UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Using branching Google Forms with multimedia to enhance word problem-solving skills in mathematics

Student Name: Yvette Uzziel Pillay
Student Number: 2395393
Supervisor: Dr Nokulunga Ndlovu
Date of Submission: 15 March 2024

A research report submitted to the Wits School of Education, Faculty of Humanities at the University of the Witwatersrand in partial fulfilment of the requirements for the Master of Education Degree (MEd)

Declaration

I hereby declare that this research report is my own work. It has been submitted exclusively to Wits School of Education, Faculty of Humanities at the University of the Witwatersrand in partial fulfilment of the requirements for the Master of Education Degree (MEd). It has not been submitted before for any degree or examination at any other University. Where sources were used, they have been acknowledged and referenced using APA 7th edition.

Signature: 

Yvette Uzziel Pillay

18 March 2024

Dedication

This one goes to you, my baby Skylar. You have been my drive and motivation to complete this research report while I was pregnant. I cannot wait to meet you!

Acknowledgements

Firstly, I am thankful to the **Lord Jesus Christ** for his strength and wisdom to complete this Master's research report. I live by the bible verse "I can do all things through Christ who strengthens me" (Philippians 4:13).

I am thankful and grateful to the following people who have assisted in making my research journey a success:

- My supervisor, Dr Nokulunga Ndlovu for her compassionate guidance, understanding and patience throughout this journey. Thank you dearly. You are one of a kind!
- My mother, Yvonne Pillay, the greatest gift in my life. You have been my support with your encouraging words and motivation through it all. Whenever I needed a shoulder to cry on, you were there.
- My husband, Reagan Achary for his calming nature and always assisting to make my life easier. Thank you for making sure that I never gave up. You have been my pillar of strength.
- To my research participants, without you this journey would not have been possible. Thank you for taking the time to participate in this research.

Abstract

South African students perform poorly in mathematics and more specifically in problem-solving. This study found it worthwhile to investigate if branching Google Forms with multimedia was able to enhance Grade 5 students’ word problem-solving skills in mathematics, at a public school in the Johannesburg East region. The chosen theoretical framework was Mayer’s Cognitive Theory of Multimedia Learning. This study employed the action research methodology and compared pre-test and post-test scores after interventions were implemented. Data was analysed using thematic analysis and descriptive statistics. There was an increase in the number of students who indicated having positive emotions towards problem-solving from 22 students in the pre-test to 31 students in the post-test. Students average marks increased from 6 to 11, the class average increased from 40% to 80% and the P value was 0.0001. Overall, out of 41 students, 36 students obtained higher marks in the post-test. All of these statistics indicate that the interventions were successful and that branching Google Forms with multimedia was able to enhance students’ word problem-solving skills in mathematics. Future researchers using Google Forms and conducting research with students from public schools who are not familiar with using the computer, should take more time teaching students how to use the computer as opposed to a computer literacy crash course, which was one of the interventions in this research.

Key terms:

Mathematics, Problem-solving, Word problems, Multimedia, Google Forms, Students, Interventions

Table of Contents

List of Figures

List of Tables

List of Abbrevniations

ADDIE	Analyze, Design, Develop, Implement, and Evaluate
CTML	Cognitive Theory of Multimedia Learning
ICT	Information Communication and Technology
SACMEQ	Southern Africa Consortium for Monitoring Educational Quality
TIMSS	Trends in International Mathematics and Science Study

CHAPTER ONE: INTRODUCTION

1.1 Introduction and Background

Mathematics is an important subject because the skills we learn from it can help us to reason and solve problems in our everyday lives. More specifically, the teaching and learning of problem-solving in mathematics is vital and has been a topic of interest for mathematics education researchers from the time the field came into existence (Liljedahl et al., 2016). Being able to solve problems is important for the development of human competencies (Tambychik & Meerah, 2010). However, Pólya (1981, as cited in Siniguian, 2017) asserts that the development of mental skills can only be attributed to non-routine problem-solving, which are questions that do not require a straightforward answer. Many students become uncomfortable when working with non-routine problems because they immediately do not know how to apply mathematical concepts (Siniguian, 2017). Research shows that students face difficulties when it comes to word problem-solving and mathematics in general. Ardington et al. (2021) explain that the COVID-19 pandemic caused learning losses in early grade reading students in South Africa. If students struggle to read then they are likely to struggle to understand the word problems. According to Schulze and Bosman (2018, p. 1), "South African students perform poorly in mathematics when benchmarked against their counterparts in other countries". Coupled with poor performances, South Africa also has a high student failure rate in mathematics (Siyepu, 2013). A recent study by Mabena et al. (2021) also confirmed students' poor performance in Nkangala district in Mpumalanga. They explain that poor performance inhibits grade progression, thus resulting in a high student failure rate in mathematics.

Teaching and learning is advancing through the use of multimedia (Rigzin & Chalermnirundorn, 2021). Studies show that multimedia can assist in promoting self-regulated learning, creative thinking and improving problem-solving skills. Using Information Communication and Technology (ICT) coupled with multimedia can allow students to see, hear and do maths problems all at once in a fun way. Rigzin and Chalermnirundorn (2021, p. 28) add that using multimedia "is more appealing than traditional techniques of learning". For students to improve their problem-solving skills in mathematics this research found it worthwhile to explore the use of branching Google Forms with multimedia when teaching Grade 5 students to tackle word problems. The branching feature in Google Forms redirects students to a different page based on how they have answered a specific question. The new page can then be embedded with multimedia to help represent the word problems in multiple ways for students to better understand. Using these technologies and features will enable the educator to scaffold and guide students through non-routine problems. There is very little research about branching Google Forms being used to tackle word problem-solving in mathematics. Therefore, it was imperative to conduct this research. This study used Mayer's (2005) Cognitive Theory of Multimedia Learning (CTML) as its theoretical framework, to ensure that multimedia was used appropriately to enhance word problem-solving skills in mathematics. It also used Pólya's (1949) four steps for problem-solving to guide students as they tackled the word problems.

1.2 Problem Statement

Many South African students are performing poorly in mathematics and are struggling with word problem-solving. The recent 2019 Trends in International Mathematics and Science Study (TIMSS) report shows that South Africa ranked 62nd out of 64 countries, for Maths and Science in the Grade 5 and 9 assessments. In the mathematics curriculum, problem-solving is an important aspect as it enables students to become more competent in solving real-life problems. The Southern Africa Consortium for Monitoring Educational Quality (SACMEQ) also highlighted a concern for South African students' competence in mathematics problem-solving and their ability to use appropriate strategies (Petersen et al., 2017). South African students' poor performance can also be seen from the 2012, 2013, and 2014 ANA results in tables 1.1 and 1.2 below. Table 1.1 shows a decline in the average percentage of mathematics marks from lower grades to higher grades.

Table 1.1: National average percentage marks – Mathematics in 2012, 2013 and 2014

GRADE	MATHEMATICS AVERAGE PERCENTAGE MARK		
	2012	2013	2014
1	68	60	68
2	57	59	62
3	41	53	56
4	37	37	37
5	30	33	37
6	27	39	43
9	13	14	11

Source: Department of Education (2014)

Table 1.2: National average percentage marks – Home Language in 2012, 2013 and 2014

GRADE	HOME LANGUAGE AVERAGE PERCENTAGE MARK		
	2012	2013	2014
1	58	61	63
2	55	57	61
3	52	51	56
4	43	49	57
5	40	46	57
6	43	59	63
9	43	43	48

Source: Department of Education (2014)

Table 1.2 shows that the average percentage mark in the Home Language, which is English, is also very poor as you go from lower grades to higher grades. One reason why students struggle with word problems is because they lack basic language tools to understand the words used in the mathematical problems (Siniguian, 2017). Howie (2003) adds that students' English proficiency level and class level affects their success in mathematics. It is important to note that English is a second language for many South African students, although it is the medium of instruction in many South African schools (Schulze & Bosman, 2018).

According to Siniguian (2017, p. 3):

> Some students were impeded in their progress in solving the problem as they did not comprehend the problem at all. Several students also committed erroneous solutions owing to careless computations. Students sometimes identify an appropriate operation or sequences of operating but do not know the procedures necessary to carry out these operations accurately. Their problem particularly in solving is confounded by the difficult terminology. These students have difficulty understanding written or verbal directions or explanations and find word problems especially difficult to translate into mathematical form and inability to use the correct mathematics.

The words echoed by Siniguian (2017) are evident in my classroom, where most of the Grade 5 students struggle to solve word problems and thus perform poorly in this section of their tests. Students' poor performance in mathematics is a serious issue because mathematics is a core subject in school and if students fail the subject, then they automatically fail the grade (Mabena et al., 2021). Introducing students to branching Google Forms with multimedia may help to represent the word problem in various ways for students to break down and understand. One of the ways that can aid students' understanding is by visually representing aspects of the word problem. According to Mayer (2005), using both words and pictures encourages deeper learning. Rigzin and Chalermnirundorn (2021) further maintain that students remember more from seeing, than reading or hearing. This may also be beneficial to students with language barriers. Google Forms can provide individual scaffolding for each student, which a teacher is unable to do personally for 45 students in a class. Thus, introducing students to branching Google Forms with multimedia may help to enhance word problem-solving skills in mathematics. Developing mathematical skills in the lower grades provides a stronger foundation for the higher grades.

1.3 Purpose Statement

Many South African students struggle to solve word problems in mathematics. Therefore, the purpose of this research was to identify effective strategies of using branching Google Forms with multimedia to enhance the word problem-solving skills of Grade 5 students in mathematics.

1.4 Research Objectives

- To identify the difficulties that students currently face when solving mathematical word problems (pre-test).
- To design branching Google Forms with multimedia and find ways to effectively integrate it into the lesson (development of the intervention).
- To implement the intervention when showing students how to tackle word problems.
- To assess the effectiveness of the intervention in enhancing students' word problem-solving skills (post-test).

1.5 Research Question

How can branching Google Forms with multimedia be used to enhance word problem-solving skills in mathematics? [Design, Development, and Implementation]

1.6 Research Sub-Questions

- What are the difficulties that students currently face when solving mathematical word problems? [Analysis]
- How do the interventions' results portray students' enhancement of problem-solving skills through branching Google Forms with multimedia? [Evaluation]

1.7 Significance of the Research

Although there is research based on the use of Google Forms, there is not much focus on the use of branching Google Forms with multimedia to enhance Grade 5 students' problem-solving skills. Therefore, conducting this research helped to fill the literature gap. Researching the difficulties that students face when solving word problems and whether branching Google Forms with multimedia can be used to enhance problem-solving skills is important, as this may assist students to improve in mathematics and guide mathematics educators' lesson planning and pedagogical practices in the future. The results from this research can encourage education stakeholders to integrate ICT into the mathematics curriculum and invest in ICT development for underprivileged schools.

1.8 Organisation of the Research

This research is organised into five chapters.

Chapter One highlighted the introduction and background, problem statement, purpose statement, research objectives, research questions and sub-questions, significance of the research and the organisation of the research. The identified problem was that Grade 5 students faced difficulties in solving word problems in mathematics. The research focuses on the use of branching Google Forms with multimedia to enhance students' word problem-solving skills in mathematics.

Chapter Two is the literature review and consists of local and international literature related to the research topic. It speaks about the poor performance of mathematics education in South Africa. It explains problem-solving and gives an example of word problems. It mentions some of the issues students face when solving problems. It goes on to speak about the benefits of using ICT in education, the types that can be used and the challenges of ICT integration. Google Forms and multimedia were the ICT tools used in this research; thus it discusses the affordances and benefits of both these tools, respectively.

Chapter Three highlights and justifies the chosen theoretical framework (Mayer's CTML), instructional design (Analyze, Design, Develop, Implement, and Evaluate [ADDIE] model), conceptual framework, research paradigm, methodology, design, data sampling techniques, research instruments, data analysis, transparency and trustworthiness, and ethical considerations.

Chapter Four is the presentation and discussion of findings using the data analysis methods. The qualitative data was analysed using thematic analysis and the emerging themes are mentioned. The quantitative data was analysed using descriptive statistics and presented in tables and graphs.

Chapter Five concludes the research by providing a summary of the entire research, indicating limitations and challenges posed while conducting the research and providing recommendations for further study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers literature on the mathematics performance in South African schools and problem-solving is mathematics education. It indicates that there is poor performance in mathematics and that students generally struggle with problem-solving. This chapter also covers literature on ICT integration in schools, different types of ICT that can be used, challenges of ICT integration, affordances of Google Forms and its branching feature, and the benefits of using multimedia in education, which this study believes can enhance students' problem-solving skills in mathematics.

2.2 Mathematics Performance in South African Schools

Despite many efforts, Education Minister Angie Motshekga states that South Africa remains a country that underperforms in education generally and mathematics particularly (Jojo, 2019). According to Gustafsson (2020), the COVID-19 pandemic impacted significantly on South Africa's already fragile education system. He adds that there are major learning losses which could possibly last until 2031. Even though South Africa opted for the less difficult assessment items, the recent 2019 TIMSS report shows that they were ranked 62nd out of 64 countries for Maths and Science in the Grades 5 and 9 assessments (Reddy et al., 2020). Out of the 11 903 students that participated in the TIMSS assessment, only 16% of students reached the international benchmark for being able to "show and apply basic mathematical knowledge to solve problems" (Reddy et al., 2020, p.). This research focused on Grade 5 students' problem-solving skills, which shows a call for concern. The SACMEQ also highlighted a concern about South African students' competence in mathematics problem-solving and their ability to use appropriate strategies (Petersen et al., 2017). South African students' poor performance can also be seen from the 2012, 2013, and 2014 ANA results which show Grade 5 students' average percentage marks as 30%, 33%, and 37% respectively (Department of Basic Education, 2014). South African students are not able to meet the 50% international average pass mark.

In an article by Jojo (2019), she mentions that the poor quality of teaching at public schools by underqualified and underprepared teachers is one of the reasons for students' poor performance in mathematics. To conclude the article, she advocates continuous professional development and mathematics training colleges provided by the Department of Education for teachers.

2.3 Problem-Solving in Mathematics Education

Problems, then, are tasks that cannot be solved by direct effort and will require some creative insight to solve (Liljedahl, 2008; Pólya, 1965). Problem-solving refers to "tasks that cannot be solved by direct effort and will require some creative insight to solve" (Liljedahl et al., 2016, p. 12). Problem-solving skills help students to think independently and reason carefully, logically and creatively (Güneri et al., 2017 as cited in Özreçberoğlu & Çağanağa, 2018). Problem-solving skills involve thinking and being able to understand the problem, using given information to identify a relevant procedure for solving the problem, finding a solution by carrying out the procedure and then evaluating the solution (Demitra & Sarjoko as cited in Riyadi et al., 2021). The current Curriculum and Assessment Policy Statement in South Africa aims to produce students who can "use critical and creative thinking in making decisions of identification and solution of the problem" (Jojo, 2019, p. 6). In the mathematics curriculum, problem-solving is an important aspect as it enables students to become more competent in solving real-life problems.

Students need problem-solving skills to be able to solve word problems (Riyadi et al., 2021). "A word problem is a few sentences describing a 'real-life' scenario where a problem needs to be solved by way of a mathematical calculation" ("What is a word problem?", n.d. para. 2). Word problems generally consist of words only. An example of a word problem linked to everyday life is as follows: "Khethi's mother sent him to the shop to get 400g of flour to bake a cake. At the shop, they only had 150g bags of flour at R15, 25 each. How many bags of flour should Khethi buy to ensure that his mother has enough to bake a cake and how much change would he get if he paid with a R100 note?" From this question, you can see that it is not a routine straightforward problem. Students would need to be able to break down the problem into coherent mental structures, to integrate it with their prior knowledge (Mayer, 2005 as cited in Sorden, 2012). According to Liljedahl et al. (2016), these are non-routine problems, and they require creative insight.

More than two decades ago, Zhen (1999) recorded the words of two mathematics students at a high school where he taught, which indicates that students had been facing difficulties with word problem-solving back then. One student went to him with a word problem and said, "I don't even know where to start", while the other one said, "I did follow the steps of solving a problem, but I have no idea which formula is supposed to be used for this problem" (Zhen, 1999, p. 2). From this quote, we can see that students require guidance when solving problems.

Therefore, students should be introduced to Pólya's (1949) four steps for problem-solving (understand the problem, devise a plan, carry out the plan, look back), coupled with branching Google Forms with multimedia, to enhance their problem-solving skills.

For students to be able to solve word problems, they need to be able to read and understand the language of the problem (Widodo et al., 2018). There is research that points out that students' poorly developed language skills impact mathematical performance. Bohlmann and Pretorius (2002, p. 196) explain that "the conceptual complexity and problem-solving nature" of mathematics and science "make extensive demands on the reasoning, interpretive and strategic skills of students, especially when carried out in a language that is not the student's primary language" which is pretty much the case in South Africa. Therefore, educators should use words and scenarios that are appropriate to students' contexts for them to easily understand..

2.4 ICT Integration in Schools to Enhance Problem-Solving Skills

The 21st century brings with it a digitised economy for which the future generation is not yet equipped. The World Economic Forum indicated that by 2020, there should have already been 1.5 million digitised jobs created around the world (Freezo, 2017 as cited in Abdul-Razak, 2020). Many students have never even used a computer before for various reasons. These students are on the less fortunate side of the digital divide and will not have an equal opportunity to compete in the new digitised economy (Herselman & Britton, 2002). According to Balanskat et al. (as cited in Cassim, 2010) when teachers recognise the value of ICT integration they begin to make a paradigm shift. Therefore, it is up to them to take every opportunity to integrate ICT into the curriculum to equip students with information technology skills to thrive in the 21st century.

According to Blurton (as cited in Das, 2019, p. 21), ICT is a "diverse set of technological tools and devices used to communicate, and to create, distribute, store, and manage information". ICT includes but is not limited to the computer, internet, hardware, software, multimedia, simulations, games, email, Bluetooth, videoconferencing, chat services, online tools, applications, calculators, smartboards, projectors and so on (Das, 2019). It allows for the dynamic representation and exploration of mathematical digital resources to be accessed anywhere and anytime.

Even though we are living in an ICT era, most of the mathematics lessons in South African classrooms are still centred on the traditional talk and chalk, as well as using text to relay information. "The traditional way of teaching mathematics therefore, presents mathematics as an abstract subject in classrooms" (Masilo, 2015, p. 98). Using ICT allows for a move beyond the formal setting of the classroom. Students can use ICT tools to do calculations, plot graphs and help them to solve problems. There are geometry systems that allow students to create an image to solve and prove geometry problems (Das, 2019). Das (2019) also speaks of another helpful math software which is called GeoGebra; it assists young students in solving problems dealing with complex numbers, vectors, and algebra among others.

Using technology when teaching has become a popular trend in the modern world (Starja et al., 2020). In an article by Starja et al. (2020), they maintain that using ICT in mathematics positively motivates students' interactions and enhances problem-solving skills by providing them with timeous feedback, strategies for solutions as well as an interpretation or evaluation of the solution. In another article by Balanskat et al. (2006 as cited in Cassim, 2010) they noted that students' marks and motivation increased, and they developed cognitive processing skills and the ability to work independently.

2.4.1 Different types of ICT that can be or have been used to enhance problem-solving skills

The computer was first used in schools during the early 1980s (Ghavifekr et al., 2016). The computer is a vital resource as it allows information to be presented in various multimedia formats to accommodate students' preferred learning styles (Selinger, 2000). This allows for word problems to be supplemented with supporting multimedia (videos, images, animations, etc). However, the teacher is tasked with the duty of ensuring that the experiences that students gain from using the computer are meaningful.

In a study by Karami et al. (2013) they used ICT in the form of Microsoft PowerPoint slideshows to teach pre-service teachers how to teach problem-solving. To show addition and subtraction they had to use entrance and exit animation effects from Microsoft PowerPoint. They also used other effects to show the perimeter and area of shapes. This is a good way to bring word problems to life. By the end of the study, many pre-service teachers who were not interested at the beginning, began to show more interest because of their pleasant experience with working with the computer and Microsoft PowerPoint. This means that more teachers would be interested in using ICT for teaching and learning if they were provided with adequate training on how to integrate ICT and its benefits.

One of the technological tools that is being used in many Albanian schools is the smartboard. The smartboard allows lessons to be enriched with memorable visual aids like colourful graphics, animations, diagrams and shapes. In general, ICT makes the invisible visible (Selinger, 2000). It also allows the teacher to browse the internet and present a wealth of information in many attractive ways. Smartboards enhance the teaching and learning of mathematics (Starja et al., 2020). In another study, Hwang et al. (2007) used a multimedia whiteboard to engage students in mathematical problem-solving. They recommend the use of the multimedia whiteboard to improve students' multiple representation skills. Multiple representation skills refer to the student's ability to translate a word problem into a verbal, picture/graphic, or arithmetic symbol representation (Hwang et al., 2007).

2.4.2 Challenges of ICT integration

According to Dlamini and Na' Allah (2015), one of the challenges is that most teachers are focused on the hardware and software when it comes to ICT integration, instead of focusing on aspects of teaching and learning with ICT. They also note that the South African context (social, economic, political, cultural and historical) is not taken into consideration when integrating ICT. In another study by Amuko et al. (2015), they mention that teachers lack technological skills and that they need to change their own attitudes and beliefs about ICT to make integration successful. This lack of technological skills and knowledge produces teachers who lack confidence and are anxious about using technology when teaching (Balanskat et al., 2006 as cited in Amuko et al., 2015). Dlamini and Mbatha (2018), mention that teachers need meaningful and effective training and support if they are to successfully integrate ICT into teaching and learning.

Some of the disadvantages of using ICT mentioned in De Witte and Rogge (2014) speak about ICT usage undermining the teacher-student relationship, increasing maintenance costs, and overuse leading to students being distracted from learning. Some of these reasons are likely to affect teachers' beliefs and attitudes towards ICT integration. A Johannesburg study with students using tablets found that in some cases distractions like games and social media resulted in their marks dropping. Other students noted that it caused eye strain and physical limitations such as the tablets being slow and the battery needing to be charged, which proved to be difficult during load shedding (Hart & Laher, 2019).Some teachers believe that using technology in the classroom is time-consuming and will create extra work for them (Kukali, as cited in Amuko et al., 2015). Amuko et al. (2015) mention more challenges such as a lack of technological infrastructure, teacher experience and teacher support and training. Further on, they mention that besides teachers learning how to use technology, they need to learn how to apply it effectively to teaching and learning. “In addition, they need to know which technologies will most effectively meet children’s skills, abilities and needs” (Girgin et al., 2011 as cited in Amuko et al., 2015, p. 12). In a South African study by Rey-Moreno et al., (2016), they mention that the TPACK framework should be used to connect technology and pedagogy. In the context of this study, it is imperative to know which technology can assist students in solving mathematics word problems.

2.4.3 Affordances of Google Forms and its branching feature

Google Forms is a free online resource that can be used if you have a Google account. It allows you to conduct formative and summative assessments such as questionnaires, quizzes, surveys or tests and you can receive feedback timeously (Gavin, as cited in Douell, 2020). The question types, response types, font, pictures and colour can all be customised to suit the level of students (Google Help, 2019). Feedback from Google Forms can be organised into charts, tables and graphs (Weber, as cited in Douell, 2020). This makes analysing data easier and saves time.

Another great feature is branching in Google Forms which redirects students to a different page based on how they have answered a specific question. In a classroom of 45 students, it is hard for the teacher to provide immediate feedback and guidance for each student based on how they tackle a problem-solving question in mathematics. From my experience in the classroom, if students do not receive feedback on a test within the same week in which they write, they lose interest and forget about the test altogether. Therefore, by using branching Google Forms students can receive immediate feedback and if they have failed to solve the word problem, then they will be directed to another page. The new page can have embedded multimedia such as videos, animations and images to visually present the word problems for students to understand them in another way. Thus, allowing for different representations of content to cater for students different learning styles. For example, if students used addition in a problem that had the word "difference", then students will be asked to try again and be redirected to a page that may have an animation showing a girl giving away some of her sweets which will indicate that the word problem involves subtraction and not addition. Using branching, Google Forms allows students to receive individual attention and is an innovative way to get students involved in their own learning. Students will be curious to know where they went wrong and how they can get the answer right, then and there, as opposed to receiving feedback days later which can cause them to lose interest. The use of Google Forms may also motivate students to work independently (Meutia et al., 2020). Hanafiah et al. (2020, p. 3091) used Google Forms-assisted student worksheets which resulted in students gaining learning independence and being able to "solve problems properly, correctly and completely".

"The use of the logic branching feature of multiple-choice Google Forms may enable teachers to customise surveys and to assess within many students' higher order thinking skills, with the convenience and efficiency of an automatic grading system" (Fonseca & Faria, 2021, p. 1). After students complete an activity or test, teachers usually capture marks and conduct data analysis manually – this is very time-consuming. By using Google Forms, teachers can save time and analyse students' performances timeously. Teachers can use this freed-up time to look for other multimedia that could be used for students who are still struggling with word problems.

2.4.4 Benefits of using multimedia in education

Widodo et al. (2018, p. 5) provide a wide range of multimedia, "photographs, books, encyclopedias, magazines, newspapers, reference books, printed products, drawings, illustrations, clippings, film frames, coupling films, transparencies, microphones, projector overheads, graphs, charts, diagrams, sketches, posters, cartoon images, maps, globes, and movies". Other types of multimedia include videos, songs, animations, and so on. Multimedia assists in facilitating understanding, strengthening memories, spurring students' interest and providing support for solving word problems (Widodo et al., 2018). Things that students fail to understand by reading the words can be represented in other formats.In their study, Primta et al. (2009) found that visual data influenced sixth-grade students' ability to solve problems. This is referred to as multimedia learning (Sorden, 2012). This is in line with Mayer's CTML which will be discussed in Chapter Three, which speaks about deeper learning taking place when words are supplemented using pictures. From my experience, young students are always eager to learn when multimedia is involved. The notion of learning through the interactivity of play is also mentioned in Cooper et al. (as cited in Cassim, 2010). Cassim (2010) adds that edutainment software and multimedia can make mathematics less painful for students who find the subject very difficult, by presenting mathematics in a fun way to capture students' interest and make it easier for them to understand.

Wang (2010, as cited in Rigzin & Chalermnirundorn, 2021, p. 29) provides seven benefits for using multimedia in education:

> 1) Multimedia technology gives students the flexibility to access learning resources at their own convenience.
>
> 2) Students can learn at their own pace without relying on an instructor with multimedia learning.
>
> 3) Text, music, visuals, and animations can be used to target a range of learning styles.
>
> 4) Multimedia learning experiences blend concrete ideas and abstractions with visuals, texts, and audio presentations in a sequential order to meet the three essential characteristics of human learning: practice, observation, and thought.
>
> 5) Hyperlinks in multimedia technology help students find additional and relevant material, creating a dynamic learning environment.

6) Graphics, animations, and designs attractstudents' interest and motivate them to learn.

7) When used alongside with traditional educational techniques, multimedia technology enhances both the interactivity and the benefits of multimedia technology.

In a study by Novotna (2014), the researcher explained how the use of e-textbooks, e-manuals and other electronic teaching materials can be used to scaffold studentsand support their creativity. The researcher adds that electronic teaching materials serve as a scaffold "in situations when routine calculations are too long or when fast access to a missing piece of information is needed" (Novotna, 2014, p. 370). Widodo et al. (2018) suggest that educators should integrate ICT-based multimedia in a structured and systematic way to help students enhance their problem-solving skills. Masilo (2015, p. 99), advocates for the use of Pólya's (1949) four problem-solving steps, together with multimedia and technology to support problem-solving. He adds that using these ICT tools and Polya's problem-solving steps "means that problem solving can be approached from diverse perspectives".

2.5 Conclusion

This chapter highlighted the poor performance of mathematics education in South Africa. It explained problem-solving and gave an example of word problems. It mentions some of the issues students face when solving problems. It goes on to speak about the benefits of using ICT in education, the types that can be used and the challenges of ICT integration. Google Forms and multimedia were the ICT tools used in this research; thus, it discusses the affordances and benefits of both these tools, respectively.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter highlights and justifies the chosen theoretical framework, instructional design, conceptual framework, research paradigm, methodology, design, data sampling techniques, research instruments, data analysis, transparency and trustworthiness, and ethical considerations.

3.2 Theoretical Framework

The theoretical framework that was used is Richard E. Mayer's CTML. This theory is rooted in cognitivism. Cognitivism focuses on how "information is received, organised, stored, and retrieved by the mind" (Ertmer & Newby, 1993, p. 51). Moore et al. (2004 as cited in Sorden, 2012) state that the mind has many information stores (types of memory) which are controlled by how stimuli are converted into information. Students are encouraged to actively construct information from the material that is presented to them.

"Multimedia learning happens when we build mental representations from words and pictures" (Sorden, 2012, p. 1). According to the multimedia principle, deeper learning takes place when words and pictures are used, as opposed to words alone (Mayer, 2005). Pictures can take the form of images, animations, videos, photos and so on, while words can be written or spoken (narrated). The CTML depicts how multimedia instruction can be best structured and which cognitive strategies can be used to ensure that students engage in meaningful, effective and efficient learning.

There are three assumptions that the CTML is premised on: dual channel, limited capacity, and active processing (Mayer & Moreno, 1998). The dual-channel assumption is based on Baddeley's 1986 theory of working memory and Paivio's 1991 dual coding theory (Sorden, 2012). This assumption speaks about working memory having an auditory and visual channel. The limited capacity assumption is premised on Sweller's 1988 cognitive load theory, which indicates that subsystems within working memory have a limited capacity. According to Mayer (as cited in Sorden, 2012, pp. 2–3) the active processing assumption states "that people construct knowledge in meaningful ways when they pay attention to the relevant material, organise it into a coherent mental structure, and integrate it with their prior knowledge". In order to capture students' attention, visual and auditory multimedia that interest students should be used but should also avoid cognitive overload. In Figure 3.1 below Mayer represents how memory works when words (narrated) and pictures are presented to students (Sorden, 2012).

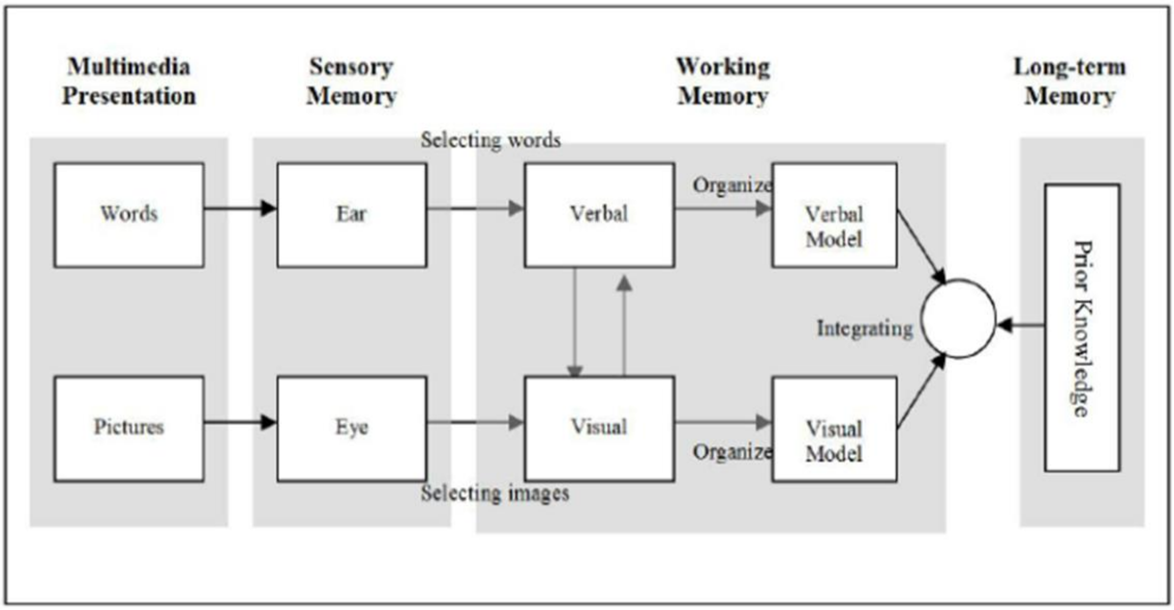


Figure 3.1: Mayer's (2005) CTML

The CTML speaks about sensory memory, working memory and long-term memory. "Sweller defines sensory memory as the cognitive structure that permits us to perceive new information, working memory as the cognitive structure in which we consciously process information, and long-term memory as the cognitive structure that stores our knowledge base" (Sorden, 2012, p. 3). Multimedia helps to "reduce the burden of students' cognitive thinking" (Zheng et al., 2009 as cited in Aadzaar & Widjajanti, 2019, p. 2). In the results of a study by Rudolph (2017), the researcher found that concise lessons are better than extended lessons, texts should be placed closer to images and pointers should be used to highlight key concepts and avoid extraneous detail – these are all important to ensure that students achieve better results in word problem-solving tasks. This speaks to the five principles for multimedia design out of which four were taken into consideration when designing the branching Google Form with multimedia. The five principles for multimedia design from Mayer and Moreno (1998) are:

Multiple Representation Principle – speaks about using two modes to represent information, rather than one. Instead of using words only, pictures and words should be used together to explain a piece of information. Students perform better in problem-solving transfer tests when they listen to narration and animation, as opposed to narration only (Mayer & Anderson, 1991, 1992 as cited in Mayer & Moreno, 1998). This was especially useful when presenting word problems on Google Forms with multimedia. The word problems were supplemented with videos and images for multiple representation, to cater for students with different learning styles.

Contiguity Principle – speaks about words and pictures presented contiguously instead of being separated. This means that words and pictures should be presented simultaneously, as opposed to presenting a picture and then a minute later having words pop up to explain the picture or viewing a picture after an explanation is given. The words can be alongside the picture and be presented together. Word problems are generally made up of words only, however when designing the word problems, pictures were presented on the same page, next to the words.

Split-Attention Principle – speaks about presenting "words as auditory narration rather than as visual on-screen text" (Mayer & Moreno, 1998, p. 3). It is easier for students to watch an animation and listen to the narration at the same time, as opposed to watching an animation and then trying to read the text at the bottom of the screen. Students' attention is split between watching the animation and reading the text, thus resulting in cognitive overload. Another example is when students are viewing a picture and reading the text next to it and then all of a sudden there is unrelated music in the background or pop-ups on the screen. This interferes with students' effective selection and organisation of relevant information. Videos were embedded into the Google form with animation and narration presented at the same time. Videos were carefully selected to ensure that students would not have to watch the animation and try to read texts, instead, they watched the animations and had to listen to the narration.

Individual Differences Principle – speaks about students with high levels of prior knowledge and students who lack prior knowledge. Students with high levels of prior knowledge can create mental images without any visual representation. They can do this just by listening to narration or reading text. They also speak about students who have a high spatial ability and "are able to hold the visual image longer in working memory and thus are more likely to benefit from contiguous presentation of words and pictures" (Mayer & Moreno, 1998, p. 4).

Coherence Principle – speaks about using fewer modes to present information rather than many extraneous words and pictures. Shorter concise summaries are better than longer summaries. When a summary is shorter, it allows the student to select and organise relevant information accordingly. Avoid using text, narrations and animations together as either the text or narration becomes redundant. This leads to cognitive overload and to avoid this, any of them can be removed. The embedded videos were concise. The majority of the embedded videos were around five minutes and about two videos were around 11 minutes. Students were asked to only watch the first five minutes of the longer videos. Longer videos were not used, to prevent students from getting bored and overloaded with information.

3.3 Instructional Design

The ADDIE model was the chosen instructional design. Using an instructional design model will assist the researcher or educator in ensuring that they develop appropriate teaching materials and efficiently implement them (Cheung, 2016). The ADDIE model provided a pathway for this research to follow. Figure 3.2 below explains the Acronym ADDIE, which represents the different phases: analysis, design, development, implementation, and evaluation. The outcome from each phase feeds into the next phase.

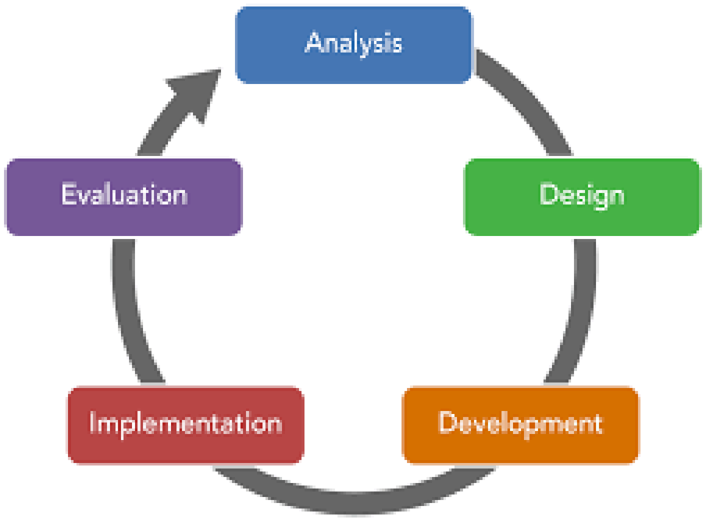


Figure 3.2: ADDIE Model (Cheung, 2016)

According to Cheung (2016), ADDIE has been used to develop online materials before and thus will be used to develop branching Google Forms with multimedia to enhance problem-solving skills in mathematics. Here is an explanation of each phase (Cheung, 2016):

Analysis: In the analysis phase the current situation was analysed and a needs analysis for students was established from the pre-test. The teacher observed the challenges that students faced when solving word problems. Thereafter, goals and objectives were determined. In this research, the current situation was that Grade 5 students were struggling to solve word problems in mathematics. The question to ask was how could the situation be improved? A plan of action was drawn up.

Design: In this phase, the plan of action was designed. I focused on what strategies, content, delivery methods, timelines, online tools, assessment instruments and theories could be used to help students improve their word problem-solving skills. These were then outlined. Students needed interventions that were focused on improving their word problem-solving skills in mathematics. Students were introduced to Pólya's (1949) problem-solving steps, how to use the computer and branching Google Forms with multimedia. A blueprint for the interventions was designed to meet the goals and objectives.

Development: In this phase, the interventions and outlines were developed using the blueprint from the design phase. Lessons to teach Pólya's problem-solving steps were created. Font, layout and colour were chosen for the Google Forms. Multimedia was chosen in line with Mayer's CTML which was embedded into the branching Google Form (example forms and post-test). The computer literacy crash course was also created. Testing of the Google Forms was also done in this phase.

Implementation: During this phase, all the interventions were implemented according to the blueprint from the design phase. There was a test implementation phase and a final implementation phase. The test phase checked if all the Google Forms and the computer literacy crash course were working fine.

Evaluation: During this phase, feedback from the interventions was evaluated to see if they had worked to improve students' problem-solving skills in mathematics or not. The evaluation was based on pre-test and post-test scores. If the evaluation showed that the design did not work, then I would have had to go back to the analysis and design phase and make the appropriate adjustments.

3.4 Conceptual Framework

Figure 3.3 is the conceptual framework which shows the pathway that was followed for this research.

Identify difficulties that students currently face when solving mathematical word problems.

- Administer the pre-test (questionnaire)
- Observations

(ADDIE: Analysis)

INTERVENTION 1

- Introduction to Polya's four steps for problem-solving.

(ADDIE: Design and Development)

INTERVENTION 2

- Computer literacy crash course and an introduction to branching Google Forms with multimedia.
- Development of the post-test using Mayer's CTML

(ADDIE: Design and Development)

INTERVENTION 3

- Administer the post-test (questionnaire)
- Observation

(ADDIE: Implementation)

Comparison of students' marks between the pre-test and post-test to establish if branching Google Forms with multimedia was able to enhance problem-solving skills in mathematics.

(ADDIE: Evaluation)

Figure 3.3: Conceptual framework to enhance word problem-solving skills in mathematics

The research pathway commenced by analysing the difficulties that students faced when solving mathematical word problems. From the analysis, interventions were designed, developed and implemented to improve the situation. An intervention in action research "refers to the plan or strategies implemented to bring about improvement or change in a specific area or problem” (Cabrera Jaime et al., 2023, p. 1221). Finally, students were given a post-test to evaluate if the interventions were a success.

3.5 Methodology

3.5.1 Research paradigm

Kuhn who coined the term ‘paradigm’ describes it as an epistemological stance which is used to establish what types of questions should be asked to gain the best understanding when doing research (McChesney & Aldridge, 2019). For this research, the interpretivist paradigm was used. According to Creswell (2009 as cited in Thanh & Thanh, 2015), interpretivists seek to understand humans’ experiences, views and background, when planning research and analysing the results. For example, when designing the word problems, the words used were relevant and relatable to the students’ contexts. It was also kept in mind that English was not the first language of most of the children. Many students were not familiar with using computers at all. The first intervention that was implemented was a computer literacy crash course with the students.

3.5.2 Research methodology

The research methodology that was used is mixed methods research, which seeks to meaningfully integrate both qualitative and quantitative methods (McChesney & Aldridge, 2019). The quantitative method looks at obtaining numerical data which is analysed objectively to accept or reject a hypothesis and make generalisations from the sample size to the wider population (Tashakkori & Creswell, 2007). The qualitative method focuses on peoples’ experiences and instead of obtaining numerical data, it gathers words and images, from interviews, observations, drawings and so on, to better understand the research topic. For this research, the quantitative method was used to gather numerical data from pre-test and post-test scores. The qualitative method was used to determine students’ feelings about word problem-solving as well as the challenges that students face while tackling word problem-solving.

3.5.3 Research design

Action research is two-fold as it involves both action and research. The action part “is usually associated with identifying and exploring an issue, question, dilemma, gap, or puzzle in your own context of work – the classroom, the school, or the institution at large” (Burns, 2009). After an issue is identified, practical changes or interventions are put in place to improve the issue. Interventions can be focused on some of these areas like teaching practice, how students learn, teaching beliefs and interaction with the curriculum (Fischer, as cited in Burns, 2009). The research part involves collecting data systematically and usually through qualitative data collection methods. The data collected from the interventions was carefully analysed and reflected on, to understand what the research was revealing. Figure 3.4 below shows the action research cycle which includes plan, act, observe and reflect. Throughout the research, observations and reflections were made. Reflection points can be seen in Chapter Four.

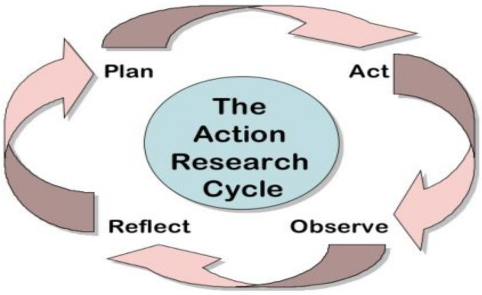


Figure 3.4: Action research cycle

I chose to use action research because the problem that I identified in my classroom was that students were struggling with word problems in mathematics. From the identified problem the following things were done: I observed the way students solved word problems on paper and identified their challenges from the pre-test; I carefully planned interventions to improve my teaching of word problems (students were introduced to Pólya's four steps for problem-solving); I integrated ICT into students lessons by introducing a computer literacy crash course and branching Google Forms with multimedia; I reflected on whether the designed Google Forms were working or not (they were improved if necessary); I gave students the post-test which had the same questions as the pre-test but this time it was conducted using the computer, to determine if branching Google Forms with multimedia enhanced problem-solving skills.

3.5.3.1 Polya's four steps for problem-solving – Intervention 1

George Pólya's four steps for problem-solving from his book "How to Solve it – 1949" were adopted in this research. Figure 3.5 shows Pólya's (1949 as cited in Liljedahl et al., 2016) four steps for problem-solving in mathematics which are: understand the problem, devise a plan, carry out the plan and look back. Providing students with these steps would help them to feel guided as they worked through the word problems.

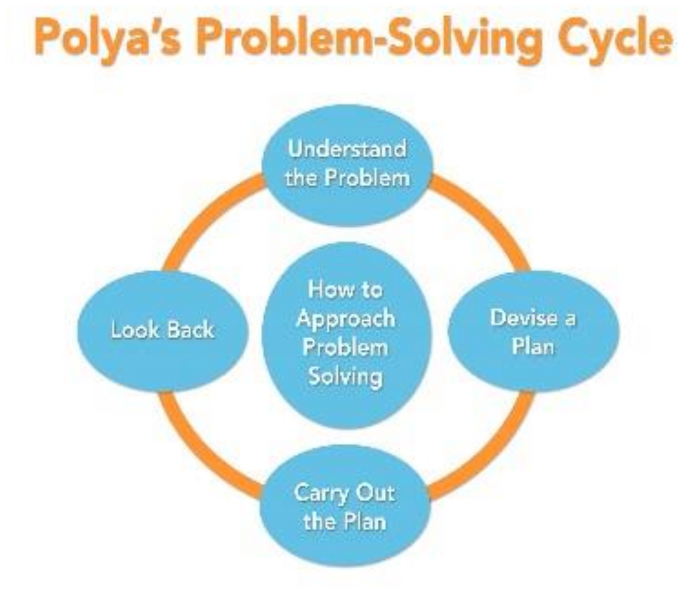


Figure 3.5: Pólya's (1949) four steps for problem-solving

The statements under each of the four steps were adapted from Pólya's original statements to avoid confusing students with too much information. These are Pólya's (1949) four steps (as cited in Liljedahl et al., 2016) with the adapted statements:

1- Understand the problem

To understand what the problem is saying, underline or highlight keywords or words that stand out or are unknown to you. Try to make sense of these words in relation to what the problem is asking. Draw pictures or diagrams to help you understand.

2- Devise a plan

Your plan to solve the problem should involve finding a connection between what you do know and what is unknown. Try to think of any other problem that you have come across that was similar. Try to link your highlighted keywords to specific arithmetic operations (+,-, ×, ÷) that you will use to solve the problem. Take into account all the information.

3- Carry out the plan

Start solving the problem by using your chosen arithmetic operation. Check to see that each step is correct; if you are using addition, check that you are carrying over numbers correctly, or if you are using subtraction, check that you are borrowing accordingly.

4- Look back

Evaluate your answer using the inverse/opposite operation. If you used addition to get the answer, use subtraction to see if you got the number you started with. If you do not get the answer, you need to go back and devise a new plan to use a different arithmetic operation. Check to see that you have provided an answer to what the problem has asked.

3.5.4 Data sampling techniques

It is difficult to conduct research using the entire population. Therefore, a sample of the population is chosen which represents the larger population (Acharya et al., 2013). For this research, convenience and purposive sampling were used. I chose to work with 41 Grade 5 students that I currently teach because they were easily accessible to me. I chose to work with the entire class and not just random students to avoid biasness. Purposive sampling is when participants are chosen deliberately to provide rich and appropriate data to answer the research question. The reason for using the Grade 5 students from this school was because they were struggling with word problems. Therefore, it was relevant and appropriate to conduct research with them. Figure 3.6 below shows the site of the research.

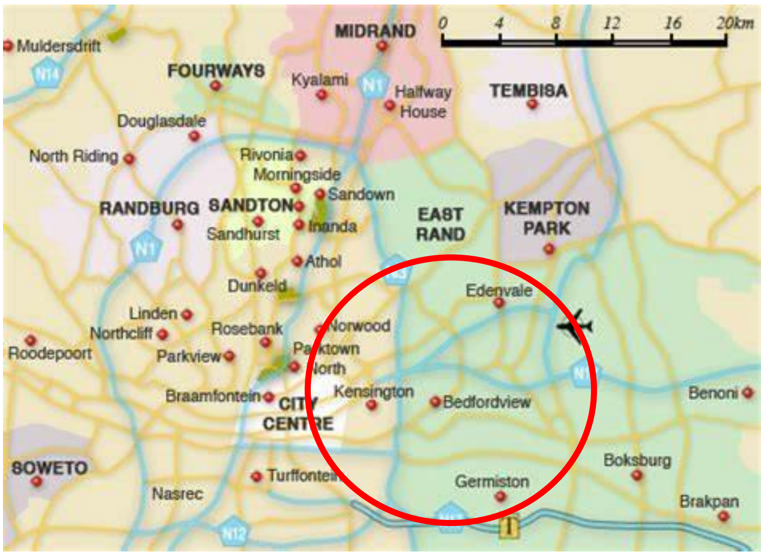


Figure 3.6: Site description

The students attended a school in the Johannesburg East region, more specifically in one of the areas circled on the map. It is a quintile 4 public school. Even though the school is classified as a quintile 4 school, most of the students do not come from wealthy surroundings and are from middle to lower-class homes.

3.5.4.1 Profile of research participants

Table 3.1 below explains the profile of the 41 students that participated in this research.

Table 3.1: Profile of research participants

Age	The students were between the ages of 10-13.
Gender	Twenty-one girls and 20 boys participated.
Race	Forty black students and one white student.
Socio-economic class	Most of the students belong to the middle and lower classes.
Language	Most of the students are second-language English speakers.

3.5.5 Research instruments

3.5.5.1 Triangulation

The triangulation method increases the credibility and validity of your research findings. "Credibility refers to trustworthiness and how believable a study is; validity is concerned with the extent to which a study accurately reflects or evaluates the concept or ideas being investigated" (Noble & Heale, 2019, p. 67). Triangulation refers to using more than one research instrument to collect data and to avoid any biasness or inconsistencies that may arise from a single instrument or a single observer (Cohen et al., as cited in Bush, 2012). For this research, observations and pre-and post-tests were used to obtain qualitative and quantitative data.

3.5.5.2 Observations

According to Cowie (2009, p. 166), "observation is the conscious noticing and detailed examination of participants' behaviour in a naturalistic setting". It helps to gather first-hand information. It is a qualitative method that is used to gather data and can be used in action research. I observed how students tackled word problems on paper (pre-test) by walking around the classroom and on the computer using Google Forms (post-test). This helped to see exactly where the majority of the students were facing difficulties.

3.5.5.3 Pre-tests and post-tests (questionnaire)

The pre-tests and post-tests were in the form of a questionnaire. The questionnaire type that was used was closed-response questions. In closed-response questions, the researcher determines an answer list and participants are required to select an answer from the provided list only (Brown, 2009). The pre-test and post-test had the same questions; however, the post-test was administered on the computer using branching Google Forms with multimedia. The pre-test and post-test were used to obtain qualitative and quantitative data, before and after the intervention.

3.6 Data Analysis

This study used thematic analysis which is a systematic way "of identifying, organising, and offering insight into patterns of meaning (themes) across a data set" (Braun & Clarke, 2012, p. 57). Thematic analysis allows the researcher to interpret shared meanings and experiences. Braun and Clarke (2012) provide six steps to conduct thematic analysis which was used in this study: familiarise yourself with the data, generate initial codes, search for themes, review potential themes, define and name themes, and produce the report. Thematic analysis was used for the qualitative data.

For the quantitative data, descriptive statistics were used. Descriptive statistics is a method "used to calculate, describe, and summarize collected research data in a logical, meaningful, and efficient way" (Vetter, 2017, p. 23). Data is then numerically reported in tables, graphs or figures. For this research, data was analysed using percentages and averages. Students' marks from the pre-test and post-test were analysed using paired sample t-test software to find the P value. If the P value was lower than the P value threshold (0.05), then this indicated a statistically significant difference between marks in the pre-test and post-test ("T Test Calculator," n.d.), further indicating that students' performance would have increased after the interventions.

3.7 Transparency and Trustworthiness

A trustworthy study has followed a set of standards, competently and ethically. The result from a trustworthy study holds merit, is credible and has benefits for future research (Rallis & Rossman, 2009). Rallis and Rossman (2009) provide three ways to ensure the transparency and trustworthiness of a study. Firstly, data should be gathered thoroughly over a longer period, not a one-shot data collection method. For this research data was collected over two months. Secondly, different data collection methods were used to make the results from the research stronger and to hold more water. This is referred to as triangulation, which was discussed earlier. Thirdly, a member-checking strategy should be used. In this strategy the results from the research should be shared with the participants, to see if they agree or disagree with them.

This is a transparent method that shows the participants that you have fully involved them in the study and not just used them to gather data. In this study, before the conclusions were drawn, the results were discussed with the students.

Furthermore, this research used techniques of prolonged engagement and persistent observation. According to Bush and Amechi (2019, as cited in Amin et al., 2020, p. 3):

> If the purpose of prolonged engagement is to render the inquirer open to the multiple influences - the mutual shapers and contextual factors - that impinge upon the phenomenon being studied, the purpose of persistent observation is to identify those characteristics and elements in the situation that are most relevant to the problem or issue being pursued and focusing on them in detail. If prolonged engagement provides scope, persistent observation provides depth.

In using the prolonged engagement technique, I took the time to learn about the culture of my students and classroom in general and persistently observed them. Prolonged engagement and persistent observation continued throughout the first two schooling terms. The research was only collected in the third term. I became mindful of the fact that students were continuously performing poorly in the problem-solving section of their tests. Students struggled to understand word problems from the textbook, therefore word problems that were created on the Google Form were made relatable to students' context. Word choice in word problems is important. A student who has never been to the opera would find it hard to relate to a problem about the opera.

3.8 Ethical Considerations

According to Creswell (as cited in Abdul-Razak, 2020, p. 49), "the researcher should always respect the rights, desires, values and needs of the participants in the study". Before the research commenced and any data was collected, the ethics application was submitted. Since the research involved Grade 5 students, informed consent was obtained from the Gauteng Department of Education, the principal, parents and students, which explained the nature of the research and requested permission for the students to participate. Informed consent gave all stakeholders involved the opportunity to consciously decide if they wanted to participate in the study or not (Creswell et al., 2003). Students were made aware that they could withdraw at any time. All documents granting permission for the research to commence are attached under appendices. All the students' identities as well as the name of the school were kept confidential, in an attempt to respect privacy rights (Cohen et al., as cited in Bush, 2012). Students were asked to create their pseudonyms and photographs were taken that did not show their faces.

3.9 Conclusion

This chapter discussed Mayer's CTML as the theoretical framework and explained the five principles for multimedia design by Mayer and Moreno (1998) of which four were used in this research. It also explained the ADDIE model as the instructional design of the entire research. The pathway of the research was explained using the conceptual framework. This was mixed-method action research with an interpretivist paradigm. The action research cycle and Pólya's (1949) four steps for problem-solving were discussed. This chapter went on further to discuss the research instruments used, how the sample was chosen, and the type of data analysis conducted. Methods to maintain transparency, trustworthiness and uphold ethical standards were also mentioned.

CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the findings according to the phases in the ADDIE model, thematic analysis and descriptive analysis. It discusses the findings from the observations as well as the pre-tests and post-tests. The design and development of each intervention is also discussed.

4.2 Findings in Response to the Analysis Phase of the ADDIE Model

As mentioned in Chapter Three, the ADDIE model was the chosen instructional design. An instructional design provides a roadmap for achieving your research objective. The ADDIE model structured the entire research and ensured that Google Forms was developed appropriately and implemented efficiently (Cheung, 2016). There are five phases in this model: Analysis, Design, Development, Implementation and Evaluation. Each phase was elaborated on in Chapter Three.

4.2.1 Observation of the pre-test

Figure 4.1 below shows students getting ready to write the pre-test. This is the way they are seated daily; this is a formal scenery for them.

Figure 4.1: Students getting ready to take the pre-test

The pre-test consisted of 10 multiple-choice questions. The first three were general questions about students' feelings, likes and difficulties with word problem-solving in mathematics. The next seven questions were word problems that students had to solve. The word problems were a mixture of different difficulty levels, easy, medium and hard. The word problems were taken from the internet (myfreemathworksheets) and modified. Names of past years' students were used in some of the questions to make it relatable and exciting for students to read. Many students struggle with the English language; therefore each question was read out aloud and explained to them. The explanations did not indicate which method students should use. Words from the general questions like "overwhelmed" and "thinking outside the box" were also discussed to cater for English second-language students. Students were given one hour to complete the pre-test. While students wrote their pre-tests, I walked around the class to observe them. At this stage, students were not taught new methods to solve mathematical word problems. The pre-test aimed to establish students' prior knowledge and to answer the research sub-question: **"What are the difficulties that students currently face when solving mathematical word problems?"** This research question responds to the analysis phase in the ADDIE model.

To answer this research question, the deductive/top-down approach was used to analyse the data. In this approach "the researcher brings to the data a series of concepts, ideas, or topics that they use to code and interpret the data" (Braun & Clarke, 2012, p. 58). The observation checklist (see Appendix H) includes my preconceived ideas and concepts which were used to analyse the data.

The following details were noted as per the observation checklist:

1. Some students were more focused than others and were very engaged in trying to solve the problems, while other students just looked around uninterestedly while writing.
2. Interesting to note was that no student underlined or highlighted keywords from the word problems.
3. Some students did not do any working out in the space provided, they just selected answers. Some of the answers were correct without the working out, while others were incorrect.
4. Some students were using the wrong operation to answer the questions. For example, they used addition instead of subtraction.

5. Students chose/identified the correct operation, but were not able to work out the sums successfully and made mistakes along the way.
6. It was noted that the majority of students did not use the inverse operation to check their answers, which is how studentswere taught previously to check their answers.

4.2.2 Pre-test analysis

4.2.2.1 The first three questions

The first three general questions were qualitative. There were multiple-choice options to choose from and an opportunity for students to select "other" and provide their own responses. There were 41 students who participated in this research. Table 4.1 below shows responses from the 41 students, per multiple-choice option. Students' own responses from the "other" option were also recorded.

Table 4.1: Students responses to the first three general questions from the pre-test

GENERAL QUESTIONS	NUMBER OF STUDENTS THAT RESPONDED PER MULTIPLE CHOICE
Question 1 - How do you feel about solving word problems in mathematics? a) Happy b) Sad c) Overwhelmed d) Angry e) If other – please specify.	a) 22 b) 2 c) 13 d) 1 e) 3 - "I don't like math's even a little bit." - "Nerveous [Nervous]" - "Some times I can understand and some times I can't understand."
Question 2 - What do you like about problem-solving? a) It challenges me to think outside the box. b) It is exciting to solve. c) The sentences are interesting to read. d) I do not like anything about problem-solving. e) If other – please specify.	a) 11 b) 8 c) 11 d) 7 e) 4 -"I don't know what must I do in problem-solving." - "That the teachers are kind." - "Confesude [Confused]" - "It may be easy but not that easy."

Question 3 - What do you find difficult about problem-solving? a) I cannot understand the words. b) I do not know which operation (+, -, ×, ÷) to use when solving the problems. c) After I figure out which operation to use, I make mistakes when calculating. d) I do not find anything difficult about problem-solving. e) If other – please specify.	a) 2 b) 14 c) 18 d) 5 e) 2 -"I don't like problem-solving." - "It is ÷ division I hate division and I don't unstand [understand] it".

Twenty-two students indicated positive feelings (happy) towards solving word problems and 19 students indicated negative feelings (sad, overwhelmed, angry, other). Thirty students indicated liking positive aspects (challenges me to think outside the box, exciting to solve, sentences are interesting to read) about problem-solving and 11 students indicated negativity (I do not like anything about problem-solving, other) towards problem-solving. From question 3 we see that 36 students face difficulties (not understanding the words, not knowing which operation to use, making mistakes when calculating, hating long division) when it comes to solving problems, while five students stated that they do not face any difficulties.

4.2.2.2 Thematic analysis

Thematic analysis was used to analyse the qualitative aspects of the research which included the first three questions from the pre-test and the observation of students writing the pre-test. Thematic analysis assisted in presenting the answer to the research sub-question: **"What are the difficulties that students currently face when solving mathematical word problems?"** Table 4.2 below shows the six-phase approach by Braun and Clark (2012) that was used to carry out the thematic analysis.

Table 4.2: The six-phase approach to thematic analysis by Braun and Clark (2012) and the process carried out to achieve it

THEMATIC ANALYSIS PHASES	PROCESS
Familiarising yourself with the data	Reading and re-reading of the first three question responses from the pre-test and of the observation findings were done.
Generating initial codes	The following codes were mainly obtained using the deductive approach/the researchers' preconceived ideas and concepts from the pre-test and observation checklist: 1. 1-Students' feelings towards word problems in mathematics. 2. 2-Students' behaviour towards problem-solving. 3. 3-Students' likes towards problem-solving. 4. 4-Difficulties faced by students working on problem-solving. 5. 5-Methods used by students to solve word problems.
Searching for themes	Codes 1, 2 and 3 were combined. 1. Students' feelings, likes and behaviours towards word problem-solving in mathematics. 2. Difficulties faced by students working on problem-solving. 3. Methods used by students to solve word problems.
Reviewing potential themes	Potential themes were reviewed.
Defining and naming themes	Students' feelings and behaviour as well as the methods they use may contribute to the difficulties that they face when solving word problems. Difficulties that students face while solving word problems impact their performance and scores. Three themes emerged from the data: 1. Impact of emotions and behaviour on problem-solving in mathematics 2. Current difficulties faced 3. Current methods used.
Producing the report	Write up conducted.

The deductive approach to thematic analysis is focused on the researchers' preconceived ideas and concepts, while the inductive approach focuses solely on generating themes from students' own responses (Braun & Clark, 2012). Thematic analysis is best achieved when it uses a combination of both the deductive and inductive approach, to ensure that the researcher's "analytic lens does not completely override" students' responses (Braun & Clark, 2012, p. 60). However, using a combination of approaches was not possible. The majority of the students chose the multiple-choice options that were provided as opposed to giving their own responses, even though they were encouraged to do so. Kaipa (2021) conducted a study to find out which question type students preferred from multiple-choice questions, essay questions and short questions. She found that 65% of students preferred multiple-choice questions as opposed to the latter two options. When students were asked why they did not write their own responses, some indicated that they felt lazy, that it was easier to choose an option and that they could not spell the words that they wanted to write. The issue of spelling can be seen from the few student responses in table 4.1, where students wrote "Nerveous" and "confesude" for nervous and confused. Therefore, the thematic analysis was based on the deductive approach.

Reflection point: From my experience of conducting this research, I would say that to gather qualitative responses when working with young students, one should make sure that the questions are completely open-ended and do not provide them with options to choose from.

- **Impact of emotions and behaviour on problem-solving in mathematics**

If students find mathematics interesting, then they are likely to be intrinsically motivated to learn and this affects their engagement and performance in the subject (OECD, 2013; Yunus & Ali, 2009 as cited in Mazana et al., 2019). This indicates that if students have positive emotions towards problem-solving in mathematics, then they are likely to be more engaged in the subject and perform better. However, even though the majority (22) of the students indicated having positive emotions towards problem-solving, the overall performance in the pre-test was poor. Students also selected statements like "it is exciting to solve and the sentences are interesting to read" but their behaviour did not match the statements. Some students seemed uninterested and looked around while writing, while others were fully engaged with their work.

- **Current difficulties faced**

This theme explains the current difficulties that students face when solving word problems in mathematics. Some students could not understand the words, keeping in mind that English was not the first language of most of the students. Some students were unable to identify the correct arithmetic operation to use, and when students did identify the correct arithmetic operation, they made mistakes while calculating.

- **Current methods used**

Some students tried to answer the questions without doing any working out. No student underlined or highlighted keywords from the problems to help them understand the question. The majority of the students did not use the inverse operation to check their answers, which is an evaluation technique that uses the opposite operation to check if the answer is correct.

4.2.2.3 The next seven questions

The next seven questions were multiple-choice word problems. Students were asked to show their working out in the space provided. Each question was 2 marks, amounting to a total mark of 14. Table 4.3 shows the percentage of students and number of students that obtained each mark, out of a total of 14 marks.

Table 4.3: Percentage and number of students that obtained each mark in the pre-test

Marks	% Percentage Marks	Number of Students That Obtained Each Mark
0	0	0
2	20	8
4	22	9
6	27	11
8	22	9
10	7	3
12	2	1
14	0	0

There were eight students who got 2 marks, nine students who got 4 marks, 11 students who got 6 marks, nine students who got 8 marks, three students who got 10 marks, one student who got 12 marks and no student who got 14 marks. The percentage shows that 69% of students got less than 50% for the pre-test, while only 31% of students managed to get more than 50%. Table 4.4 below indicates that the average student mark was 6 and the class average was 40%.

Table 4.4: Students' average mark and class average for the pre-test

Average Student Mark	Class Average as a Percentage (%)
$\frac{232}{41} \times \frac{100}{1} = 5.6 \approx 6$	$\frac{232}{574} \times \frac{100}{1} = 40\%$

Although in South African primary schools 40% is considered a pass mark in mathematics, it is way too low. This can mean that students have only mastered 40% of the content and this sets low expectations (Wedekind, 2013). It also gives students false confidence that they are doing well in mathematics, when they pass at 40%. Furthermore, they are not able to compete internationally with most countries because the pass mark is higher in those places.

Table 4.5 explains each word problem and suggests a way to solve them. Some problems have more than one method to solve them, but only one is mentioned.

Table 4.5: A dive into the seven multiple-choice word problems

Word problem	Explanation of the operation (+,-,×,÷) required to solve the problem	Number of students that got each question correct
Question 4 The chicken pen held 7 chickens. Each chicken lays 6 eggs a day. How many eggs would they get altogether after 30 days?	Multiplication This is a non-routine problem that does not have a straightforward answer. Students first have to multiply 7x6 and then take that answer and multiply it by 30.	16
Question 5 Khanya cut 4 pieces of wood for her school project. The pieces of wood were 4.2 m, 3.5 m, 3.7 m, and 9.2 m. She put them altogether to form one long piece of wood. How long was it?	Addition This is a routine problem with a straightforward answer. Students have to add all the 4 wood measurements together.	24
Question 6 Njabulo ordered 9 pizzas for his birthday party. Each pizza had 8 slices. There were 12 people (including Njabulo) at his party. How many slices did they each get?	Multiplication and Division This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations. Students first have to multiply 9x8 then take that answer and divide it by 12.	17

Question 7 A local car company was able to make 12 cars a week for 4 weeks. They doubled this amount over the next 4 weeks. How many cars did they make after the 8 weeks?	Multiplication and Addition This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations. Students first have to multiply 12x4, then take that answer and add it to 48x2. This is the number sentence (12 x 4) + (48 x 2) = $\square$	11
Question 8 Emmanuel makes toy cars. He wants to make 1,500. Emmanuel can make 18 cars a day. He has already made 492. How many days will it take him to get to 1,500?	Subtraction and Division This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations. Students first have to work out 1500-492 then take that answer and divide it by 18.	19
Question 9 Melusi and his 2 friends read 55 books each for the year. Each book had an average of 320 pages. How many pages did they all read in total that year?	Multiplication This is a non-routine problem that does not have a straightforward answer. Students first have to work out 3x55 then take that answer and multiply it by 320.	6
Question 10 Amahle wants to buy a car that costs R152 000. The car dealership is willing to give her a R7 000 discount. How much will the car cost after the discount?	Subtraction This is a routine problem with a straightforward answer. Students have to work out R152000 – R7000.	23

Table 4.5 also shows the number of studentsthat got each question correct. According to Castro (2018, slide 3), “routine problem-solving involves using at least one of the four arithmetic operations and/or ratio to solve problems that are practical in nature”. The four arithmetic operations are addition, subtraction, multiplication and division. While non-routine problem-solving is defined as “any complex problem that requires some degree of creativity or originality to solve” and “typically do not have an immediate apparent strategy for solving them” (Castro, 2018, slide 5).

Routine problems are easier to solve because they require students to only use one arithmetic operation and are straightforward. Questions 5 and 10 are routine problems and require the use of addition and subtraction, respectively. More students got these particular two sums correct, indicating that they were easier. The majority of the students got the non-routine problems incorrect, indicating difficulties with these. This is in line with what was mentioned earlier in Chapter One, that students become uncomfortable with non-routine questions because they immediately do not know which operation to use and how to apply mathematical concepts (Siniguian, 2017).

Reflection point: In order to find out how many students got each question correct, manual analysis had to be done, meaning that each pre-test script had to be looked at individually. This was time-consuming. There was one student who left four questions blank, even though I was walking around and reminding them to make sure to answer each question. However, this will not happen when using Google Forms because each question is marked as "required" and it does not allow students to submit if they have skipped a required question.

4.3 Findings in Response to the Design, Development and Implementation Phase of the ADDIE Model

Results from the analysis phase about the difficulties that students face when solving word problems guided the design and development phase. By finding out the difficulties that students face, their needs were established, and two interventions were designed and developed. The third intervention was to conduct the post-test. For this research, the interventions were focused on improving students' word problem-solving skills in mathematics using branching Google Forms with multimedia. The interventions were aimed at answering the research question: **"How can branching Google Forms with multimedia be used to enhance word problem-solving skills in mathematics?"** This research question responds to the Design, Development, and Implementation phase in the ADDIE model.

4.3.1 Design and development of intervention one

This intervention focused on introducing students to Pólya's (1949) four steps to approach problem-solving. Looking at the analysis of the observation and pre-test, it was necessary to introduce students to steps that would guide them as they tackle word problems. From the analysis I saw that students did not highlight keywords, show working out or use the inverse operation to check their work.

Students were introduced to Pólya's (1949) four steps which were written on the board: understand the problem, devise a plan, carry out your plan, and look back. Examples were done together with students, taking them through each step, and then students were given examples to try on their own. Figure 4.2 below shows a photograph of a student's workbook where they were using Pólya's (1949) four steps to solve the word problem. From the photograph, you can see that the student drew stick figure people to help them understand the problem. Students enjoyed learning a new method for problem-solving and many of them got the examples correct.

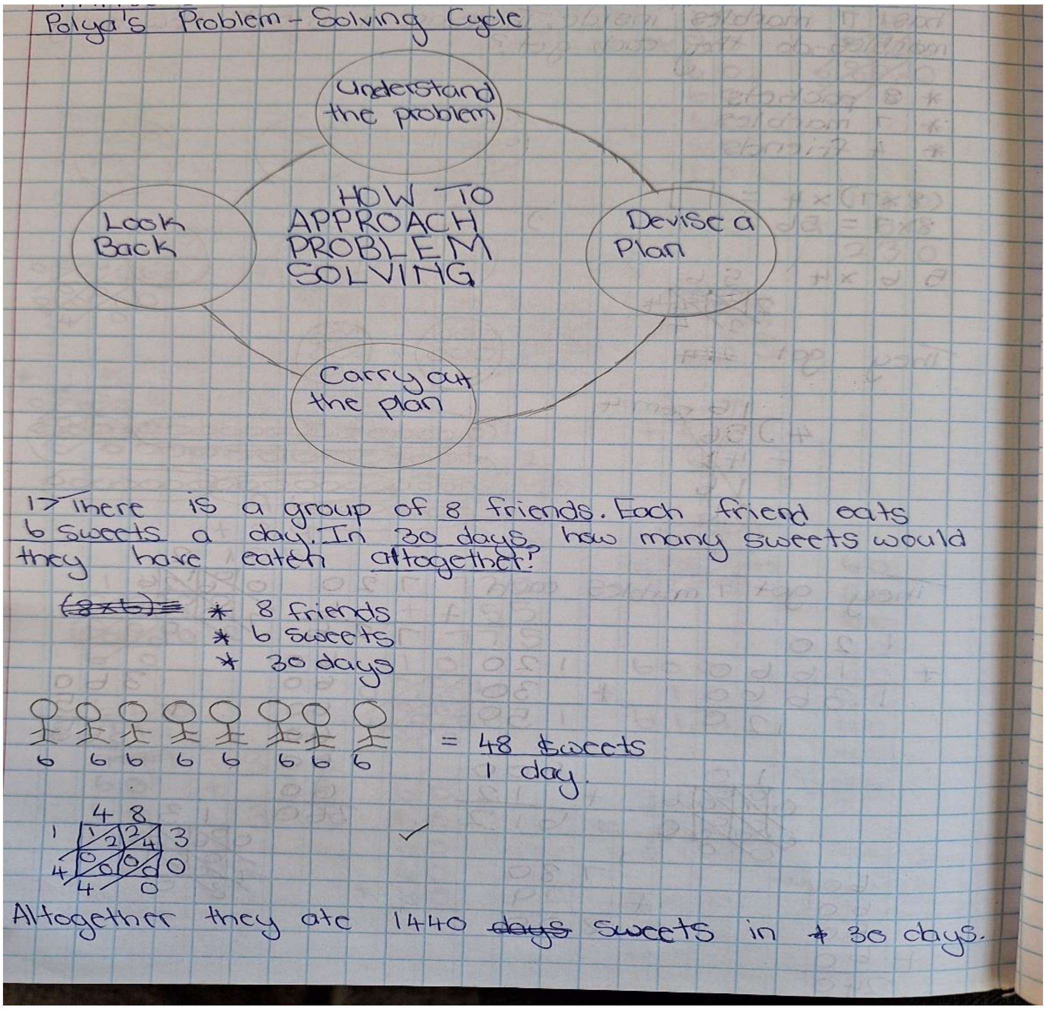


Figure 4.2: Student using Pólya's (1949) four steps to solve the word problem

4.3.2 Design and development of intervention two

This intervention focused on teaching students how to use the computer because many of them had never used one before. Time was limited; therefore, a computer literacy crash course was done, showing students basics like the parts of the computer, how to use the mouse and keyboard, switch the computer on/off and so on. A projector and PowerPoint presentation were used to show students how to navigate their way around the desktop, for example, which tab to click on to switch the computer off. Figure 4.3 below shows students at the computer lab during their computer literacy crash course. Students looked forward to going to the computer lab because it was a change from the formal scenery for them, as opposed to being in the classroom the whole day. Thereafter, students were introduced to branching Google Forms with multimedia and students were given a tester Google Form to fill in. Very few students struggled to use the computer after they were taught and made mistakes when submitting the Google Form. Once students displayed competency with using the computer and Google Forms they were then required to do the post-test.

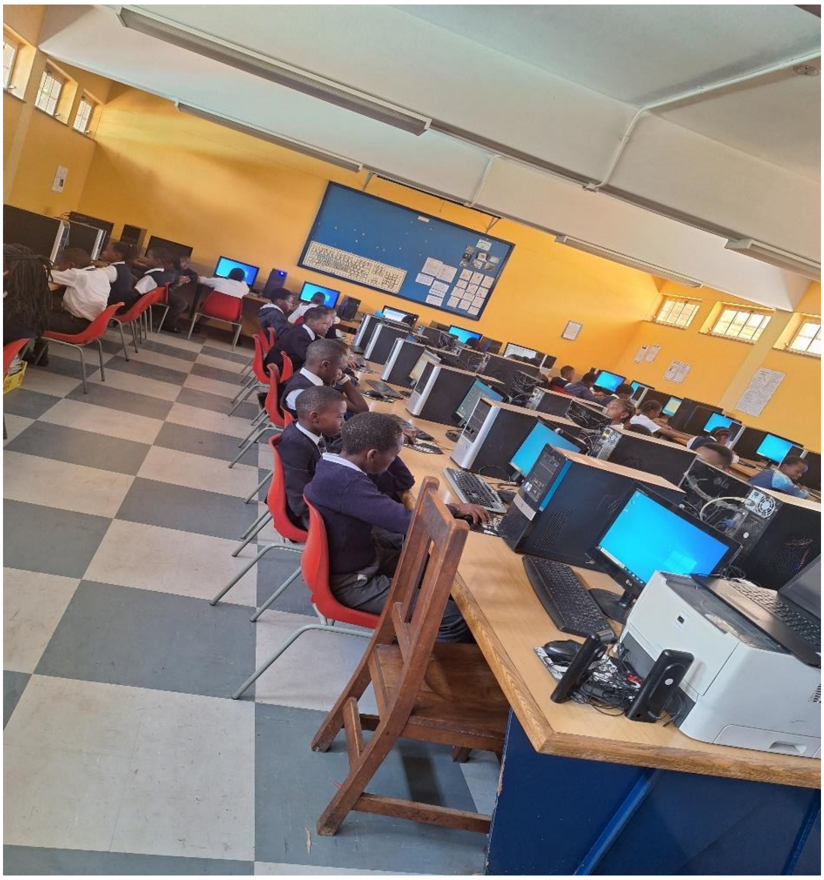
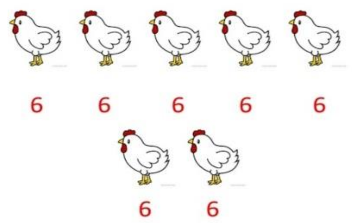
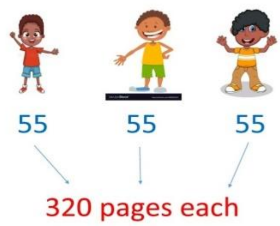


Figure 4.3: Students at the computer lab

The development of the branching Google Form with multimedia was in line with Mayer's CTML. Four multimedia design principles from Mayer and Moreno (1998) were taken into consideration when designing the branching Google Form with multimedia. The four principles were: the multiple representation principle, contiguity principle, split-attention principle and coherence principle. Each principle is elaborated on in Chapter Three. Some of the questions had pictures with numbers and words next to the picture. This adhered to Mayer and Moreno's (1998) contiguity and split-attention multimedia design principle. For each of the seven word problems, YouTube videos were embedded as immediate feedback and guidance. The videos helped students to choose the correct arithmetic operation, but students were still expected to work out the answer themselves. The videos also assisted in reminding students how to carry out the arithmetic operation. The videos served as a reinforcement and summary of what students already knew how to do. Students learn better when visuals are presented as opposed to text only (see Mayer's CTML in Chapter Three). Lopez (as cited in Rigzin & Chalermnirundorn, 2021, pp. 31–32) states that students "remember 10% from the reading, 20% from the hearing, 30% from the seeing, and 50% from the hearing and seeing". Table 4.6 below explains the YouTube videos and images that were chosen for each of the questions.

Table 4.6: Embedded YouTube video for each word problem

Word Problem	**Embedded YouTube Video**
Question 4 The chicken pen held 7 chickens. Each chicken lays 6 eggs a day. How many eggs would they get altogether after 30 days?	Video reminding students how to do lattice multiplication using 2 digits by 2 digits. Aspects of the word problem were visually depicted using images of 7 chickens with the number 6 below each one. 
Question 5 Khanya cut 4 pieces of wood for her school project. The pieces of wood were 4.2 m, 3.5 m, 3.7 m, and 9.2 m. She put them altogether to form one long piece of wood. How long was it?	Video example of another addition problem similar to question 5.
Question 6 Njabulo ordered 9 pizzas for his birthday party. Each pizza had 8 slices. There were 12 people (including Njabulo) at his party. How many slices did they each get?	Two videos were embedded, one explaining how to share equally and the other reminding students how to conduct long division. Aspects of the word problem were visually depicted using images of 9 pizzas with 8 slices each. 
Question 7 A local car company was able to make 12 cars a week for 4 weeks. They doubled this amount over the next 4 weeks. How many cars did they make after the 8 weeks?	A video/song explaining the meaning of doubles.

Question 8 Emmanuel makes toy cars. He wants to make 1,500. Emmanuel can make 18 cars a day. He has already made 492. How many days will it take him to get to 1,500?	Video example reminding students how to conduct long division using 4 digits by 2 digits.
Question 9 Melusi and his 2 friends read 55 books each for the year. Each book had an average of 320 pages. How many pages did they all read in total that year?	Video example reminding students how to use lattice multiplication for 3 digits by 3 digits. Aspects of the word problem were visually depicted showing three boys with the number 55 below each of them, and arrows pointing to “320 pages each”. 
Question 10 Amahle wants to buy a car that costs R 152 000. The car dealership is willing to give her a R7 000 discount. How much will the car cost after the discount?	Video explaining the meaning of discount.

4.3.3 Design and development of intervention three

This intervention was solely based on conducting the post-test which was the branching Google Form with multimedia. This took place in the school’s computer lab. Below is the link to access the Google Form:

https://docs.google.com/forms/d/e/1FAIpQLSdgLI3pHZAJ7Tc2F5_u0qjuRnsKauyYbj2OaEIjLwy19W5rJw/viewform?usp=sf_link

4.4 Findings in Response to the Evaluation Phase of the ADDIE Model

This phase of the ADDIE model evaluates the results from the post-test to ascertain if the interventions were successful.

4.4.1 Observation of the post-test

There was no checklist used for this observation, but important notes were made while students wrote the post-test. Figure 4.4 below shows students at the computer lab working on the post-test. Students were asked to bring earphones if they had, and we shared them. The earphones were needed to watch the YouTube videos that were embedded in the Google Form. Students were asked to bring a page and pencil into the computer lab to do their working out. They were reminded to use Pólya's problem-solving steps. Figure 4.5 below shows one student with earphones listening to the YouTube videos and another student with a page in front of them to do the working out. The post-test was the same as the pre-test, with the same word problems. The post-test aimed to answer the research sub-question: **"How do the intervention results portray students' enhancement of problem-solving skills through branching Google Forms with multimedia?"** This research question responds to the Evaluation phase in the ADDIE model.

Figure 4.4: Students doing the post-test at the computer lab

Figure 4.5: Students working on the post-test

All the questions were read out aloud. Each question was 2 marks, amounting to a total mark of 14. Students were given two hours to complete the post-test, taking into consideration that they were still getting used to using Google Forms on the computer. Each student got two attempts to take the test. After the first attempt, they got the opportunity to see which answers they got incorrect and then retake the test. For each wrong answer that students got, they were provided with immediate feedback, encouraging words and guidance in the form of explanations with pictures or embedded YouTube videos using the Google Forms branching feature. Immediate feedback with encouraging words is positive reinforcement in behaviourism (Ertmer & Newby, 1993).

The following observations were made:

1. Students were excited and eager to take the post-test using the computer.
2. The majority of the students were taking note of the keywords on paper.
3. More students did their working out on a page as opposed to the pre-test, but there were still two students who did not do any working out at all, they just selected the answers.
4. There were still a few students using the wrong operation to answer the questions.
5. There were still a few students who chose/identified the correct operation but were not able to work out the sums successfully and made mistakes along the way.
6. Only about half of the students used the inverse operation to check their answers, even though they were reminded to use Pólya's problem-solving steps.

7. A few students were still struggling to use the computer even though we had a computer literacy crash course. Three students closed the Google Form mistakenly. Their responses were deleted and they were asked to start again.

Reflection point – In future make it compulsory for all students to show their working out and evaluation using the inverse operation. However, this was hard to do on the computers that we used because they were old and did not have touch screens. If they were touch screens, students' working out could have been captured and used for analysis purposes.

4.4.2 Post-test analysis

Again, the first three general questions were qualitative but tweaked in response to using branching Google Forms with multimedia. There were multiple-choice options to choose from and an opportunity for students to select "other" and provide their responses. The same 41 students participated in the post-test and were asked to use the same pseudonyms. Table 4.7 below shows students' responses to the first three general questions from the post-test.

Table 4.7: Students responses to the first three general questions from the post-test

General Questions	Number of Students That Responded Per Multiple Choice
Question 1 - How do you feel about solving word problems in mathematics using Google Forms with multimedia? a) Happy b) Sad c) Overwhelmed d) Angry e) If other - please specify.	a) 31 b) 0 c) 6 d) 2 e) 2 - "I feel like I don't understand a bit" - "Confused"
Question 2 - What do you like about problem-solving using Google Forms with multimedia? a) It helps me to understand the question better and to find the correct operation b) It tells me when I am wrong and points me in the right direction c) The multimedia is very helpful	a) 10 b) 19 c) 8 d) 3 e) 1

d) I still do not like anything about problem-solving e) If other - please specify.	- No specification
Question 3 - What do you find difficult about problem-solving <u>using Google Forms with multimedia?</u> a) Using the computer b) Using Google Forms c) After I figure out which operation to use, I make mistakes when calculating d) I do not find anything difficult e) If other - please specify	a) 9 b) 6 c) 14 d) 11 e) 1 -No specification

Table 4.7 shows an increase in the number of students (from 22 to 31) who indicated positive feelings (happy) towards solving word problems and a decrease in the number of students (from 19 to 10) who indicated having negative feelings (sad, overwhelmed, angry, other) when compared to the pre-test responses. Students were happier to do the post-test on the computer as opposed to writing on paper in class. Thirty-seven students in question 2 indicated liking positive aspects (It helps me to understand the question better and to find the correct operation, it tells me when I am wrong and points me in the right direction, the multimedia is very helpful) about using Google Forms to solve word problems and four students indicated negativity (I still do not like anything about problem-solving, other). From question 3 we see that 29 students still indicated facing difficulties (using the computer, using Google Forms, making mistakes when calculating) when it comes to solving problems using Google Forms, while 12 students indicated not facing any difficulty.

<u>Reflection point:</u> More time needs to be spent teaching students how to use the computer. There was limited time due to many challenges that arose.

A comparison between students' performance before the intervention (pre-test) and after the intervention (post-test) was done to evaluate if branching Google Forms with multimedia was able to enhance students' problem-solving skills or not. Table 4.8 shows a comparison between the number of students that obtained each mark in the pre-test and post-test. Results from the post-test show that four students got 6 marks, five students got 8 marks, 10 students got 10 marks, seven students got 12 marks and 15 students got full marks which is 14/14. Overall, more students obtained higher marks in the post-test.

Table 4.8: Comparison between student marks in the pre-test and post-test

Total Marks	**Number of Students That Obtained Each Mark** **Pre-Test**	**Number of Students That Obtained Each Mark** **Post-Test**
0	0	0
2	8	0
4	9	0
6	11	4
8	9	5
10	3	10
12	1	7
14	0	15

Figure 4.6 below shows us that a higher percentage of students obtained higher marks in the post-test as opposed to the pre-test. In the pre-test, 69% of students got less than 50%, while 31% got more than 50%. In the post-test, there was a massive increase whereby 90% of students got more than 50% and 10% got less than 50%.

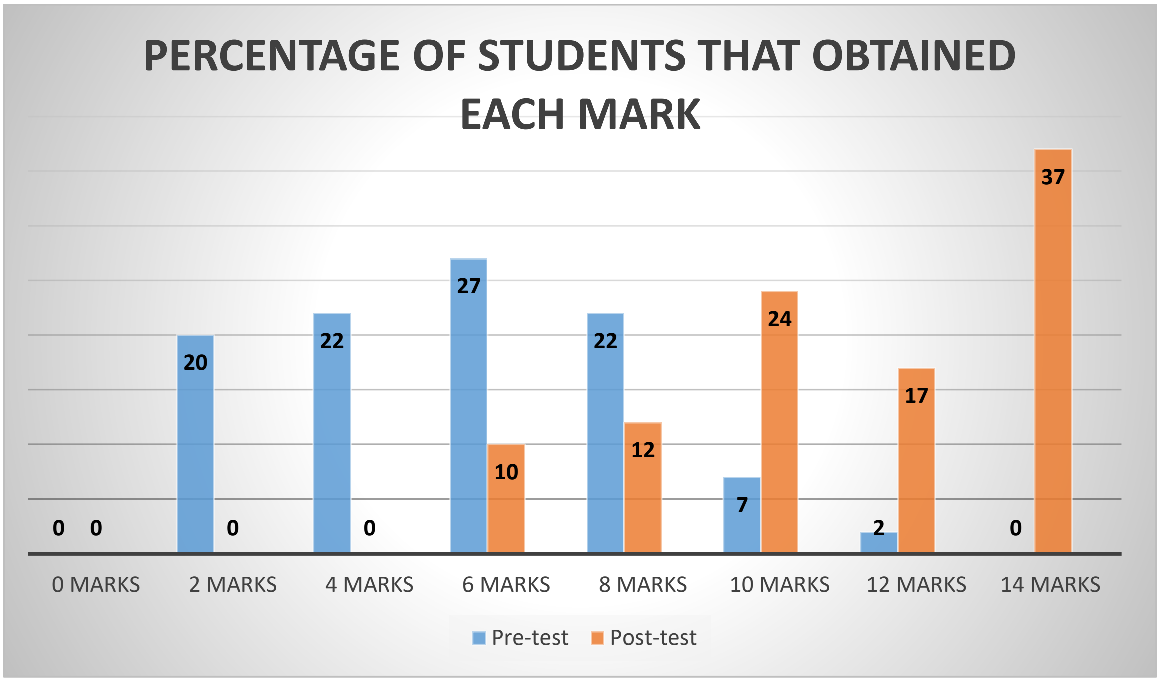


Figure 4.6: Comparison between the students' percentages obtained in the pre- and post-tests

Table 4.9 and Figure 4.7 below show that students' average marks and the class average percentage from the post-test were comparatively higher than the pre-test. This indicates an improvement after the interventions. Students' average marks almost doubled from 6 to 11 marks, while the class average as a percentage did double from 40% to a significant 80%. The improvement in averages indicates that the interventions were effective and that branching Google Forms with multimedia was able to enhance students' word problem-solving skills in mathematics.

Table 4.9: Comparison between students' average mark and class average for the pre-test and post-test

Average Student Mark Pre-Test	Class Average As A Percentage (%) Pre-Test	Average Student Mark Post-Test	Class Average As A Percentage (%) Post-Test
$\frac{232}{41} \times \frac{100}{1} = 5.6 \approx 6$	$\frac{232}{574} \times \frac{100}{1} = 40\%$	$\frac{458}{41} \times \frac{100}{1} = 11.1 \approx 11$	$\frac{458}{574} \times \frac{100}{1} = 80\%$

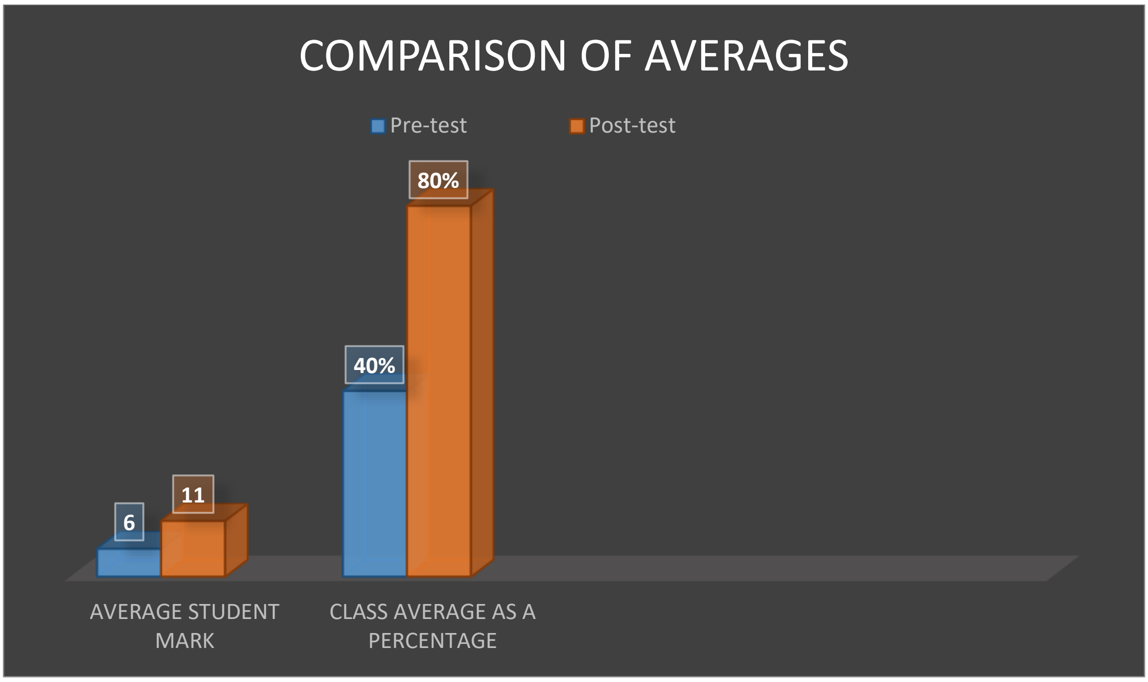


Figure 4.7: Comparison of student average mark and the class average as a percentage

Students' marks from the pre-test and post-test were also compared using a paired sample t-test software. The means were not mentioned in this test because the averages were already calculated manually. However, what was looked at was the P value: (P value) 0.0001 < 0.05 (P value threshold). The P value that resulted from the test was 0.0001 which is less than the P value threshold and is considered to be extremely statistically significant. This means that there is a significant difference between the pre-test scores and post-test scores.

Table 4.10 and Figure 4.8 below show us an overall increase in the number of students who got each question correct. This time, the majority of the students performed best in questions 4 and 6, which were non-routine problems. Question 9 showed the highest increase in the number of students that got the question correct, from six students in the pre-test to 29 students in the post-test. Results from this table and figure show us that the interventions were successful in that students' performance in the post-test increased significantly. Students were now able to perform better in non-routine problems.

Table 4.10: A comparison between students that got each question correct for the pre-test and post-test

Word Problem	**Explanation of the Operation (+,-,×,÷) Required to Solve Problem**	**Number Of Students That Got Each Question Correct In Pre-Test**	**Number of Students That Got Each Question Correct in Post-Test**
Question 4 The chicken pen held 7 chickens. Each chicken lays 6 eggs a day. How many eggs would they get altogether after 30 days?	Multiplication This is a non-routine problem that does not have a straightforward answer. Students first have to multiply 7x6 and then take that answer and multiply it by 30.	16	36
Question 5 Khanya cut 4 pieces of wood for her school project. The pieces of wood were 4.2 m, 3.5 m, 3.7 m, and 9.2 m. She put them altogether to form one long piece of wood. How long was it?	Addition This is a routine problem with a straightforward answer. Students have to add all the 4 wood measurements together.	24	34
Question 6 Njabulo ordered 9 pizzas for his birthday party. Each pizza had 8 slices. There were 12 people (including Njabulo) at his party. How many slices did they each get?	Multiplication and Division This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations. Students first have to multiply 9x8 then take that answer and divide it by 12.	17	36
Question 7 A local car company was able to make 12 cars a week for 4 weeks. They doubled this amount over the next 4 weeks. How many cars did they	Multiplication and Addition This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations.	11	29

make after the 8 weeks?	Students first have to multiply 12x4, then take that answer and add it to 48x2. This is the number sentence (12 x 4) + (48 x 2) = $\square$		
Question 8 Emmanuel makes toy cars. He wants to make 1,500. Emmanuel can make 18 cars a day. He has already made 492. How many days will it take him to get to 1,500?	Subtraction and Division This is a non-routine problem that does not have a straightforward answer. This question requires the use of two different operations. Students first have to work out 1500-492 then take that answer and divide it by 18.	19	31
Question 9 Melusi and his 2 friends read 55 books each for the year. Each book had an average of 320 pages. How many pages did they all read in total that year?	Multiplication This is a non-routine problem that does not have a straightforward answer. Students first have to work out 3x55 then take that answer and multiply it by 320.	6	29
Question 10 Amahle wants to buy a car that costs R152 000. The car dealership is willing to give her a R7 000 discount. How much will the car cost after the discount?	Subtraction This is a routine problem with a straightforward answer. Students have to work out R152000-R7000.	23	34

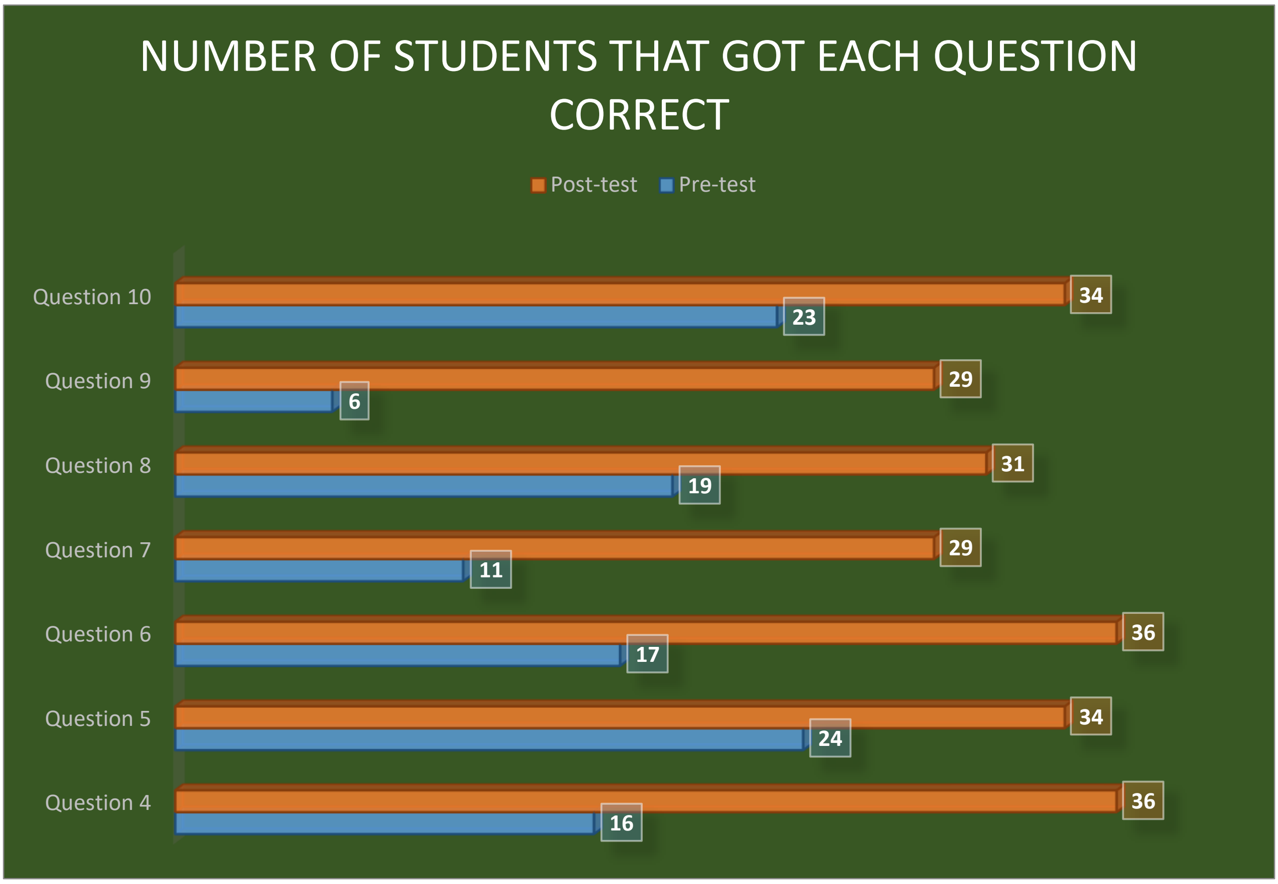


Figure 4.8: Bar Graph showing comparison between the number of students that got each question correct for the pre-test and post-test

<u>Reflection point:</u> Google Forms helped to save a lot of time in terms of analysing how many students got each question correct. Google Forms has the option to display students' responses in charts and graphs as opposed to manually analysing each student's pre-test script, which was rather time-consuming.

Table 4.11 below shows a comparison between students' marks for the pre-test and post-test. Students used the same pseudonym for both the tests which allowed marks to be compared. This was time-consuming, but it was done to supplement the analysis.

Table 4.11: Comparison between students' performance on the pre-test and post-test

Students Pseudonym	Pre-Test Mark	Post-Test Mark
1- Loreen the great	8	12
2- Cramberry Cross	4	12
3- Doctor strange	6	10
4- Kasi girl	6	12
5- Power girl	8	14
6- Thor	8	10
7- Gde	4	8
8- Frozen 3	6	14
9- Tandoobamboo	4	12
10- Rose Mary	6	12
11- Rachel	6	10
12- Sne	2	6
13- Ubabakaduduzani	8	14
14- Frozen 2	12	14
15- Good girl	2	14
16- Ishowspeed cccc	6	10
17- Lu	10	8
18- Pynociounos	2	10
19- The ccb boy	2	10
20- Koko 1 5	4	6
21- Neymar Jr	6	14
22- Whatsapp	4	14
23- Uber eats	8	14
24- Cj the b boy	10	14
25- Betman	6	14
26- Carparking 7	4	14
27- Agent 47	8	14
28- Undertaker	2	14
29- Layla	2	8
30- Speedy	6	6
31- King Jason	10	14
32- Mrs Multiples	6	10
33- Black spy	2	10
34- Afromen	6	6
35- Gabisele	8	8
36- Spongebob	2	12
37- Kairo. Sk	4	10
38- Sky	8	8
39- The frozen star 1	8	10
40- Oman	4	12
41- Black cat	4	14

Out of the 41 students, 36 students' marks improved when using branching Google Forms with multimedia, which is a significant improvement. There were four students whose marks remained the same for both the pre-test and post-test (highlighted in green) and one student who performed worse in the post-test than the pre-test (highlighted in red).

4.5 Summary of findings

The presentation of the findings aimed to answer the following research questions.

1- **"What are the difficulties that students currently face when solving mathematical word problems?"**

A pre-test was used to establish the answer to this question. Students were facing difficulty with understanding the words in the problems, not knowing which operation to use, and making mistakes when calculating.

2- **"How do the intervention results portray students' enhancement of problem-solving skills through branching Google Forms with multimedia?"**

Pólya's four steps and Google Forms provided guidance and feedback to students while they tackled the word problems. The YouTube videos helped to represent the word problems through narration and animation, to ensure that deeper meaningful learning takes place. Overall, students' performance scores significantly increased from the pre-test to the post-test. This indicates that branching Google Forms with multimedia was able to enhance students' word problem-solving skills in mathematics.

CHAPTER FIVE: DISCUSSION, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

This chapter begins with a discussion of the findings that leads to the conclusion, indicating limitations and challenges posed while conducting the research and providing recommendations for further study.

5.2 Discussion

This action research began with the issue of Grade 5 students struggling to solve word problems in mathematics.

5.2.1 The significance of using Pólya's four steps for problem-solving and branching Google Forms with multimedia to enhance students' word problem-solving skills in mathematics

Pólya's four steps for problem-solving guided students as they tackled the word problems. Google Forms provided immediate feedback to students showing them which questions they got correct and incorrect. Words of encouragement were attached to each correct and incorrect answer, serving as a positive reinforcement for students. The branching feature redirected students to the embedded multimedia that was attached to each incorrect question. The multimedia used were YouTube videos which included narration and animation, for students to hear and see aspects of the word problem. According to Mayer (2005), deeper learning takes place when words (narration or text) and pictures are used, as opposed to either one alone. This adhered to Mayer and Moreno's (1998) multiple representation principle. Therefore, multimedia helped to reduce the cognitive load of students by representing word problems visually and auditory (Zheng et al., as cited in Aadzaar & Widjajanti, 2019).

The videos served as a reminder and summary of how to calculate arithmetic operations (+, -, ×, ÷) as well as explaining words (for example: discount, doubles) to students. Most students already knew how to do arithmetic operations, however, they struggled to identify the correct operation to use or the steps to complete the operation successfully. In Mayer's active processing assumption, he speaks about meaningful construction of knowledge taking place when students are able to focus on relevant material and integrate it with prior knowledge (Sorden, 2012). Mayer's CTML ensured that only relevant videos were selected, to avoid cognitive overload and to ensure that students focus on exactly what they need to solve the word problems.

Numbers and words were also placed closer to the pictures, and both were presented simultaneously, which adhered to Mayer and Moreno's (1998) contiguity and split-attention multimedia design principle. By eliminating cognitive overload, students were able to focus on the relevant material and integrate it with their prior knowledge of how to solve arithmetic operations. As mentioned earlier, students are able to remember 50% from hearing and seeing, as opposed to 10% from reading only, 20% from hearing only and 30% from seeing only (Lopez, as cited in Rigzin & Chalermnirundorn, 2021). Students were able to remember more from the videos which enabled them to do better with their second attempt at the test.

5.2.2 Contingencies put in place to ensure intervention success

Students were excited and showed interest in working on word problems in the computer lab, thus improving their marks in the post-test. As mentioned earlier, intrinsic motivation increases students' engagement and performance in a subject (OECD, 2013; Yunus & Ali, 2009 as cited in Mazana et al., 2019). In this study, this was facilitated by the support the teacher gave in terms of alleviating frustration that may have been caused by the technology use. As a result, more students were engaged and focused on their work. There was an increase in the number of students who indicated having positive emotions towards problem-solving from 22 students in the pre-test to 31 students in the post-test. Students enjoyed the fact that Google Forms helped them to understand the questions better and to find the correct operation, told them when they were wrong and pointed them in the right direction and they found the multimedia helpful. This agrees with the study conducted by Hart and Laher (2019, p. 7) with 276 Johannesburg students, where they found that "access to technology does not predict students' achievement but rather that attitudes towards technology – enjoyability, in particular, predict learner achievement".

More students started taking note of the keywords in problems and doing their working out on a page. The earlier support and the videos could have contributed to this behaviour that facilitates the identification of the problem. Videos allowed students to have more freedom to identify the problem by being able to replay, pause and skip video sections (Wu et al., 2021). Half of the students used the inverse operation to evaluate their answers. This indicates that students were applying Pólya's four steps for problem-solving which proved to be beneficial. Although students' performance increased significantly after intervention, there were still 29 students who indicated facing difficulties with problem-solving using Google Forms. The difficulties that students mentioned were different from the pre-test. New difficulties emerged such as difficulty using the computer, using Google Forms, and still making mistakes while calculating. If students find technology difficult to use then they will most likely not want to continue using it (Hart & Laher, 2019). From the observations, there were still a few students who used the wrong operation. More time needs to be spent teaching students how to use the computer and Google Forms.

5.2.3 Outcome of the intervention

For this research, the interventions were focused on improving students' word problem-solving skills in mathematics by using branching Google Forms with multimedia. To evaluate if there was an improvement, performance scores from the pre-test and post-test were compared. Students' average marks increased from 6 to 11, the class average increased from 40% to 80% and the P value was 0.0001. Overall, 36 students obtained higher marks in the post-test. All of these statistics indicate that the interventions were successful and that branching Google Forms with multimedia was able to enhance students' word problem-solving skills in mathematics. It must be noted that as much as the interventions were successful, there are facilitating learning factors that must be taken care of to ensure that student engagement is inclusive. In this study, for instance, all students had to be trained on how to operate the hardware and the software to ensure that the lack of computer skills does not interfere with their academic engagement. This agrees with the study by Heidari et al., (2021) where they maintain that digital competence and skills can increase students' academic engagement.

5.2.4 Response to the main question

"How can branching Google Forms with multimedia be used to enhance word problem-solving skills in mathematics?"

From the analysis of their difficulties, three interventions were designed and developed to enhance students' problem-solving skills. The first intervention aimed at teaching students a method for working through word problems, using Pólya's four steps for problem-solving. The second intervention aimed to teach students computer skills and to introduce them to branching Google Forms with multimedia. The third intervention was to conduct the post-test in the computer lab using branching Google Forms with multimedia.

5.3 Limitations of the Study

Even though the school has a computer lab, there is still a need to address the lack of ICT software and hardware. The school lacked basics like keyboards and mouses, which had to be ordered and then connected, this impacted on time. The school also needs an onsite computer technician to address problems that arise immediately. Further to the time constraint, the school experienced three break-ins during that school term. During one of the break-ins the cables were stolen which took about another two weeks to sort out. Lastly, the school does not have a generator for the computer room, therefore load-shedding affected contact time with the students. These were the main reasons why students had less time learning how to use the computer and Google Forms.

5.4 Recommendations

Future researchers using Google Forms and conducting research with students from public schools who are not familiar with using the computer should take more time teaching students how to use the computer as opposed to a computer literacy crash course. Google Forms could be created using multiple languages to cater for non-English speaking students and be used in all subjects, not just mathematics. For example, Google Forms can be used for quizzes and students would receive immediate feedback. This would also free up a lot of time for educators, instead of having to manually mark papers. The government should also consider investing in ICT infrastructure for underprivileged schools and more training and support for teachers to successfully integrate ICT into their daily teaching. Curriculum planners should integrate ICT into the annual teaching plan and curriculum, to equip students with ICT skills that are needed to thrive in the 21st century. Computers can be implemented into the curriculum as a subject on its own or have allocated time in other subjects (for example: computers for 30 minutes a week in mathematics). Educators should seize every opportunity to introduce technology into their lessons. According to Abdul-Razak (2020), the Department of Basic Education has developed guidelines for managing and using ICTs in public schools, but it is up to individual schools and all their stakeholders to get on board with the successful integration of ICT. When trying to gather qualitative responses in research, it is recommended that the questions are completely open-ended and to not provide students with options to choose from. Students are more likely to choose options than give their own responses. Future researchers can continue this research by using a larger sample size in different geographical locations to see if the results show consistency.

5.5 Conclusion

This chapter concluded the entire research by providing a summary of how the research unfolded. It explained the significance of using Pólya's four steps for problem-solving and branching Google Forms with multimedia. It provided a summary of the findings using thematic analysis and descriptive statistics which indicated that the interventions were successful in enhancing students' problem-solving skills through the use of branching Google Forms with multimedia. Limitations of the study and recommendations for future research were also mentioned. In a final remark, it is evident that ICT has the potential to contribute positively to teaching and learning. However, it is up to all stakeholders in the education system, to take the initiative and ensure the successful integration of ICT into schools.

References

Aadzaar, R. M., & Widjajanti, D. B. (2019). Multimedia: An alternative to improve self-regulated learning and mathematical problem-solving skills. In *Journal of Physics: Conference Series* (Vol. 1320). IOP Publishing.

Abdul-Razak, N. (2020). *Teachers' experiences of ICT use in Grade 5 mathematics classrooms* [Unpublished doctoral dissertation]. University of Pretoria.

Acharya, A. S., Prakash, A., Saxena, P., & Nigam, A. (2013). Sampling: Why and how of it. *Indian Journal of Medical Specialties*, *4*(2), 330-333. http://dx.doi.org/10.7713/ijms.2013.0032

Amin, M. E. K., Nørgaard, L. S., Cavaco, A. M., Witry, M. J., Hillman, L., Cernasev, A., & Desselle, S. P. (2020). Establishing trustworthiness and authenticity in qualitative pharmacy research. *Research in Social and Administrative Pharmacy*, *16*(10), 1472-1482.

Amuko, S., Miheso, M., & Ndeuthi, S. (2015). Opportunities and challenges: Integration of ICT in teaching and learning mathematics in secondary schools, Nairobi, Kenya. *Journal of Education and Practice*, *6*(24), 1-6.

Ardington, C., Wills, G., & Kotze, J. (2021). COVID-19 learning losses: Early grade reading in South Africa. *International Journal of Educational Development*, *86*, 102480.

Bohlmann, C. A., & Pretorius, E. J. (2002). Reading skills and mathematics: the practice of higher education. *South African Journal of Higher Education*, *16*(3), 196-206.

Braun, V., & Clarke, V. (2012). *Thematic analysis*. American Psychological Association.

Brown, J. D. (2009). Open-response items in questionnaires. In J. Heigham & R. A. Croker (Ed.), *Qualitative research in applied linguistics: A practical introduction* (pp. 200-220). Springer.

Burns, A. (2009). Action research. In J. Heigham & R. A. Croker (Eds), *Qualitative research in applied linguistics: A practical introduction* (pp. 112-135). Springer.

Bush, T. (2012). Authenticity in research: Reliability, validity and triangulation. *Research Methods in Educational Leadership and Management*, *6*(19), 75-89.

Cabrera Jaime, S., Martinez, C., Gonzalo Bachiller, V., Zarza Arnau, N., Martin Maldonado, L., Belén Manrique Palles, A., & Cabrera Jaime, L. (2023). Participatory action research intervention for improving sleep in inpatients with cancer. *Journal of Clinical Nursing*, *32*(7-8), 1218-1229.

Cassim, V. (2010). *The pedagogical use of ICTs for teaching and learning within grade eight mathematics in South African schools* [Unpublished doctoral dissertation]. North-West University.

Castro, R. (2018) *Routine and non-routine problems* [PowerPoint slides]. https://www.slideshare.net/reycastro1/routine-and-non-routine-problems

Cheung, L. (2016). Using the ADDIE model of instructional design to teach chest radiograph interpretation. *Journal of Biomedical Education*, 1-6.

Cowie, N. (2009). Observation. In J. Heigham & R. A. Croker (Eds), *Qualitative research in applied linguistics: A practical introduction* (pp. 165-182). Springer.

Creswell, J. W., Clark, V. L. P., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed. *Handbook of mixed methods in social & behavioral research* (p. 209). Sage.

Das, K. (2019). Role of ICT for better mathematics teaching. *Shanlax International Journal of Education*, *7*(4), 19-28.

De Witte, K., & Rogge, N. (2014). Does ICT matter for effectiveness and efficiency in mathematics education? *Computers & Education*, *75*, 173-184.

Department of Basic Education. (2014). *Report on the Annual National Assessment of 2014.* https://www.education.gov.za/.

Dlamini, R., & Mbatha, K. (2018). The discourse on ICT teacher professional development needs: The case of a South African teachers' union. *International Journal of Education and Development using ICT*, *14*(2), 1-21.

Dlamini, R., & Na'Allah, D. M. (2015). Beyond policies and programs: Contextualizing ICT integration in South African schools. In *South Africa International Conference on Educational Technologies* (Vol. 162).

Douell, M. (2020). Integrating Google Forms as a means of formative assessment in the elementary math classroom. https://egrove.olemiss.edu/cgi/viewcontent.cgi?article=2472&context=hon_thesis

Ertmer, P. A., & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *6*(4), 50-72. https://psycnet.apa.org/doi/10.1111/j.1937-8327.1993.tb00605.x

Fonseca, A., & Faria, H. (2021). Adaptive knowledge assessment using advanced concept maps with logic branching multiple-choice Google Forms. *ELearn*, *2021*, (Special Issue), 1-12. http://dx.doi.org/10.1145/3466623

Ghavifekr, S., Kunjappan, T., Ramasamy, L., & Anthony, A. (2016). Teaching and learning with ict tools: Issues and challenges from teachers' perceptions. *Malaysian Online Journal of Educational Technology*, *4*(2), 38-57. https://files.eric.ed.gov/fulltext/EJ1096028.pdf

Google Help. (2019). Changing the theme or font of your form. https://support.google.com/docs/answer/145737?hl=en

Gustafsson, M., & Deliwe, C. N. (2020). *How is the COVID-19 pandemic affecting educational quality in South Africa. Evidence to date and future risks.* University of Stellenbosch.

Hanafiah, H., Priyanda, R., & Fadhelina, N. (2020). The effectiveness of using google form assisted student worksheets in increasing learning independence and student mathematic communication skills in SMP Negeri 5 Langsa. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, *3*(4), 3091-3092.

Hart, S. A., & Laher, S. (2019). The role that access and attitudes toward tablets have on learners' achievement in a Johannesburg school. *South African Journal of Education*, *39*(3), 1-11.

Heidari, E., Mehrvarz, M., Marzooghi, R., & Stoyanov, S. (2021). The role of digital informal learning in the relationship between students' digital competence and academic engagement during the COVID-19 pandemic. *Journal of Computer Assisted Learning*, *37*(4), 1154-1166.

Herselman, M., & Britton, K. G. (2002). Analysing the role of ICT in bridging the digital divide amongst learners. *South African Journal of Education*, *22*(4), 270-274.

Howie, S. J. (2003). Language and other background factors affecting secondary pupils' performance in Mathematics in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, *7*(1), 1-20.

Myfreemathworksheets. (n.d.) https://www.myfreemathworksheets.com

Hwang, W. Y., Chen, N. S., Dung, J. J., & Yang, Y. L. (2007). Multiple representation skills and creativity effects on mathematical problem solving using a multimedia whiteboard system. *Journal of Educational Technology & Society*, *10*(2), 191-212.

Jojo, Z. (2019). Mathematics education system in South Africa. In J. Porto (ed.), *Education systems around the world* (pp. 129-140). Intech Open. https://doi.org/10.5772/intechopen.77636

Kaipa, R. M. (2021). Multiple choice questions and essay questions in curriculum. *Journal of Applied Research in Higher Education*, *13*(1), 16-32.

Karami, M., Karami, Z., & Attaran, M. (2013). Integrating problem-based learning with ICT for developing student-teachers' content knowledge and teaching skill. *International Journal of Education and Development using ICT*, *9*(1), 36-49.

Liljedahl, P. (2008). Teachers' insights into the relationship between beliefs and practice. In In J. Maaß & W. Schlöglmann (eds), *Beliefs and attitudes in mathematics education: New research results* (pp. 33-44). Sense Publishers.

Liljedahl, P., Santos-Trigo, M., Malaspina, U., & Bruder, R. (2016). *Problem solving in mathematics education*. Springer Nature.

Lovemore, T. S., Robertson, S. A., & Graven, M. (2021). Enriching the teaching of fractions through integrating mathematics and music. *South African Journal of Childhood Education*, *11*(1), 899.

Mabena, N., Mokgosi, P. N., & Ramapela, S. S. (2021). Factors contributing to poor learner performance in mathematics: A case of selected schools in Mpumalanga province, South Africa. *Problems of Education in the 21st Century*, *79*(3), 451.

Masilo, M. (2015). Keeping pace with advances in multimedia to improve mathematical problem solving skills in classrooms. In *ISTE INTERNATIONAL CONFERENCE ON MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION* , 98.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), The *Cambridge handbook of multimedia learning*. Cambridge University Press.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*(2), 312–320. https://doi.org/10.1037/0022-0663.90.2.312

Mazana, Y. M., Suero Montero, C., & Olifage, C. R. (2019). Investigating students' attitude towards learning mathematics. *International Electronic Journal of Mathematics Education*, *14*(1), 207-231. https://doi.org/10.29333/iejme/3997

McChesney, K., & Aldridge, J. (2019). Weaving an interpretivist stance throughout mixed methods research. *International Journal of Research & Method in Education*, *42*(3), 225-238.

Meutia, I., Maulidiansyah, D., & Istiyono, E. (2021, March). Identifying the drawbacks of the problem-solving skills by using a three-tier diagnostic test with Google Form assistant. *6th International Seminar on Science Education (ISSE 2020)* (pp. 483-488). Atlantis Press.

Noble, H., & Heale, R. (2019). Triangulation in research, with examples. *Evidence-based Nursing*, *22*(3), 67-68.

Novotna, J. (2014). 13th European Conference on e-Learning ECEL-2014.

Özreçberoğlu, N., & Çağanağa, Ç. K. (2018). Making it count: Strategies for improving problem-solving skills in mathematics for students and teachers' classroom management. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1253-1261.

Petersen, B., McAuliffe, S., & Vermeulen, C. (2017). Writing and mathematical problem solving in Grade 3. *South African Journal of Childhood Education*, *7*(1), 1-9. https://dx.doi.org/10.4102/sajce.v7i1.483

Polya, G. (1949). *How to solve it.* Princeton University Press.

Polya, G. (1965). *Mathematical discovery: On understanding, learning and teaching problem solving* (vol. 2). Wiley.

Primta, S., Tayraukham, S., & Nuangchalerm, P. (2009). Factors influencing mathematic problem-solving ability of sixth grade students. *Online Submission*, *5*(4), 381-385.

Rallis, F., & Rossman, B. (2009). Ethics and trustworthiness. In J. Heigham & R. A. Croker (Eds), *Qualitative research in applied linguistics: A practical introduction* (pp. 263-288). Springer.

Reddy, B. V., Winnaar, L., Juan, A., Arends, F., Harvey, J., Hannan, S.,... & Zulu, N. (2020). *TIMSS 2019: Highlights of South African grade 9 results in mathematics and science: Achievement and achievement gaps*. Department of Basic Education.

Rey-Moreno, C., Blignaut, R., Tucker, W. D., & May, J. (2016). An in-depth study of the ICT ecosystem in a South African rural community: unveiling expenditure and communication patterns. *Information Technology for Development*, *22*(1), 101-120.

Rigzin, K., & Chalermnirundorn, N. (2021). The application of multimedia technology in teaching and learning mathematics of grade 5 Bhutanese students. *Academic Journal Phranakhon Rajabhat University*, *12*(2), 226-242. https://so01.tci-thaijo.org/index.php/AJPU/article/view/248043

Riyadi, Syarifah, T. J., & Nikmaturrohmah, P. (2021). Profile of students' problem-solving skills viewed from Polya's four-steps approach and elementary school students. *European Journal of Educational Research*, *10*(4), 1625-1638.

Rudolph, M. (2017). Cognitive theory of multimedia learning. *Journal of Online Higher Education*, *1*(2), 1-10.

Schulze, S., & Bosman, A. (2018). Learning style preferences and Mathematics achievement of secondary school learners. *South African Journal of Education*, *38*(1), 1-8.

Selinger, M. (2000). *Information and communication technology in schools*. Imfundo Knowledge Bank.

Siniguian, M. T. (2017). Students' difficulty in solving mathematical problems. *International Journal of Advanced Research in Engineering and Applied Sciences*, *6*(2), 1-12.

Siyepu, S. (2013). The zone of proximal development in the learning of mathematics. *South African Journal of Education*, *33*(2), 1-13. http://dx.doi.org/10.15700/saje.v33n2a714

Sorden, S. D. (2012). The cognitive theory of multimedia learning. *Handbook of Educational Theories*, *1*, 1-22. https://www.academia.edu/29834388/The_Cognitive_Theory_of_Multimedia_Learning

Starja, D., Shity, B., & Nikolova, N. (2020). The role of ICT in improving problem-solving in teaching mathematics. *EDULEARN20 Proceedings* (pp. 2651-2659). IATED.

T test calculator. (n.d.). http://www.graphpad.com

Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: What do they say? *Procedia-Social and Behavioral Sciences*, *8*, 142-151. https://doi.org/10.1016/j.sbspro.2010.12.020

Tashakkori, A., & Creswell, J. W. (2007). The new era of mixed methods. *Journal of Mixed Methods Research*, *1*(1), 3-7. https://doi.org/10.1177/2345678906293042

Thanh, N. C., & Thanh, T. T. (2015). The interconnection between interpretivist paradigm and qualitative methods in education. *American Journal of Educational Science, 1*(2), 24-27. https://www.semanticscholar.org/paper/The-Interconnection-Between-Interpretivist-Paradigm-Thanh-Th%C3%A0nh/79e6888e672cf2acf8afe2ec21fd42a29b2cbd90

Vetter, T. R. (2017). Descriptive statistics: reporting the answers to the 5 basic questions of who, what, why, when, where, and a sixth, so what? *Anesthesia & Analgesia*, *125*(5), 1797-1802. https://doi.org/10.1213/ane.0000000000002471

Wedekind, V. (2013). *NSC pass requirements*. Umlasi.

What is a word problem? (n.d.). https://www.theschoolrun.com

Widodo, S. A., Darhim, K., & Ikhwanudin, T. (2018). Improving mathematical problem-solving skills through visual media. *Journal of Physics: Conference Series* (Vol. 948). IOP Publishing.

Wu, C., DeBoer, J., Rhoads, J. F., & Berger, E. (2022). Use of worked-example videos to support problem-solving: An analysis of student behavior. *Computer Applications in Engineering Education*, *30*(1), 195-221.

Zhen, Y. (1999). *Improving students' math problem-solving skills in a computer-assisted learning environment* [Unpublished master's thesis]. California State University.

Appendices

Appendix A: Approval Letter from the Graduate Studies Committee

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HUMANITIES

15 May 2023

Person Number: 2395393

Ms Yvette Pillay
By Email: 2395393@students.wits.ac.za
Cc: Dr. Nokulunga Ndlovu

RESULTS FOR THE DEGREE OF MASTER OF EDUCATION PROPOSAL

I am pleased to be able to advise you that the readers of the Graduate Studies Committee have reviewed your proposal entitled ***"Using branching Google Forms with multimedia to enhance word problem-solving skills in Mathematics"*** and recommended the research proposal can pass subject to minor revisions to the satisfaction of the supervisor.

I confirm that **Dr. Nokulunga Ndlovu** has been appointed as your supervisor.

Kindly liaise with your supervisors regarding the contents of the reader's report.

The reader's report has been emailed to your supervisor.

The research report is normally submitted to the Faculty Office by 15 February, if you have started the beginning of the year, and for mid-year the deadline is 31 July. All students are required to RE-REGISTER at the beginning of each year

Please note that should you miss the deadline of 15 February or 31 July you will be required to submit an application for extension of time and register for the research report extension. Any candidate who misses the deadline of 15 February will be charged fees for the research report.

Please keep us informed of any changes of address during the year.

Note: All MA and PhD candidates who intend graduating shortly must meet the ETD requirements at least 6 weeks after your supervisor has received the examiners reports. **A student must remain registered at the Faculty Office until graduation.**

Regards,

Faith Herbert

Faith Herbert
Senior Faculty Officer
Faculty of Humanities
Education Campus
Tel: +27 11 717 3018
Email: faith.herbert@wits.ac.za

Private Bag 3, WITS 2050, South Africa | T +27 11 717 4007 | E help.humanities@wits.ac.za | www.wits.ac.za/humanities

IYUNIVESITHI YASEWITWATERSRAND | YUNIVESITHI YA WITWATERSRAND

Appendix B: Permission from the Gauteng Department of Education

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**31 July 2023**
Validity of Research Approval:	**08 February 2023– 30 September 2023** **2023/294**
Name of Researcher:	**Pillay YU**
Address of Researcher:	**51 Avalon Road**
	Modderfontein
Telephone Number:	**084 502 1401**
Email address:	**yvetteuzzielpillay@gmail.com**
Research Topic:	**Using branching Google Forms with multimedia to enhance word problem-solving skills in Mathematics**
Name of University:	**Wits**
Type of qualification	**Masters**
Number and type of schools:	**1 Primary School**
District/s/HO	**Johannesburg East**

Re: Approval in Respect of Request to Conduct Research

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

31|07|2023

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

1

Making education a societal priority

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

Appendix C: Letter Requesting Permission from the School Principal

University of the Witwatersrand,

School of Education,

Educational Technology,

27 St Andrews Road,

Parktown,

Johannesburg,

2193

[redacted]

Johannesburg,

2094

21 June 2023

Dear Sir/Madam,

Re: Permission to conduct research at [redacted] School.

My name is Yvette Uzziel Pillay.

I am studying for a Master's Degree in the School of Education at the University of the Witwatersrand. I am seeking permission to do research at [redacted] School.

Many students' struggle to solve word problems in mathematics. Therefore, I am conducting research about using Information and Communications Technology (ICT) to assist students with problem-solving in mathematics. The study title is "Using branching Google Forms with multimedia to enhance word problem-solving skills in mathematics".

The research will entail collecting data from about 40 Grade 5 students, depending on the number of consents granted. Students will be invited to take part in a questionnaire and to be a part of the intervention where I show them how to tackle word problems, use a computer and use Google Forms. This research will last for 9 hours. The research activities will take place at the school's computer lab from 14:00 to 14:30 on Mondays and Fridays from the 24th of July to the 22nd of September. On Tuesdays, Wednesdays, and Thursdays there will be no research activities because of the after school remedial classes.

Students will be asked to give their written or verbal consent before the research begins. I will explain to students that this research may have the potential to help them in mathematics and to improve their word problem-solving skills. I will make them feel comfortable and tell them that it is not for marks. It should be done as a normal classwork activity, so they do not feel overwhelmed or anxious.

Their responses will be treated confidentially, and identities (their real names and the name of the organisation) will be anonymous. Students will be asked to create a fun pseudonym. After students write their pseudonym on the pre-test page, I will get another student to collect all the pages. In this way I will not know which pseudonym is for which student. For the post-test, students will enter their pseudonym on the Google Form, I will not be standing next to them at this time, to avoid finding out who the pseudonym belongs to. Individual privacy will be maintained in all published and written data resulting from the study.

Given that parents and students permit, I would like to take a few photos of the students in the computer lab. The photos will be taken to capture and document the experience. Photos will be taken out from behind students, so their faces will not be shown.

All research data will be stored in a password protected computer and for future secondary analysis. Only the researcher will have access to the data. This research study will be written up as a research report. If you would like to receive a summary of this report, I will be happy to send it to you.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. If students do not want to participate anymore, then they can do something else while they wait till 14:30. Their parents will then be notified of their withdrawal.

There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

I therefore request permission in writing to conduct my research at your organisation. The permission letter should be on your organisation's headed paper, signed and dated, and specifically referring to myself by name and the title of my study.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Yvette Uzziel Pillay

Researcher:
Yvette Uzziel Pillay, 2395393@students.wits.ac.za, 084 502 1401

Supervisor:
Dr Nokulunga Ndlovu, Nokulunga.Ndlovu@wits.ac.za, 011 717 3077

Appendix D: Participant Information Sheet - Parents

Dear Sir / Madam

My name is Yvette Uzziel Pillay. I am a Master's student in Educational Technology at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Nokulunga Ndlovu. Many students' struggle to solve word problems in mathematics. Therefore, I am conducting research about using Information and Communications Technology (ICT) to assist students with problem-solving in mathematics. The research title is "Using branching Google Forms with multimedia to enhance word problem-solving skills in mathematics".

I am inviting your child to take part in a questionnaire and to be a part of the intervention where I show them how to tackle word problems, use a computer and use Google Forms. They will be asked to take a pre-test and post-test (which will be done as a normal classwork activity). This research may have the potential to help them in mathematics and to improve their word problem-solving skills. If you decide to allow your child to take part, their participation in this research will last for 9 hours. The research activities will take place at the school's computer lab from 14:00 to 14:30 on Mondays and Fridays from the 24th of July to the 22nd of September.

With your permission, I would like to take a few photos of the students in the computer lab. The photos will be taken to capture and document the experience. Photos will be taken out from behind students, so your child's face will not be shown. Data gathered from this research will be stored in a password protected computer and for future secondary analysis. Only the researcher will have access to the data.

The questionnaire will be confidential and anonymous. When I share the results of the research study, I will not include your child's name or anything else that could identify them. They will be asked to create a fun pseudonym. After students write their pseudonym on the pre-test page, I will get another student to collect all the pages. In this way I will not know which pseudonym is for which student. For the post-test, students will enter their pseudonym on the Google Form, I will not be standing next to them at this time, to avoid finding out who the pseudonym belongs to. With your permission, other researchers may use the data collected from this research study, but your child's name and any personal information will not be used or passed on.

If you decide to let your child take part in the research study, it should be because he/she wants to volunteer. He/she does not have to take part. He/she can stop being in the study at any time. He/she does not have to answer any questions if he/she does not want to. If students do not want to participate anymore, then they can do something else while they wait till 14:30. Other educational games could be played on the computer. You will then be notified of their withdrawal.

Your child will not get any direct benefits if he/she chooses to join the research study. He/she will not lose any benefits, or rights that he/she would normally have if he/she decides not to join. Taking part in the research study will not cost anything. He/she will not be paid for being in this research study. If you decide to let your child participate in this research, please make the necessary transport arrangements to pick your child up after school. The risks for this research study are no more than what happens in everyday life. This is considered as a low-risk research study. This research study will be written up as a research report. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,
Yvette Uzziel Pillay

Researcher:
Yvette Uzziel Pillay, 2395393@students.wits.ac.za, 084 502 1401

Supervisor:
Dr Nokulunga Ndlovu, Nokulunga.Ndlovu@wits.ac.za, 011 717 3077

Appendix E: Consent Form – Parents

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Consent Form

Using branching Google Forms with multimedia to enhance word problem-solving skills in Mathematics

Researcher: Yvette Uzziel Pillay

I, ……………………………………. agree to allow my child ………………………………….. to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES NO
I understand that my child can volunteer to take part in the study.	YES NO
I agree that photographs can be taken, provided that my child's face is not showing.	YES NO

I agree that direct quotations from the questionnaire and the tasks/activities that my child has to do, may be used by the researcher in their research report.	YES NO
I agree that my child's participation will remain anonymous (their real name will not be used by the researcher in their research report).	YES NO
I agree that other researchers may use the information my child provides in the questionnaire (depending on their own ethics clearance being obtained) but their name and any personal information will not be used or passed on.	YES NO

…………………………………… (signature)

…………………………………… (name of parent/guardian)

…………………………………… (date)

Appendix F: Participant Information Sheet - Students

Good Day Student

My name is Ms Pillay. I am a Master’s student in Educational Technology at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Nokulunga Ndlovu.

Many students’ struggle to solve word problems in mathematics.

Therefore, I am conducting a research study about using computers to assist students with problem-solving in mathematics. The research title is “Using branching Google Forms with multimedia to enhance word problem-solving skills in mathematics”.

I am inviting you to take part in a questionnaire and to be a part of the intervention where I show you how to tackle word problems, use a computer and use Google Forms. You will be asked to take a pre-test and post-test (which will be done as a normal classwork activity). This research may have the potential to help you in mathematics and to improve your word problem-solving skills. If you decide to take part, your participation in this research study will last for 9 hours. I am asking that you come to the school’s computer lab from 14:00 to 14:30 on Mondays and Fridays from the 24th of July to the 22nd of September.

With your permission, I would like to take a few photos of the intervention in the computer lab. Your face will not be shown in any photos. The photos will be taken out from behind you. The photos will be taken to capture and document the experience.

☺

When I share the results of the research study, I will not include your name or anything else that could identify you. You can create a fun pseudonym (example – MATHS GURU). After you write your pseudonym on the pre-test page, I will get another student to collect all the pages. In this way I will not know your pseudonym. For the post-test, you will enter your pseudonym on the Google Form, I will not be standing next to you at this time, to avoid finding out your pseudonym.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. If you do not want to participate anymore, then you can do something else while you wait till 14:30. Other educational games could be played on the computer. Your parents will then be notified of your withdrawal.

You will not get any direct benefits if you choose to join the research study. This is not for your school marks. Taking part in the research study will not cost anything. You will not be paid for being in this research. If you decide to participate in this research, please ask your parents to make the necessary transport arrangements to pick you up after school.

If you have any questions during or afterwards about this research study, feel free to contact me on the details listed below.

Yours sincerely,
Ms Pillay

Researcher:
Ms Pillay, 2395393@students.wits.ac.za, 084 502 1401

Supervisor:
Dr Nokulunga Ndlovu, Nokulunga.Ndlovu@wits.ac.za, 011 717 3077

Appendix G: Assent form – Students

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Assent Form

<u>Using branching Google Forms with multimedia to enhance word problem-solving skills in Mathematics</u>

Researcher: Yvette Uzziel Pillay

I, ……………………………………….., agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES NO
I understand that I can volunteer to take part in the study.	YES NO

I agree that photographs can be taken, provided that my face is not showing.	YES NO
I agree that direct quotations from the completion of the questionnaire and the tasks/activities that I have to do, may be used by the researcher in their research report.	YES NO
I agree that my participation will remain anonymous (my real name will not be used by the researcher in their research report).	YES NO
I agree that other researchers may use the information I provide in my questionnaire (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on.	YES NO

…………………………………… (signature)

…………………………………… (name of participant)

…………………………………… (date)

Appendix H: Observation Checklist

OBSERVATION CHECKLIST (PRE-TEST AND POST-TEST)

1. Were students focused during the pre-test?
2. Did students underline or highlight key words from the problems?
3. Did students use the space provided to do their working out?
4. Did students use the correct operation (+,-,×,÷) to answer the questions?
5. If students chose the correct operations, were they able to solve the sums successfully?
6. Did students evaluate their answers?
7. Any other meaningful observations.

Appendix I: Pre-test

GRADE 5 MATHEMATICS PROBLEM-SOLVING PRE-TEST

Pseudonym: ________________________________

General questions

1. How do you feel about solving word problems in mathematics?
   a) Happy
   b) Sad
   c) Overwhelmed
   d) Angry
   e) If other - please specify

   ____

   ____

   ____

2. What do you like about problem-solving?
   a) It challenges me to think outside the box
   b) It is exciting to solve
   c) The sentences are interesting to read
   d) I do not like anything about problem-solving
   e) If other - please specify

   ____

   ____

   ____

3. What do you find difficult about problem-solving?
   a) I cannot understand the words
   b) I do not know which operation (+,-,×,÷) to use when solving the problem
   c) After I figure out which operation to use, I make mistakes when calculating
   d) I do not find anything difficult about problem-solving
   e) If other - please specify

____

____

____

Word problems – Circle the correct answer and show your working out [7×2 = 14 marks]

4. The chicken pen held 7 chickens. Each chicken lays 6 eggs a day. How many eggs would they get altogether after 30 days?
   a) 1200
   b) 1000
   c) 1260
   d) 2500

____

____

____

____

____

5. Khanya cut 4 pieces of wood for her school project. The pieces of wood were 4.2 m, 3.5 m, 3.7 m, and 9.2 m. She put them altogether to form one long piece of wood. How long was it?
   a) 30,6 m
   b) 20,6 m
   c) 24,2 m
   d) 32,3 m

____

____

____

____

____

6. Njabulo ordered 9 pizzas for his birthday party. Each pizza had 8 slices. There were 12 people (including Njabulo) at his party. How many slices did they each get?
   a) 2
   b) 3
   c) 5
   d) 6

7. A local car company was able to make 12 cars a week for 4 weeks. They doubled this amount over the next 4 weeks. How many cars did they make after the 8 weeks?
   a) 140
   b) 144
   c) 44
   d) 100

8. Emmanuel makes toy cars. He wants to make 1,500. Emmanuel can make 18 cars a day. He has already made 492. How many days will it take him to get to 1,500?
   a) 56
   b) 46
   c) 20
   d) 5

9. Melusi and his 2 friends read 55 books each for the year. Each book had an average of 320 pages. How many pages did they all read in total that year?
   a) 26 820
   b) 12 600
   c) 52 800
   d) 17 400

   ____

   ____

   ____

   ____

   ____

10. Amahle wants to buy a car that costs R 152 000. The car dealership is willing to give her a R7 000 discount. How much will the car cost after the discount?
    a) R150 000
    b) R100 000
    c) R143 000
    d) R145 000

    ____

    ____

    ____

    ____

    ____

TOTAL: ______________________

Appendix J: Editor's Letter

Nikki Watkins
Editing/proofreading services
Cell: 072 060 2354 E-mail: nikki.watkins.pe@gmail.com

18 March 2024

To whom it may concern

This letter confirms that I have language edited and proofread the master's thesis

Using branching Google Forms with multimedia to enhance word problem-solving skills in mathematics

By

Yvette Uzziel Pillay

Professional EDITORS' Guild
30 1993–2023
Promoting excellence in editing

Nikki Watkins
Associate Member

Membership number: WAT003
Membership year: March 2023 to February 2024

072 060 2354
nikki.watkins.pe@gmail.com

www.editors.org.za

UK Centre of Excellence Editing and Proofreading Diploma
SA Writers College Certificate of Copy-Editing and Proofreading

All changes were indicated by Track Changes (MS Word) for the author to verify. As the editor I am not responsible for any changes not implemented, any plagiarism or unverified facts. The final document remains the responsibility of the author.

Appendix K: Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | WSoE Wits School of Education

SCHOOL OF EDUCATION ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: 2023ECE044M**
PROJECT TITLE	Using branching Google Forms with multimedia to enhance word problem-solving skills in Mathematics
INVESTIGATOR	Yvette Uzziel Pillay
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	10 July 2023
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	**LOW RISK**
EXPIRY DATE	Date of submission of the Research Report
ISSUE DATE OF CERTIFICATE	24 JULY 2023
CHAIRPERSON	Mbokane Dr. Batseba Mofolo-Mbokane

cc: Dr. Nokulunga Ndlovu