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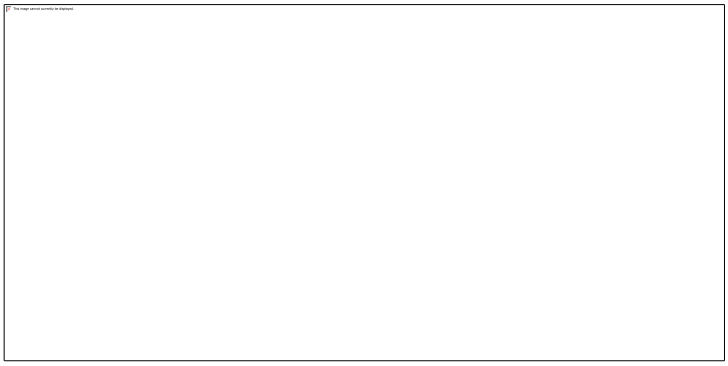

FACULTY OF SCIENCE EDUCATON

DEPARTMENT OF SCIENCE AND MATHS EDUCATION

RESEARCHTOPIC: ERRORS MADE BY ORDINARY LEVEL LEARNERS WHEN CALCULATING MAGNITUDE OF VECTORS AT A SCHOOL IN MAKONDE DISTRICT.

BY

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REGISTRATION NUMBER: B225905A

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF BACHELOR OF SCIENCE HONOURS DEGREE IN MATHEMATICS EDUCATION.

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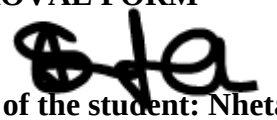

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DEDICATION

To my beloved family, whose unwavering support and encouragement fueled my passion for research and learning. This project is dedicated to you, with love and gratitude.

ABSTRACT

This research investigates the errors made by ordinary level learners when calculating magnitude of vectors at one secondary school in Makonde District in Mashonaland west, with a particular focus on identifying the types of errors encountered. The sample had sixteen learners drawn from a population of forty-five learners. Three teachers were also interviewed. The method used to select learners and teachers was unbiased. Through a mixed- methods approach, data were collected from general exercises, test and interviews with teachers and students to analyze their problem-solving processes. The findings reveal three primary categories of errors: computational, procedural and conceptual. Computational errors often stem from arithmetic mistakes during calculations, while procedural errors arise from misunderstandings of steps required to calculate vector magnitude. Conceptual errors are characterized by lack of understanding of the fundamental properties of vectors and their magnitudes. This study highlights the need for targeted instructional strategies that address these specific error types, thereby enhancing learners' comprehension and skills in vector calculations. The study recommends that teachers use a variety of methods, provide additional support to learners and learners should use online resources to supplement their learning.

Contents

CHAPTER 1

1.1 Introduction

This chapter focuses on the background of study, statement of the problem, significance of the study, research questions and objectives, limitations of the study and delimitations of the study. Key terms are also defined

1.2 Background of the study

Vector calculation is a fundamental concept in mathematics and physics, and errors made by learners in this area can have significant implications for their future academic and professional pursuits (Harrison & Treagust, 2017). According to Kaur &Ayub, (2019) learners worldwide struggle with vector calculations, particularly when it comes to calculating magnitude of vectors. A study by Redish &Smith, (2017) found that even university students struggle with vector calculations, highlighting the need for effective teaching strategies at elementary school to address these errors. In Africa, the teaching and learning of mathematics and science have been identified areas of concern.Mji & Makgato, (2017) say African learners often struggle with abstract concepts such as calculating vector magnitude and that teachers often lack the necessary training and resources to effectively teach these concepts. A study by Otieno & Mbugua (2020) found that Kenya High School students made different errors in vector calculations particularly when it comes to calculating magnitude.

The study of vectors is a fundamental component of secondary level mathematics curriculum, with topics such as vector addition, subtraction and magnitude playing a pivotal role in shaping students' mathematical reasoning and problem solving abilities. Despite the importance of vectors in various academic disciplines, students often exhibit misconceptions and errors when

working with vector quantities, particularly in determining the magnitude of vectors accurately (Dhlamin, 2019). In Zimbabwe, teaching and learning of vectors has been identified as a priority at secondary school (Ministry of Primary and Secondary Education, 2019). Machingambi & Musemwa, (2020) comment that Zimbabwean learners often make errors when dealing with vectors especially calculating magnitude of a vector.Nyamapfene & Moyo, (2019) found that Zimbabwean ordinary level students faced some challenges when calculating magnitude of vectors.

Understanding the nature of these errors is crucial for educators to design targeted interventions that support students in overcoming these challenges and developing a robust understanding of vector concepts. According to Dhlamini, 2019 errors in vector magnitude calculations can arise from misconceptions about vector properties, difficulties in applying mathematical principles to vector operations and confusion regarding the relationship between direction and magnitude in vector quantities. By delving into these errors educators can gain valuable insights into the specific hurdles that ordinary level students face when dealing with calculating magnitude of vectors and tailor teaching strategies to address these errors effectively.

1.3 Statement of the Problem

The primary focus of this research project is to look at the errors made by ‘o’ level students when calculating the magnitude of vectors. By identifying common misconceptions and difficulties faced by students in this specific area, the study aims to shed light on the errors made by ordinary level learners when calculating magnitude of vectors and inform teaching strategies that can enhance students’ proficiency in vector calculations.

1.4 Significance of the Study

This study holds significant implications for learners, teachers, parents, school heads and curriculum Development Unit.

For learners, understanding the errors they make when calculating vector magnitudes can help them identify and address their misconceptions. By recognizing their mistakes, learners can improve their problem solving skills and develop a deeper understanding of vector concepts. This in turn can lead to better performance in mathematics and physics courses that involve vector calculations.

Teachers can benefit from studying learner errors in vector magnitude calculations by gaining insights into common misconceptions and difficulties faced by students. This knowledge can inform instructional strategies and help teachers design more effective lessons that target specific areas of weakness. By addressing these errors proactively, teachers can enhance student learning outcomes and promote a deeper understanding of vector concepts.

Parents play a crucial role in supporting their children's education and understanding the errors made by learners when calculating vector magnitudes can help them provide targeted assistance at home. By being aware of common misconceptions and difficulties faced by students, parents can offer guidance and support that complements classroom instruction. This can help reinforce learning and improve student performance in mathematics and physics.

School heads can use insights from studies on learner errors in vector magnitude calculations to inform curriculum development and teacher training initiatives. By identifying areas of weaknesses and implementing targeted interventions, school heads can improve overall student

achievement and enhance the quality of education provided at their institutions. This can lead to better outcomes for students and contribute to the overall success of the school.

Curriculum Development Unit can benefit from studying learner errors in vector magnitude calculations by identifying areas of the curriculum that may need revision or improvement. By addressing common misconceptions and difficulties faced by students, the Curriculum Development Unit can design more effective learning materials and assessments that promote a deeper understanding of vector concepts. This can lead to a more robust and comprehensive curriculum that better prepares students for future academic and professional courses.

1.5 Research Questions

1.5.1. What are the common errors made by ‘o’ level students when calculating the magnitude of vectors?

1.5.2. What factors contribute to errors made by learners when calculating vector magnitude?

1.5.3. How can educators develop effective teaching strategies to help students overcome these errors?

1.6 Objectives

1.6.1. To identify common errors and misconceptions made by ‘o’ level students when calculating vector magnitudes.

1.6.2. To investigate factors which contribute to errors made by learners when calculating magnitude of vectors.

1.6.3. To propose teaching strategies to address student errors and enhance their understanding of vector concepts.

1.7. Assumptions

1.7.1. This researcher assumes that 'O' level students have a basic understanding of mathematical concepts related to vectors and are familiar with fundamental algebraic operations

1.7.2. The researcher assumes that the interviewees will honestly answer the questions.

1.8. Limitations of the Study

Some limitations of this research project include:

The study focuses specifically on 'O' level students and may not generalize to other educational levels. The research is limited to investigating errors in calculating vector magnitudes and does not encompass other aspects of vector operations.

1.9. Delimitation of the study

This study was carried out at a school in Makonde District. The School is found in Mashonaland West Province. It is located some 50 kilometers from Chinhoyi Town. Most of the pupils from this school reside in the surrounding farms. The school has a total of ten teachers and the school head. There are one hundred and fifty-five learners. The research was carried out with form three learners. There are forty-five learners in form three. The researcher dealt with a sample of sixteen learners from a total of forty-five. The researcher used random sampling method maintaining the gender balance. Eight boys and eight girls were involved in the study. To come up with the number the researcher designed forty-five cards with sixteen of them written "YES"

and twenty-nine written “NO” Those who picked the cards written “YES” were selected to be part of the research. The researcher used the criterion that girls will pick first from twenty-three cards of which eight were written “YES”. The same was done with boys, twenty-two cards were given with eight of them written “YES”. Since this school has only three teachers who teach mathematics from form one to form four. All the three teachers were involved in the study.

1.10. Definition of terms

1.10.1.Vector: A mathematical quantity that possesses both magnitude and direction (Makgakga, 2017)

1.10.2 Magnitude: The size or length of a vector, irrespective of its direction (Jones and Smith, 2018)

Ordinary level: Basic level of education attained by learners of form four in different areas in Zimbabwe (www.zimsec.org.zw)

1.10.3. Learners: School children or students who are being taught by a teacher (www.learnersdictionary.com)

1.10.4. Secondary school: A school intermediate between elementary school and college usually offering general, technical and vocational or college preparatory courses (apply.uncarf.org). In Zimbabwe it is an institution specializing in the levels of forms one to form six.

1.11 Summary

This chapter has given the background of study, statement of the problem, objectives together with research questions and significance of the study. The next chapter discusses a review of related literature. The intention of the literature study is to gain more understanding on magnitude of vectors.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Mathematics has long been regarded as a critical subject in developing problem-solving and analytical skills. Among many topics covered in Mathematics at ordinary level, vector calculations hold an essential place, particularly in physics and engineering related fields. However, most learners at this level often struggle with the concept vectors especially when calculating their magnitudes. This chapter reviews existing literature on the errors made by students in this area focusing on conceptual, procedural and computational challenges they face. Additionally, the chapter explores pedagogical approaches to teaching vectors and strategies to mitigate these errors.

2.2 The Concept of Vectors and Their Magnitude

Vectors are mathematical quantities characterized by both magnitude and direction. Their application spans various disciplines, including physics, engineering and computer science, making their understanding crucial (Kaur and Ayub, 2019) The magnitude of a vector is calculated using the formula: $IvI=\sqrt{(x^2+y^2)}$ for a two dimensional vector and $IvI=\sqrt{(x^2+y^2+z^2)}$ for a three dimensional vector, where x, y and z represent the vector components. Despite the relative simplicity of these formulas, many Ordinary level learners face difficulties when applying them due to conceptual and procedural misunderstandings.

2. 3 Common Errors in Calculating Magnitude of Vectors

2.3.1 Conceptual errors

Conceptual errors stem from a lack of understanding of what vectors represent and how their magnitudes are derived. According to Jones and Smith (2018), many students confuse vectors with scalar quantities, failing to grasp the distinction between direction and magnitude. These misunderstandings often lead to incorrect interpretations of vector components, such as treating them as scalar additions instead of squared values summed under a square root.

Furthermore, students may misinterpret the role of negative components in vectors. Studies by Tartaro (2015) reveal that learners frequently disregard the contribution of negative components in magnitude calculations, leading to incorrect results. For instance given vector V= (-3, 4), students calculate the magnitude as **I-3+4I=1** rather than $\sqrt{((-3)^2+4^2)} = 5$

2.3.2 Procedural Errors

Procedural errors occur when students fail to follow correct steps in applying the magnitude formula. As emphasized by Khoza and Mutodi, (2017), these errors often arise due to poor arithmetic skills or an inability to recall the proper sequence of operations. For example, students may square the vector components correctly but forget to sum them before applying the square root, leading to incomplete or erroneous results.

Another procedural issue involves error in identifying the correct components of a vector in word problems. Learners may struggle to extract the numerical values of x, y and z from contextual information, especially when the vector is described in diagrams or textual formats (Jonson & Lee, 2021).

2.3.3 Computational Errors

Computational errors are prevalent among Ordinary Level learners and often result from insufficient practice or weak foundational skills in arithmetic and algebra. Common mistakes include incorrect squaring of numbers, miscalculating square roots, or substituting wrong values into the magnitude formula. For instance, a student might calculate $\sqrt{(3^2+4^2)}$ as $\sqrt{(9+16)}$ $=21$instead of $\sqrt{25}=5$

2.4. Factors Contributing to Errors

Several factors contribute to the errors made by learners when calculating vector magnitude. These include:

2.4.1. Weak Foundational Knowledge:

Students often lack a solid foundation in basic algebra and geometry which are pre requisites for understanding vectors (Brown & Wilson 2019).

2.4.2. Instructional methods: Traditional teaching methods that rely heavily on rote memorization rather than conceptual understanding may hinder students' ability to apply formulas correctly (Luneta and Makonye, 2020).

2, 4.3. Limited practice Opportunities: Insufficient practice in solving vector problems reduces learners' confidence and proficiency in applying magnitude formulas (Makonye, 2018)

2.4.4 Cognitive load: The multi-step nature of vector magnitude calculations can overwhelm students, especially those with limited working memory capacity (Khoza and Mutodi 2017)

2.5Strategies for reducing Errors

2.5.1 Conceptual Teaching Approaches

Emphasizing the geometric interpretation of vectors can help students better understand their magnitude. For example, visualizing vectors as arrows in a coordinate system reinforces the idea of direction and the role of components in determining magnitude (Johnson and Lee, 2021). Interactive tools, such as graphing software and dynamic geometry platforms, have also been shown to improve conceptual understanding. Visual aids such as graphs, diagrams and vectors on coordinate plane can help learners understand the concept of vector magnitude Brown (2017)

2.5.2 Practice and Feedback

Providing learners with practice problems, including real-world applications can enhance their computational accuracy and procedural fluency. Additionally, immediate feedback on errors allows students to identify and correct misconceptions before they become ingrained (Hattie & Timberley, 2020)**.** Regular practice and feedback can help learners develop their skills and confidence in calculating vector magnitude.

2.5.3 Scaffolding Techniques

Scaffolding involves breaking down complex problems into smaller, more manageable steps. For instance, teachers can guide students through the process of identifying vector components, squaring them, summing them and finally taking the square root. This step by step approach reduces cognitive load and builds confidence (Babbie, 2015).

2.5.4 Use of technology to support learning

Technology such as graphing calculators and computer software can provide learners with interactive and visual tools to explore and understand vector magnitude (Schoenfeld, 2020). Simulations and animations can be used to demonstrate the concept of vector magnitude and how it changes as the vector is scaled or rotated. According to Makgakga (2016) computer algebra systems such as Mathematica or Maple can be used to perform calculations and visualize vector magnitude allowing learners to focus on the underlying mathematical concepts.

2.6 Summary

This chapter has reviewed literature on the errors made by Ordinary Level learners when calculating the magnitude of vectors. Conceptual misunderstandings, procedural missteps and computational inaccuracies were identified as the primary sources of error. Factors such as weak foundational knowledge, ineffective teaching methods, and insufficient practice contribute to these challenges. To address these issues the use of a combination of conceptual teaching, practice with feedback, and scaffolding techniques are recommended. The next chapter will focus on the research methodology employed to examine these errors in detail.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the research methodology employed in the study, which aims to look at the errors made by Ordinary Level learners when calculating the magnitude of vectors at a Secondary school in Makonde District. The methodology includes the research design, target population, sample selection procedures, data collection methods, instruments used and data analysis techniques. The chapter concludes by addressing the ethical considerations observed during the research process.

3.2Research Design

Research design is a detailed plan outlining how to conduct a research study, including the methods and procedures for collecting and analyzing data (Kothari, 2014). A research design serves as a roadmap for the research project, ensuring that the study is conducted in a systematic and efficient manner. The study employed a descriptive research design, which is suitable for identifying and analyzing the types and causes of errors learners make in calculating vector magnitude. A mixed-method approach was used, integrating both qualitative and quantitative methods. Quantitative data were collected through general exercises and a diagnostic test administered to learners, while qualitative data were gathered from interviews with mathematics teachers to gain deeper insights into the challenges learners face and the strategies teachers use to address these issues. The combination of these methods provided a comprehensive understanding of the problem.

3.3Target Population

Population refers to the entire group of individuals, objects or events that the researcher is interested in understanding or describing (Babbie, 2015).The target population comprised of forty-five form three learners studying mathematics and three mathematics teachers responsible for teaching Ordinary Level mathematics. Form Three learners were selected because they are at a stage where vectors are introduced in their curriculum, making them an ideal group to study errors related to magnitude calculations.

3.4 Sample size and sampling Procedures

3.4.1 Sample.

Jackson and Brown (2017) define a sample as a small group of people or things taken from a larger group and used to represent the larger group. Murray (2015) agrees that sampling is a process used in statistical analysis in which a predetermined number of observations will be taken from a larger population. The sample used in this study consisted of sixteen form three learners, selected randomly from the forty-five learners and three teachers all of which were included in the study.

3.4.2 Sampling Techniques

There are many sampling techniques that can be implemented in sampling. The most relevant used is the simple random sampling. This is the technique that the researcher used in this research. A random sampling was used to select sixteen learners from a population of forty-five learners. Random sampling ensured that each learner had an equal chance of being selected, reducing bias and making the sample representative of the population. It was also used to select teachers who were interviewed in this study.

3.4.3 Simple Random Sampling.

Jackson (2016) says simple random sampling is a procedure that provides an unbiased cross section of the population. Kohen (2016) also asserts that random sampling is a subject of individuals that are selected from a population. Therefore random sampling is a sampling procedure in which all members of a selected population have a chance of being selected.

3.4.3.1 Advantages of Random Sampling.

It is cheaper to collect data from a part of the whole population and is economically advanced. Jackson and Brown (2019) comments that random sampling gives more time in data collection, so it is quick and has a lot of time for collection of information. This means that random sampling gives the researcher enough time to do the study and come up with comprehensive information.

3.4.3.2Disadvantages of Random Sampling

Jackson and Brown (2019) propose that if the information is required for each child, it is difficult to interview all pupils in sampling method. Random sampling is also not possible without a complete list of population members.

3.5Data Collection instruments

To collect data, the study used general exercises, a test and interviews.

3.5.1. General Exercises

General exercises were considered important to monitor consistence and deviations in the investigated problem. Consistence in this case refers to systematic traceable abilities in solving the magnitude of vector problems and the deviation is referring to the errors starting to manifest

in the computation of vectors. Two exercises were considered sufficient to make some inferences. The first exercise had six questions and carried fifteen marks. The second exercise had five questions carrying fifteen marks as well.

3.5.1.1 Advantages of general exercises.

General exercises can help researchers to gain a deeper understanding of the research topic and identify potential issues or areas for further investigation (Creswell, 2017). For example, in a study on learners' errors in calculating magnitude of vectors, general exercises can help researchers to identify common misconceptions and areas where learners struggle. According to (Patton, 2015) general exercise can help researchers to develop their research skills, such as data collection, analysis and interpretation.

3.5.1.2. Disadvantages of general exercises.

Creswell, (2017) says general exercises can be time-consuming to design and implement, particularly if they involve complex data collection and analysis procedures. Kvale, (2017) also comment that general exercises maybe subject to bias, particularly if the researcher has preconceived notions or hypothesis that influence the design and implementation of the exercises.

3.5.2. Test

A test according to Nadler (2018) is a means of finding out pupils' performance about a set standard. Cock (2021) also says a test as a suitable way for monitoring children's progress and is used in assessing and finding out the strength and weaknesses of the children. This means that a

test is a tool used to measure if pupils have mastered the concepts. The researcher used one test and the main purpose of the test was to measure if pupils had understood and grasped all concepts covered. The researcher also wanted to identify some strength and weaknesses of pupils as far as calculating the magnitude of vectors is concerned. A diagnostic test was designed to assess learners' understanding and ability to calculate the magnitude of vectors. The test included eight questions that focused on:

1. Basic magnitude Calculations: Learners were required to calculate the magnitudes of 2D and 3D vectors.
2. Negative Components: Questions tested learners' ability to handle negative components in calculations.

The test was validated by experienced mathematics teachers to ensure it aligned with the curriculum and effectively assessed the intended skills.

3.5.2.1 Advantages of Testing

Tests help the teacher in monitoring progress of pupils. They help the teacher to assess whether pupils mastered the concepts taught or not. Nadler 2018) notes that, testing helps the teacher to establish how progress of each child relates to his or her own previous standards.

3.5.2.2 Disadvantages of testing.

Anderson (2017) asserts that the results of tests may discourage pupils especially slow learners. The excitement for writing a test also makes pupils make unnecessary errors. In setting a test some of the questions asked may not cater for individual differences of pupils.

3.5.3 Interviews.

The researcher began by seeking permission from the District Education office in Makonde to conduct the interviews. The researcher got responses from interviewees and participants who had adequate time to respond to questions without the interference of other parties. The researcher conducted a verbal interview to come up with trusted and reliable data. Recording of answers was done. The researcher made sure that no harm was done to any of them as the researcher was observing the frequent information, more frequent data would be assumed to be an indicator of the true value of research topic as supported by statistical calculations as well. Semi-structured interviews were conducted with sixteen learners and three mathematics teachers to gain qualitative insights into: The common types of errors learners make when calculating vector magnitudes, the teaching methods used to address these errors and the challenges teachers encounter when teaching vector related topics. The semi-structured format allowed for open ended responses enabling the researcher to probe further for clarification and additional details.

3.5.3.1. Advantages of interviews

Interviews allow researchers to gather in-depth detailed information from participants, which can provide rich insights into the research (Kvale, 2017). For example, in a study on learners'errors in calculating magnitude of vectors, interviews with learners can provide detailed information on their thought processes and problem-solving strategies. Interviews provide a personal perspective on the research topic, allowing researchers to gain deeper understanding of participants' experiences and opinions (Cresswell, 2017).

3.5.3.2. Disadvantages of interviews.

Interviews can be time- consuming to conduct and analyze, particularly if the researcher is conducting in-depth, semi-structured interviews (Kvale, 2017). This can be a challenge for

researchers with limited time and resources. Patton, (2015) notes that the data collected may be influenced by the researcher's own biases and assumptions. This can impact the validity and reliability of the research findings.

3.6 Data Collection Procedures

The following steps were followed to collect data:

3.6.1. Administering the General exercises and a Test: The general exercises and a test were administered, the randomly selected learners were under controlled conditions to ensure fairness and consistency. Learners were given enough time to complete the test, and their responses were collected for analysis.

3.6.2 Conducting Teacher Interviews: The researcher conducted one-on-one interviews with each of the 3 mathematics teachers in a conducive environment. Each interview lasted approximately 30minutes.

3.7 Data Analysis Techniques

3.7.1 Quantitative analysis:

Data from the general exercises and test were analyzed using descriptive statistics (graphs, tables and pie charts), including frequencies and percentages. Errors were categorized into three main types:

3.7.1.1. Conceptual Errors: Misunderstanding of vector properties such as the role of components or the formula for magnitude.

3.7.1.2. Procedural Errors: Mistakes in following correct steps to solve vector magnitude problems.

3.7.1.3 .Computational Errors: Arithmetic errors such as incorrect squaring, summation or square root calculations.

3.7.2Qualitative analysis

Qualitative data from teacher interviews and document analysis were analyzed thematically. Recurring themes such as misconceptions, teaching challenges and teaching strategies were identified and linked to the findings from the exercises and test. The analysis highlighted the underlying causes of errors and provided insights into how they can be addressed.

3.8 Validity and Reliability

3.8.1 Validity

3.8.1.1 Content Validity:

The diagnostic test was reviewed by mathematics teachers to ensure it adequately assessed learners' understanding of vector magnitude calculations.

3.8.1.2 Triangulation:

Data were collected from multiple sources (diagnostic test, general exercise and teacher interviews) to ensure the findings were comprehensive and accurate.

3.8.2 Reliability

Creswell, (2017) defines reliability as the consistency and dependability of research findings. The exercises and test were administered under standardized conditions to ensure consistency in learner responses. There are several strategies that can be used to enhance the reliability of research findings which include: pilot testing which can help to identify and address any issues with the research design or data collection methods, data triangulation which involves using multiple data sources or methods to verify the findings and inter-rater reliability checks which can help to ensure that the findings are consistent across different researchers or raters Kvale, 2017).

3.9 Ethical Considerations

The study adhered to ethical principles to protect participants and ensure the integrity of the research process. Key ethical considerations included:

3.9.1. Informed Consent

Participants were informed about the study's purpose, procedures and their rights. Written consent was obtained from learners, parents and teachers.

.3.9.2Voluntary Participation:

Participation in the study was voluntary and participants were free to withdraw at any point without consequences.

3.9.3 Confidentiality:

Learners and teachers' identities were anonymized and all data were stored securely to ensure privacy

3.9.4 Accurate reporting;

Findings were reported honestly and without manipulation to ensure the credibility of the study.

3.10 Summary

This chapter outlined the research methodology used to investigate errors made by Ordinary Level Learners at a school in Makonde District when calculating vector magnitudes. A descriptive research was with data collected through general exercise, diagnostic test and teacher and learner interviews. A random sampling method was employed to select sixteen learners while all three teachers were included in the study. Both qualitative and quantitative methods were used to analyze data ensuring a comprehensive examination of the errors and their causes. Ethical considerations were observed to protect participants and maintain the integrity of the research. The next chapter will look at data presentation, analysis and interpretation.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1Introduction

The main goal of this research study was to examine errors made by Ordinary Level learners when calculating magnitude of vectors and also to find out the causes of the errors and how they can be solved. Learners committed several errors in calculating magnitude of vectors. This chapter presents a discussion of the findings of the study and relates the theoretical background and literature review connected to the study. The discussions of the findings are presented in tables, graphs and pie charts. The researcher is going to analyze two written exercises and a test together with interview data from three teachers and sixteen learners.

4.2. Data Analysis

The data collected was analyzed using descriptive statistics including frequencies and percentages

4.3. Data Presentation

Table 4.1.Gender of students

Variable	Frequency	Percentage
Male	8	50%

Female	8	50%
Total	16	100%

Sixteen learners were selected using random sampling to be part of this research. There was gender balance in students' selection with eight being girls and the other eight being boys.

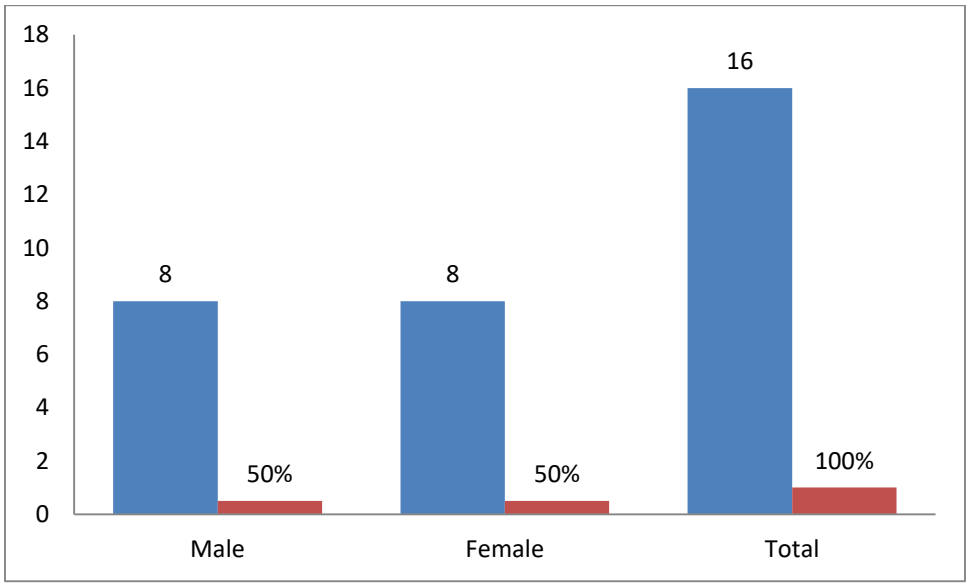


Fig 4.1. Gender of students

Table 4.2 Age of students

AGE(YEARS)	FREQUENCY	PERCENTAGE
16	7	43,75%
17	9	56,25%
TOTAL	16	100%

Table 4.2 reflect that the age of students was 16 to17 years, with the seven out sixteen (43, 75%) and nine out of sixteen (56, 25%)

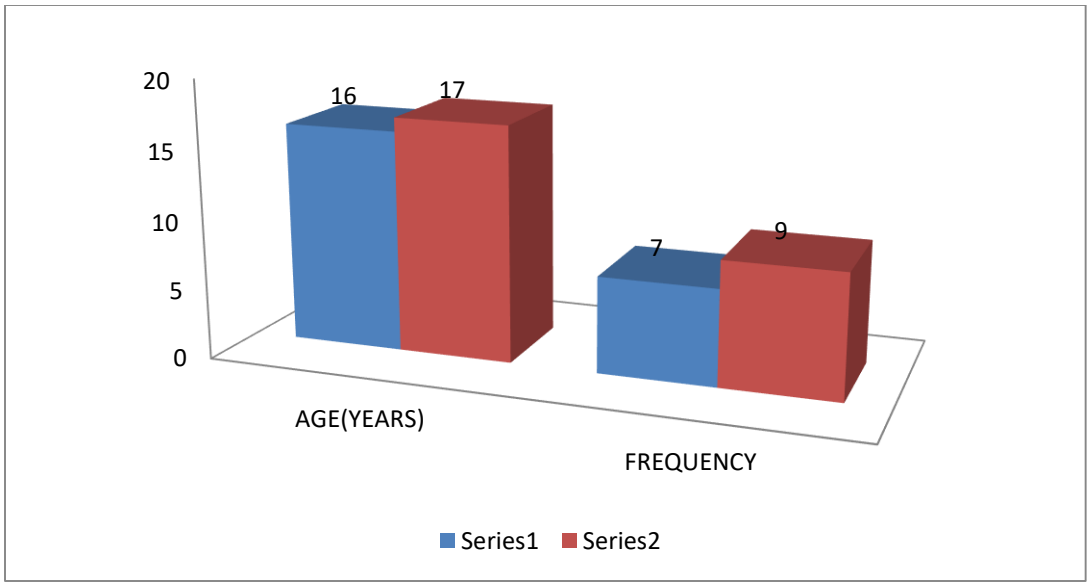


Fig 4.2. Age of students

TABLE 4.3 GENDERS OF TEACHERS

GENDER	FREQUENCY	PERCENTAGE
MALES	2	66,7%
FEMALES	1	33.3%
TOTAL	3	100%

Table 4.3 indicates that there was no gender balance in terms of females and males who were interviewed. Two males (66, 7%) and one female (33, 3%)

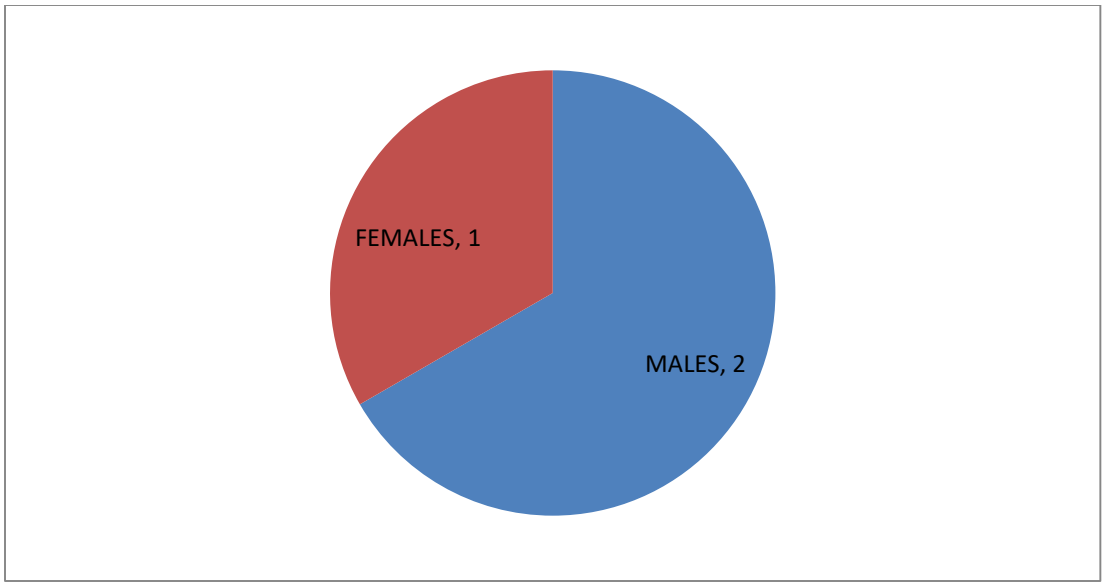


Fig 4.3. Gender of teachers

TABLE 4.4 AGE OF TEACHERS

AGE	FREQUENCY	PERCENTAGE
20-30	1	33,3
31-40	1	33,3

41-50	1	33.4
OVER 50	0	0
TOTAL	3	100

Table 4.4 shows that there is equal number of teachers in the age groups 20-30 (33, 3%), 31-40 (33, 3%) and 41-50 (33, 3%). There were no teachers above the age of 50 years

TABLE 4.5 TEACHERS' QUALIFICATIONS

PROFESSIONAL QUALIFICATION	FREQUENCY	PERCENTAGE
CERTIFICATE IN EDUCATION	-	-

DIPLOMA IN EDUCATION	2	66,7
HBSC EDUCATION-MATHEMATICS	1	33,3
MASTERS DEGREE	-	-
OTHER	-	-
TOTAL	3	100

Two of the teachers (66, 7%) had Diploma in Education from teachers' colleges as their highest professional qualifications. One (33, 3%) had Bachelor of Science Education in Mathematics which is an added qualification after attaining Diploma in Education.

TABLE 4, 6 TEACHING EXPERIENCE

TEACHING EXPERIENCE (YEARS)	FREQUENCY	PERCENTAGE
0-5	1	33.3
6-10	-	-
11-15	1	33,3
16-20	1	33,4
Over 21	-	-
TOTAL	3	100

TABLE 4.6 shows that two teachers were experienced as they had been teaching for over 6 years. One teacher had less than six years working experience.

4.3.1Exercise 1

In the first lesson on calculating magnitude of 2D negative and non negative vectors, learners participated very well. They involved themselves in the lesson. The exercise had six questions which had fifteen marks. Conceptual errors such as misunderstanding vector components and ignoring the Pythagoras Theorem, computational errors such as incorrect addition and squaring components wrongly for example miscalculating $\sqrt{x^2+y^2}$ were observed in their work. Some learners were forgetting to take the square root after summing the squares of the components. Procedural errors were also noticed which include incorrect formula application and skipping steps in their calculations leading to incomplete reasoning or errors that propagate through their work. The errors made by learners are recorded in the table below

Table 4.7 Types of errors made by learners when calculating magnitude of vectors.

TYPE OF ERROR	FREQUENCY	PERCENTAGE
CONCEPTUAL ERRORS	8	50%
COMPUTATIONAL ERRORS	6	37.5%

PROCEDURAL ERRORS	2	12.5%
TOTAL	16	100%

Table 4.7 shows that 50% of the learners made conceptual errors, another 37.5% computational errors and finally 12.5% procedural errors. Based on the table above, it is evident that conceptual errors were significant challenge for learners with eight out of sixteen making conceptual errors. According to Kilpatrick (2017) conceptual errors are a common challenge in mathematics especially when dealing with vectors. The results also indicate that computational errors were another significant challenge for learners, with six out of sixteen learners making computational errors. Schoenfeld (2020) says computational errors are common challenge for learners in mathematics particularly when dealing with vectors. In contrast procedural errors were less common with only two out of sixteen learners making procedural errors. This finding suggests that learners were generally able to follow the correct procedures for calculating the magnitude of vectors but struggled with conceptual and computational aspects.

The results also highlight the importance of addressing conceptual and computational errors in the teaching and learning of vectors. As noted by Niss (2020), conceptual and computational errors can have a significant impact on learners' understanding and application of mathematical concepts. Therefore teachers should prioritize addressing these errors in their instruction and provide learners with opportunities to practice and reinforce their understanding of mathematical concepts.

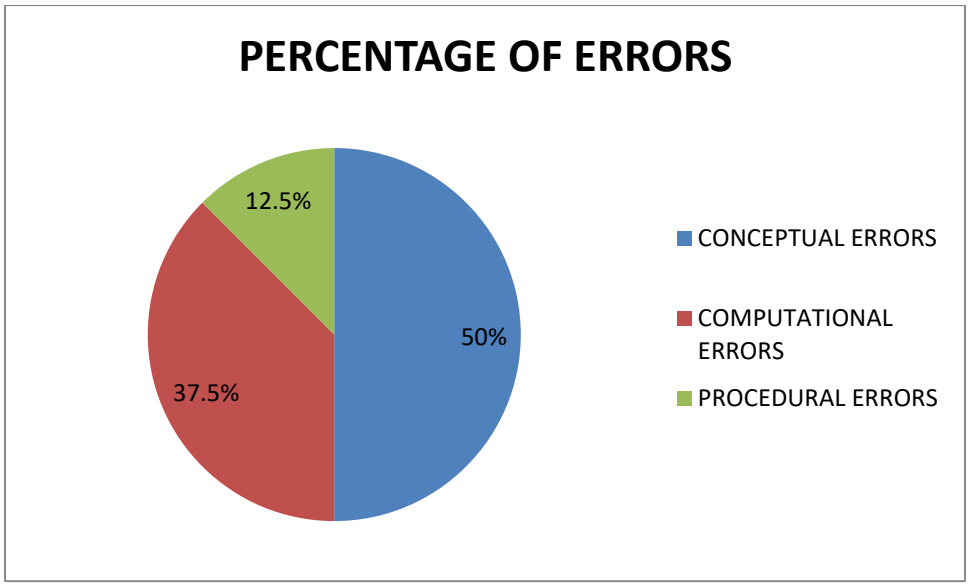


Fig 4.4. Percentages of errors made by learners

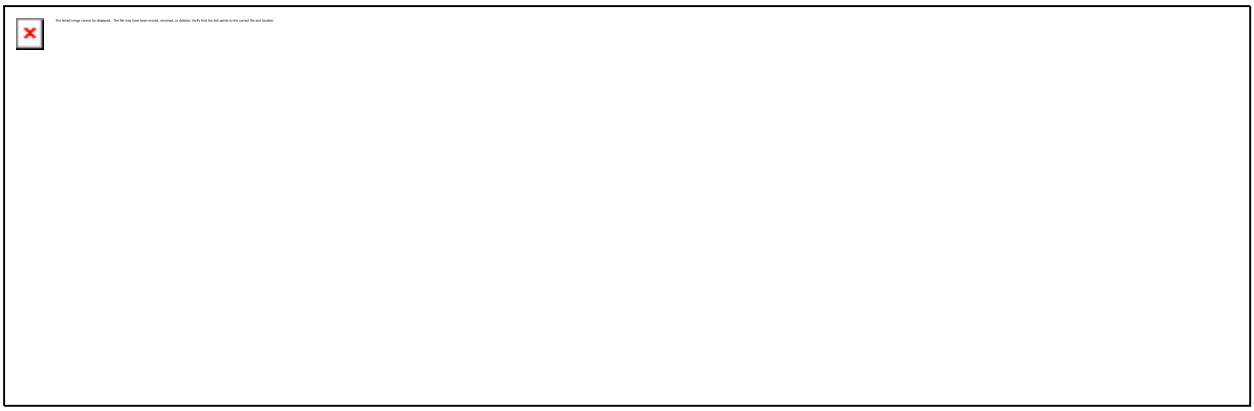
Table 4.8 Conceptual errors made by learners when calculating magnitude of vectors

CONCEPTUAL ERROR	FREQUENCY	PERCENTAGE
Failure to understand vector concept	4	25

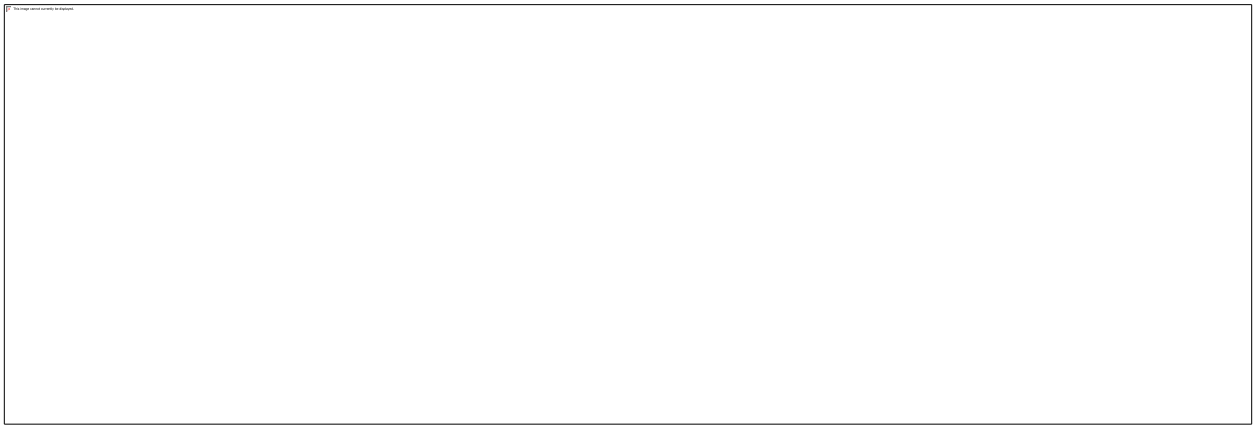
Incorrect interpretation of vector form	3	18.75
Ignoring the Pythagorean theorem	1	6.25
TOTAL	8	50

A closer examination of the conceptual errors on table 4.4 reveals that four learners failed to understand the vector concept which is a fundamental concept in mathematics (Kilpatrick, 2017). This suggests that learners may have difficulty in grasping the abstract nature of vectors which can make it challenging for them to apply vector concepts to solve problems.

Below is an extract from the exercise 1 written by learner A who failed to understand the factor concept. Since the vectors on the picture are two dimensional vectors the learner was supposed to show knowledge of understanding vector concept by using the Pythagoras Theorem ($\sqrt{x^2+y^2}$). This type of error is normally caused by insufficient understanding of fundamental mathematics concepts and focusing too much on procedural calculations rather than conceptual errors.



Additionally, three learners made an incorrect interpretation of vector form, which highlights the importance of clear and concise instruction in mathematics. This error may be attributed to learners' lack of understanding of mathematical notation and conventions used to represent vectors. The picture below shows a vector calculation made by learner B who made an incorrect interpretation of vector form.



Furthermore one learner experienced difficulty in using the Pythagoras Theorem, which is a critical aspect of vector mathematics (Borasi, 2017). This finding suggests that learners may benefit from the use of visual and geometric representations to help them better understand and

visualize vector concepts. The picture below is an extract from exercise 1 written by learner E who experienced difficulty in using Pythagoras Theorem. This might have been attributed by lack of understanding of right-angled triangles and difficulty with formula recall.

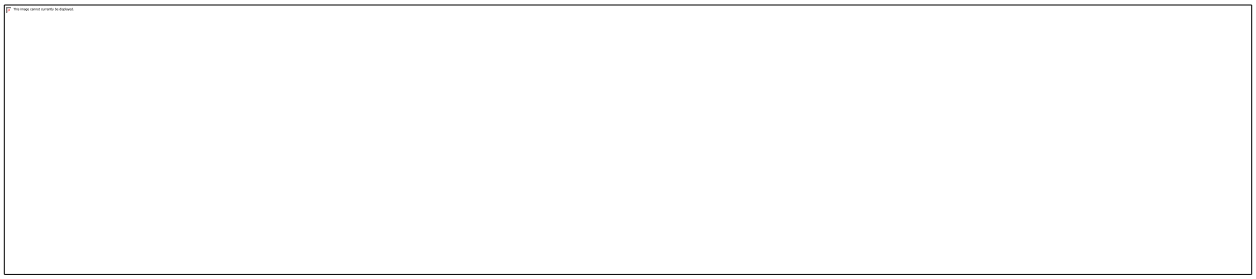


Table 4.9 Computational Errors Made by Learners when calculating Magnitude of Vectors

COMPUTATIONAL ERROR	FREQUENCY	PERCENTAGE
Incorrect calculation of vector components	2	12.5
Failure to apply correct formula	3	18.75

Incorrect substitution of values	1	6.25
TOTAL	6	37.5

Based on the results presented above it is clear that computational errors were a significant challenge for learners. Specifically the table shows that six learners made computational errors which accounted for 37.5% of the total errors made by learners. Two learners made an incorrect calculation of vector components, which shows the importance of paying attention to detail and accuracy in mathematical calculations (Schoenfield 2020). This error may be attributed to learners' lack of practice in calculating vector components or their failure to check their calculations for accuracy. The picture below shows the calculations performed by learner C who failed to calculate vector components correctly.

Three learners failed to apply the correct formula for calculating the magnitude of vectors, which is a critical aspect of vector mathematics. This indicates that learners may not have deep understanding of mathematical concepts underlying vector calculations or they may have difficulty in applying mathematical formulas to solve problems.

Furthermore, one learner made an incorrect substitution of values, which highlights the importance of careful reading and interpretation of mathematical problems. The picture below shows incorrect substitution of values made by learner E in exercise 1.

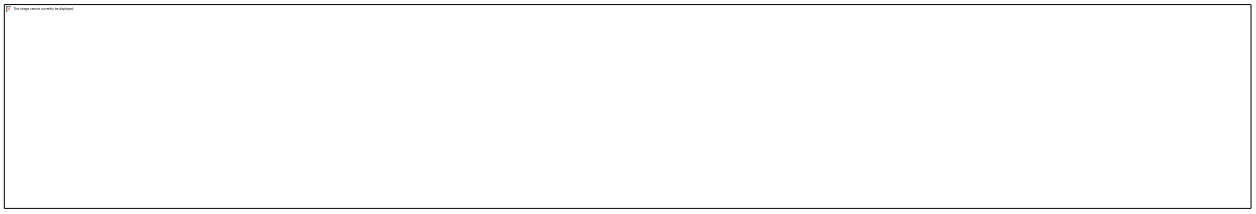
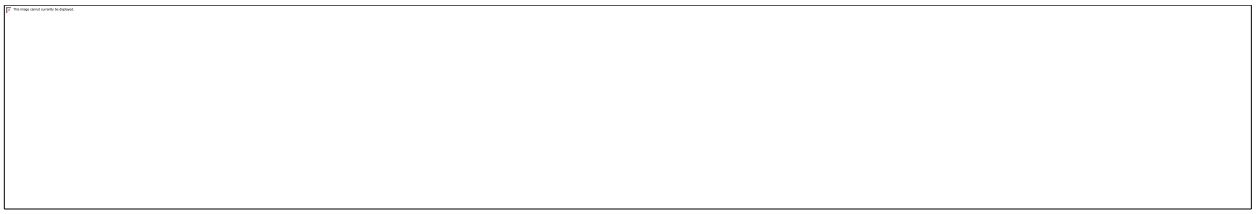


Table 4.10 Procedural Errors Made by Learners when Calculating Magnitude of Vectors

PROCEDURAL ERROR	FREQUENCY	PERCENTAGE
Failure to follow correct order of operations	2	20
TOTAL	2	20

Table 4.10 shows two learners who failed to follow the correct order of operations which is a critical aspect of mathematical problem solving. Learners may not have fully understood the importance of following a specific order of operations when performing mathematical calculations. As noted by (Schoenfeld (2020), the order of operations is a fundamental concept in mathematics that requires learners to follow a specific sequence of steps when performing calculations. Failure to follow this sequence can lead to errors and incorrect results. The fact that two learners failed to follow the order of operations highlights the need for mathematics teachers to emphasize the importance of this concept and to provide learners with opportunities to practice and reinforce their understanding of order of operations. As recommended by Niss (2020), teachers can use a variety of strategies to help learners develop a deeper understanding of mathematical concepts including order of operations. These strategies can include the use of visual aids, real world examples and technology to support learning. The picture below highlights how learner F failed to follow correct order of operations.



4.3.2 Exercise 2

The second exercise was about calculating magnitude of 3D negative and non negative vectors. The exercise had five questions with three marks each. Conceptual errors, procedural errors and computational errors were also observed in the exercise.

Table 4.11Types of errors made by learners when calculating magnitude negative and non-negative 3D vectors.

TYPE OF ERROR	FREQUENCY	PERCENTAGE
Conceptual	7	43,75
Procedural	3	37.5
Computational	6	18.75

Total	16	100

The table above is evident that learners made a range of errors when calculating the magnitude of negative and non-negative 3D vectors. Specifically the table shows that seven learners made conceptual errors, three learners made procedural errors and six learners made computational errors. According to Jones and Smith (2018) conceptual errors occur when learners lack a deep understanding of mathematical concepts. This can be due to insufficient knowledge, inadequate instruction and lack of practice. Brown (2017) is of the view that to help solve conceptual errors teachers should provide clear and concise instruction to help learners understand mathematical concepts, visual aids such as diagrams, graphs and charts can help learners visualize mathematical concepts and using real world examples can help learners see the relevance of mathematical concepts. Machingambi and Musemwa (2020) also note that procedural errors occur when learners have difficulty in applying mathematical procedures or algorithms. This can be due to inadequate practice, lack of understanding of mathematical notation and difficulty with problem-solving. As a remedy to this Machingambi and Musemwa (2020) propose the use of step-by-step instruction, practice exercise, technological integration and collaborative learning. Computational errors occur when learners make mistakes in mathematical calculations like lack of attention to detail and lack of practice with mathematical calculations (Nyamapfene and Moyo, 2019). Encouraging learners to pay attention to detail and checking their calculations can help reduce computational errors

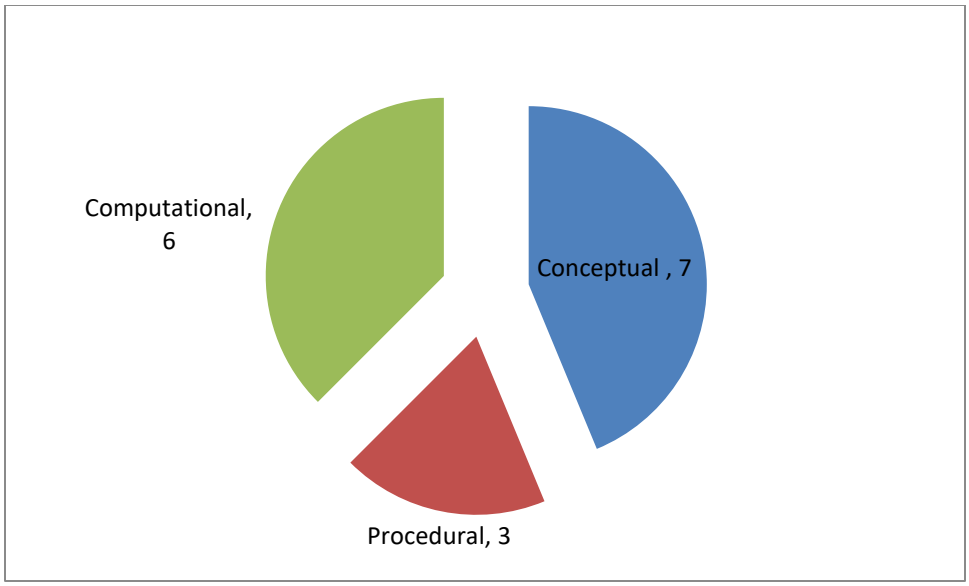


Fig 4.5. Types of errors in second exercise

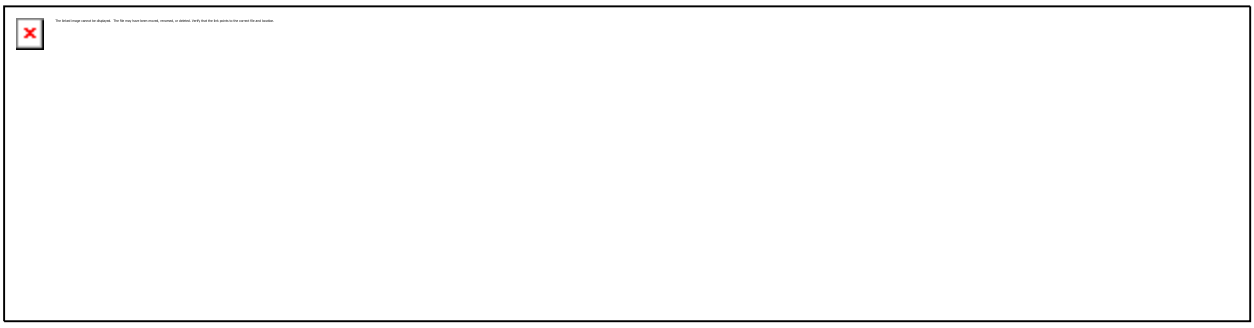
Table 4.12. Conceptual errors made by learners when calculating magnitude of negative and non-negative 3D vectors.

Conceptual error	Frequency	Percentage
Failure to understand vector concept	4	25
Incorrect interpretation of vector form	2	12.5

Incorrect formula	1	6.25
Total	7	43.75

Table 4.12 indicates that four learners failed to understand vector concept. These learners struggled with grasping the basic idea of vectors, which is a crucial foundation for further learning. This error suggests that they may not fully comprehend the concept of vectors as mathematical objects with both magnitude and direction. Two learners incorrectly interpreted vector form. This could be due to lack of exposure to different vector forms or insufficient practice in working with vectors.

One learner had incorrect formula use. This indicates lack of understanding of the underlying vector concepts. This could be due to failure to comprehend the derivation of the formula and insufficient practice. The picture below shows an extract from exercise 2 written by learner F who had incorrect formula use.



Teachers should ensure that learners have a solid grasp of vector concepts before moving on to more advanced topics. Learners need opportunities to practice working with vectors to reinforce their understanding and teachers should provide feedback and support to help learners identify and address their errors and misconceptions.

Table 4.13. Computational errors made by learners in exercise 2 when calculating magnitude of negative and non-negative 3D vectors.

COMPUTATIONAL ERROR	FREQUENCY	PERCENTAGE
Incorrect calculation of vector components	1	6.25
Incorrect rounding	3	18.75
Incorrect calculation of squares	2	12.5
Total	6	37.5

Table above shows that three learners failed to round off the answer correctly. Learners' inability to round off numbers accurately can be attributed to several factors. One major cause is the lack

of understanding of place values, where learners struggle to identify the digit in the specified place value, leading to incorrect rounding (Johnson and Lee, 2021). Additionally, insufficient practice with various rounding scenarios can result in learners being unable to apply the concept flexibly (Kilpatrick, 2017). Furthermore, difficulty with mental math calculations can also hinder learner's ability to round off numbers quickly and accurately (Johnson and Lee, 2021). Below is an extract from the work written by learner G who had difficulty in rounding the answer.

Two learners did not calculate the squares correctly. According to Kilpatrick (2017) these computational errors arise when learners face difficulty in understanding fundamental concepts of vectors and their application to different contexts. The fact that two incorrectly calculated the squares when calculating the magnitude of 3D vectors suggests that these learners may have problems in understanding the concept of direction and its relationship to the magnitude of vectors. The results above suggest that learners may benefit from additional support and instruction in addressing computational errors when calculating the magnitude of 2D negative and non-negative 3D vectors.

Table 4.14. Procedural errors made by learners when calculating magnitude of negative and non-negative 3D vectors.

PROCEDURAL ERROR	FREQUENCY	PERCENTAGE
Incorrect order of operation	1	6.25
Failure to simplify the expression	2	12.5

Total	3	18.75

Table 4.14 shows that two learners failed to simplify expression. This is an indication that these learners may have difficulty in algebraic manipulation and simplification. Schoenfeld (2020) says learners often struggle with algebraic manipulation and simplification, particularly when working with complex expressions. Difficulty with applying mathematical rules to new contexts can hinder learners' ability to simplify expressions when calculating magnitude of vectors (Kilpatrick, 2017). A picture below shows a part of an exercise written by learner K who failed to simplify the square roots to get the final answer.

One learner performed incorrect order of operations suggesting that this learner may have had difficulty with procedural aspect of mathematical problem-solving. Borasi, (2017) comments that learners often struggle with procedural aspect of mathematical problem- solving.Kilpatrik (2017) also says learners' failure to perform correct order of operations when calculating the

magnitude of vectors is a common pitfall. This error often stems from a lack of understanding of BODMAS rule, which dictates the order in which mathematical operations should be performed. Specifically, learners may incorrectly perform calculations within the square root, such as adding or multiplying components before squaring them.

4.3.3 Test

A test was also given to learners after the exercises and the findings were recorded below.

Table 4.15. Errors by type in the test.

Error Type	Frequency	Percentage
Conceptual Error	5	31.25%

Procedural Error	4	25
Computational Error	7	43.75
Total	16	100

The analysis of the learner performance reveals that conceptual, procedural and computational errors are prevalent. Conceptual errors 31.25% indicate that learners struggle to understand the underlying mathematical concepts such as the definition of vector magnitude and its relationship to the components of vectors.Procedural errors (25%) suggest that learners struggle to apply mathematical procedures such as calculating the magnitude of a vector using the Pythagorean Theorem. Computational errors (43.75%) indicate that learners struggle with numerical computation such as calculating square roots and simplifying expressions. According to Brown (2020) educators should focus on developing teaching strategies that address these errors and provide learners with opportunities to practice and reinforce their understanding of vector magnitude.

Fig 4.6. Percentages of errors made in the test.

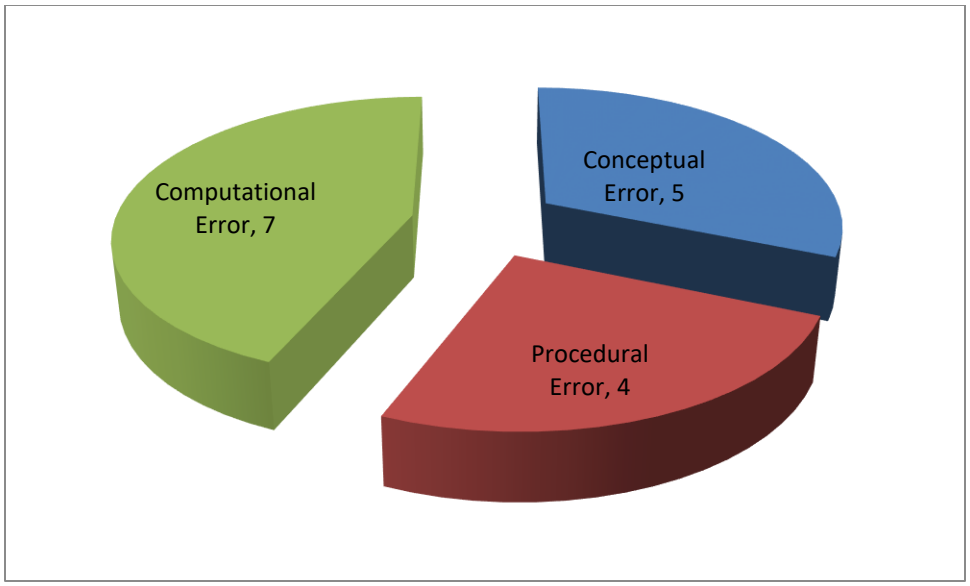


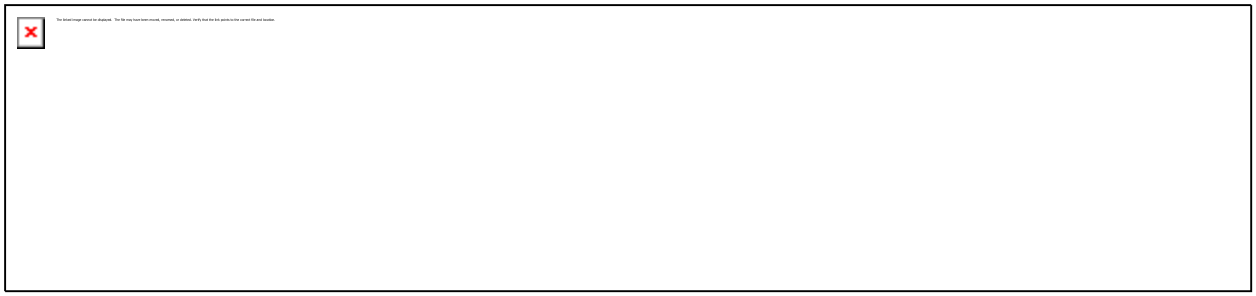
Table 4.16. Conceptual errors made in the test.

CONCEPTUAL ERROR	FREQUENCY	PERCENTAGE
Failure to understand the vector concept	3	18.75
Interpreting vector form incorrectly	1	6.25

Ignoring to use the Pythagorean Theorem.	1	6.25
TOTAL	5	31.25

Table 4.16 shows that three learners failed to understand vector concept, one learner had problems with interpreting vector form correctly and one learner ignored to use Pythagoras theorem.

The picture below shows the calculations done by learner J who failed to understand vector concept. Kilpatrik, (2017) notes that learners who fail to understand the vector concepts often struggle when calculating the magnitude of vectors. A fundamental cause of this struggle is a lack of comprehension of the vector as quantity with both magnitude and direction. Johnson and Lee, (2021) also says limited understanding of vector concepts can lead to difficulties in recognizing that the magnitude of a vector is a scalar value.



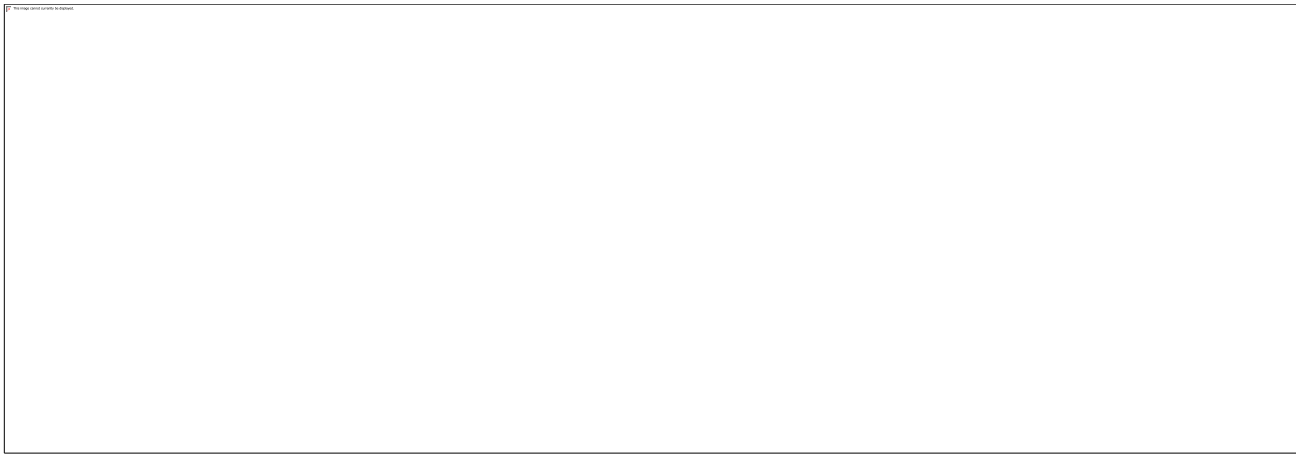
The picture shows an extract from the test written by learner I who failed to interpret the vector form. According to Luneta and Malonye, (2020) learners who fail to interpret the vector concept accurately often encounter challenges when calculating the magnitude of vectors. A primary cause to this difficulty is a misinterpretation of the vector's components. Kilpatrik, (2017) says learners may incorrectly assume that the magnitude of a vector is equal to one of its components.

Table4.17 Computational errors made in the test

COMPUTATIONAL ERROR	FREQUENCY	PERCENTAGE
Incorrect calculation of vector form	2	12.5
Failure to apply correct formula	3	18.75

Incorrect substitution of values	2	12.5
TOTAL	7	43.75

Table 4.17 clearly shows that there was incorrect calculation of vector form by two learners. These learners may have difficulties with mathematical operations such as addition and multiplication of vectors. Failure to apply correct formula by three learners indicates lack of mathematical concepts or lack of attention to detail. Incorrect substitution of values by 2 learners shows that these learners struggled with accurate substituting of values into the formula. This could be due to carelessness or inadequate checking of work. Below is the calculations performed by learner C who failed to apply the correct formula used when calculating magnitude of vectors.



Incorrect calculation of vector form below was done learner H in the test.

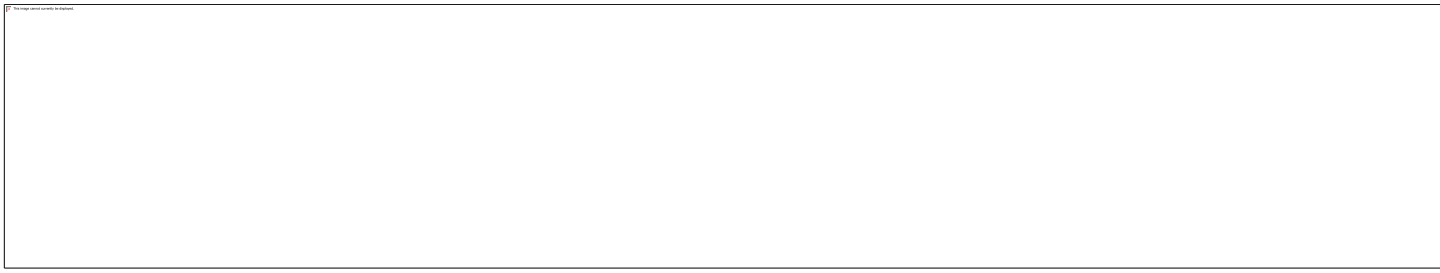


Table 4.18, Procedural errors made in the test

PROCEDURAL ERROR	FREQUENCY	PERCENTAGE
Failure to follow the correct order of operations	1	6.25
Struggling to simplify expressions	1	6.25
Failure to calculate squares	2	12.5
TOTAL	4	25

The table above shows one learner who failed to follow correct order of operations. One learner who struggled to simplify expressions and two learners who failed to calculate the squares.

The picture below shows an extract from the calculations performed in test by learner K who failed to simplify the expression. The learner failed to recognize that the magnitude of a vector is the square root of the sum of the squares of its components.

Below is an extract from the test written by learner G who failed to calculate the squares properly. The learner struggled to comprehend the notation of squaring one of the components of vector leading to incorrect calculations. This might be due to inadequate practice.

4.3.4 Learner interview questions and responses

4.3.4.1 Are you interested in learning vectors?

25% of the learners who were interviewed confirmed that they were very interested in learning vectors. The response from learner B was that, “Yes, I’m very interested in learning vectors. I have heard they are used in physics and engineering and I want to pursue a career in one of those fields.’ The other 75% were not interested in learning vectors and they gave a number of reasons. Learners K said, “Honestly, I’m not really interested in learning vectors. I find them confusing and difficult to understand.”

4.3.4.2 Can you tell me any concept that falls under the topic vectors?

Most learners were aware of the concepts that falls under the topic vectors. A response from learner B of the learners was as follows, “One concept that falls under the topic vectors is scalar multiplication.” However among those who were not sure of the concepts learner G said, “I’m not really sure. I think we learned about addition. Maybe?

4.3.4.3 Is it easy to calculate magnitude of vectors?

70% of the learners said they find calculating magnitude of vectors challenging but they were getting better with practice and 30% confessed that calculating magnitude of vectors is easy once you understand the formula. Some said it’s straight forward once you practice a few examples.

4.3.4.4 How do you calculate magnitude of a two dimensional vector?

The responses from learners indicated that almost 60% of them were struggling to recall the formula used to calculate magnitude of two dimensional vectors. Most answers were concerned with adding x and y components together and adding the squares of x and y together. However, 40% of the learners were very aware of how to calculate the magnitude of a two dimensional vector. Learner A said to calculate magnitude of two dimensional vectors, we use Pythagoras theorem. We square the x component and the y component and then add them together and then take the square root of the result.

4.3.4.5 Can you calculate the magnitude of a vector with components [2, 5, 1]?

About 75% of the learners failed to give the correct answer for this question. Learner C said, "I have no idea…I don't think I can do that." Learner J said it's a three dimensional vector but she was not aware of how to calculate the magnitude. Among those who managed to give the correct response learner D said, "To calculate the magnitude of this vector I would use the same approach as for 2D vectors. I would square each component and add them together and then take the square root of the result. So it would be $\sqrt{(2^2+5^2+1^2)} = \sqrt{(4+25+1)} = \sqrt{30}$

4.3.4.6 What errors do you make when calculating magnitude of vectors?

80% of the learners admit to making mistakes with the signs of the components, substituting wrong components, confusing the formula for magnitude with the formula for direction and forgetting to take the square roots of sum of the squares. However, 20% indicated that they rarely make mistakes they often double check their work to avoid errors.

4.3.4.7 What do you do to reduce those errors?

Most learners listed the errors that they make and then gave the strategies to reduce the errors. They said the double check their work especially when squaring the components or taking square root. Trying to breakdown the problem into smaller units was another response from learners. Learner D said, “To reduce these errors, I try to focus on understanding the underlying concepts rather than just memorizing the formula. I also practice solving different types of problems, so I can become more comfortable with the calculations and develop a deeper understanding of the concepts.”

4.3.4.8 How does your teacher help you to reduce those errors?

70% of the learners said their teacher doesn’t help them well, they don’t provide feedback on homework and they just tell them to be more careful, but doesn’t explain how. However, 30% were very confident that their teacher provides enough feedback and guidance.

4.3.4.9 Do you think your teacher is knowledgeable in vectors?

Learners had different views on this question. 60% said their teachers struggle with explaining the concepts and that is why they find it difficult to understand calculating magnitude of vectors. They don’t think the teachers have a strong grasp of vectors as they often rely on the textbook instead of explaining it themselves. They also noted that teachers often give incorrect examples and make mistakes on board. However, 40% of the learners said their teachers are knowledgeable but they don’t prepare for the lessons.

4.3.4.10 Do you think your teacher cover all concepts when teaching vectors?

For this question 68% of the learners believe their teachers do not cover all concepts and topics when teaching vectors. They also complained that they feel like rushing through certain topics and they end up having to study extra outside the classroom. 32% 0f the learners under study confessed that their teachers cover all concepts and topics very well.

4.3.4.11What teaching strategies does your teacher use when teaching magnitude of vectors?

30% of the learners said they appreciate their teachers' use of examples and practice questions. However, 70% said their teacher just give them worksheet and doesn't really explain it. They have to look for help from other gifted learners for them to understand the concepts.

4.3.4.12 Do you think these teaching strategies are effective enough to help you understand the concept vector magnitude?

Learners gave different opinions as far as these teaching strategies are concerned. Here are some of the responses, learner A: "I'm not sure these strategies are effective. I feel like the focus too much on the procedure for calculating vector magnitude, rather than the underlying concept. I need more help understanding why the procedure works rather than just memorizing the steps." Learner B: "I don't think these strategies are effective enough. I need more practice problems to

really solidify my understanding of vector magnitude. The worksheets are helpful, but I wish there were more examples and practice problems to work through." Learners did not give negative responses only about these strategies. Learner K said, "Using these strategies has given me more confidence in my ability to calculate vector magnitude. I feel like I have better grasp of the concept and can apply it more easily to different problems."

4.3.4.13 what can you say about time allocated to mathematics lessons?

All the learners believe that the time allocated to mathematics lessons is insufficient. They said they need more time, the lessons always feel rushed.

4.3.5 Teacher Interviews questions and responses

4.3.5.1 What is your highest professional qualification?

The response from the three teachers show that two of them had a diploma in education and one had a Bachelor of Science degree in mathematics. The teachers are qualified to teach all the topics in mathematics like vectors.

4.3.5.2 At which level do you teach mathematics?

Responses compiled shows that all the three teachers teach mathematics from form one to form four.

4.3.5.3 What can you say about the performance of your learners when calculating magnitude of vectors?

The responses recorded indicate that learners often struggle significantly with calculating magnitude of vectors. Two teachers confirmed that learners seem to find the concept very challenging. The other teacher said the learners' performance is below average.

4.3.5.4 What do you think is needed to improve their performance?

Teachers' responses were as follows, Teacher A: "To improve learners' performance, I believe we need to provide more differentiated instruction and feedback. Some learners may need additional support with the mathematical procedures, while others may need more challenging problems to extend their understanding. By providing targeted feedback and adjusting our instruction to meet the need of individual learners, we can help them build confidence and proficiency in calculating vector magnitude." Teacher B said, "To improve learners' performance in vector magnitude, I believe we need to integrate more technology and real-world applications into our instructions. This could include using software or apps to visualize and explore vectors or using real world examples such as physics or engineering problems to illustrate the relevance and importance of vector magnitude. By making the learning experience more engaging, interactive and relevant, we can help learners develop a deeper understanding and appreciation of vector magnitude.

4.3.5.5 What teaching strategies do you use when teaching magnitude of vectors?

The responses from two teachers indicate that they often rely on textbooks which are not engaging or effective for learners. The other teacher often uses a combination of teaching strategies including discussions and lectures.

4.3.5.6 Do you think these strategies are effective?

Two teachers were of the view that while textbooks provide a good introduction to vector magnitude, they may not offer enough opportunities for learners to practice and apply knowledge. There is need to supplement with more hands-on activities, simulations and real-world problem application to help learners develop their problem solving skills. The other teacher said these strategies may be too theoretical and abstract for some learners. There is need to incorporate more concrete and visual aids such as diagrams, graphs and videos to help learners visualize and understand the concept vector magnitude.

4.3.5.7 What errors do students make when calculating magnitude?

The responses shows that learners forget to square the components of the vector before adding them, incorrect application of the formula, incorrect calculation of the square root, failure to check their work, failure to simplify their answers and lack of understanding of the concept.

4.3.5.8 How do you assist your students so that they don't repeat those errors?

The common response from all the teachers is that they don't have resources to adequately assist the learners. The other response was that they struggle to provide individualized support to learners due to large class sizes. However one teacher said sometimes he encourages learners to work in pairs so that they share ideas and make sure they check their work regularly to catch any mistakes.

4.3.5.9 What teaching strategies should be emphasized when teaching magnitude of vectors?

The response from one of the teachers was that of emphasizing the importance of understanding the concept of magnitude, rather than just memorizing the formula. Use of more interactive and

engaging teaching strategies such as group work and games was also mentioned in the responses by teachers. They said this would help learners to better understand the concept. The need to check one's work was also raised.

4.3.5.10 Do you get enough resource for teaching vectors from school administrators?

The responses show that teachers do not receive adequate resources from the school administrators. They often have to purchase their own materials and rely on outdated textbooks.

4.3.5.11 Do you think the time allocated to mathematics lessons is enough to cover all topics for the term?

Two teachers do not think time allocated to mathematics lessons is sufficient to cover all topics for the term. They often feel rushed and struggle to give learners the support they need. The other teacher said the time allocated is sufficient but sometimes feel that the pace is too fast for some learners.

4.3.6 Summary

In this chapter the researcher has analyzed data which was on tables, pie charts and graphs. The results showed that learners made various errors including, conceptual, computational and procedural errors. Conceptual errors were most prevalent followed by computational errors. Procedural errors were less common but still significant. The next chapter will give the recommendations based on the research and lastly conclude the research.

CHAPTER 5: SUMMARY, FINDINGS AND RECOMENDATIONS

5.1 Introduction

Calculating the magnitude of vectors is a fundamental concept in Mathematics and Physics. However, many ordinary level learners struggle with this concept, leading to various errors. This chapter presents the findings on the errors made by learners when calculating the magnitude of vectors.

5.2 Findings

The study revealed that learners made various errors when calculating the magnitude of vectors. These errors can be categorized into conceptual, computational and procedural errors.

Conceptual errors were the most prevalent, with learners struggling to understand the vector concept, interpreting vector forms incorrectly and having difficulty in visualizing vectors. Computational errors included incorrect calculation of vector forms, failure to apply the correct formula, and incorrect substitution of values. Procedural errors were less common but still significant, with learners failing to follow the correct order of operations, failure to calculate squares and struggling to simplify expressions.

The errors observed in exercise 1and 2, as well as the test were consistent with learners struggling with same concepts and calculations. The study also found that 10% of learners reported liking vectors, while the majority found calculating the magnitude of vectors challenging.

The teacher interviews revealed that teachers also face challenges in teaching the concept of vector magnitude. Two teachers had a diploma in mathematics, while one had a Bachelor of Science education in mathematics. Despite their qualifications, teachers reported that learners struggle with calculating the magnitude of vectors and that they rely heavily on textbooks, discussions and lectures to teach the concept. Teachers reported that the time allocated to mathematics lessons is insufficient, making it difficult to provide adequate support to learners.

The learner interview revealed that several issues that contributed to the errors made when calculating the magnitude of vectors. These include:

Lack of understanding of the vector concept, insufficient practice exercises, difficulty in visualizing vectors, lack of confidence in applying mathematical formulas, inadequate support from teachers and insufficient time allocated to mathematics lessons.

5.3 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Teachers should use a variety of teaching methods, including visual aids and practical examples to help learners understand the concept of vector magnitude.

2. Teachers should provide additional support to learners who struggle with calculating magnitude of vectors including one-on-one tutoring and extra practice exercises.

3. Teachers should be provided with ongoing professional development opportunities to help them stay up-to-date with best practices in teaching mathematics.

4. Learners should ask questions and seek clarification when they do not understand a concept, rather than struggling in silence.

5. Learners should form study groups to collaborate and learn from one another.

6. Learners should use online resources and educational apps to supplement their learning and gain a deeper understanding of vector magnitude concepts.

7. Mathematics teachers have the task to demystify the belief that the topic vectors are tough. They have to motivate the learners so that they win their hearts.

5.4 Limitations

The study had several limitations. Mathematics books are written in English which make it a challenge to learners to translate it to meaningful instructions. Economic hardships have dragged the parental support into uncertainty especially to the middle and lower income earners in rural dwellers, subsequently learners fail to buy individual textbooks, which is very important in the

learning of vectors. The same has also affected schools which are failing to purchases enough textbooks for learners.

5.5. Conclusions

This study found that ordinary level learners make various errors when calculating the magnitude of vectors, including conceptual, computational and procedural errors. Teachers also face challenges in teaching this concept, including learners' lack of understanding and insufficient time allocated to mathematics lessons. The study recommends that teachers use a variety of teaching methods, provide additional support to learners, learners should take the initiative to seek additional support, practice regularly and use online resources to supplement their learning.

APPENDIX I. Interview guide for ordinary level students
Bindura University in Science Education

Bindura

Introduction

This interview aims to gather information about errors made by ordinary level learners when calculating magnitude of vectors. Your responses will help us identify the errors and understand teaching strategies that are effective in addressing those errors

1. Are you interested in learning mathematics
2. Can you tell me any concept that fall under the topic vectors?
3. Is it easy to calculate the magnitude of vectors?
4. How do you calculate magnitude of a two dimensional vector?
5. Can you calculate the magnitude of [2, 5, 1]?
6. What errors do you make when calculating magnitude of vectors?

7. What do you do to reduce those errors?
8. How does your teacher help you to reduce those errors
9. Do you think your teacher is knowledgeable in vectors?
10. Do you think your teacher cover all concepts when teaching vectors?
11. What teaching strategies does your teacher use when teaching vectors?
12. Do you think these teaching strategies are effective enough to help you understand the concept vector magnitude?
13. What can you say about time allocated to mathematics lesson?

Conclusion

Thank you for taking the time to share your thoughts and experiences. Your feedback is valuable to me.

APPENDIX II. Interview guide for Teachers

Bindura University of Science Education

Bindura

Preamble

I am a student at Bindura University of Science Education doing Bachelor of Science Education in Mathematics. I am carrying out a research about errors made by ordinary level students when calculating magnitude of vectors. Everything discussed in this interview is going to be confidential and used for academic purposes only.

1. What is your highest professional qualification?

2. At ordinary level, which other levels do you teach mathematics?

3. What can you say about the performance of your students when calculating the magnitude of vectors?

4. What do you think is needed to improve their performance?

5. What teaching strategies do you use when teaching magnitude of vectors?

6. Do you think these strategies are effective?

7. What errors do students make when calculating magnitude of vectors?

8. How do you assist your students so that they don't repeat those errors?

9. What teaching strategies should be emphasized when teaching magnitude of vectors?

10. Do you get enough resources for teaching and learning vectors from school administrators?

11. Do you think the time allocated to mathematics lessons is sufficient to cover the topics planned for the term?

Conclusion

Thank you for the time and insights. Do you have any additional comments or suggestions regarding teaching mathematics, particularly in relation to vectors?

APPENDIX III. Exercise 1

1 (a) what is magnitude of a vector? [1]

(b) Given A= [3, 4] and B= [2, 9]. Find $|B|$ [3]

2. (a) What is the magnitude of the vector A [4, 3] [2]

(b) If vector A= [6, 8] and Vector B= [3, 4], which vector has the greatest magnitude? [3]

3 (a) If vector P= [-2, 5]. What is the magnitude of the vector? [2]

(b) Find the magnitude of the vector D= [-3,-4] [2]

4. Two vectors A and B have magnitudes of 6 and 8, respectively. If they are added together, what is the maximum possible magnitude of the resulting vector? [2]

5. A vector C has a magnitude of 9. If it is multiplied by a scalar of 3, what is the new magnitude of the vector? [2]

APPENDIX IV Exercise 2

1 (I) A vector A= [6, 8, 10] is given. Find $|A|$. [2]

(ii) Calculate the magnitude of the vector C= [4,-5, and 6] [2]

2 (i) What is the magnitude of the vector C= [-1, 2,-3]? [2]

(ii) Find the magnitude of the vector D= [-2,-3,-4] [2]

3 A= [3,-4, 2] and B= [-1, 7, 3]

(i) Find $|A|$ [2]

(ii) Which vector has the greatest magnitude? [3]

4 (i) A vector B has a magnitude of 15. If it is multiplied by a scalar of 2, what is the new magnitude? [2]

(ii)Calculate the magnitude of the vector E= [3, 4, and 5]

5. What is a unit vector? [1]

APPENDIX V. Test

1. Vector **a**= [3, 2, 5] and **b**= [6, 2, 1] are given. Find

   (a) $|\mathbf{a}|$ [2]

   (b) $|\mathbf{b}|$ [2]

2. Given B= (3, 4) and vector C= [2, 9]. Find

(a) $|C|$ [2]

(b) $|BC|$ [3]

(c) Which vector has the greatest magnitude? [3]

3. A vector D = [3, 4, 5] is given. Find $|D|$ [2]

4. What is the magnitude of the vector A= [-6, 8, 6]? [3]

5. If PQ= [12,-35] and QR= [4, 14]. Find (i) $|PR|$ [3]

APPENDIX VI: Research letter

APPENDIX VII: Permission to carry out the research from Mashonaland West Province.

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