing in Denmark, which was where their research was located, and to situate and shape their interpretations based on this understanding. Furthermore, Hashim and Jones (2014, p. 19) argued that many researchers in the education, humanities and information systems have discovered that activity theory gives a profitable framework for an understanding of their field of study.

Engeström's (1987, 1999) stated that activity theory has also been used as an educational field framework. This suggests that activity theory is not only relevant in computer, information science and psychological fields; it is also beneficial to educational researchers. This study will not be an exception to its benefits. Pohio (2016), showed how Activity Theory gave a useful visual framework for understanding the organizational culture that stakeholders could find easy to understand and giving the possibilities for examining contradictions within remnants of historically formed practices. According to the research carried out by Nardi (1996, p. 94-95), four methodological considerations were described for activity theory.

Firstly, enough time should be allocated to understand the user's object such that the focus will be on broad patterns of activity. Also, varied sets of data collection techniques should be used without relying on one method and finally, a user-centred inquiry process must be used. The analysis of data from an activity theory perspective reveals that how subjects use tools, effective performance of their roles by community members and the use of tools to resolve real-life problems positively influences the promotion of open-mindedness, the achievement of expected outcomes, and meaningful engagement of subjects in the application of tools. Also, it was reported by Gedera and Williams (2016, p. 142) that data analysis through the lens of activity theory provides evidence of subjectivity production referred to as active shaping of our identity based on others expectations and as a result of the activity system one is exposed to, or engaged in. Gedera and Williams (2016, p. 143) further explained that the application of activity theory helps identify contradictions in elements such as rules in the development of teachers' pedagogical content knowledge.

Farrell (2016) also established that activity theory is a potential framework for identifying, categorizing, and resolving educational tensions prevalent in language education. On the other hand, Naidoo (2017) stated that using visual tools as a framework for teaching and learning of mathematics is aimed at exploring the use of activity theory. Naidoo (2017) showed that the use of visuals as tools within the different activity systems made the abstract nature of certain mathematics concepts more concrete. This implies that using visual tools under the activity system made the mathematics concept more meaningful to learners, which is what is has been exhibited in this research. Furthermore, Naidoo (2017) stressed that the high level of student engagement and interaction in the different activity systems seemed to indicate that mathematics teaching and learning were more effective through activity theory.

Hashim and Jones (2014, p. 9) then concluded that activity theory is an essential tool that needs to be incorporated into their collection. It provides a means of discovering human activity without the express process of analyzing and developing tasks by participants. Instead, through the mediated study of the participant's tools, an understanding of activity is revealed, which includes clearly stated and understood actions.

Song and Kim (2016) also stated that there had been recent interests among foreign and second language education researchers in applying Activity theory as a theoretical lens. Furthermore, Farrell; (2016) postulated that Activity theory is a potential framework for identifying, categorizing, and resolving educational tensions common in language education.
Many researchers have recognized activity theory as being holistically rich in terms of understanding how things are done together with the assistance of sophisticated tools (Crawford & Hasan, 2006; Hakkinen & Korpela, 2006; Liaw, Huang & Chen, 2007; cited by Hashim & Jones 2014, p. 11).

Firstly, enough time should be allocated to understand the user's object. The focus should be on broad patterns of activity, and varied sets of data collection techniques should be used without relying on one method. Finally, a user-centred inquiry process must be used. Researchers from across the discipline have testified to the effectiveness as well as benefits and prospects of the ability of Activity theory.

## 3.3 Activity theory principle

According to Nardi (1996) & Uden (2007), activity theory takes in the notion of organization, working out, history and cooperation to understand that awareness and activity connected to one another and unified. For activity theory to be used, there is a possibility of discussing issues that belong to different framework levels (Kuutti, 1996). The different levels comprise of actions, activities and operations. Furthermore, Engeström (1999) suggested that activity theory may be summarized with the help of five principles; he further said that they stand as a declaration of the current state of the theory.

In the first principle, the unit of analysis in the activity theory is the activity system. In this instance, considering a mathematics classroom where the individual within the activity system would be the teachers and learners. The individual is focused on the teaching and learning of specific concepts in mathematics and ensuring that as a researcher, activities can be given or interviews conducted which will reveal different perspectives and that which is more pronounced as individual experiences are different.

The second principle, which is the notion of multi-voicedness, has to be considered as a researcher. This connotes several viewpoints and interests will be evident in the activity system, which is possible of causing friction within an activity system. The third principle of activity theory focuses on the history of an activity system. Focusing on an activity system's history may help explain and give insight about a particular system for the proper conclusion to be drawn, which can only be applicable in that context as experienced cannot be generalized. Focus on history tells us how an individual teacher or learner had been working before the intervention and how such is now working after an intervention.

Through this history, conclusion starts to build up then. Fourthly is the principle of contradictions, which plays a key role as the source of change and development. The fifth principle is the expansive transformation which can only be accomplished when the object and the motive of the activity are formed in a new way to accept broader possibilities than in the mode of activity studied previously.

### 3.4 The use of Activity theory and this study

In the study carried out, the activity system is the intervention carried out in the form of teaching in a mathematics classroom. The tasks are the activities given to learners to complete in the classroom: the pre and post-task, the examples used during the intervention strategies administered, and the visual tools used whilst the intervention strategies were carried out. The community in this study refers to the grade 7 learners in the mathematics classroom and the teacher.

Activity theory has helped provide a descriptive framework to better understand and classify the processes involved in a task performance. For learning to occur in this study, subjects (learners) engaged and interacted with the actual activity, which produced instruments, tools that then transform an activity. Learning cannot occur alone as it is not an isolated deed. It occurs when individuals interact with each other; tools bring about these interactions.

Activity theory has helped to establish the correlation between learning, the use of tool, the content covered, community and the context. Vygotsky's first generation activity theory is what I did use in my study as it created a media for mediation. In the process of interacting with this theory, it was seen that development in learning occurs through social interaction and children become better learners when their imaginations are put into use while engaging in learning activities, with proper support given for development.

## 3.5 Concepts used in this study and their definition

Activity, as used in this study, refers to the teaching and learning of mathematics. Leont'ev (1978) made it known that activity does not exist without a motive or reason. A tool is a mediating device by which the action is executed; it also refers to all that was used to help teach and learn visualization strategies in this study. It could be in the form of the language used, unspoken words, gestures, and materials that can be in the form of the whiteboard and coloured marker. In carrying out this study, the intervention process tools were diagrams, textbook, gestures, pictures, whiteboard and markers. Learners also used some tools to complete their activity and gestures/unspoken words when the interview was being carried out. According to Vygotsky, the use of artefacts helps to obtain success which would have been unreachable if not used.

Subject refers to an individual to be understudied. The 'subject' in this study is the group of learners that participated in the study. In obtaining information from them, they had to learn some visual skills in the form of intervention, completed a task after which interviews were conducted. The activity is directed towards the object; in this study, the object is the intervention strategy used in the mathematics classroom to solve word problems. These are in form visualization strategies and skills. According to Vygotsky (1978), the object can also be taking them from the known to the unknown. In simple terms, it is acquiring new knowledge for some or improving upon what already existed in others.

Leont'ev (1978) stated that actions are carried out by individuals or groups and are aimed at a particular goal. Action in this study refers to how learners acted upon what had been learned: their interaction with the knowledge acquired.

The outcome is then the result of the activity (teaching and learning of mathematics). After the intervention was carried out in this study, the outcome is what was intended to be achieved. Based on this study, rules are what practice was acceptable whilst the activity was being carried out. Going by this study, learners were not restricted to using any strategy during the pre-intervention task. They were to use prior knowledge from previous lessons or grade to complete the task given to them. Community in relation to this study are learners who partook in this study, learners who were used in the pilot study and the colleague who helped check the fairness and reliability of the task. Figure 3.2 presents Engestrom’s Activity Theory Model.

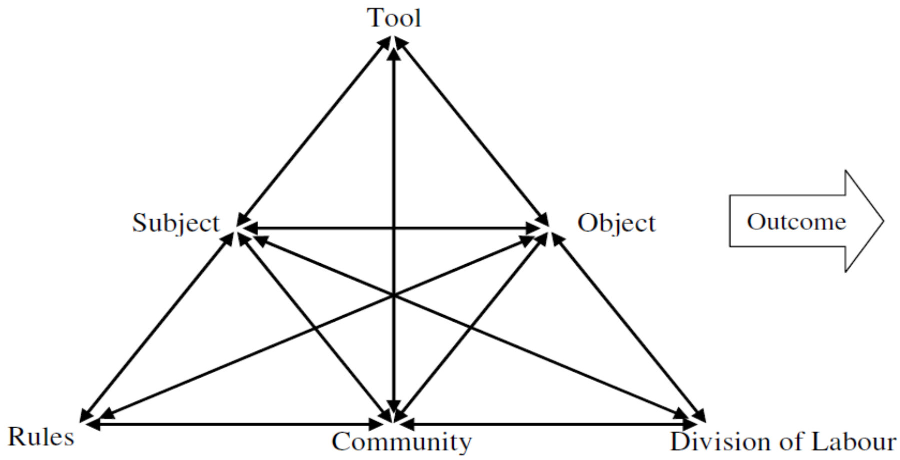



**Figure 3.2:** Engestrom's Activity Theory Model (Engestrom, 2001)

### 3.6 Summary of the chapter

Chapter 3 explored the theoretical framework that underpinned this study, discussion on activity theory and its principle, and the generations of activity theory were discussed. It was also important to touch and find out about activity theory and its relation to other research studies and its relation to the study being carried out. Considering activity theory as a framework that is to be used in research requires that qualitative and interpretive research methods be followed, which was evident in this research study. The use of Activity theory in the teaching and learning of mathematics has been seen to be more effective and helpful. The next chapter discusses the research design and methodology for this study.

# CHAPTER FOUR

## 4 Research Methods and Methodology

Chapter three focused on the theoretical framework, and the theory that underpinned this study was discussed. This chapter aims to describe the methodologies employed in conducting this study. Methods can be seen as approaches used in educational research to gather data to be used as a basis for inference, interpretation, explanation and prediction (Cohen, Manion and Morrison 2007). Kaplan (1973) stated that the methodology aims to describe approaches to, kinds, and paradigms of research. This means that the methodology aims to help us have a better understanding of the research process. The research questions, research paradigm, research design, study area and participants, sampling techniques, data collection methods and instruments, interview questions, data analysis, validity and reliability, and ethical clearance are discussed in detail. The processes and stages involved in this study are discussed, as well.

The purpose of the study was to explore the visualization intervention in a grade 7 mathematics classroom in the Pinetown District. This research was qualitative in nature, and it is located in an interpretive paradigm.

### 4.1 Research questions

The research looked into exploring the visualization strategies used in a grade 7 mathematics classroom. The aims and objectives of the study were used to formulate the research questions, which were:

- What visualization strategies do grade 7 learners use in a mathematics classroom?
- How effective are their strategies in solving problems?
- How can their problem-solving strategies be improved through a visualization intervention?

### 4.2 Research Approach

This study aimed to provide a visualization intervention in a grade 7 mathematics classroom to enable learners to become good problem solvers. In answering the research questions outlined, the research approach was first determined as it served as a guide on how the topic was researched systematically. This was done to help draw a conclusion that was reliable and valid.

A case study approach was used to carry out this research. According to Rule and John (2011, p. 4), a case study is a systematic and in-depth study of one case in its context. Case studies make every effort to portray 'what it is like to be in a particular situation, catch the close-up reality, and 'thick description' (Geertz 1973) of participants' lived experiences, thoughts, and feelings about a situation. In a case study, events and situations are allowed to speak for themselves, which was the case in the research. Evaluating and interpreting was done by the researcher. In other words, the data collected was allowed to speak for itself, having collected data systematically, which allowed for a reliable conclusion to be drawn.

This study was conducted in an interpretive paradigm, which often involves working in a naturalistic setting, and meaning was derived from the learner's information and the researcher. Bertram and Christiansen (2016, p. 189) asserted that interpretive research attempts better to understand a social situation from the participant's perspectives. For that to be possible, there is a need to spend time reading through the data. The data collected was well studied as time was spent reading through to have a better understanding.

According to Walsham (1993), there are no right or wrong theories in an interpretive paradigm. They should preferably be examined according to the meaning given to them by the researcher and participants in the same context. Bertram and Christiansen (2016, p. 26) argued that the researcher's goal is not to envisage what people will do but are meant to have a description and understanding of how people make sense of the world they live in and how meanings are made of their particular actions. The researcher had to make sense of how learners solved their task. The strategies they employed before and after the intervention were explored, and their views all through the process. Their thoughts were expressed and understood from their interview responses. Reeves and Hedberg (2003, p. 32) noted that it is necessary to put analysis in a context in an interpretive paradigm.

Lincoln and Guba (1985) argued that a naturalistic approach to research is promoted when people are being studied, including the qualitative approach to research. Also, Bertram and Christiansen (2016, p. 42) stated that case studies are a style of research often used by researchers in the interpretive paradigm that may use qualitative data. The case may be a person, teacher, principal, school or class of learners. Concerning this study, two (2) classes of grade 7 learners were engaged in the process and data was collected within the classroom settings. Creswell (2003, p. 8) also stated that researchers working in an interpretive paradigm tend to depend on the 'participants' views of the situation being studied. Therefore, applying an interpretive paradigm allowed for QUALITATIVE data to be collected. It helped deepen and strengthened the research that was carried out, which also enabled a deeper understanding of the study.

### 4.3 Qualitative approach

Qualitative researchers believe that individuals experience the truth and that these truths are socially constructed and are defined by the environment in which they occur (Cohen, Manion & Morrison, 2011). Johnson and Christensen (2008) asserted that qualitative research is often set in the subject's natural setting and enables subjects to express their perspectives. Sixty-Nine grade seven (7) learners were given tasks to complete. Their views were explored through interview responses derived from 12 learners (pre and post-intervention). This helped for conclusions to be drawn, having analyzed the data. Cohen, Manion and Morrison (2011) ascertained that advocates of qualitative research believe that this approach is the best when people are being understudied, and it is particularly relevant in school settings. The study was conducted in a naturalistic setting of the classroom at a school in the Pinetown District, hence the reason why this approach was chosen.

The research is a qualitative representation of what visualization strategies grade 7 learners used in the mathematics classroom and how effective it was. The intent was to focus on grade 7 learners, understand the strategies used, interpret and explore the visualization intervention that grade 7 learners used in a mathematics classroom. This was determined from the task completed in the classroom as well as their responses to the interview conducted. This helped to gain an in-depth understanding of visual tools usage and the effectiveness of the administered intervention.

### 4.4 Description of study area and participants

This research study was conducted in the Pinetown district of the KwaZulu-Natal province. It is a Senior Primary School, comprising of learners from different background and races. It is one of the public primary schools in urban Pinetown suburb, Durban in KwaZulu-Natal province of South Africa. It is a section 21 school and classified under quintile 5. The learners attending this school are multiracial and predominantly black.

The purposive sampling method was intentionally selected. Purposive sampling was defined by Bertram and Christiansen (2016, p. 60) as when the researcher makes specific choices about which people, groups or objects to include in the sample. A specific group which were the grade 7 mathematics learners taught by me, were targeted. This group does not represent a wider population as it only represents itself; hence, the results cannot be generalized. Also, sampling was convenient as the sample chosen were within reach. They were easily accessible and willing to participate—however, they are not representative of all learners in grade 7 at the school.

## 4.5 Population and sample study

According to Polit and Beck (2014), population is the entire collection of units that meet an allotted set of criteria. The study population was the grade 7 learners in quintile 5 school in the Pinetown District of KwaZulu-Natal. The school chosen is in an urban settlement; grade 7 learners were chosen as the population to work with because they were learners taught by me; they were convenient to reach and gain access to as a researcher. They were also chosen because they were the exit grade from primary school, and it was of interest to find out their visualization ability as they headed for high school. Bertram and Christiansen (2016, p. 59) asserted that sampling entails making decisions about which people, settings, events, or behaviour should be included in a study. The decision of choice of people or sample is to be made by the researcher. The sample was chosen to generate the required data needed for the study.

Below is an illustration of how learners were selected for the interview.

Twelve learners were interviewed, six from each class.

- 2 who used diagrams → 1 got it right
  → 1 got it wrong
- 2 who used some diagrams → 1 got it right
  → 1 got it wrong
- 2 who didn't use a diagram at all → 1 got it right
  → 1 got it wrong

## 4.6 Pilot study

A pilot study is crucial as it increases the instruments' validity and reliability and procedures used in research. The task sheet was given to a colleague to go through before learners were allowed to complete it. The pilot study was carried out on three learners from the third grade 7 class, and the results were analyzed. The aim was to ensure fairness and find out if the tasks were understood the way they intended. Bertram and Christiansen (2016, p. 49) stated that a pilot study forms part of the preparatory stage where the research instruments are tried out with people who are close to the actual study participants. The pilot study ensured the validity and reliability of the instruments used. It was also done to ensure that the language and the terms used were well understood by the learners. The feedback gotten from the pilot study helped the researcher better understand the study, hence the need to continue with the instruments and the chosen participants.

## 4.7 Informed consent

In carrying out this research as a researcher, it was essential to consider the consent factor. Participants had to be informed that whatever information they gave was confidential and that they had the rights to withdraw at any time. Fairness was also ensured. Before the pilot and main study commenced, an introductory letter was sent to parents and learners who participated in the study. The letter stated what the research entailed, informed consent, the right to withdraw at any time and confidentiality. Participants were also informed of the purpose of carrying out the study, and the procedures the research entailed was explained to them. Parents/guardians were given the consent letter, and they had to give their consent as learners were between the ages of 11 and 14. Relevant contact details of the University were also provided. A copy of the letter can be found in **Appendix C.**

## 4.8 Data collection

Data was collected in a naturalistic setting, which was in the classroom. Sample was convenient and purposeful. Working in an interpretative paradigm, allowed for qualitative data collection. Interview questions which were unstructured, were used to collect data, before and after the intervention process. The gatekeeper in the person of the school principal was consulted before the study commenced, and permission was granted for the collection of data.

## 4.9 Interview

Bertram and Christiansen (2016, p. 80) stated that an interview is a conversation between the researcher and the interviewee. According to De Vos., Delport, Fouche and Strydom (2005, p. 287), interviews are mostly a predominant mode of data or information collection in qualitative research. Researchers also attempt to understand the world from the individual's point of view. Interviews also permit the researcher to understand the interviews' stories (De Vos et al., 2005). An interview can also be used to investigate and better understand participants' views on an area of interest or topic, hence the reason for its choice. The interview questions set assisted and served as a lead that helped with the investigation that was carried out. The Interview process was audio-taped, as each participant answered the questions asked. Interview responses were transcribed for the purpose of analysis. The interview was unstructured as few basic questions were outlined to start off the process, and questions also built up based on the learner's responses. The interview also helped in having a better understanding of how learners solved the task and what they thought of the whole process. A copy of the interview questions, both pre-intervention and post-intervention, may be found in **Appendix D.**

### 4.9.1 Pre-intervention interview

In the study carried out, data was collected through the use of interview questions. The interview was unstructured, the questions posed at learners were open-ended as learners were allowed to answer the questions freely, and questions also did arise from the respondent's responses. Pre-intervention task was used to investigate the visualization strategies used by learners in a grade 7 mathematics classroom. Also, the effectiveness of their strategies was considered after the task sheets were administered. The task sheets were analyzed, 12 learners were randomly selected after the pre-task were analyzed, and a one-on-one interview was conducted. Learners had to respond to six basic questions, but their responses led to further questioning.

### 4.9.2 Post-intervention interview

After the initial task and interview, learners were introduced to three lessons with explicit teaching using visualization techniques. A post-intervention task sheet was administered after the intervention. Tools in the form of (pictures, drawings, mathematics manipulatives, use of colour, diagrams, and gestures) were used to teach mathematical word problems. After the third lesson, learners were given the same task sheet to solve as this helped reveal the effectiveness of the intervention given as well as a self-analysis of my own teaching. Learners task sheet were analyzed; a selection of 12 learners was done and were interviewed. Respondents had to answer ten (10) questions freely, and further questions also arose from their responses. Mudaly (2014, p. 3) stated that finding the relationship between the visual and the mathematics requires investigation to be further carried out on the role of visualization in the mathematization process. This statement forms part of the basis of why learners' responses to the interview questions were of importance, as they also helped suggest a conclusion based on the educational intervention.

## 4.10 Validity and Reliability and Rigour

Validity, like Cohen, Manion and Morrison (2007, p. 152) stated, is crucial to effective research. Validity, reliability and trustworthiness are necessary when carrying out research as, without it, research becomes invalid and worthless. Lincoln and Guba (1985) emphasized the need for validity in research, which is how far research can be trusted and the concept of triangulation of data using different data collection methods, as this helps researchers ensure that data collected are reliable and trustworthy. In qualitative data, Winter (2000) stated that validity might be handled or managed through its truthfulness, deepness, and range of the data achieved; the participants focused on the researcher's length of triangulation and objectivity. When sampling is cautiously done in qualitative data, validity is likely to be improved. Hence, it is vital to check for validity, reliability, and trustworthiness in an interpretive paradigm.

Trustworthiness, a concept introduced by Guba and Lincoln (1985) for interpretive research, has been vastly used and has four components: credibility, transferability, dependability, and confirmability. These components were looked into during data collection and analysis. The concept of credibility helps to reveal if findings from the research conducted show reality, and the participants' lived experiences. In terms of transferability, it is quite essential as it is the extent to which research can be transferred to a different context. Construct validity is necessary as this will ensure that the instruments and data collection method, in this case, the initial task sheet, post-intervention task sheet, and interview that is intended to be used, measure what they are meant to measure. Hence the need for piloting, which was to test the instrument before its usage. When carrying out this research, it was necessary to ensure that the data collected measured learners' knowledge of visualization and the different approaches used by learners. If validity in data collection is ensured, then the research can be carried out under the same conditions and will yield the same result; it can then be said that the test is reliable. According to Bertram and Christiansen (2016, p. 186), a test is reliable if it can be repeated using the same or similar group and yields the same or similar results. Validity in data collection can be ensured if the researcher audio-records the interview verbatim, as it will ensure the accuracy of the data collected. This was ensured in the collection of data process, as interviews were audio-recorded, after which they were transcribed. Observations were also jotted down in terms of gestures made by a few learners. Few learners were also interviewed before participants could be interviewed to ensure validity as well.

Furthermore, Bertram and Christiansen (2016, p. 123) stated that a way of increasing the trustworthiness of a specific interpretation is to use "thick description" in qualitative data. Thick description in qualitative research can be said to be the depth of the explanation that a researcher needs to detail (Bertram and Christiansen 2016, p. 123). Since the research was conducted in a naturalistic setting, it was impossible to generalize, but using thick description with enough explanation provided as a researcher, which is also referred to as the depth of what's been researched, readers can then decide whether discoveries can be transferred to another context. Also, since it was a case study and the sample was small and purposive, it was important to emphasize the data's depth. Bertram and Christiansen (2016, p. 123) argued that results could be generalized in large studies if the sample has been selected randomly;. However, if small-scale research was conducted and the sample was purposive, then transferability can be used. In the research carried out sample was purposive and small-scale.

Triangulation of data in this research study ensured that data is reliable and trustworthy. This was aimed at, as the researcher probed further by asking the same question differently and learners giving the same or similar response. This was corroborated by Bertram and Christiansen (2016, p. 189), who stated that triangulation could be done in a single data collection instrument and in this instance, an interview, by asking the question in a slightly different way or in more than one way. This was done to check if participants answered both questions in a similar way. Also, to ensure validity in data analysis, time was spent reading through the data thoroughly to ensure credibility. Pseudonyms were used as supposed to their real names.

## 4.11 Data analysis

Analysis, according to Bertram and Christiansen (2016, p. 115), is a systematic study, or the detachment of a whole into its part, for the aim of the study. Data analysis consists of three flows of activity as stated by Miles and Huberman (1994, p. 10,11), and they are data reduction, data display and conclusion drawing and verification. Data was collected using pre and post-task sheets and interviews. Data reduction was used as there was a need to sort out data into categories and patterns or relationships; this made it easier to make sense of them.

Conclusion drawing and verification also helped with explanations and drawing of conclusions from the onset of data collection, which was then concluded at the end of the analysis. In analyzing the data, an inductive approach was used. This entailed starting with the raw data that was collected.

Firstly, the task sheets were sorted out based on how they answered the questions; learners who used diagrams and did not use diagrams. Those who used diagram and got it right and those who used diagrams but got them wrong were sorted separately. Those who used some diagrams and got them right, and those who used some diagrams and got them wrong. Lastly, those who did not use diagrams at all and got them all right and those who did not use diagrams but got them all wrong were all separated, after which interviews were conducted in an area that was conducive, with fewer distractions. These ones were interviewed, and the audio-taped interviews transcribed, patterns were detected for conclusions to be made. Bertram and Christiansen (2016, p. 117) asserted that in inductive reasoning, categories emerge from the data.

## 4.12 Confidentiality

In order to ensure confidentiality, the names of the school and participants were not mentioned so as to ensure privacy and anonymity. Pseudonyms were used to provide protection for each of the participant. The interview was also conducted in a place where participants felt comfortable.

## 4.13 Ethical considerations

Ethical considerations form a vital part of a research study. In carrying out this research, three ethical principles were considered: autonomy, non-maleficence and beneficence.

According to Bertram and Christiansen (2016, p. 66), autonomy implies that consent of all participants must be obtained before they participate in the study, and they are to voluntarily participate, having received a clear explanation of what is expected of them as well as withdraw at any time. Secondly, Bertram and Christiansen (2016, p. 66) described maleficence as research not being harmful to participants or anyone. This was why the confidentiality of participants was assured as well as their identities, to prevent them from harm. Lastly, beneficence, as stated by Bertram and Christiansen (2016, p. 67), suggested that research should be beneficial to the participants, researchers or society. It is envisaged that this research will be beneficial and also add to the body of knowledge.

Permission had to be obtained from the principal of the school, the parents and learners before the research could commence. The researcher also ensured that participants' right was not compromised as they could withdraw at any time during the course of the research process. A letter requesting permission to use the school and participants was sent to the principal before the commencement of the study **(Appendix B).** A letter of consent was given to each participant to sign, which contained a detailed explanation of what the study was all about **(Appendix C).** An option of participating and/or withdrawing at any stage was also made mention in the consent letter. Pseudonyms were used to guarantee the anonymity and confidentiality of the participants. Furthermore, before letters of consent were sent out, full ethical permission was obtained from the necessary authority **(Appendix A).**

### 4.14 Summary of the chapter

This chapter is an overview of how the research study was conducted by outlining the methods and processes employed in carrying out the research, with ethical considerations taken into account. The chapter started with a list of research questions and the approach taken to carry out the research study, a case study approach. A discussion of the paradigm used was discussed, which was interpretive and qualitative in nature. This was followed by a discussion on the research design, methods and methodology, which was how data was collected, and the procedures followed. Data collection and research instruments were also discussed in this chapter. Figure 4.1 below shows a visual plan of the data collection process; this can be found below. After the data collection process and transcription of the interviews, the data analysis process started. The analysis of data is discussed in full detail in chapter 5.

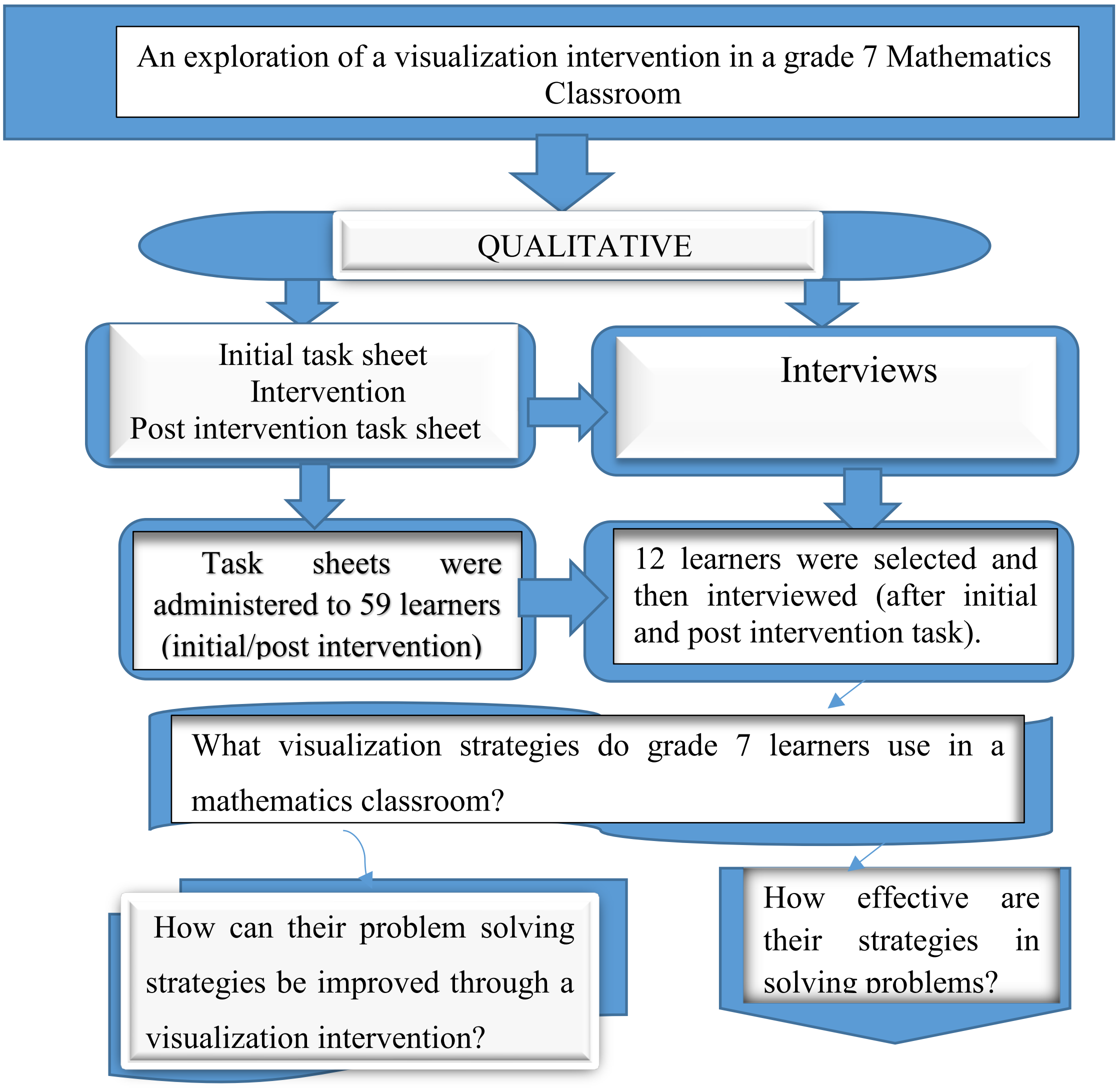



**Figure 4.1:** Flow chart representation of processes of data collection

# CHAPTER FIVE

## 5 Findings and Analysis

In the previous chapter, methods and data collection processes were discussed in detail. This chapter focused on analysing the data collected for this study. Results of the pre and post-intervention task sheets completed by learners were analysed. Participants' selections to be interviewed were made based on how the task was answered, with responses analysed and presented in this chapter. The interview sessions were based on learners thought on visualization before and after the intervention processes.

### 5.1 Findings of Learner's perception of visualization pre-intervention

Learner's perception of visualization was investigated through an interview approach after an initial task had been administered. It was observed that some learners were not enthusiastic whilst solving the task because it was mathematics; they seemed less interested as it is not their favourite subject. Before a detailed discussion of their responses, the summary of results from the completed task, which has been analysed and tabulated, is shown in **Table 5.1.** These results were categorized per question into learners who used diagrams and learners who used no diagram per question. These were further categorized into learners who got each question right using or showing evidence of visualization and learners who got it wrong using a visual approach as well. The same was applicable for learners who attempted the question using a different method other than visualization. Learners who did not bother attempting a question were also included.

**Table 5.1: Summary results of learner's application of visualization in the Initial task**

| Questions | No. of learners who used diagram | | No. of learners who did not use diagram | | Not attempted |
|---|---|---|---|---|---|
| | got it right | got it wrong | got it right | got it wrong | |
| 1 | 3 | 11 | 9 | 28 | 8 |
| 2 | 8 | 0 | 42 | 8 | 1 |
| 3 | 3 | 2 | 25 | 25 | 4 |
| 4 | 1 | 0 | 8 | 39 | 11 |
| 5 | 5 | 1 | 20 | 20 | 13 |
| 6 | 2 | 0 | 18 | 24 | 15 |
| 7 | 0 | 0 | 37 | 7 | 15 |

A total of 59 learners participated in the initial task; from the analysis, in question 1 only 14 learners attempted to use a form of visualization, 3 got the question right, and 11 out of 14 got the answers wrong. One of the learners who got the question right highlighted the essential points and used a diagram for the question. However, her diagram was not accurate. 2 learners attempted using a diagram, but their diagrams were incomplete/inaccurate. 37 learners used other preferred methods, 9 of them got it right, while the remaining 28 got the question wrong and 8 learners were seen not to have attempted the question.

In question 2 only 8 out of all the learners used diagram and got it right; out of those who did not use any form of visualization, 8 learners got it wrong while 42 got the answers right. There was a learner who did not attempt the question.

In question 3, out of the 59 learners who attempted the task, only 5 used diagram. 3 out of the 5 learners got the question right, while 2 got it wrong. 25 out of the remaining 58 learners used conceptual methods and got the question right, while 25 of them got it wrong. 4 out of the 59 learners did not attempt the question.

In question 4, only 1 learner attempted the question using a visualization approach and got it right. Out of the 47 learners who used different methods, 8 got it right and 39 learners got the question wrong, while 11 learners did not attempt the question.

In question 5, 6 learners attempted the question visually. 5 of the 6 got it right, and 1 learner was not successful in attempting the question visually. Out of the 53 learners who did not use diagrams, 20 of them got it right, 20 learners got it wrong, while 13 did not attempt the question.

Out of the 59 learners that attempted question 6, only two learners attempted using the diagram and got it right, while 42 learners out of the 59 did not use any visual representation as they used a method of their choice. 18 learners got it right using other methods, while 24 of them got it wrong. 15 learners were recorded not to have attempted the question at all.

In question 7, none of the 59 learners attempted the question visually. The 37 learners who got the question right used conceptual methods. Seven learners got it wrong, and 15 learners did not attempt the question at all.

A learner used diagrams for 3 out of the four questions attempted and got all three questions right in one of the analysed task sheets.

Based on the initial task sheets results, it was observed that learners who attempted the questions using some form of visualization showed that they understood visualisation techniques. It was also revealed that most learners experienced difficulty visualising the questions, while some could not comprehend the questions. The findings from the initial task reveal that learners are not naturally inclined to use visualization in solving mathematical word problems. It is also evident, from the very few that solved the problem using visual in the combined grade 7 classes, only a few got the questions right. The observation noted from the task sheets showed that learners are not visually inclined, resulting from not being able to interpret the word problems diagrammatically or lack of correct interpretation of information and visual application.

### 5.1.1 Pre-intervention Interview analysis

After the initial task sheet had been completed, the aim of interviewing was to gather learners' thoughts on how they answered the questions, why they used a preferred method and their thoughts on visualisation. Learners' responses to the questions gave an insight into their understanding of visualisation strategies and word problems. In selecting learners for the interview, no single learner used diagrams for all questions, whether they answered the question correctly or not. Selections had to be based on choosing learners who solved without diagrams and got five or more out of the seven questions right and learners who got the majority wrong. Also, two out of the learners who used some sort of diagrams were not consistent in its usage as one of them used it in two questions, and the other learner used it (diagram) in only a question.

**Learners' responses (pre-intervention)**

Teacher: ***When solving word problems in mathematics, what methods do you like to use?***

*Learner Mv: I like to use methods that are easy, and I understand well.*

*Learner As: I use long methods.*

(Learner implied that she uses calculation methods when solving word problems in mathematics).

*Learner Sb: It depends, I use calculations*

*Learner E: I sometimes like using methods that explain what the process of me getting into the answer.*

*Learner Lg: Column method*

Teacher: *That's just for an aspect in maths. I am talking about maths in general, what methods do you like to use?*

*Learner Lg: Any method ma'am.*

Teacher: *When you say any method, what do you mean by that?*

*Learner Lg: The one based on the question.*

From the above, the learner's choice of method is always dependent on the question asked. It is observed and worthy of note from learners combined responses that their choice of method or approach is based on the question asked.

*Learner P: The long method.*

Teacher: *When you say the long method, what do you mean?*

*Learner P: The long division.*

Teacher: *If it's not division, I mean a method that will help you solve mathematics problems.*

*Learner P: Calculations.*

*Learner Sp: drawing*

*Learner Mn: hmm….It's long division and multiplication (teacher probes further...)*

Teacher: ***What methods do you use, not concepts, when solving word problems in maths?***

*Learner Mn: Word problems, I use…drawings.*

*Learner Aw: I like to use easy methods and more of drawing.*

*Learner Lw: Usually I use the column method.*

Teacher: *If it's not a question that requires a column method, then what method do you use?*

*Learner Lw: I use a visual method, I think it in my mind and then I solve it.*

The above response showed that learner may have the tendency to visualize internally, though he stated that he uses calculation method when solving problems in mathematics. He is also one of the learners that was introduced briefly to using visual approach in mathematics, in the previous grade.

*Learner Ang: Hmm…I like to draw first, so that I get a better picture of what I'm doing, then I will first do it on a separate piece of paper and once I feel confident that it is right, then I'll put it onto the test sheet or activity page.*

Teacher: *But looking at the task you completed you didn't draw, you used a different approach and you also didn't use any diagram, what's the reason for that?*

*Learner Ang: When I draw I did it on a separate piece of paper, so I think my drawings are not that neat, so if I draw here it's going to look untidy.*

*Learner Sn: Well, I like to use visualization mostly if it has to do with people, I draw their faces and maybe if there is a number you divide them into groups and just give each person one, one each.*

Teacher: *Is this applicable to all questions that you solve in mathematics?*

*Learner Sn: No, which is why I use diagrams for other questions if I can.*

It was observed that most of the participants here claim to use some diagrams; one of them uses it as a form of a check to better understand what she needs to do. Once she has arrived at an answer, she then uses a non-visual approach. To learner Ang, diagrams and drawings are helpful for the purpose of checking in mathematics and not being able to present a neat representation of the solution has served as a means of discouragement to her.

Also, one participant uses a diagram to solve questions because she feels it is of benefit and can help arrive at the desired answer. She, however, uses a non-visual method to solve questions during a class activity, like the task given to her during this pre-intervention process. If follow-up interview questions were not conducted after the task, concluding based on her task sheet would have given a wrong conclusion. Such learners should be encouraged to use visuals to represent word problems when completing class task and activity.

It can also be observed that diagrams or any form of visual strategy are the first calls for some of these learners when solving word problems in mathematics. This observation is based on the responses given by them. Learner Mv and Aw aside, others gave similar responses that they prefer to use easy methods to arrive at the correct answer. It can then be concluded based on their responses that most of the learners in this particular context prefer to use methods they are used to and understand well.

Teacher: ***Does your method usually work?***

> *Learner Aw: Yes.*
>
> Learner Mv: *Sometimes they do work ma'am, but my calculations are wrong.*
>
> *Learner As: Yes ma'am.*
>
> *Learner Sb: Sometimes.*
>
> *Learner E: Ermm…75% of the time.*

Teacher: ***Does your method usually work?***

> *Learner Sp: Yes.*

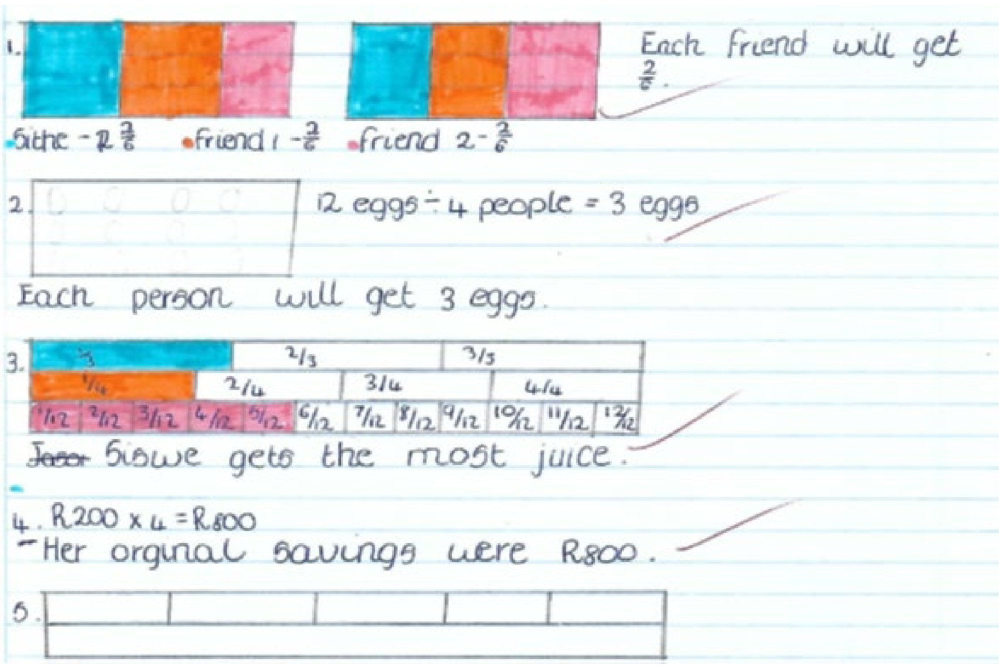



**Figure 5.1:** Sp's representation of the pre-task.

From the above participant's task sheet, it was evident that she could only answer four out of seven questions because of the time factor. She used diagrams/drawings for all four questions and got them all right. This confirmed the learner's claim to be accurate and showed that she, to an extent, understood her method of choice. Using diagrams to solve problems in mathematics is what learner Sp has been exposed to in grade six; this has made it an easy choice for her.

Teacher: ***Does your method usually work?***

*Learner Sp: Yes*

Teacher: ***Is it like the way your teacher has taught you?***

*Learner Sp: Yes, in Grade 6*

Teacher: ***And it's been working for you?***

*Learner Sp: Yes.*

The above participant has been exposed to visualization strategies by her teacher in the previous grade. This experience has helped her apply these strategies correctly to solve word problems in mathematics, which has also made her a better visualizer. From the above, it is evident that if learners are introduced to visualization early enough in mathematics, they can become better visualizers and good problem solver with constant practice.

*Learner Sn: Yes, most of the time.*

Teacher: ***Which of the methods work better for you?***

*(this question was asked based on learner's task sheet)*

*Learner Sn: Visual methods normally work for me.*

Teacher: ***I saw that you highlighted some important aspects of the questions based on the task solved, what's the reason for that?***

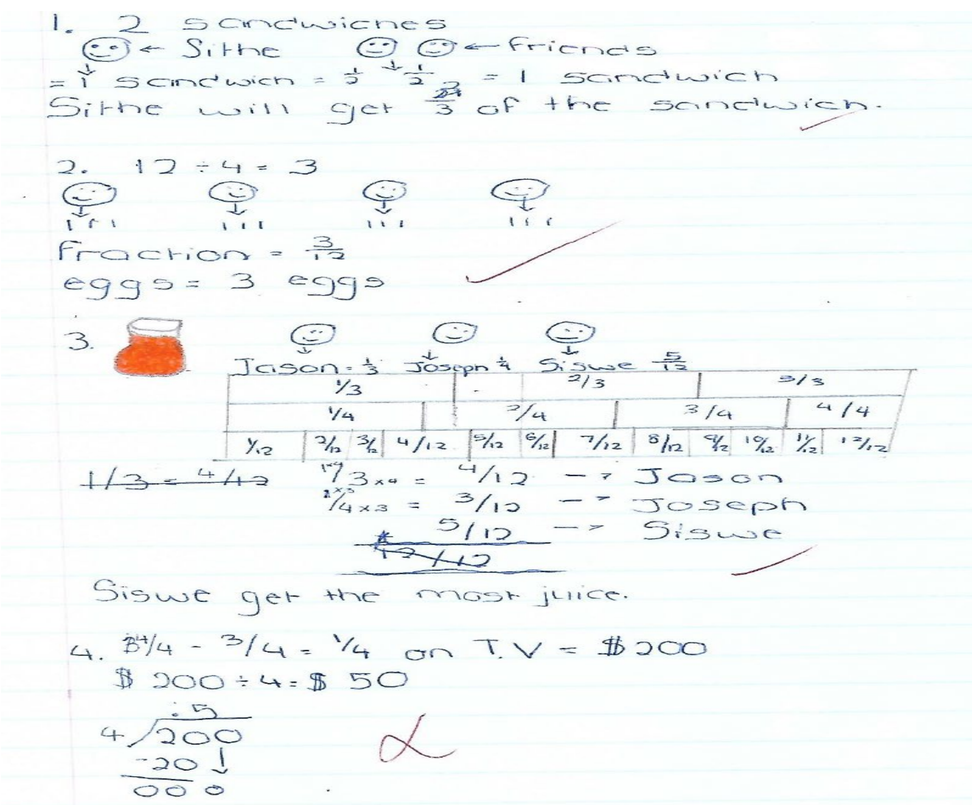
*Learner Sn: Hmm…to understand it better and to have an image in my mind of the settings.*

The above learner was introduced to some form of visualization strategies in grade six; this has helped her solve the task as her first approach was to highlight the essential aspects in the question. From the response given, she claimed highlighting helped her create an image in her mind, which further developed into an external interpretation of the task. This response shows that visualization has taken place in the head, after which she translated what was in her thought process into an image, picture or diagram.

Teacher: ***From the task you solved, I also saw that you did not use diagram for all the questions, why is that so?***

> *Learner Sn: Hmmm…most of them had numbers, so I tried using visuals but they didn't work for all.*

Though learner Sn highlighted essential aspects of the questions before proferring a solution, she could not use diagrams or pictures to solve all the questions. The subject (participant) believes that not all questions involving fractions can be represented using diagrams or drawings, so she used diagrams for some but did not for the others. Her solutions were visual and non-visual related from the task sheet shown below, and both approaches seem to work for her. For the questions she solved using pictures and diagrams, she arrived at a correct answer.



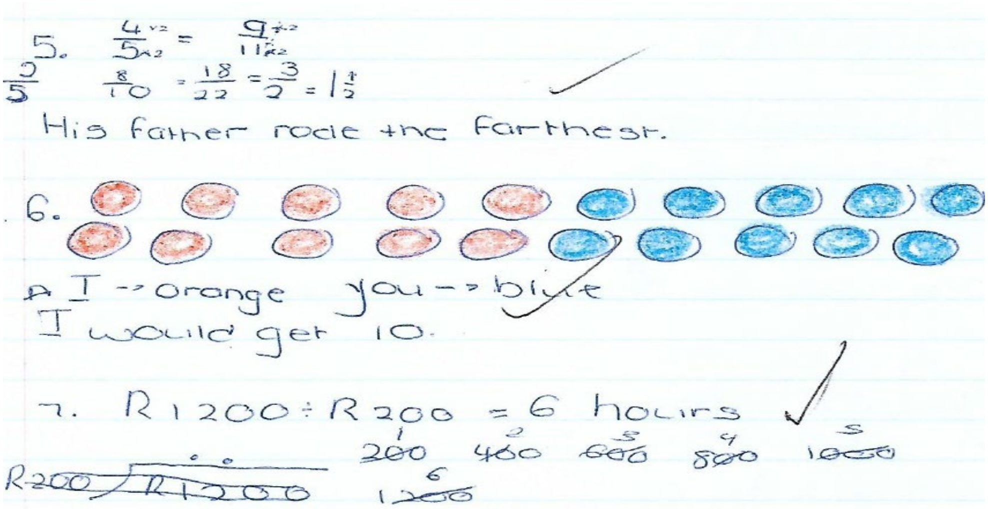



**Figure 5.2:** Learner Sn's solution of the pre-task

Teacher: ***Does your method usually work?***

> *Learner Lw: Yes.*
>
> *Learner Lg: Sometimes, if I do it in a correct way.*
>
> *Learner P: Yes ma'am it works.*
>
> *Learner Ang: Yes, it does.*

Teacher: ***Which method works well for you?***

> *Learner Ang: hmmm…drawing first, but then I put it into words when I'm done.*

The learner preferred to use diagrams or drawings first for rough workings when solving a problem from the above responses. This, the participant claimed, will help her get a better picture of what she is doing and understand the question. Once she is sure of what is expected, she then solves the problem using a different approach.

This particular learner uses diagrams or drawings to her own advantage, which has helped solve the task.

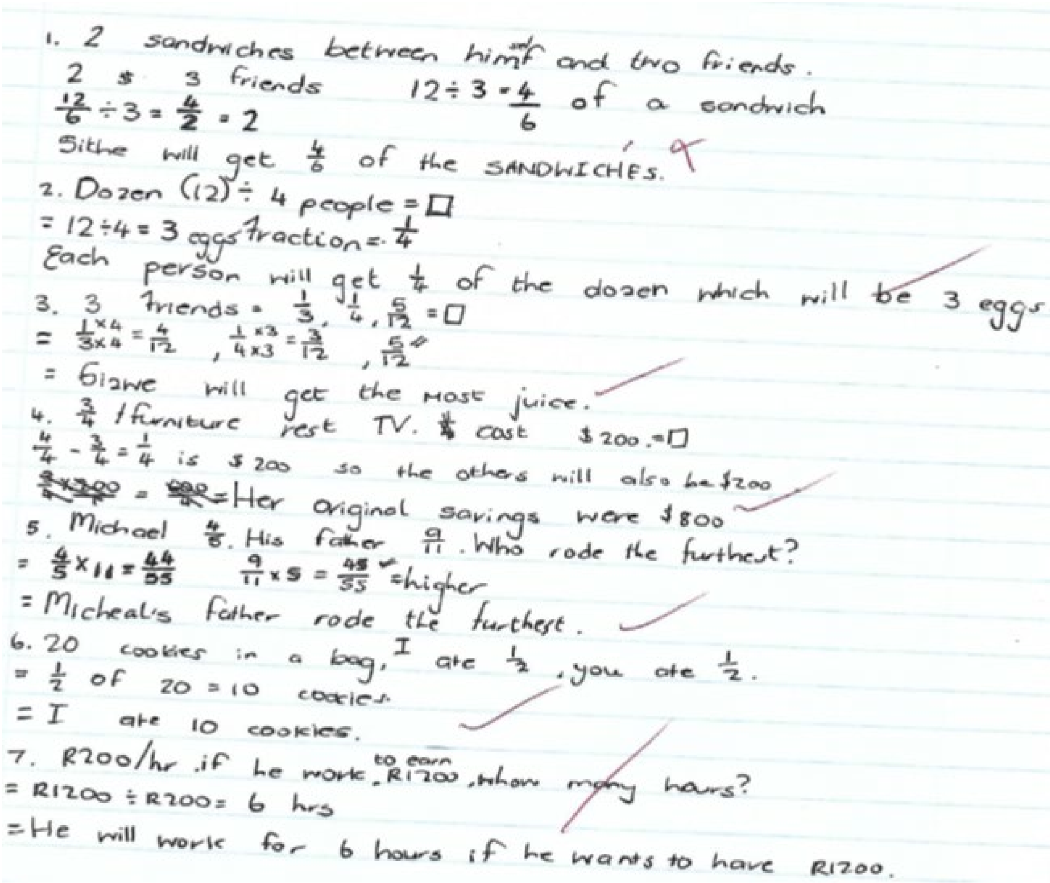



**Figure 5.3:** Ang's representation of the pre-task

> *Learner Mn: Sometimes, sometimes it doesn't. Sometimes ma'am, it only works in certain word problems, but in others you can't draw cos you can't actually draw the word problems…*

(Teacher probes further based on learner's task sheet…)

Teacher: ***If we look at the task here, you only used drawing in two questions, why didn't you use it for the other questions?***

> *Learner Mn: Miss I couldn't find a way to draw the…the…word problem. I was rushing through…*

It is observed from learner Mn's response, who already has prior knowledge of visualization, that his method does not always work and is only applicable to specific questions. Visualization strategy was briefly introduced to him and a few of the learners in a particular grade six class. His participation in some visualization lessons the previous year formed the basis of his prior knowledge in visualization, especially the use of diagrams. Also, from the above responses, the learner claimed to use diagrams when solving problems in mathematics, but from his task sheet, he only used it for two questions and only got one right. The participant's inability to use diagrams might result from not being able to interpret the questions given correctly. From other learners responses, their method of choice, which is not visuals or any form of diagram, always work for them.

Teacher: ***Is your method like the way your teacher has taught you?***

> *Learner Mn: Yes ma'am it is, but no……not completely, I sometime use my own, when they say a third or a fifth of something, I draw those fractions.*

Teacher: *You only draw when it is fraction?*

> *Learner Mn: Yes ma'am, could only visualize when it involves fractions.*

This was so for the two questions solved, as he only used diagrams in questions involving fractions. This learner is only able to use diagrams for questions that are fraction based, as he finds them easy to represent and solve than other concepts.

(responses from other learners continues…)

> *Learner Aw: Some of them are.*

> *Learner As: Yes ma'am, some other methods are from Grade 6, how I learned them.*

> *Learner E: Yes.*

> *Learner Lg: Usually, yes.*

> *Learner Mv: Sometimes, he is fast ma'am and sometimes ma'am I just don't understand him and I'm scared to ask.*

By the above response, the learner meant that his other teacher's teaching approach is too fast to understand, which has then affected his interest in Mathematics. (It was necessary to ask the question again to establish how he learned his methods.)

> *Learner Mv: Yes, ma'am, it's the way he taught us.*

> *Learner Sb: No, some I usually tutor it from my dad, my dad usually teaches me how to solve my problems.*

> *Learner Lw: Sometimes, No.*

Learner explained further.

*Learner Lw: Sometimes I use it the way our teacher has taught us, eish…and sometimes I don't.*

*Learner P: No, sometimes I change the method, the way I want it ma'am. The way I understand it.*

From the above responses, participants choice of method is dependent on the extent to which the question is understood. If meaning is derived from the questions, learners will be able to use the information to form an image or representation in their minds.

(Learners responses continues….)

*Learner Ang: Yes.*

*Learner Sn: It's sort of is because I was taught to use a method that I prefer most, and I prefer visualization.*

This is what I am observing from responses given by learners to the above question. Their choice of method in solving word problems in mathematics is mainly based on how they learned it from their teachers. This implies that the teacher is an external force that can influence learner's decision and choices. If these strategies had been introduced to them early enough and consistently, perhaps, it would have impacted their choice of it.

Teacher: ***Do you like to draw, highlight or see something differently when writing the solution?***

*Learner Mn: No, usually I just…only draw, I only draw.*

*Learner Aw: Yes.*

Teacher: *Okay, if you say you like to draw, from the task completed I see that you only used diagram in one question, whilst others you didn't. Can you explain?*

*Learner Aw: I found the ones without the drawing, I found them much easier to solve without the drawing.*

*Learner Mv: I am not used to that ma'am. I do draw.*

Learner claimed to use diagrams in mathematics, but his task sheet did not reveal this as he did not use diagram for any of the questions; he only got one question right. It is interesting to find out from learner Aw that she only uses diagrams for questions that she perceives as difficult and prefers to use other methods for easy questions. Her perception of any form of visual strategy from her response could be that it should be used for very technical or challenging questions.

From their responses, two of them (learner Mn and Aw) said they sometimes use diagrams, though one of them said she likes to use diagrams but, it is also dependent on the type of question asked and would not draw a diagram if the question is easy. Learner Aw said she does not use diagrams if she cannot find a way of interpreting the problem. The reason given by both learners differs but also showed that visualizing or drawing diagrams is not their first approach to solving mathematics problems.

*(Learners responses continues)*

> *Learner As: No ma'am I don't.*

Teacher: *why?*

> *Learner As: Ma'am, because…ahh...hmm… I have my own way to see things and when I draw it's kind of difficult for me to see than when writing the solution.*

The learner is of the opinion that diagram, highlighting is of no benefit to her, as she is used to her usual way of solving problems. (Teacher saw the need to probe even further.)
Teacher: *So, when you draw it becomes difficult for you to see the solution?*

> *Learner As: Yes*

> *Learner Sb: I don't like to draw, I like explaining, like calculations*.

Teacher: *Why don't you like to draw?*

> *Learner Sb: To me it's…, sometimes I get confused on how I arrived at the answer but, when I explain I know I can check how I explained the answer.*

For this learner, the only form of visual strategy that he feels can be used when solving problems in mathematics is the diagram. The difficulty he claimed to encounter is how to check whilst completing the task using this approach. He can check and explain the process of arriving at a solution when he uses other methods.

*Learner E: No.*

Another learner responded that she does not like to draw or highlight when writing her solution. The teacher probed further.

Teacher: *Why?*

*Learner E: Ermm…when I understand the concept and what we are being tested and asked what to do, I don't like using drawing because I know what I'm supposed to be doing. But when it comes to fractions, algebraic expressions and input and output values I have problems because sometimes I don't understand the question itself, so I use diagrams to explain it.*

Teacher: *So, using visuals or diagrams is dependent on the concept?*

*Learner E: Yes.*

The teacher had to probe further based on the learner's task sheet as she claimed she uses diagrams for concepts like fractions, Patterns to name a few but did not use them in the task solved.

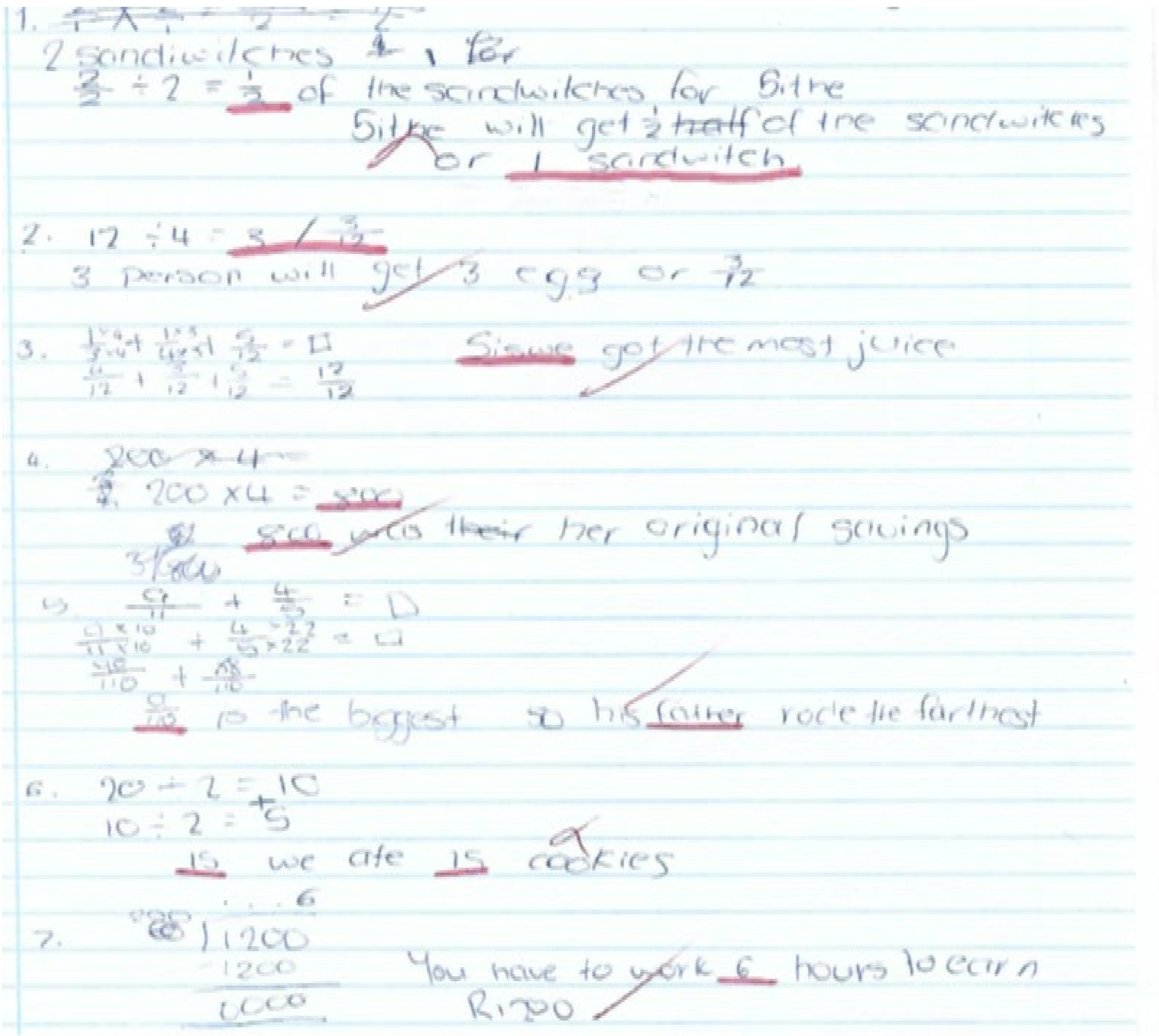



**Figure 5.4:** Learner E’s representation of the pre-task.

Teacher: *I looked through your task sheet and saw that you didn’t use diagrams at all, why*?

> *Learner E: Because for me, I find fractions not that hard because you have to understand the denominator part and how to incorporate it with the other questions that are being asked.*

Again, it is observed from all the responses given that learners would rather prefer to use other methods to solve mathematical problems than to highlight or draw. Their mind is not yet opened to either internal or external way of visualizing when it comes to word problems.

Of the three learners with a similar response to the above question, learner As and Sb both said they use calculation method (that is, non-visual method) when it comes to solving problems in mathematics, while learner E says she uses any method that explains the process and will enable her to get to the answer. The three of them (*As, Sb and E*) said they do not like to draw; this means that diagrams will not be the first approach they would choose for solving mathematics problems. However, learner Aw and E believe that using diagrams or drawings depends on the question asked and/or concepts. Also, their responses are similar in that they only use diagrams or drawings if the questions are complex.

*(Learners response continues…)*

> *Learner P: Yes ma'am, I like to highlight because I can visualize colours, I can see colours.*

Teacher: *But looking through your task sheet, you didn't highlight?*

> *Learner P: It's because…I wasn't ready ma'am.*

Teacher: *What do you mean by you were not ready?*

> *Learner P: Ma'am I didn't understand some of the questions.*

Knowing what to look out for in a word problem could help a learner, as it is the first step to solving the problem. This was lacking in this learner and made it difficult to choose an appropriate strategy to lead to the solution. Focusing on important aspects of a question by highlighting may have helped reduce the ambiguity of the question.

> *Learner Lg: Yes.*

Teacher: *Yes what?*

> *Learner Lg: Yes, I highlight.*

Teacher: *Looking at your task sheet, you didn't highlight. (Teacher repeats the question)*

> *Learner Lg: drawing.*

(Teacher had to probe further, based on learner's response)

Teacher: *You only used diagram in a question. Why didn't you use more of drawing in this task?*

> *Learner Lg: I didn't understand the question.*

Of the seven questions attempted by this learner, she tried using a diagram approach for question one but got stuck as the solution was incomplete. In solving the other six questions, she used a non-visual approach to arrive at the answer, but only two of the six questions were correctly solved. It also showed that the learner lacked conceptual understanding, which was needed to interpret the questions correctly.

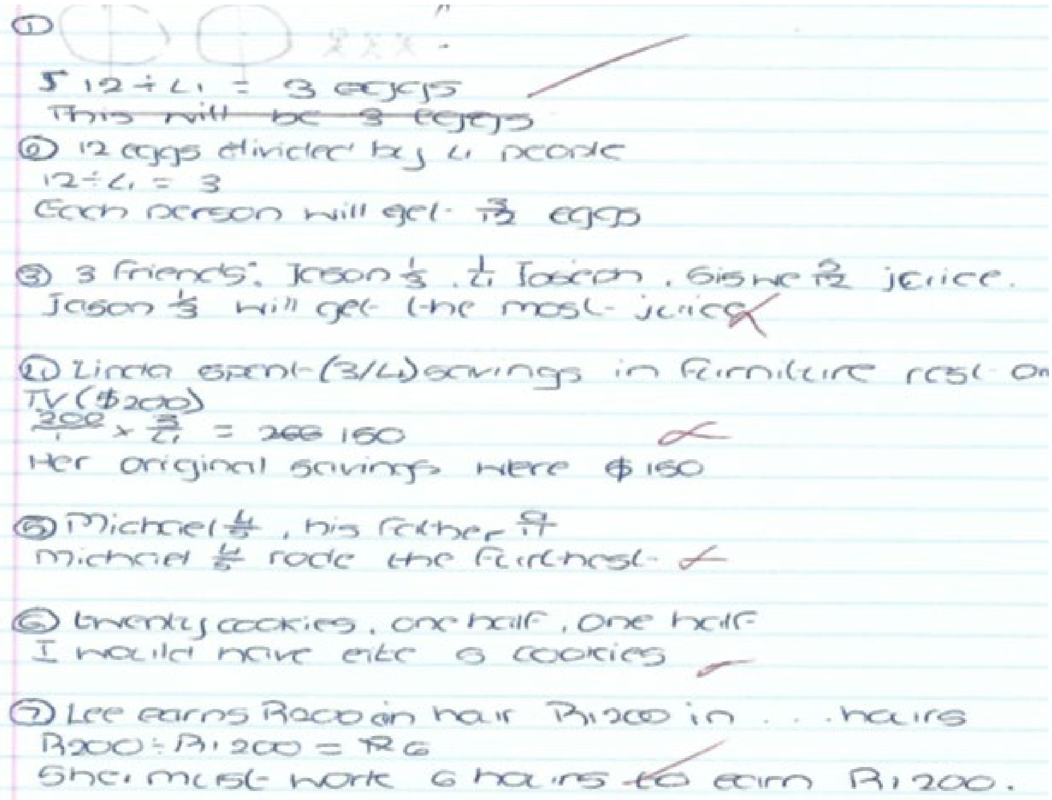



**Figure 5.5:** Lg's representation of the pre-task.

It can then be said that if learners lack adequate understanding, and if the required skills and knowledge isn't acquired it could pose as a barrier when solving problems in mathematics.

Teacher: *Do you like to draw, highlight or see something different when writing the solution?*

> *Learner Sp: I like to draw and highlight.*

> *Learner Sn: Yes, I do because when you highlight it, you get 2 stories and understand it better.*

Learner stated that she highlights because it helps separate the important and needed information from what is not required. Which then helped for better understanding and solving of the problem at hand. This can be seen as an aspect of visualization before further representation.

*Learner Ang: Yes, I do that.*

Teacher: *What do you do?*

*Learner Ang: If it's a test, I highlight the most important words, so I break them down, and then I find out what I must do and how to get the answer.*

Teacher: In other words, if it is a test you highlight, draw first on a separate page, and once you feel confident, you then use other methods to write the solution on the page. Was that what you did in this task?

*Learner Ang: Yes ma'am.*

Learner (Sp, Ang & Sn) all responded to using diagrams or some form of visuals. Of the three learners, Learner 'Ang' said that she preferred to draw on a separate paper to understand better what the question was asking and what she was doing. Her reason for not using it formally was because it makes her work look untidy. She mentioned during the interview that she also highlights the most important words to know what to do before solving the problem. This learner from our conversation possesses some visualization strategy skills, which has helped her in her task as she got six out of the seven questions right. Though she did not show it on the actual task sheet, she used it on a separate paper.

*Learner Lw: I like to draw.*

Teacher: *When I looked at the tasks solved, you only used diagram in a particular question, why is it so?*

*Learner Lw: Some were easy, so I thought the one that I drew in was challenging so I draw.*

Learner claimed he only uses diagrams or drawings for challenging questions and uses calculation methods if found easy. It showed here that there is no natural inclination to using diagrams when solving word problems in mathematics.

Learner Sp did not highlight, but she solved four problems using diagrams, as time did not permit her to complete the task. All four questions were solved correctly, and she also went ahead to using different colours in her representations. She believes that using diagrams or drawing makes problem-solving easy for her, so she prefers to use it. Learner Sn, on the other hand, used drawings as she drew faces to represent her problems. Of the six questions answered, she used diagrams for three, which were all correct, and the non-visual method for the remaining three. She pointed out that visuals did not work for all the questions as she was unable to represent the solution diagrammatically. She also stated that she has learned from her teacher always to use the most preferred method. These three learners exhibit one or more forms of visualization skills from their responses and the task solved, which has further helped them in the task. **Sample of the 3 learners task has been shown above.**

Teacher: ***Do you think a diagram, or a drawing would make solving problems easier?***

> *Learner Mn: On most occasions yes, but in some questions, you have to really think and mentally not you, but you can't use drawings.*

> *Learner Aw: Yes.*

Teacher: *Why?*

> *Learner Aw: I like drawing and if I draw it makes it easier for me to remember if I have to do it again.*

> *Learner Mv: Yes ma'am.*

Teacher: *Can you explain* w*hy?*

> *Learner Mv: Because I can picture it and I can understand it well.*

Teacher: *Why didn't you use it?*

> *Learner Mv: I never thought of it maybe.*

It is observed that learner Mv and Aw believe that a diagram or drawing will make mathematics problem easier, but only used it for 1 or 2 questions. Learner Mv says he likes to draw, but diagram is not his first call when solving mathematics. He thinks it will make solving mathematics easier as well.

(responses from other learners continues…)

*Learner As: No.*

Teacher: *Why do you say so?*

*Learner As: Because ma'am I like to, hmm…I like to calculate my solutions, I like to calculate them.*

*Learner Sb: Yes, I think so.*

Teacher: *Why?*

*Learner Sb: Because when you are actually doing diagrams, I think it's just because I sometimes get lazy to draw. It's because when I draw the diagrams I sometimes see it as a waste of time, just because when I do the calculations is much easier.*

*Learner Sp: Yes*

Teacher: *Why?*

*Learner Sp: Because you can see it and if there is something wrong you can see.*

Participant believes that diagrams make problem-solving more accessible, but mistakes or errors are easily picked up as well.

*Learner Lg: Yes.*

Teacher: *Why?*

*Learner Lg: Because it helps me understand the question better.*

*Learner P: No ma'am.*

Teacher: *Why did you say so?*

*Learner P: Ma'am I don't like drawing diagrams ma'am. I stick to methods.*

By the above response, learner P meant he only uses calculation methods.

*Learner Ang: Yes.*

Teacher: *Why did you say so?*

*Learner Ang: Hmmm…because it gets a better picture of the question, and as it says here, if it says two sandwiches I can draw two sandwiches and then I can cut them into the fractions they say I must cut them into.*

*Learner Lw: Yes.*

Teacher: *Why did you say so?*

*Learner Lw: Because it explains…then I understand then I solve it.*

*Learner Sn: Yes, because you can see how you can solve your problem.*

From my observation and the above response pattern, most of the learners responded that diagram or drawing would make solving word problems easier. Learner Mv believes that if he can have a picture in mind, it will make for a better understanding. This also means that the above learner can visualize internally, but it was not his first choice when it came to solving the problems given. It could be that learners not choosing visuals as their first call method may be as a result of not being used to it. If learners have been encouraged to using it consistently, their confidence level could have been boosted.

Learner Lg, P and Lw gave a similar response on their method of choice, as they all preferred the calculation method when solving problems in mathematics. Learner L and P both said they liked to highlight, while learner Lw prefers to draw when writing the solution, but none of them did that in this task. Learner P said he does not believe diagram will make the solving of word problem easier. When the educator probed further, he said it is because he does not like to draw. The other two affirmed that diagram and drawing would make solving problems easier, as it will help better understand the problem. Two of the learners tried using a diagram in one of the six questions; one of them got stuck and could not complete it, thereby using the calculation method. The other learner got the question he solved using a diagram right but resorted to solving the other six questions differently, using a calculation method. When asked why he used a diagram for one out of the six questions he said, he only uses diagram when the questions are challenging.

Teacher: ***How often do you use diagrams or drawings to solve problems?***

*Learner Mn: Half of the time when I am answering a maths question or any question*

Teacher: *Do you use it in classwork or tests?*

*Learner Mn: Only in classwork.*

Teacher: *Why?*

*Learner Mn: I don't really because when you are doing it in classwork, I know it's not for marks, so the one I trust the most, I use other methods.*

*Learner E: 10% of the time.*

*Learner Aw: Most of the time.*

*Learner Sb: Once a while.*

*Learner Mv: I use drawings a lot.*

Teacher: *Glancing through your task sheet, you didn't use diagrams or drawings at all, why?*

*Learner Mv: Because I wasn't serious.*

*Learner As: Sometimes I use it… It's kind of difficult when I use them.*

*Learner Sn: I use them most of the time when completing my homework or classroom activities.*

*Learner Sp: Not all the time, but most of the time*

Learner Sn and Sp used more visualization strategies compared to the other four learners. Learner Sn highlighted the important information that she claimed helped her understand and know what to do and how to solve the problem. She mentioned from our conversation that when she highlights, it paints two different stories and develops an image on her mind that helps with the solving process. This is very important and worthy of note based on responses given by learner Sn that visualization starts in the head, internally before it is then translated on paper this is based on what she has pictured in her mind.

*Learner Lg: In tests.*

*Learner P: I don't usually use them a lot ma'am.*

*Learner Ang: It's not that often but then, mostly half of my tests and work I do diagrams first, then I will write in words.*

*Learner Lw: Most of the time I use it. I practice it at home but I don't do it in class.*

The above responses to the questions asked showed that learners have different perception with regards to diagrams and drawing in solving word problems in mathematics. Some of the learners claimed that diagrams are complicated and see no need for their usage. Learner Mn only uses diagrams for questions that he is sure of and uses other methods for difficult questions. This is different from responses given by two of the interviewed learners that they use diagrams or some form of visualization for difficult questions in the previous question asked. Learner Aw responded to using diagrams most of the time and claimed in one of her previous responses that she uses diagrams for difficult questions.

Teacher: ***Do you think using diagrams or drawings when solving a problem takes a lot of time?***

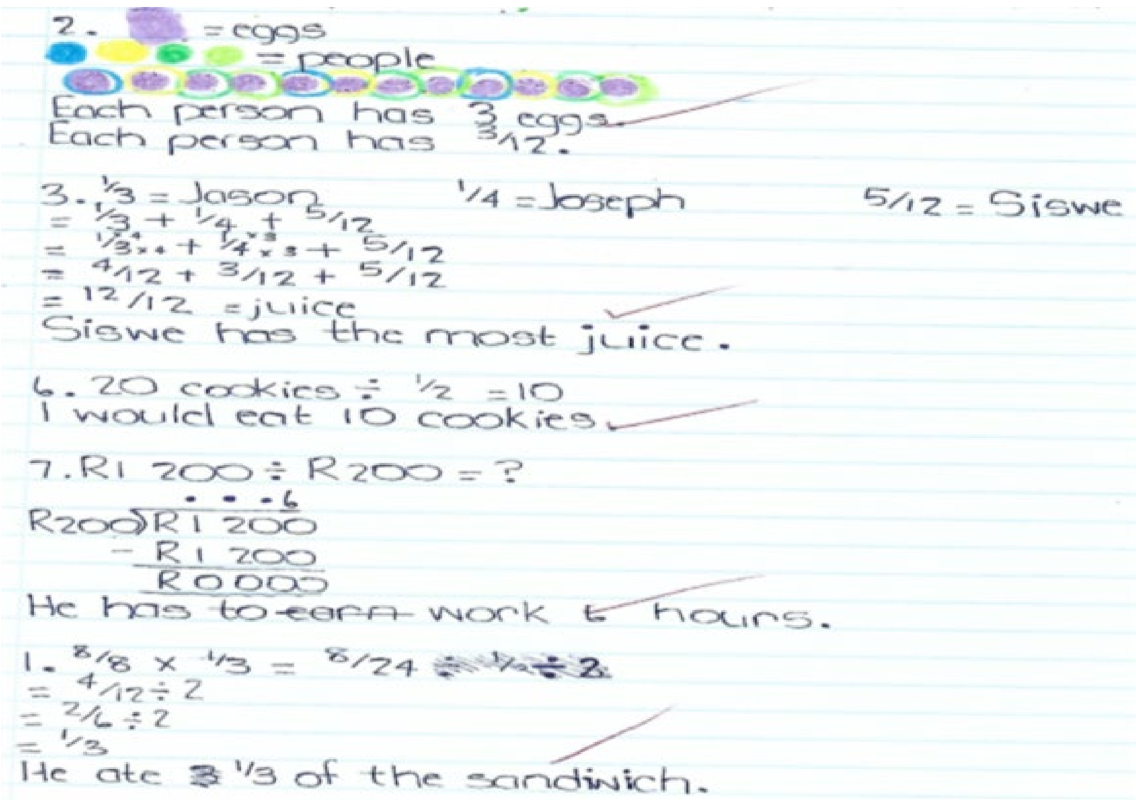
*Learner Mn: Yes, because you have to draw the correct diagram or your entire question is going to be wrong.*

(Educator had to probe further)

Teacher: *Why?*

*Learner Mn: Because it needs to be accurate and you need to see through your own eyes, but if you want to make it quick, then you will be rushing through, you can't think properly.*

*Learner Aw: It depends on the kind of question. Like if you have to do more of the thinking and solving, then I will use the drawing. If it's easy, then I wouldn't use the drawing.*


2. = eggs
= people
Each person has 3 eggs.
Each person has 3/12.

3. 1/3 = Jason 1/4 = Joseph 5/12 = Siswe
= 1/3 + 1/4 + 5/12
= 1/3 x 4 + 1/4 x 3 + 5/12
= 4/12 + 3/12 + 5/12
= 12/12 = juice
Siswe has the most juice.

6. 20 cookies ÷ 1/2 = 10
I would eat 10 cookies.

7. R1 200 ÷ R200 = ?
R200)R1 200 = 6
− R1 200
R0000
He has to ~~earn~~ work 6 hours.

1. 8/8 x 1/3 = 8/24 ÷ 2
= 4/12 ÷ 2
= 2/6 ÷ 2
= 1/3
He ate ~~3~~ 1/3 of the sandwich.

**Figure 5.6:** Learner Aw's representation of the pre-task.

The above sample solution showed that the learner chose not to use visuals except for one question because the non-visual method was an easy choice for her.

(Learners responses continues)

> *Learner Mv: Yes ma'am.*

Teacher: *Why did you say so?*

> *Learner Mv: Because you have to draw it properly, so you can get the thing right, and you are wasting time while drawing the thing.*
> *Learner As: For me I think so*

Teacher: *Why?*

> *Learner As: Because…hmm…for me it takes a lot of thinking* for drawing, *and drawing is not my thing. (learner continues with her response) I see them kind of difficult for me to do.*

Learner Mn is of the opinion that before you can use diagrams for solving word problems, it has to be carefully thought of, and you need to see it internally before it can be represented on paper. The process of thinking through and representing problems diagrammatically is what takes a lot of time. Learner Mv on the other hand, already made his conclusion that using a diagram or any form of visualization in mathematics is time-consuming. This might be one of the reasons he chose not to use it. Also, from experience over the years, learner Mv has shown little or no interest in mathematics and has to be constantly motivated.

The responses given by learner As, showed that she does not like drawing and did not see a need for it. In all the seven questions answered from the task sheet (got five right), she did not attempt to use visuals or diagrams for any of the questions because she perceived diagram/visualization as difficult, time-consuming and requires critical thinking skills. (See the above figure for her solution)

> *Learner Sb: Yes, I think so*

Teacher: *why?*

> *Learner Sb: Because ma'am…let's say if you want to solve like a pattern, you have to draw the table, the position of sequence, and that takes a lot of time, like getting to the book and writing, like maybe what's the answer and the rule.*

It can also be seen from the above responses from learner Sb and his sample solution that his perception of diagram usage or any form of visualization skills in a mathematical word problem is termed a waste of time and confusing.  Also, learners need to be able to think critically in order to be real problem solvers. However, very few possess this quality, going by learner Sb's response that he is lazy to put some thought into interpreting the questions.

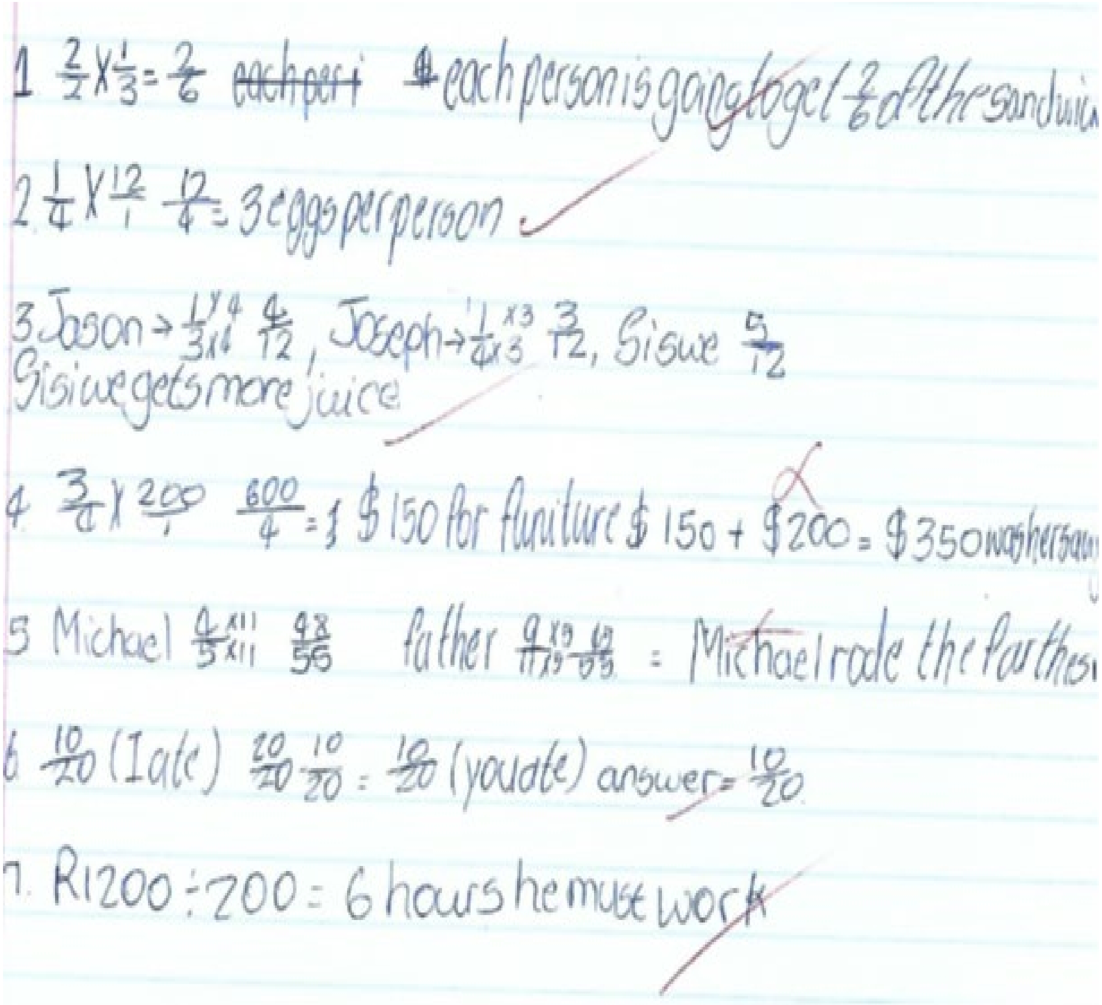



**Figure 5.7:** Sb's representation of the task.

Teacher: ***Do you think using diagrams or drawing when solving problems takes a lot of time?***

> *Learner E: It's based on, do you really understand what you are doing? If you don't understand, it is going to take quite some time to actually draw it, but if you do understand what you are doing, it doesn't take that long.*
>
> *Learner Sp: Yes, because it has to be…eish... correct.*

Teacher: *So, does that mean you spend your time thinking about the diagram before you draw it?*

> *Learner Sp: Yes, because then if I don't think about it I will draw something that's wrong and highlight it and then it will take more time to do it.*

For the learner to represent the problem diagrammatically, careful thoughts had to be put into the interpretation of the questions to have a correct representation, which then leads to the learner arriving at the right answer. This, she said, takes a lot of time.

*Learner Lg: No.*

Teacher: *Why did you say it doesn't take time?*

*Learner Lg: If you understand it, it doesn't take time.*

Teacher: *And if you don't understand it?*

*Learner Lg: It takes a bit of time.*

The learner is of the opinion that using diagrams or drawings would not waste time if the question is well understood. From her responses, and looking through the task completed, a lack of understanding of the questions resulted in the use of a non-visual approach. It was also picked up that two of the questions answered correctly were solved using the calculation method. This could then mean that, this learner does not have the required skill/s to visualize.

*Learner P: Yes ma'am, it takes a lot of time ma'am.*

Teacher: *Why did you say so?*

*Learner P: Ma'am because you still have to calculate and draw ma'am.*

Teacher: *But you mentioned earlier that you visualize?*

*Learner P: Yes ma'am.*

Teacher: *What do you understand by that?*

*Learner P: Visualize ma'am it's like seeing the answers, I like to calculate in my head, so I can hurry up and finish the work.*

It's interesting to find out that this particular learner can, to an extent, visualize internally as he claims he sees the answer by calculating in his head. He believes that it is a quicker way of completing the task. His responses and task sheet can be deduced that he lacks the necessary skills needed to assist him in representing the word problems diagrammatically. For him, visualization starts in the head, where he is able to picture the problem in his head and come up with an answer.

*Learner Ang: Hmm…not that much, if I do simple drawings then it will not take much of my time.*

Teacher: *Why do you think it takes time when using diagrams?*

*Learner Ang: Hmm…because sometimes if the questions I don't get it, I don't understand that properly…hmmm I take a lot of time doing if I don't understand the question.*

Teacher: *And if you understand the question?*

*Learner Ang: It takes less time to draw the diagrams.*

*Learner Lw: No, if you do understand it, it won't take time, you will spend less time, but if you don't understand it will take a lot of time.*

According to the above responses, learner Lw believes that if a question is well understood, if a learner knows what to look out for in a problem, then solving it becomes easy and will not take time. Moreover, if the question is not well understood, it could take a lot of time trying to figure out how to represent it visually.

*Learner Sn: No, if you don't spend too much time on accuracy.*

Teacher: *Why?*

*Learner Sn: Hmmm…when you get too accurate just for something that you just need to visualize and see the picture, you might end up losing focus because you end up drawing more than understanding.*

From the conversation with learner Sn, it could be deduced that she is not a natural visualizer, as she uses diagrams at will and decides when to use them and when not to. Her usage of visualization in any form is also dependent on the concepts that are to be solved and how easy or difficult it is. It can then be put that learner's use of visualization is dependent on her understanding of the problem posed at her and the concept; this then determines the time to be spent, and for her, it will consume a lot of time if not understood.

Of the twelve interviewees, eight of them gave similar responses when the last question was posed at them. They were of the opinion that diagrams or drawings are time-consuming. One of them added that if what is required is not understood, it will take time to solve, but interpreting using drawings or diagrams becomes easy and quick if the question is understood. The remaining four learners thought using diagrams or drawings is not time-consuming if the question is well understood and if much time is not spent on making the diagram or drawing perfect. The participant's opinion is worthy of mention here because diagram or drawing is time-consuming because more time is spent thinking of what to draw, how to draw it, such that it fits the problem and provides a solution before she starts. This, she said, is being done so as to ensure accuracy. This was evident from the learner's task sheet, as she only completed four out of the seven questions correctly. Diagrams and colours were also used in the four questions solved.

### 5.1.2 Summary of the findings of pre-intervention interview

The above analysis revealed that very few of the twelve learners interviewed from both grade seven classes could solve the problem using diagrams or drawings. Only one learner highlighted to draw attention to the very important information required to solve the problem. Participants choice of method was dependent on the questions asked.

Learners in this context do not have a natural inclination to use diagrams or drawings when solving a problem in mathematics; this was noted before the intervention was administered. Lack of a natural inclination towards visualization from their responses was based on the following: Most of them did not know what to look out for in a problem and how it can be represented; this could result from a lack of adequate understanding on their part. Not possessing the required skills and knowledge could also be seen as a challenge. Thirdly, most of the learners interviewed thought it was time-consuming, while some said they were not good at drawing, which demotivated them from using diagrams or drawings. Other reasons could be:

- the teacher not using it during lessons in the classroom and not encouraging learners to use it.
- Learners not being able to picture or visualize and their inability to interpret the problems visually affect its completion.

Also, not all the learners who attempted using diagrams or drawings arrived at the correct solution. One of them got stuck in the process and gave up completing the particular question as she was unable to process the information provided, thereby resorting to using the calculation method.

After the initial task and interview process represented above, learners were taken through an intervention process to teach them some visualization skills. After the intervention process, a post-intervention task sheet was given, which contained the same problems that were answered in the initial task sheet. Table 4.3 shows the tabulated results of the post-intervention task sheet.

## 5.2 Post-intervention analysis

Table 5.2 shows the tabulated results of the post-intervention task sheet. Learners were introduced to three (3) lessons on visualization strategies. The educator showed and taught learners how to use visual strategies when solving word problems in mathematics. Lessons were teacher and learner-centred, with different approaches being introduced to them. After the intervention process, learners were given the same task sheet to complete. This was done in order to find out if the intervention helped learners and also to investigate the various strategies that were used. The post-intervention task sheet was also aimed at finding out if learners were successful in their problem-solving strategies. Below is the tabulated results and analysis of the task solved by learners in both classes.

**Table 5.2: Summary results of learner's application of visualization in the post-intervention task**

| Questions | No. of learners who used diagram | | No. of learners who did not use diagram | | Not attempted |
|---|---|---|---|---|---|
| | got it right | got it wrong | got it right | got it wrong | |
| 1 | 19 | 25 | 4 | 7 | 5 |
| 2 | 42 | 11 | 6 | 1 | 0 |
| 3 | 31 | 9 | 6 | 10 | 4 |
| 4 | 8 | 12 | 6 | 24 | 10 |
| 5 | 13 | 13 | 15 | 10 | 9 |
| 6 | 13 | 22 | 6 | 7 | 12 |
| 7 | 8 | 1 | 26 | 7 | 18 |

After the intervention process, the same task sheet was administered to the 60 learners that were present at school. Learners were asked to use visualization strategies putting into use the skills they had acquired during the lessons. The tabulated result analysis showed that the number of those who used diagrams or visualization skills after the intervention has increased compared to the pre-intervention task.

The above results also showed that not all the 60 learners used diagrams, drawings, colours and highlighting of important words on the task sheet. Of the 44 learners who used diagrams for question one, only 19 got it right while the other 25 attempted but were not accurate. 11 learners used other methods; 4 of the learners arrived at the correct answer while the remaining 7 got it wrong. 5 out of the 60 learners did not attempt the question.

In question two, 53 learners used diagrams/or drawings, with 42 arriving at the correct answer, while 11 gave a wrong representation and answer. Only 7 out of the 60 learners used the calculation method, 1 learner got it right, while the remaining 6 arrived at the correct answer.

40 learners used diagrams in question three, with 31 being accurate while 9 got it wrong. 16 out of the 60 learners that participated in the task did not use any visualization strategy; instead, they used a choice method. 4 learners did not bother attempting the question.

In question four, few learners used diagrams. 20 out of the 60 learners used diagrams, with 8 being correct and 12 incorrect. 30 learners used a different method other than visualization strategies and the remaining 10 learners did not attempt the question. Fewer learners using visualization for this particular question could be due to learners not understanding the question and/or not knowing what to look out for in a question. Learners experienced difficulty in solving this particular question before the intervention strategy.

Question five showed that 26 learners used diagrams, 13 got it right, and 13 gave an incorrect representation. 25 learners used a different approach, while 9 learners did not attempt the question.

Only 35 out of the 60 learners completed question six using a diagram or any form of visuals. Out of the 35, only 13 got the answer right, while the other 22 learners got the question wrong. 13 learners used a different approach, with 12 of the 60 not attempting the question. Most of the learners used a form of visual strategy, but less than half of them got it right.

In question seven, 8 out of the 9 learners that used diagram got it right. 33 out of the 60 learners that wrote the task used a different method, while 18 learners did not bother attempting the question.

An interview process was used to investigate further the intervention carried out. Its effect on learners is discussed below.

### 5.2.1 Learners interview responses post-intervention

It was necessary to interview learners after the intervention process; this was done to find out if the intervention process helped their problem-solving skills and if the strategies learned were put into use. Also, the interview was to derive more insight into what participants thoughts were before and after they had been introduced to the object (strategies). Learners were given the same task to complete and were encouraged to use any visualization strategy of choice. Twelve learners were selected to participate in an interview from the total number of learners who completed the task, and their responses have been analysed below.

Teacher: ***How often do you use visualization in solving mathematical word problems?***

> *Learner Ak: Not often, like I don't use visualization method, I use…like methods that we usually use at school.*

> *Learner As: Not often*

Teacher: *Why did you say so?*

> *Learner As: Because I find visualization more hard and if you can teach me a method to do something I could, that's the way I would use it in each and every problem I will have.*

The above response showed that this learner tends to follow whatever method she is taught in class, this is also based on the task sheet completed by this learner. It then implies that the educator's strategy to solving word problems in mathematics will impact the learner as she will trust that the method chosen by her teacher will provide an answer to the problem at hand.

> *Learner Mi: Not that often*

> *Learner El: Not really, not often*

Teacher: ***Why is that so?***

> *Learner El: Sometimes it's because I understand the concept and I don't really need to*

*use visualization, but sometimes if when the task requires me to do so, I do.*

*[The teacher had to rephrase the question for learner Lu to understand.]*

Teacher***: Do you use visualization in solving mathematical word problems often****?*

*Learner Lu: I'm using shapes and fractions.*

Having looked through Lu's task sheet, it showed that her understanding of using visualization strategies to solve word problems in mathematics has improved as she interpreted each question visually, but for the last one. Of the six questions solved visually, four were accurately represented, leading to the correct answer. The last question was also solved correctly, but the learner used a non-visual approach.

*Learner Md: Not every day, Miss, not often.*

*Learner Nom: Not a lot, a few times*

*Learner Nt: hmm I do not usually use it a lot, I use it when like in mathematical problem is written like for example has fraction problems in it.*

The above three learners had similar responses to the question asked, but their task sheet differs. Learner Md used diagrams for all the questions, but only two were accurately represented, leading to the correct answer. She was excited about using diagrams from her responses and expression but, it showed from her task sheet that she has a problem understanding/comprehending the questions. On the other hand, Learner Nom does not use visualization often, but she could correctly solve all four questions visually after the intervention process. Learner Nt used diagrams for four of the questions, but two were wrongly interpreted and represented. From her claim, she only uses a diagram or any form of visualization strategy if the questions are fraction based. The use of visualization strategy in this instance diagram for learners like the above is dependent on how well the questions are understood.

*Learner Abo: I use it mostly, all the time.*

*Learner Ne: I use visualization most of the time when we mostly solve word problem with fractions.*

*Learner Aw: I usually use visualization most of the times.*

Teacher: *Why?*

*Learner Aw: It's much easier to answer most of the hard questions.*

*Learner Mn: I only use it when it involves fractions because it's much easier to separate the diagrams into pieces when you know what fraction you are dealing with it.*

The above responses showed that visualization strategy is not a method that learners opt for when solving word problems in mathematics. It does not come to them naturally as only 3 to 4 learners were confident of using it. The intervention strategy administered improved the number of learners who attempted the strategies during the post-task than the pre-task.

Learner Ak preferred methods that are primarily used at her school, which is not inclusive of visualization. Getting her to use more visualization strategy when attempting word problems in mathematics will involve its continuous use in the classroom, though she made an effort after the intervention strategies. Learner 'As', on the other hand, viewed visualization as a problematic strategy. In contrast, learner El does not see the need to use diagrams if the task is well understood and can solve the problems using a non-visual approach. However, she can only use it when and if asked to by the teacher. Diagrams to these learners are not their priority. Responses from these three learners showed that visualization had not been promoted the way it ought to in our mathematics classrooms, so it is not a preferred method.

Learner Abo and Ne are used to diagrams, especially when it involves word problems in mathematics before now. Learner Abo, in the pre-intervention interview, stated that she uses diagrams for her rough workings, which was why it was not used when completing the initial task. She has made progress and now comfortable with visualization, as she used diagrams in the post-task, which was neatly done and resulted in getting all five questions correct. Learner Ne highlighted the essential aspects of the questions, which led to her ability to visualize the questions, thereby using diagrams and colours for six out of the seven questions. Five of the six questions were answered correctly; this showed that her visualization skills had improved.

Learner Aw of the twelve learners used visualization because it is a straightforward approach, especially when it involves complex problems in mathematics. She has been exposed to using these approaches as she was part of a few of the learners briefly introduced to visualization strategies in the previous grade. This opportunity has helped improve her skills when solving word problems in mathematics and has developed confidence in its usage. This evidence clearly shows that when learners are continuously provided with opportunities to improve their visualization skills by their teachers, they become better at visualizing. Learner Mn would only use diagrams or visualization for concepts that make it easy for him to give diagrammatical representations, like fractions.

Teacher: ***What was different in the approach you used? Do you think you did it differently?***

*Learner As: The difference is that I didn't know what I was doing, I wasn't sure.*

*Learner Ak: Yes, it helped me a lot when using visualization.*

*Learner El: I think I might have got all the questions right because I use peach in colour, and Mrs C told us in Arts that when you use colours and peaches it makes it easier to understand and remember, so I think I use colours and peaches to break it down to make it simpler for me to understand.*

*Learner Aw: Yes*

*Learner Mn: Yes, because usually I only used to think that you can only divide fractions into circles, but then I saw you can also divide them into pieces like squares and everything, and that's how I managed to complete the task.*

*Learner Mi: Yes*

*Learner Lu: Yes*

Teacher: *Why?*

*Learner Lu: I tried different methods, but then they didn't work, so I decided to use rectangular visuals.*

*(By rectangular visuals, learner meant the use of diagrams.)*

*Learner Md: Yes, Miss.*

*Learner Nom: I don't understand.*

[Teacher had to rephrase the question for the learner to understand it better.]

Teacher: ***The approach used in solving this task, do you think it was done differently****?*

*Learner Nom: Yes, yes.*

*Learner Abo: Yes, I did.*

*Learner Ne: Yes, because hmmm here I use more of… if there are people, I section them and gave them something I will represent them with, like a circle or a star.*

*Learner Nt: I think I did this one differently.*

There was a significant improvement in the post-task as compared to the pre-task. From learners responses and the task completed, it was evident that eleven out of the twelve learners knew what to do and did it differently from the pre-task (before the intervention process), either using different shapes and pictures to represent the questions. Three of the twelve learners highlighted essential aspects of each question before representing it visually. The above selection and looking through their task sheets showed that learner As and learner Ak were unsure and confident of the approach used. It was interesting to find out from leaner 'As' response that she was not sure of what she was doing, even though she used diagrams in five of the seven questions. She could also come up with a diagram for the questions attempted, but they were inaccurate, resulting in an incorrect answer. It is believed that with constant intervention and avenues to use diagrams or other forms of visuals, learner As can progress to becoming a better visualizer and problem solver. On the other hand, learner Ak represented six of the seven questions diagrammatically and got two of six right. When asked the above question, she responded that she did it differently as she was sure her representations were correct.

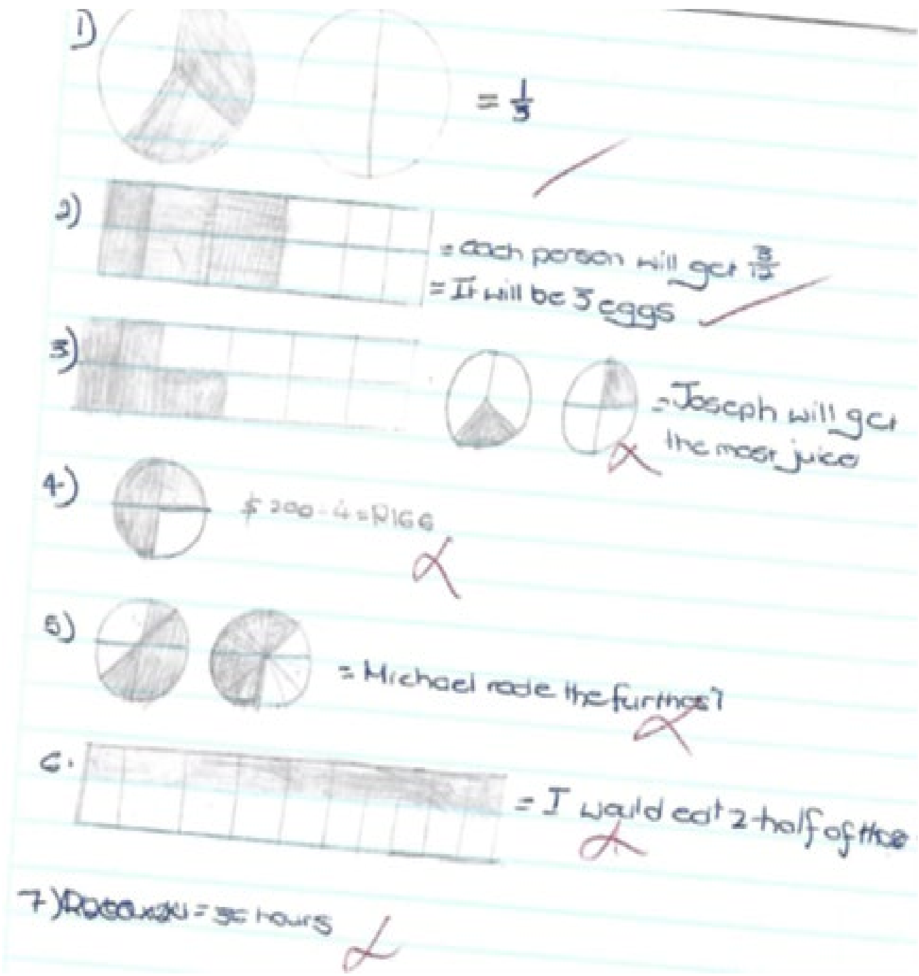



**Figure 5.8:** Learner Ak's post-intervention task

It is worthy of note here that using diagrams, pictures, or any visual strategy will not yield the result it is intended to if learners cannot detect when they are wrong or when their representations are wrong. Educators need to ensure that learners solve problems visually and detect when they are wrong in their approach, which will lead to successful and accurate results from learners.

Teacher: ***Do you think visualization strategies makes it easy to solve word problems in mathematics?***

*Learner Aw: Yes*

Teacher: ***Why did you say so****?*

*Learner Aw: I'm using visualization as I like drawing and pictures, it makes it easier to understand what I'm doing.*

*Learner Ak: It's easier because you can… like see. It helps me a lot because now I can see where I can work more on one question and what you did in the sum.*

*Learner El: Yes.*

Teacher: ***Why did you say so****?*

*Learner El: Because it helps you to really understand how you get into the answer, because when you use like sums to solve, sometimes you don't really understand because they are numbers and sometimes one number can mean a different value, but then when you have your peaches there, you can understand what this means…*

*Learner Mi: Yes, it does*

Teacher: ***Why did you say so****?*

*Learner Mi: Because you will be able to visualize the problem, it will be easy to see it than writing it down.*

*Learner Mn: For some word problems that involve fractions, but for others it usually doesn't really work.*

Teacher: ***Is it only fractions, how about maybe geometry and other concepts****?*

*Learner Mn: No, I don't think so, I don't think it works.*

Most of the learner's responses to the above question after the intervention process and the task was that visualization strategies make it easy to solve word problems in mathematics. Learner (Aw, Ak, Mi and El) all ascertained that they can get a clearer picture of what they are doing as it's easy to visualize the problem at hand and mistakes are easily picked up.

*Learner Lu: Yes*

Teacher: ***Why did you say so****?*

*Learner Lu: I see the difference between working out numbers and visuals because visual show how much of the sum it is and it's easier for me to count properly.*

*Learner Md: Yes ma'am! [Learner answered with excitement in her voice and on her face]*

*Learner Nom: Yes, yes it does*

[Teacher probes further….]

Teacher: ***Why did you say so****?*

*Learner Nom: If you can see the picture, it gives you an idea of what you are doing and what you are working on.*

*Learner Abo: Yes, it makes it easier.*

Teacher: ***Explain****?*

*Learner Abo: Because hmm…you understand the question easily and when you write, it gets complicated and you get lost, and you get the answer wrong.*

*Learner Ne: Yes…*

Teacher: ***Why****?*

*Learner Ne: It gives you a picture and an image of how you supposed to solve your problem.*

*Learner Nt: Yes*

Teacher: ***Why did you say so****?*

*Learner Nt: Because if like you visualise it, it's more easier and if you have to write it down in numbers as it is more harder.*

*Learner As: No*

Teacher: ***Why did you say so****?*

*Learner As: Because ma'am I struggle with diagrams, I don't know, but I find it easier when you use equations.*

Visualization strategies have made it easy for learners to solve word problems in mathematics based on their responses and task sheet. Some of the learners, from their responses, have seen how beneficial the intervention process has been to them when solving word problems in mathematics. Learner Nom believes that if the problem can be pictured, then arriving at an accurate solution is possible.

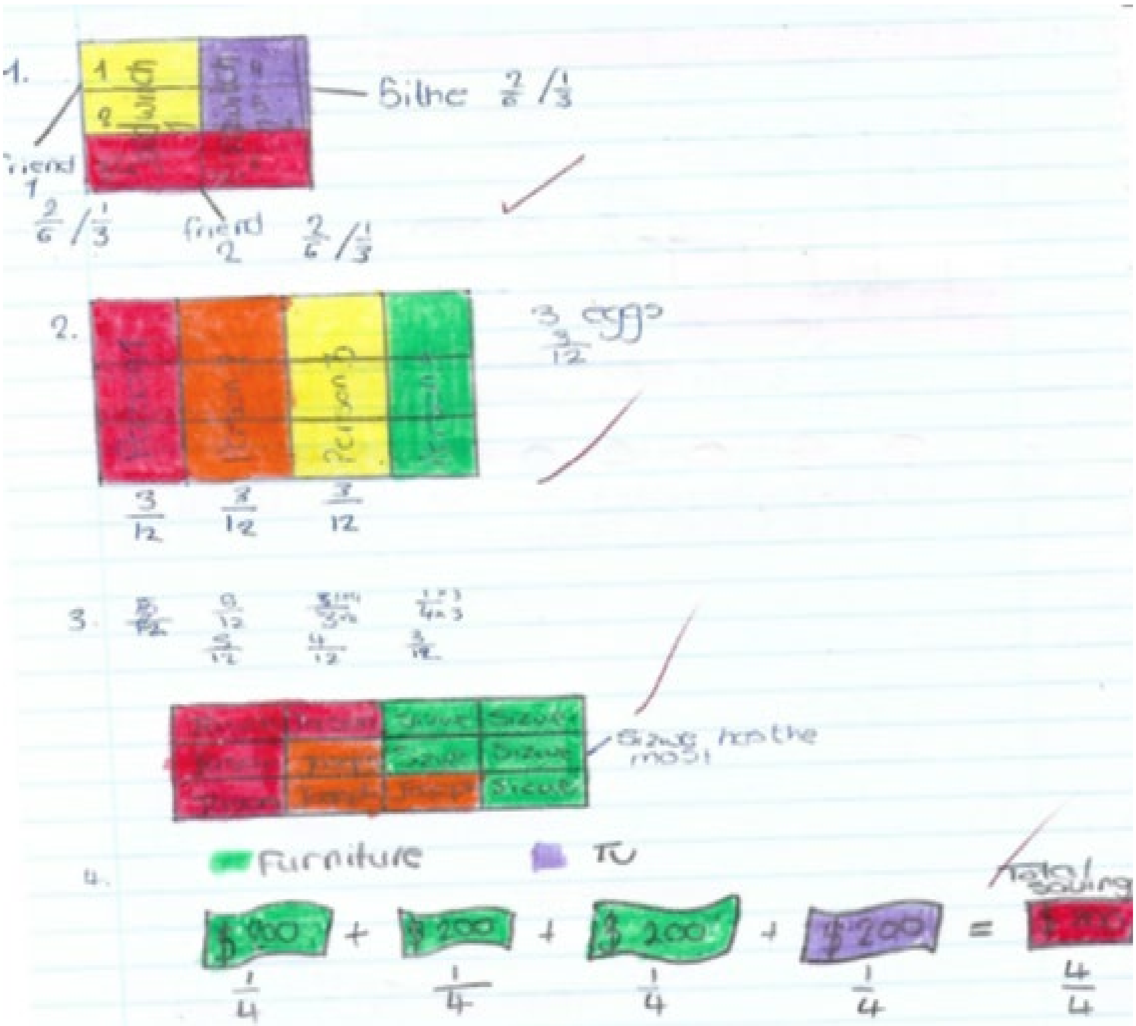



**Figure 5.9:** Learner E's post-intervention task

Learner Mn was of a different opinion as he concluded that visualization could only be used for some word problems that involve fractions and not all problems can be visualized or represented using diagrams or pictures. The teacher had to correct the misconception by pointing out to this learner that it can be used in some concepts other than fraction, as it was used in integers in one of our mathematics lessons. The learner has not fully understood that highlighting, gestures and internal visualization, to mention a few are all part of visualization strategies.

Furthermore, the same learner who used diagrams but was unsure of what she was doing felt visualization strategies does not make it easy to solve word problems in mathematics. She struggled when it came to diagrams. This participant concluded that visuals make solving word problems difficult. Perhaps a continuous use and teaching of visualization strategies without any restriction to the different concepts in a mathematics classroom will improve her interest in its usage.

Teacher: ***How well do you understand visualization strategies now?***

> *Learner Ak: I understand visualization strategies now because it uses pictures and pictures are easy to understand.*
>
> *Learner El: I really understand them because I also use them when like maybe my parents give me questions to answer at home just for to see how well I have listening skills at school. I understand it.*
> *Learner Aw: I understand it very much*
>
> *Learner Mn: I understand it better than how I used to understand before because now I have been taught by my teacher that there's different ways that you can visualize things.*
>
> *Learner Mi: I understand it well now.*
>
> *Learner Lu: Well enough.*
>
> *Learner Nom: hmmm...I do understand them, they are quite easy to use than regular methods.*

Learner Nom before now had little or no knowledge on how to solve problems visually, but upon introducing them to these strategies, she now finds them easier than she thought with a good gesture that follows.

> *Learner Abo: I understand it well, yes.*
>
> *Learner Ne: I understand it better because you have taught me that there are different ways and strategies you can use instead of just working it out.*
>
> *Learner Mid: It's 100% Miss, it helped me a lot.*
>
> *Learner Nt: hmm…I understand it well now, although there is some difficulty that I'm facing, but it's much better.*

Teacher: ***Can you tell me the difficulty****?*

*Learner: You see when the fraction says like one over say…*

*Learner then points to a question…*

*Learner Nt: Like for this one, I really didn't understand it, when they say that Michael only manages to cycle 4 ½*

Teacher: *learner was corrected as she confused {$\frac{4}{5}$}for 4 ½*

*Learner Nt: $\frac{4}{5}$ and then the father manages to complete $\frac{9}{11}$, I didn't understand that.*

*Learner As: A bit ma'am, not too much.*

Teacher: ***Why****?*

*Learner As: I don't understand diagrams clearly.*

The post-intervention strategies taught to the learners have benefitted and helped in the solving of the post-task. Responses from the selected sample of interviewees showed that most of them understood visualization strategies better now than when they completed the initial task. This is also evident in the results produced, as some of the questions attempted were solved correctly. Those struggling showed that they are beginning to grasp the strategies. If the process is followed up, a significant improvement will be recorded among these learners. The same learner who stated that she had difficulty with diagrams, thereby depicting the word problems wrongly, stated that she is beginning to understand it. Anecdotal evidence from learners task and interview showed that learners exposed to visualization briefly in the previous grade have, after this intervention, improved and gained confidence compared to learners who only got introduced to it in grade 7. Learner Mid claimed to have understood visualization strategies used diagrams to solve the questions, but most were incorrect. An observable reason could be her inability to interpret the questions correctly, which also lacks in her comprehension skills. Learner Nt's difficulty from her response could be based on her inability to comprehend the problem because of the different fractions she finds confusing.

Teacher: ***Do you think if you use visualization strategies more often you will get better at it?***

*Learner Ak: Yes, because I struggle with maths, so using visualization helps me to understand a lot now.*

*Learner El: Yes.*

*Learner Aw: Yes (teacher needed to probe this learner further based on her task sheet)*

Teacher: ***Can you explain why you say that****?*

*Learner Aw: As I get more used to visualization it gets more easier to complete more tasks.*

*Learner Mn: Yes ma'am, because practice makes perfect ma'am. If I keep…continue doing it, maybe I will understand it better.*

*Learner Mi: Yes*

*Learner As: Yes ma'am*

*Learner Lu: Yes, if I keep practising it.*

Learner believes that if she practises using visualization strategies more often, she will get better at it. Her response here is not far fetched, as anecdotal evidence has proven this to be true. The learner used diagrams for six out of the seven questions and successfully solved four of all the questions. There has been a noticeable improvement as compared to the first task completed.

*Learner Mid: Yes.*

*Learner Nom: Yes, yes.*

Teacher: ***Why did you say so****?*

*Learner Nom: hmm, because visualization is easy and it's understandable and it's very easy to work out what you are working on.*

Based on the above responses from learners, mathematics educators need to ensure that learners are constantly given an avenue to better their visualization skills to become better visualizers and problem solvers. Very few responses included above are those of learners who previously were not comfortable using visualization strategies when solving a problem in mathematics. However, after the intervention strategies, they have found these strategies easy as they are becoming better at it.

*Learner Abo: Yes, I will get better at it.*

Teacher: ***Why did you say so****?*

*Learner Abo: Because by highlighting it's easier to find a picture in your mind and then you draw it and you get the answer, right.*

*Learner Ne: Yes, because half of the time when you use visuals, you get it correct.*

*Learner Nt: Yes ma'am.*

They all agreed that with constant practice, they would get better at using visualization strategies, which could be in the form of highlighting, diagrams or having a picture in mind, to mention a few.

Suppose visualization strategies are promoted in a mathematics classroom by educators, encouraging them to engage in its usage continuously. In that case, learners will be confident/used to it and get better at it. Mathematics educators should therefore endeavour to practise using some of these strategies in their lessons for the benefits of:

- making learners become better visualizers and
- making them become better problem solvers

This is in line with Muchoko, Jupri and Prabawanto (2019, pg. 2), who claimed that visualization has been identified as a required skill. It is a powerful tool that helps learners better understand the concept taught.

Teacher: ***Do you like solving word problems in mathematics?***

*Learner Ak: Not that much, I don't like it.*

Teacher: ***why you don't like it****?*

*Learner Ak: Sometimes it confuses me because when they say like the word problem, because now I have to understand the person and how much, and how much is left, and that's what I don't like.*

*Learner Aw: Not exactly*

Teacher: ***Why****?*

*Learner Aw: Somehow, I don't like maths that much, sometimes there are questions that are hard, and some are easy.*

*Learner Mn: I only like the one that don't involve you to think that much ma'am.*

*Learner As: I like it because it's a brain teaser.*

*Learner El: Yes*

*Learner Mi: Yes*

Teacher: ***Why did you say so****?*

Learner Mi: *Because ma'am I like thinking and thinking of ways to solve problems in different kinds of ways than only having one way to solve it.*

*Learner Lu: Yes*

Teacher: ***Why did you say so****?*

*Learner Lu: Because I liked maths since I was young and it's my favourite subject.*

*Learner Nom: Yes*

Teacher: ***can you explain further****?*

*Learner Nom: It gets your mind thinking critically.*

*Learner Abo: Yes, I do.*

Teacher: ***why did you say so****?*

*Learner Abo: It makes me think out of the box.*

*Learner Ne: Yes, I enjoy them because they challenge me.*

Out of the twelve learners responses above, seven of them responded to liking word problems in mathematics because it makes them think critically, 'it is a brain teaser,' said one of them. One of the many objectives of introducing word problems in mathematics to learners is to make them critical thinkers, which is evident in the above learners.

*Learner Mid: No, Miss I just can't… [with a facial expression…]*

Teacher: ***You can't, why****?*

*Learner Mid: Especially with the fractions, but after using miss, it was like I like it now.*

*Learner Nt: hmmm…no, I don't like it.*

Teacher: ***Why****?*

*Learner Nt: Because ma'am it's complicated sometimes.*

*[Teacher probes further….]*

Teacher: ***What makes it complicated****?*

*Learner Nt: It's the language and how they ask the questions.*

Learner Mid and Nt view word problems as complicated because of how questions are being asked and perhaps difficulty understanding the problems, which can be attributed to language barriers. Over the years and from experience gathered from teaching, learners are seen to have developed a notion that mathematics is a complicated subject, especially when it came to word problem. Responses from the above learners have highlighted some of the reasons why they do not like solving word problems in mathematics:

- Lack of understanding when the problem is read could result from a language barrier, thereby making it difficult to interpret it.
- Maths has been envisaged as a difficult subject.

Therefore, it is part of the educator's duty to make learners view it as an exciting subject by making it easy for learners to understand rather than a difficult or boring subject. This approach has worked in my classroom, as learners who were less interested in mathematics because of their notion, which led to them failing the subject, began to show keen interest and succeeded at the end of the year. Educators hold an essential role when it comes to learner's success in mathematics.

- Also, the need to think critically, which one of the interviewees pointed out that he does not like to do, can be addressed for this learner to improve on his thinking skills.

Part of The National Curriculum Statement's (2012, p. 5) aim is to ensure that learners who can identify, solve problems and make decisions by thinking creatively and critically are produced in our mathematics classroom. It is essential that teaching these skills should be part of every educator's aim in a mathematics classroom. Learners should be exposed to more real-life problems, promoting and developing their critical thinking skills.

Four of the learners interviewed were interested in and liked word problems as they have been able to deduce that it helps them think critically. Another learner said that it challenges her aside from being a brain teaser. We need more problem solvers in real-life settings, and we as educators, should be a driving force in making that happen.

Teacher: ***Do you think visualization has helped you understand word problems in mathematics better?***

> *Learner Ak: Yes, it has helped me a lot because now I can use visualization in the word problem.*
>
> *Learner El: Yes*

Teacher: ***Why did you say so****?*

> *Learner El: It's because now I understand how you supposed to get your answer, not just writing the answer alone, because sometimes the teacher wants you to explain when you write down the solving without the peaches, they take away marks because you didn't really explain, you just gave us the answer.*
>
> *Learner Aw: Yes*

Teacher: ***Why did you say so****?*

> *Learner Aw: If I get question, I don't take time to think I just solve it.*
>
> *Learner Mn: Yes, I get to…because visualization helps me with important aspects of the word problems and then I see how I can move further and solve the question.*
>
> *Learner As: Yes.*
>
> *Learner Mi: Yes, it has.*

Teacher: ***Why did you say so****?*

*Learner Mi: Because now when I solve problems, I can just use visualization and I can visualize it, then I draw it then I will be able to solve it easily.*

The post-intervention strategies (object) have helped most of the learners understand word problems in mathematics better. This was evident in the completion of their task. For learners who are still struggling, the educator should make a continuous effort to ensure that these strategies are reinforced in the classroom. If learners are encouraged to use some of these strategies, they will become good, if not better problem solvers, and visually promote effective communication. Diagrams are an easy way to represent word problems according to the response given by one of the learners, as a step by step explanation is not required, which sometimes become confusing.

*Learner Lu: Yes*

Teacher: ***Why did you say so****?*

*Learner Lu: I work out sums easily.*

*Learner Mid: Yes, Miss*

From learner Mid's previous responses and past experiences, she had stated that she does not like word problems in mathematics. She has developed an interest after the intervention process and has ascertained that visualization has helped her understand word problems better. Having looked through her task sheet, she tried to develop diagrams in all seven questions; however, only two out of the seven were accurate. She has made progress as compared to the initial task completed.

*Learner Nom: Yes, yes*

*Learner Abo: Yes*

Teacher: ***Why did you say so****?*

*Learner Abo: hmmm…If you read a question, see a picture in your mind and put it down on paper it makes it easier to get the answer correctly.*

*Learner Ne: Yes*

Teacher: ***Why did you say so****?*

*Learner Ne: hmmm because I have a better understanding when I solve it now, instead of just running away from the question.*

*Learner Nt: Yeah it has, because instead of working it out, now I can visualize it, and like draw it and like get better marks.*


**Figure 5.10:** Abo’s representation of the post-intervention task

It is worthy of note from all the participant's responses that visualization has improved their understanding of word problems in mathematics. Most of them can picture in their minds and come up with accurate diagrams that helped solve the problem. Learner Abo’s response to the above question is worthy of note. Visualization commences in the head of this particular learner, after which she then translates what she thought of into a diagram. After the intervention process, some learners have moved from no understanding of visualization to having little or better understanding of visualization strategies, hence attempting the questions rather than avoiding them.

Teacher: ***I see that you have highlighted and you have used diagrams to answer the questions, can you explain why? (****the question was asked based on the strategies used by each learner****)***

*Learner Ak: I used diagrams because it could be easier for me if I write it down in diagram form. So, it's going to be easier for me to understand that because it takes time for me to calculate.*

Teacher: ***I also saw that you highlighted; why?***

*Learner Ak: I highlighted because it reminds me what I must focus on, because if I didn't highlight it would distract me because sometimes I don't understand the word or the word problem and then it might confuse me. So, highlighting makes it a bit easier to know what you are dealing with.*

Teacher: ***You have used diagrams and underlined, can you explain why?***

*Learner As: Underlining helps me to understand the question more. Diagrams, I thought maybe if I could try, I could get better at it.*

This is the first time learner 'As' will be introduced to use any form of visualization in solving word problems in mathematics. She needs to keep at it to become a better visualizer. The intervention process has helped move her from the unknown in visualization to the known.

Teacher: ***I see from your task sheet that you used diagrams, pictures and you have highlighted, can you explain why?***

*Learner El: It's because I use rectangles because they are accurate, and they are neater rather than circles and I use colours because I like colours and I use them.*

Teacher: ***Did diagrams and colours make you understand the problem better, or why did you use them?***

*Learner El: It's because I felt if I use this method it will help me understand better rather than just writing down the answer without really explaining what I was doing.*

Teacher: ***You have used diagrams to solve the questions, can you explain why?***

*Learner Mn: Because when I found out that we could separate it into other things than circles, then I just wanted to see how many of them I could use to solve the questions.*

Teacher: ***There was a question you did not solve; why is that so?***

*Learner Mn: Because, I couldn't find a way to visualize it and to make it into diagram, and so I just left it.*

Teacher: ***You have used diagrams and pictures here; can you explain why?***

*Learner Mi: When I read the question, I saw that it was easy for me to visualize and to write it out.*

It's interesting to see that after learners interacted with the object (intervention lessons), they could apply the strategies learned in the classroom to complete their task. They were able to deduce that highlighting and or underlining makes it easier to know what to focus on when given word problems to solve. Also, it helped not to get distracted from the keywords and made it easier to understand the question at hand. This then helped them interpret the questions into a diagram/or picture.

Teacher: ***Looking through your task sheet, you highlighted and also used some diagrams. Can you explain why?***

*Learner Aw: When I use visualization that's how I understand the question and it makes it easier to solve it.*

Teacher: ***Why did you highlight?***

*Learner Aw: When I highlight, I highlight the key words and I focus more on the key words than the question.*

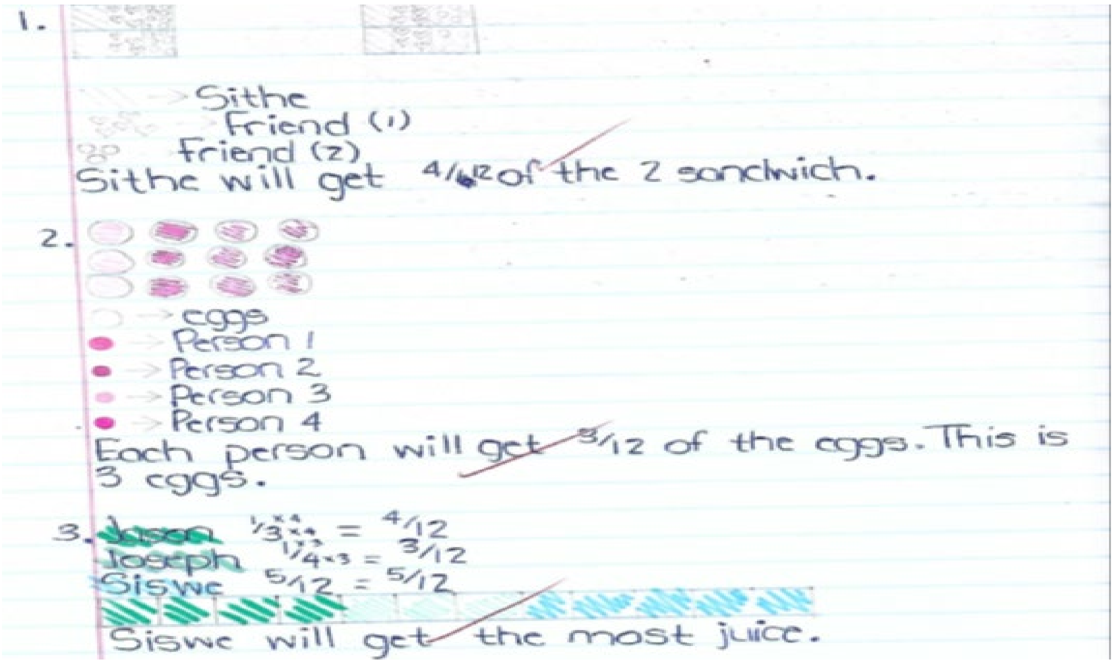



**Figure 5.11:** Aw's post-intervention task representation

Teacher: ***You have used diagrams in solving the problems (looking at learner's task sheet), can you explain why?***

*Learner Lu: The working out was easy and I guess I found the answer easy.*

Teacher: ***You have used diagrams for all the questions, [pointing at the task sheet] can you explain why?***

*Learner Mid: So that I can see what I'm doing because at times when I calculate it with my mind, I get it wrong…*

Teacher: ***But when you use diagrams****?*

*Learner Mid: It get better ma'am because I can see it*

The above response could mean that learner is able to create an image in her mind, looking through her task sheet, though some were incorrect. This could be a result of a lack of conceptual understanding. With continuous practise and help from a more knowledgeable other in this instance, the teacher or the learner, such learner can improve and become better.

Teacher: ***I see you have used diagrams, circled and underlined, can you explain why?***

*Learner Nom: hmm the underlining and the circling is to get what the question really wants from me, what it wants, what is the main course in the question.*

Teacher: ***And the diagrams****?*

*Learner Nom: If I can see it, it's much easier to work out the answer if I can put it into another form. Hmm… cos if I just think it through my mind and use a regular method, it might get confusing, but if I use visualization and see if I could work out the answer using hmm diagrams then it's much easier.*

Teacher: ***You have used diagrams, looking through your task sheet, can you explain why?***

*Learner Abo: hmm… It's much easier because when you see it you can understand it better, by having different hmmm keys so you can hmmm differentiate the different people.*

Teacher: ***I see that you have used diagrams, and you also highlighted here, can you explain why?***

*Learner Ne: hmm… for the highlighting I want to see what is important in the word problem and for the diagrams is to picture how many the person will get.*

Teacher: ***Also, there was a question where you didn't use diagram, why is that so?***

*Learner Ne: hmm….I couldn't find a way how I could use a diagram, so I just solved it normally.*

Teacher: ***I see that you have used diagrams, and also highlighted the questions. Can you explain why?***

*Learner Nt: I highlighted the questions because to see hmmm….to understand the word problems better and know what they are asking for and know the important highlights only not the rest of the unimportant ones.*

*(Teacher probes further)*

Teacher: ***I noticed from the task completed that you did not use diagrams for some questions, can you explain why?***

*Learner Nt: Because I really didn't understand how was I going to use visualization, and for question 5, I just saw the fractions and I just used my general knowledge.*

Learners who highlighted circled and or underlined gave almost the exact reason for doing so. Learner Aw, in her response, said, '*When I highlight, I highlight the key words and I focus more on the key words than the question.*' As stated by the learners, highlighting and underlining makes their attention drawn to the essential aspects of the questions rather than the whole story. One of the learner's responses to the above question was that if she is able to see it (picture it in her mind and come up with a diagram), then working out an answer becomes easy. Highlighting the questions made learners focus on what was necessary for getting the problem solved. Another learner deduced that if she can see it, then understanding is made possible. A conclusion can be drawn from the above responses that visualization started from the mind with these learners, making for an appropriate representation and solution. The strategies also helped them develop an appropriate diagram that helped with the solving of the task. The responses from probing into why diagrams were not used for a few questions could be ascribed to learners not being able to picture the particular question, which can also be due to a lack of proper understanding, resulting in using the calculation method. Mudaly (2010a) acknowledged that diagrams are exceptional tools for sense-making and should be carefully used when a task is being presented to learners.

Teacher: ***Previously, you were solving questions like this; how did you find them?***

*Learner Ak: I used to go back on how we used to solve them like in Grade 4 and 5, and then I used that method to solve the questions.*

Teacher: ***Is the way you solve it now better than then****?*

*Learner Ak: Yes, it's better, it's much better and it's helping with other things that I do when practicing for maths and so forth.*

*Learner El: Some questions I didn't understand until I asked the teacher and then she explained them to me, but now I understand them better because I have read the question. I highlighted the important parts of the question and then I used peaches and diagram to explain what the question was really about.*

*Learner Aw: They were a bit harder than now as I'm using visualization.*

*Learner Mn: Before I just rush through them I used calculations only, not visualization and so I got most of the answers wrong, but then when I did the second one it was much better because I understood the questions.*

*Learner As: I found it much easier because I wasn't using visualization, I was using equations, it was much easier but then I made mistakes.*

*Learner Mi: I found most of the questions hard to solve.*

Teacher: *And now, do you still find it hard to use visuals?*

*Learner Mi: No*

*Learner Lu: I used to do it the usual way.*

The learner was used to the non-visual method when solving mathematical word problems.

*Learner Mid: It was hard Miss, I didn't like it, every time I got a headache…*
*Learner Abo: They were hard because I had to use words and I didn't have to draw pictures, it was harder, but now when I use visualization, it was better.*

*Learner Nt: I find it hmmm….not hard and not easy like in the middle.*

Teacher: ***Why did you say so?***

*Learner Nt: Because some I still don't understand it clearly, but then now I… [Learner couldn't find the right words to explain]*

Teacher: ***But now?***

*Learner Nt: But now, although I do understand some of it but then I don't understand the rest.*

Eleven out of the twelve participants found the methods they used before the intervention confusing and complex as they could not detect their mistakes and got stuck in the process. Also, one learner before the intervention process did not have the necessary skills to visually solve problems. She mainly used the calculation method, which she referred to as the 'usual way'. Others saw some of the methods they used as hard, and one of the learners was indecisive because the method used was dependent on how well the questions were understood.

Teacher: ***I taught you some strategies; how did that intervention help?***

*Learner Ak: The intervention helped me a lot and that I could do more with the visualization strategies, and now it's going to be easier for me to understand the question, I don't need to like think so hard. So, visualization actually helped me a lot.*

*Learner El: They helped me know how to do, instead of just trying my own method and get it wrong. Mrs Bakare broke it down and helped us understand what we are supposed to do in the task.*

*Learner Aw: It helped me a lot.*

Teacher: ***In what way****?*

*Learner Aw: Like I usually waste time when I wasn't using visualization, but now I don't waste time I just solve them easily and the way I understand them.*

*Learner Mn: For starters, I realized that you could use diagrams other than circles like squares and triangles to do visualization and so that helped me divide the fractions into like 8s and 12s and all that. It helped me very much.*

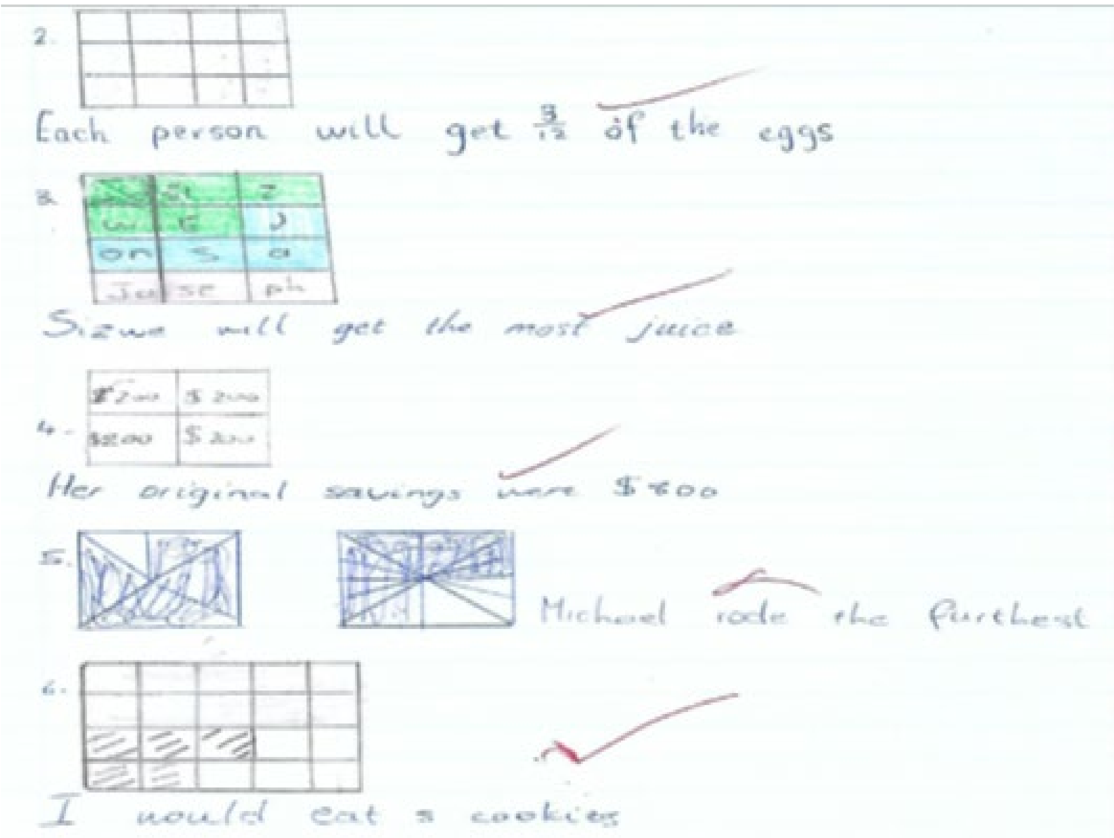


**Figure 5.12:** Learner Mn's post-intervention task

*Learner As: The strategies that you taught me really helped me a lot, but then it just that I learned them once.*

*Learner Mi: It helped me a lot, now I can solve the questions easier.*

*Learner Lu: It helped me understand maths easier. I learned new strategies.*

*Learner Mid: It made me understand it better Miss.*

*Learner Nom: It really helped me because now I know that visualization is the easiest method to work out word problems.*

*Learner Abo: It really helped because I understand the questions really better.*

*Learner Ne: hmmm…It helped by firstly, making me understand what was going on and getting the answer partly correct, and now with visualization I now understand how to solve problems better.*

*Learner Nt: It helped me a lot because some of the strategies that I know didn't work, and some of the strategies you taught me did work.*


**Figure 5.13:** Ne's post task representation

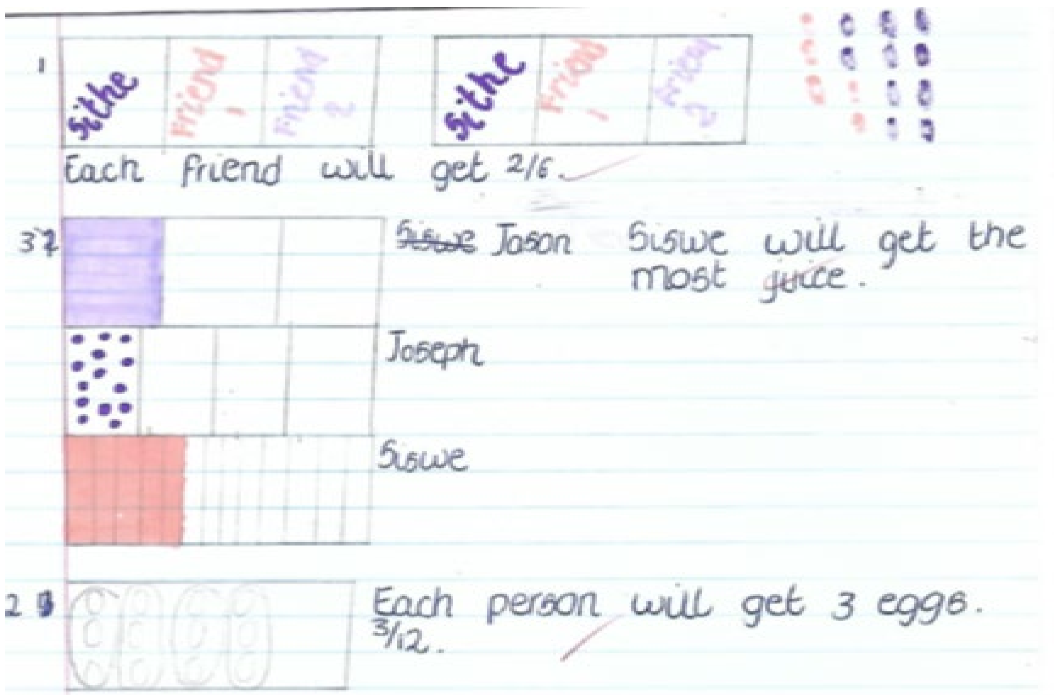



**Figure 5.14:** Sp's post-task representation

All subject (twelve learners interviewed) concluded after the intervention process (object) and having completed the task and putting into practice what they learned (action) that; visualization strategies have helped them become better problem solvers. It also helped them concentrate on essential aspects in a question by either highlighting, underlining, or having a picture of the problem in the head, referred to as the internal visualization, leading to an appropriate solution. A conclusion can be drawn from these responses that visualization takes place in the head of learners. What is thought of in their head leads to proffering a solution to the problem. One of the participants emphasized that the short period of intervention made a difference in solving word problems would benefit even more if she is exposed to more visualization lessons.  Skills required to become a better problem solver will be built over time.

### 5.2.2 Summary of the findings of post-intervention interview

It was evident from the responses gotten from the object (pre-intervention interview) that learners were not used to visualization strategies and had not been exposed to them until after the intervention process was administered. This has resulted in its lack of usage in solving mathematical word problems in the classroom before now.

The intervention process has resulted in learners having a better understanding of visualisation and its usage in solving word problems in mathematics. It is, however, necessary that continued practice is ensured so that learners can be more confident in solving mathematical word problems.

## 5.3 Summary of the chapter

In this research, the Activity carried out was the teaching and learning of visualization strategies in solving word problems in mathematics, which has been effective and helpful to learners. The object and subject brought about the outcome; these are interwoven according to the triangle. The intervention introduced brought about a noticeable outcome.
Findings and interpretation of the data collected through a task-based worksheet and interview (the instrument) used were outlined in this chapter.

The data collected during the post-intervention, which was used to triangulate the evidence derived, outlined the effectiveness of a visualization intervention in a grade 7 mathematics classroom. The study established the type of visualization strategies used by grade 7 learners when solving word problems in mathematics.

The instrument (pre-intervention interview) allowed the researcher to better understand the task completed by the learners, the methods used, and their perception on whether or not diagrams or drawing helped solve problems easier. The instrument used in the form of a post-intervention interview allowed the researcher to understand learner's thought and perception of visualization and how well they (subject) understand visualization strategies (object) after the intervention. The chapter also focused on finding out if the strategies taught helped them (learners) become a better problem solver. Patterns also emerged from each question asked, based on participants responses. These were discussed and summarized per class. Participants' use of diagrams before intervention was minimal, and it was dependent on the question asked. Some learners believed that diagrams would not make solving problems easy; some participant thinks it is time-consuming. However, after the intervention process, participants' (subject) use of tools in the form of diagrams, colours, highlighters increased whilst solving the post-intervention task. They also saw the outcome of visuals in solving word problems in mathematics; this was evident in the tabulated results and the recorded conversation that ensued during the interview.

# CHAPTER SIX

## 6 Conclusion and Recommendation

In the previous chapter, the findings and analysis of the data collected were explored in detail. An overview of the study, the conclusion, limitations and recommendations are presented in this chapter.

The study's overall aim was to introduce a visualization intervention strategy in a grade 7 mathematics classroom, which will enable learners to become good problem solvers. This study's objectives were to investigate learners' visualization strategies in a grade 7 mathematics classroom to determine the effectiveness of their strategies in solving mathematical word problems and finding ways to improve problem-solving skills through a visualization intervention. In carrying out this research, grade 7 learners from a Senior Primary School in the Pinetown district were selected as participants. Six learners per class were further selected to participate in the audio-recorded interview. The study was interpretative, and a qualitative data collection approach was used. Twelve learners from the two grade 7 classes were selected after the initial task sheet was completed for the pre-intervention interview. A further 12 learners were selected after the same task sheet were administered for the post-intervention interview process. Learner's selection for the interview process was based on a selection process outlined in chapter 4. These interviews were conducted before and after the intervention strategies were introduced.

## 6.1 Discussion of findings

The study sought to explore a visualization intervention in a grade 7 mathematics classroom. The data collected in this study was used to investigate and provide answers to three research questions.

- What visualization strategies do grade 7 learners use in a mathematics classroom?
- How effective are their strategies in solving problems?
- How can their problem-solving strategies be improved through a visualization intervention?

In answering the first research question, and based on the pre-intervention interview analysis, evidence from the study suggested that most learners from the two grade 7 classes use other methods (mostly calculation methods) when solving mathematics problems. Learners were allowed to solve the problem in their preferred way. Very few of the learners used diagrams while solving the task, while only one of the learners highlighted to focus on the essential information required to solve the problem. Also, from some of the learner's responses, they found it easy to interpret word problems that involved fractions using diagrams or drawings than with other concepts. The above finding showed that learner's use of visualization is concept dependent.

It was observed that the subject being understudied did not have a natural inclination to use diagrams or any visualisation form before the intervention strategies were introduced whilst completing their task. This resulted from some notable reasons from the responses given. Most of the learners did not possess the required skills needed to visualize. This finding is in line with Presmeg, (2014, p.7) article that stated that learners' unwillingness to use visualization when solving mathematical problems is due to little attention given to the aspect of visualization in the mathematics classroom.

Secondly, learners did not know what they should look out for when solving a mathematical word problem and how these word problems can be represented. This was a result of a lack of a better understanding of the problems. Thirdly, part of learners' reasons for not using diagrams was because they believe it will be time-consuming, as many thoughts had to be put into thinking of how and what to draw.

Other observable reasons are the lack of motivation from teachers to use these strategies as it was not the teacher's first choice when solving problems during lessons. One of the learner's responses for not using a visual strategy was that she uses the teacher's approach. It can also be seen that not all these learners have had the privilege of being introduced to visualization strategies. The very few that used diagrams or highlighted said they were introduced to it (visualization) in the previous grade. For the questions attempted, only a few were represented visually.

Evidence from this study helped answer the second research question and suggested that the strategies chosen by learners in completing the initial task administered were not all effective. From the table of analysis given in Table 5.1, results and responses showed that not all the learners that used calculation or a non-visual method were successful. The effectiveness of their method was dependent on how well the problem is understood. The analysis also showed that learners are not natural visualizers; the very few that solved some of the problems using a form of visual in the two groups were not entirely accurate. These observations could result from not being able to interpret word problems to number form or visual format as well as lack of correct interpretation of information and application.

In answering the third research question, which was to find out how learners' problem-solving strategies can improve if a visualization intervention was introduced. Learners were taken through some lessons on visualization strategies and how problems can be solved in mathematics using some of these strategies. After the intervention strategies, they were given the same task sheet to solve using the strategies they learned.

There was a significant improvement in learner’s performance, visuals, and the accuracy of their methods from the tabulated results (see Table 5.2). Twelve learners were selected for the post-intervention interview, and their responses resulted in providing answers to the question.

Evidence suggested that learners’ problem-solving strategies have improved from their task sheets and the post-intervention interview analysis due to their action to the intervention process. Visual tools that were the mediating device used to help in the teaching and learning of visualization, as introduced by the teacher and used by learners, improved their problem-solving skills. This finding is supported by Muchoko, Jupri and Prabawanto (2019, pg. 2), who claimed that visualization had been identified as a required skill, as it is a powerful tool that helps learners have a better understanding of the concept taught. The visualization intervention strategies were only introduced over a short period of time, with a notable level of progress observed in their problem-solving strategies, resulting in most learners having an accurate solution. Evidence also revealed that learners were not used to applying these strategies as most of them were not exposed to such until the intervention process was administered. The visualization intervention process also resulted in a better understanding of the strategies and their application when solving mathematical word problems. This has also boosted their confidence level, created a positive mindset, and helped their critical thinking ability. Making The National Curriculum Statement (2012, p. 5) achievable, which stated that the aim is to ensure that learners produced in our mathematics classrooms can identity, solve problems and make decisions by thinking critically and creatively. Cappello and Walker (2017 p. 317) believed in visuals and visual thinking to provide opportunity and support in terms of the curriculum that will assist students in reaching their academic goals. The above is in line with the National Curriculum Statement and has been seen from the findings carried out in this study that it (visualization) is very effective.

Also, according to Kashefi, Alias, Kahar, Buhari and Othman (2015, p. 803), visualization for learners should be enhanced so as to boost the knowledge insight in mathematics. This was so of the three learners that were interviewed as they were interested in, and have developed interest as time went by, in word problems. Visualization intervention has boosted their knowledge in mathematics, as they (learners) have deduced that it helps them think critically. Another learner referred to it (word problem) as a brain teaser.

For us (educators) to produce more problem solvers in real-life settings, we (educators) need to be a driving force in making such happen. This finding is supported by a report given by Kadunz and Yerushalmy's claim (2015, p. 463), which asserted that mathematics educators since the beginning of the 1980s are interested in the practical challenges of teaching visualization. Anecdotal evidence has also shown that if educators make word problems easy for learners to understand rather than present them as difficult to solve, their view changes, making it more exciting and approachable for them. One of the learners interviewed expressed his view about mathematics. His lack of interest was due to how his teacher presented each aspect and that his approach is always too fast for him (learner), which has made it a boring subject for him. Govender (2016. p. 26) stated that when a teaching system is learner-driven, it brings about greater learner involvement and control, promoting meaningful classroom interaction. Also, findings by Kashefi, Alias, Kahar, Buhari and Othman (2015, p. 803) showed that learners have not been provided with enough avenue that will expose them to visual strategies in mathematics. This is why the research findings showed that there were difficulty and lack of interest in learners' usage of visualization.

Learners like those mentioned above require the teacher's intervention that is learner-centred to succeed in concepts that are foreseen as difficult. The above learner previously was not comfortable using visualization strategies when solving problem in mathematics. However, after the intervention strategies, she has found them easy to use. This is supported by Ho (2010, p. 2), who defined visualization as the centre of problem-solving in mathematics, as it also helps learners see and have a better understanding of a problem situation.

Findings from this study have revealed that visualization is a powerful tool for solving word problems in mathematics. Drawing and diagrams have been seen as effective strategies that can help learners become good problem solvers, as Bansilal and Naidoo (2012) also remarked that visualization promotes investigation and discovery through diagrams and concrete manipulatives and models.

It was evident that if an intervention (object) is given over a short period of time, it stands the chance of being effective. This is based on the outcome (the result of the activity) produced and learners responses. Also, it was noted that the time taken to solve a problem in mathematics using visualization strategies was not much if learners know what to look out for and if much attention is not paid to the neatness of the diagram.

## 6.2 Recommendation

Findings showed that very few learners had prior knowledge of visualization before the intervention process; this was a skill acquired from their previous grade. Evidence showed that they got better at it after the intervention process. To ensure that learners keep getting better at visualization, Boonen, Reed, Schoonenboom, and Jolles (2014, p. 60) stated that teachers should help encourage learners to use visual representations differently but flexibly and in a functional way. Therefore, for learners to achieve their full potential in problem-solving, continuous intervention should be provided for them to grow both in internal and external representations. Teachers need to teach learners the use of visual representations in the form of diagrams, pictures which then helps them with problem-solving in mathematics.

Also, if these learners had further knowledge of visualization before the intervention process and were encouraged to continuously use these strategies, they would have gone from fair to good if not better problem solvers. Learners would have also made visualization their first choice whenever they had to solve word problems in mathematics. Therefore, it is recommended based on these findings that teachers should make efforts to introduce and incorporate some visualization skills and strategies into their lessons in the classroom. Learners should be shown the benefits of visualization, diagram, and drawing to appreciate the strategies and become independent visualizers. Cappello and Walker (2017 p. 317) stated that visuals and visual thinking can provide opportunity and support in terms of the curriculum that will assist students in reaching their academic goals. It is also recommended that visualization strategies involving other mathematics concepts aside from fractions be taught to learners in the classroom. Hence, educators need to have a sound knowledge of visualization skills and strategies to be able to apply them to various concepts and improve learners' comprehension of questions.

Suppose educators are not exposed to these strategies? In that case, opportunities should be provided for them to acquire these skills as it will be beneficial to learners and improve their performance rates. The intervention process has resulted in learners having a better understanding of visualisation and its usage in solving word problems in mathematics. However, it is necessary that continued practice is ensured so that learners can be more confident in solving mathematical word problems. Also, for learners that language may prevent them from understanding the problem, plans should be put in place to improve their reading and comprehension abilities, understand and interpret problems, and identify important information and success in visualizing.

The study carried out is important in showing that when teachers introduce visualization strategies in the teaching and learning of mathematics, learners' problem-solving strategies will improve. Therefore, continuous promotion of visualization strategies is encouraged in class and at an early grade, with educators ensuring that learners are constantly given avenues to better their visualization skills. This will make them become better visualizers and problem solvers. Educators need to shift from choosing visualization strategies based on how convenient it is. Boonen, Reed, Schoonenboom & Jolles (2016, p. 76) affirmed from the research carried out that educators choice of the use of visual representations was based on their personal preferences rather than basing it on the best fit with the word problem characteristics.

It is worth noting here that using diagrams, pictures, or any visual strategy will not yield the result it is intended to if learners cannot detect when they are wrong or when their representations are wrong. Educators need to ensure that learners not only solve problems visually but are able to detect when they are wrong in their approach. Visualization intervention can make a difference in learners' approach to problem-solving if promoted in the classroom environment by teachers. Zimmerman and Cunningham (1991) support this in an important research forum where visualization was described as a medium for meaningful problem-solving in algebra aside from other topics.

For learners to pick up more interest in problem-solving through visualization skills and become critical thinkers, improving their problem-solving abilities, educators have an important role to play. This is supported by The National Curriculum Statement (2012, p. 5) that its aim is to ensure that learners produced in our mathematics classrooms are able to identify, solve problems and make decisions by thinking critically and creatively. In other words, educators need to ensure that more problem solvers are produced in our mathematics classrooms.

## 6.3 Limitations

Findings cannot be generalized as the study only focused on a particular context. However, attention should be paid to these findings to further promote visualization and minimize the challenges encountered by learners and teachers. This study may be conducted in another context with different learners to compare results, leading to further study and research. The intervention lessons had to be planned within the curriculum teaching time, as learners do not have mathematics planned on their timetable daily. Also, few minutes had to be taken out of learners' 30 minutes break time, ($2^{nd}$ break, each interview was not up to 10minutes) to conduct the interview. Few minutes had to be taken after lessons had been covered for the day, to have selected learners interviewed. Interviews could not be conducted after the curriculum had been covered, which was towards the end of the term, as over the years, learners' attendance rate dropped at this period and after year-end assessments have been completed. Most of the interview were conducted towards the end of my lesson and learners' were not deprived of their break time.

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# APPENDIX

## Appendix A

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

04 November 2019

Mrs Mercy Onozare Bakare (209530659)
School Of Education
Edgewood Campus

Dear Mrs Bakare,

**Protocol reference number**: HSSREC/00000417/2019
**Project title**: An exploration of a visualization intervention in a grade 7 mathematics classroom in the Pinetown district.

**Full Approval – Expedited Application**

This letter serves to notify you that your application received on 02 September 2019 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.**

This approval is valid for one year from 04 November 2019.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

Yours sincerely,

[redacted]

**Professor Urmilla Bob**
**University Dean of Research**

**/dd**

**Humanities & Social Sciences Research Ethics Committee**
**Dr Rosemary Sibanda (Chair)**
**UKZN Research Ethics Office Westville Campus, Govan Mbeki Building**
**Postal Address:** Private Bag X54001, Durban 4000
**Website:** http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

# Appendix B

**Informed Consent Letter to School Principal**

Dear Principal

**Re: Permission to conduct a research study in your school**

I am writing to request your permission to conduct a research study in your school. This research study is entitled: **An exploration of a Visualization intervention in a grade 7 mathematics classroom.**

**Title**

My name is Onozare Mercy Bakare and I am currently studying towards a Master's Degree at the University Of KwaZulu-Natal (UKZN). As part of the requirements of this degree, I am required to complete a research thesis. This study focuses on exploring how learners use visualization in solving of mathematical word problems, and how effective a visualization intervention will be.

I require the participation of two classes of grade 7 learners, 68 in total both boys and girls between the ages of 12 -14 to participate in this research. I would be very grateful if you would consent to these learners participating in this study. They will be selected from your school.

If you agree to this, they will be invited to complete task sheets in the classroom, as well as an in-depth individual interview, this interview will be carried out with 12 learners who will be selected by me.

All discussions, interviews and dialogues with participants will be audio-recorded using a dictaphone, and thereafter transcribed verbatim to produce transcriptions. This research information (data) is required for the analysis of data and completion of the actual write up of the thesis. Collecting research information for this study will take approximately a month. All focus group discussions, in depth individual interviews and group and individual activities will take place on the school premises that is, the classroom with your permission. Times and dates will be discussed and arranged with you and the participants at a later stage. I will try to ensure that this takes place during their lunch breaks and free periods, in an attempt to avoid any disruptions during lessons. Participants will also be encouraged to eat their lunch during discussions, interviews and activities, as well as make use of the school toilet should the need arise. I will not deprive them of these opportunities, especially since I intend to use some of their free time in order to collect sufficient data for my study.

Data generation activities will also take place in the classroom with your consent. If I am unable to collect my data during school hours, I will make arrangements with your consent and that of my participants' parents/guardians, to perhaps do this after school hours, on days when school closes early or during weekends. I will also provide transport for some of my participants to return home, should the need arise.

**Please note:**

* Times and dates of this data generation process will be at your sole discretion. I have merely presented you with an outline of what I intend to do, however you are free to make any changes and suggestions, if necessary.
* Participation is completely voluntary and participants have the right to withdraw from this study at any time. They will not be penalized if they choose to do so.
* Confidentiality and anonymity will be maintained at all times. The identity of your school and all participants will not be revealed at any time, as pseudonyms (different names) will be used to protect everyone's right to privacy.
* Any information provided by the participants will not be used against them, or against the school, and will be used for purposes of this research only.
* Participation in this study <u>will not</u> result in any cost to your school or the participants.
*Neither the participants nor your school will receive financial remuneration. However costs incurred by participants as a result of their involvement in this project will be covered.

* This study does not intend to harm the participants in any way.
* Both parents/guardians as well as participants will be handed letters of consent which they will have to carefully read and sign, before I begin data collection.

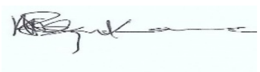
I may be contacted at:
Email address: bbf2ng@gmail.com
Tel: 0847762620

My supervisor’s contact details are: Prof. V. Mudaly
Email address: Mudalyv@ukzn.ac.za
Tel: 031 2607326

You may also contact the Research Office through:
Mariette Snyman
HSSREC Research Office,
Tel: 031 260 8350 E-mail: **snymanm@ukzn.ac.za**

If you would like any further information or if you are unclear about anything, please feel free to contact me at any time. Your co-operation and consent will be greatly appreciated.
If you grant permission to conduct this research at your school, please complete the form below and return to me.

Warm regards,



Mercy Bakare

## DECLARATION

I …………………………………………………………… (full name/s of school principal) of ……………………………………….….. (name of school) hereby confirm that I understand the contents of this document and the nature of this research project, and I consent to the learners participating in this research project. I also grant permission for my school to be used as the research site.

***Additional consent***

I understand that interviews will be audio-recorded and I grant permission for this.

YES/NO

I understand that the learners and the school are free to withdraw from the research project at any time

YES/NO

**SIGNATURE OF SCHOOL PRINCIPAL** **DATE**

**………………………………………..** **……………………**…

## Appendix C

# UKZN HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE (HSSREC)

**For research with human participants**

## INFORMED CONSENT RESOURCE TEMPLATE

**Information Sheet and Consent to Participate in Research (children assent form)**

Date: November, 2019

Dear learner,

My name is Mercy O. Bakare a Masters of Education student (Mathematics Education) of Prof. V. Mudaly from the School of Humanities, faculty of Education at the University of KwaZulu-Natal.
I may be contacted at: Email address: **bbf2ng@gmail.com** or 209530659@ukzn.stu.ac.za
Tel: 0847762620

My supervisor's contact details are: Prof. V. Mudaly

Email address: Mudalyv@ukzn.ac.za

Tel: 031 2607326

You may also contact the Research Office through:

Mariette Snyman

HSSREC Research Office,

Tel: 031 260 8350 E-mail: **snymanm@ukzn.ac.za**

You are invited to consider being involved in a study that involves research.
This research study is entitled: **An exploration of a Visualization intervention in a grade 7 mathematics classroom.**

This study focuses on finding out how learners use visualization (that is: diagrams, pictures, highlighter, drawings etc.) to solve maths word problems, and how effective a visualization intervention will be. The intervention process will involve teaching learners how they can use visuals (that is diagrams, pictures, highlighter, drawings etc.) to solve problems in mathematics. This will only be taught to the learners once they have completed the task sheet, it is a way of equipping learners with some mathematics skills.

I require the participation of two classes of grade 7 learners, 68 in total both boys and girls between the ages of 12 -14. To participate, you are required to solve some problems in mathematics and the aim is to see how learners use visualization when they solve problems in mathematics.

I would be very grateful if you would agree to participate in this study.

If you agree to this, you will be invited to complete task sheets in the classroom, as well as an individual interview, this interview will be carried out with 12 learners who will be selected by me.

All discussions and interviews with participants will be audio-recorded using a dictaphone/recorder, and thereafter written down word for word. The interview questions will be based on how you completed the task sheet and the problems you experienced in the process. This research information (data) is required for the analysis of data and completion of the actual write up of the thesis. Collecting research information for this study may take approximately a month. All classroom teaching/intervention, individual interview and completing of task sheet will take place on the school premises that is, the classroom once you have agreed. I will try to ensure that this takes place during your lunch breaks and free periods, in an attempt to avoid any disruptions during lessons. You will also be encouraged to eat your lunch during discussions, interviews and activities, as well as make use of the school toilet should the need arise. I will not deny you of these opportunities, especially since I intend to use some of your free time in order to collect enough information for my study. The study will provide no direct benefits to you as a participant, but you, through the intervention process will be equipped with some visualization skills.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number HSSREC/00000417/2019).

In the event of any problems or concerns/questions you may contact the researcher at:

Pinetown Senior Primary School
Email address: **bbf2ng@gmail.com**
Tel: 0847762620

or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: **HSSREC@ukzn.ac.za**

* Participation is completely voluntary and you have the right to withdraw from this study at any time. You will not be penalized/punished if you choose to do so.
* Confidentiality and anonymity will be maintained at all times. The identity of your school and all that partake will not be revealed at any time, as pseudonyms (different names) will be used to protect everyone's right to privacy.
* Any information you provide will not be used against you, or against the school, and will be used for purposes of this research only.
* Participation in this study <u>will not</u> result in any cost.
*Neither you nor your school will receive financial payment. No cost is intended to be incurred as a result of your involvement in this project.
* This study does not intend to harm you in any way.
* Letter of consent will be handed to you which you will have to carefully read and sign, before I begin data collection.

The research data will kept for a minimum of 5 years by my supervisor and I, in a safe cupboard. Disposal of data will be determined by my supervisor and will be done accordingly.

------------------------------------------------------------------------------------------------------------

**CONSENT (children assent form)**

I ..........................................................................have been informed about the study entitled

...................................................................................................................................................................

by ...........................................................................(provide name of researcher/fieldworker).

I understand the purpose and procedures of the study as explained.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time.
If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at:
Pinetown Senior Primary School
Email address: **bbf2ng@gmail.com**
Tel: 0847762620

If I have any questions or concerns about my rights as I participate in this study, or if I am concerned about an aspect of the study or the researchers then I may contact:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: **HSSREC@ukzn.ac.za**

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview YES / NO

| | |
|---|---|
| **Signature of Participant** | **Date** |

**Signature of Witness** **Date**
**(Where applicable)**

**Signature of Translator** **Date**
**(Where applicable)**

# UKZN HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE (HSSREC)

**For research with human participants**

## INFORMED CONSENT RESOURCE TEMPLATE

**Information Sheet and Consent to Participate in Research (parental consent form)**

Date: November, 2019

Greeting: Dear Parent/guardian,

My name is Mercy O. Bakare a Masters of Education student (Mathematics Education) of Prof. V. Mudaly from the School of Humanities, faculty of Education at the University of KwaZulu-Natal.
I may be contacted at: Email address: **bbf2ng@gmail.com** or 209530659@ukzn.stu.ac.za
Tel: 0847762620

My supervisor's contact details are: Prof. V. Mudaly

Email address: Mudalyv@ukzn.ac.za

Tel: 031 2607326

You may also contact the Research Office through:

Mariette Snyman

HSSREC Research Office,

Tel: 031 260 8350 E-mail: **snymanm@ukzn.ac.za**

Your child/ward is being invited to consider participating in a study that involves research.
This research study is entitled: **An exploration of a Visualization intervention in a grade 7 mathematics classroom.**

This study focuses on finding out how learners use visualization (that is: diagrams, pictures, highlighter, drawings) to solve mathematical word problems, and how effective a visualization intervention will be. The intervention process will involve teaching learners how they can use visuals to solve problems in mathematics. This will only be taught to the learners once they have completed the task sheet, it is a way of equipping learners with some mathematics skill.

I require the participation of two classes of grade 7 learners, 68 in total both boys and girls between the ages of 12 -14. In participating, they are required to solve some problems in mathematics and the aim is to see how learners use visualization when they solve problems in mathematics.

I would be very grateful if you would consent to your child/ward participating in this study.

If you agree to this, they will be invited to complete task sheets in the classroom, as well as an in-depth individual interview, this interview will be carried out with 12 learners who will be selected by me.

All discussions and interviews with participants will be audio-recorded using a dictaphone, and thereafter transcribed word for word to produce transcriptions. The interview questions will be based on how they completed their task sheet and the problems they encountered in the process. This research information (data) is required for the analysis of data and completion of the actual write up of the thesis. Collecting research information for this study may take approximately a month. All classroom teaching/intervention, in-depth individual interview and completing of task sheet will take place on the school premises that is, the classroom with your permission. I will try to ensure that this takes place during their lunch breaks and free periods, in an attempt to avoid any disruptions during lessons. Participants will also be encouraged to eat their lunch during discussions, interviews and activities, as well as make use of the school toilet should the need arise. I will not deprive them of these opportunities, especially since I intend to use some of their free time in order to collect sufficient information for my study. The study will provide no direct benefits to participants, but they, through the intervention process will be equipped with some visualization skills.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number HSSREC/00000417/2019).

In the event of any problems or concerns/questions you may contact the researcher at:
Pinetown Senior Primary School

Email address: **bbf2ng@gmail.com**
Tel: 0847762620

or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

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Research Office, Westville Campus
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4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: **HSSREC@ukzn.ac.za**

* Participation is completely voluntary and participants have the right to withdraw from this study at any time. They will not be penalized if they choose to do so.
* Confidentiality and anonymity will be maintained at all times. The identity of your school and all participants will not be revealed at any time, as pseudonyms (different names) will be used to protect everyone's right to privacy.
* Any information provided by the participants will not be used against them, or against the school, and will be used for purposes of this research only.
* Participation in this study will not result in any cost to your school or the participants.
*Neither the participants nor your school will receive financial remuneration. No cost is intended to be incurred by participants as a result of their involvement in this project.
* This study does not intend to harm the participants in any way.
* Both parents/guardians as well as participants will be handed letters of consent which they will have to carefully read and sign, before I begin data collection.

The research data will kept for a minimum of 5 years by my supervisor and I, in a safe cupboard. Disposal of data will be determined by my supervisor and will be done accordingly.

----------------------------------------------------------------------------------------------------------

**CONSENT**

I ……………………………………………………………………….have been informed about the study entitled

………………………………………………………………………………………………………………………

(provide details) by ……………………………………………………………………….(provide name of researcher/fieldworker).

I understand the purpose and procedures of the study as explained.

I allow my child/ward to be given an opportunity to answer questions about the study and answer to his/her own satisfaction.

I am aware that his/her participation in this study is entirely voluntary and that my child/ward may withdraw at any time.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at:
Pinetown Senior Primary School
Email address: **bbf2ng@gmail.com**
Tel: 0847762620

If there are questions or concerns about your child/wards right to participate, or if concerned about an aspect of the study or the researchers then I may contact:

**HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION**
Research Office, Westville Campus
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Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: **HSSREC@ukzn.ac.za**

Additional consent, where applicable (for the learner)

I hereby provide consent to:

Audio-record my interview YES / NO

____________________ ____________________

**Signature of Participant** **Date**

____________________ ____________________

**Signature of Witness** **Date**
**(Where applicable)**

**Signature of Translator** **Date**
**(Where applicable)**

# Appendix D

**Initial task sheet**

1. Sithe shares his two sandwiches between himself and two friends. Calculate the fraction of the sandwich that Sithe will get.
2. A box of 12 eggs (a dozen) is divided between four people. What fraction of the 12 eggs will each person get? How many eggs will this be?
3. A bottle of juice is divided between 3 friends. Jason gets $\frac{1}{3}$ of the juice, Joseph gets $\frac{1}{4}$ of the juice bottle and Siswe gets $\frac{5}{12}$. By comparing the fractions, calculate who will get the most juice.
4. Linda spent 3/4 of her savings on furniture and the rest on a TV. If the TV cost her $200, what were her original savings?
5. While taking part in a bicycle race, Michael only manages to cycle $\frac{4}{5}$ of the way. His father manages to complete $\frac{9}{11}$ of the race. Who rode the farthest?
6. There are twenty cookies in a bag. If I ate one-half of them, and you eat one-half of those, how many would you eat?
7. Lee earns R200 an hour. Calculate how many hours he must work to earn R1 200.

# Appendix E

**Pre-intervention interview questions** (after initial task sheet)

1. When solving word problems in mathematics, what methods do you like to use?
2. Does your method usually work?
3. Is it like the way your teacher has taught you?
4. Do you like to draw, highlight or see something different when writing the solution?
5. Do you think a diagram or a drawing will make solving your problem easier?
   Why?
6. How often do you use diagrams or drawing to solve problems?
7. Do you think using diagrams or drawings when solving word problems takes a lot of time?
   Why?

**Post intervention interview questions**

1. How often do you use visualization in solving mathematical word problems?

2. What was different in the approach you used? Do you think you did it differently?

3. Do you think visualization strategies makes it easy to solve word problems in mathematics?

4. How well do you understand visualization strategies now?

5. Do you think if you use visualization strategies more often, you will get better at it?

6. Do you like solving word problems in mathematics?

7. Do you think visualization has helped you understand word problems in mathematics better?

8. You have used diagrams/pictures, underlined and highlighted here, can you explain why?

9. Previously you were solving questions like this, how do you find them?

10. I taught you some strategies, how did the intervention help?

AN EXPLORATION OF A VISUALIZATION INTERVENTION IN A GRADE 7 MATHEMATICS CLASSROOM IN THE PINETOWN DISTRICT

ORIGINALITY REPORT

| 17% | 16% | 3% | 7% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | researchspace.ukzn.ac.za<br>Internet Source | 5% |
| 2 | Submitted to University of KwaZulu-Natal<br>Student Paper | 2% |
| 3 | files.eric.ed.gov<br>Internet Source | 1% |
| 4 | repository.nwu.ac.za<br>Internet Source | 1% |
| 5 | www.omicsonline.org<br>Internet Source | <1% |
| 6 | docplayer.net<br>Internet Source | <1% |
| 7 | hdl.handle.net<br>Internet Source | <1% |
| 8 | pdfs.semanticscholar.org<br>Internet Source | <1% |

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