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BACHELOR OF SCIENCE EDUCATION HONORS DEGREE IN MATHEMATICS

EXPLORING PROBLEMS FACED BY LEARNERS IN THE LEARNING OF VECTORS AT ORDINARY LEVEL. A CASE OF SECONDARY SCHOOL IN HARARE METROPOLITAN DISTRIC.

BY

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   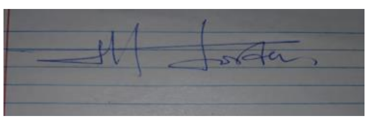

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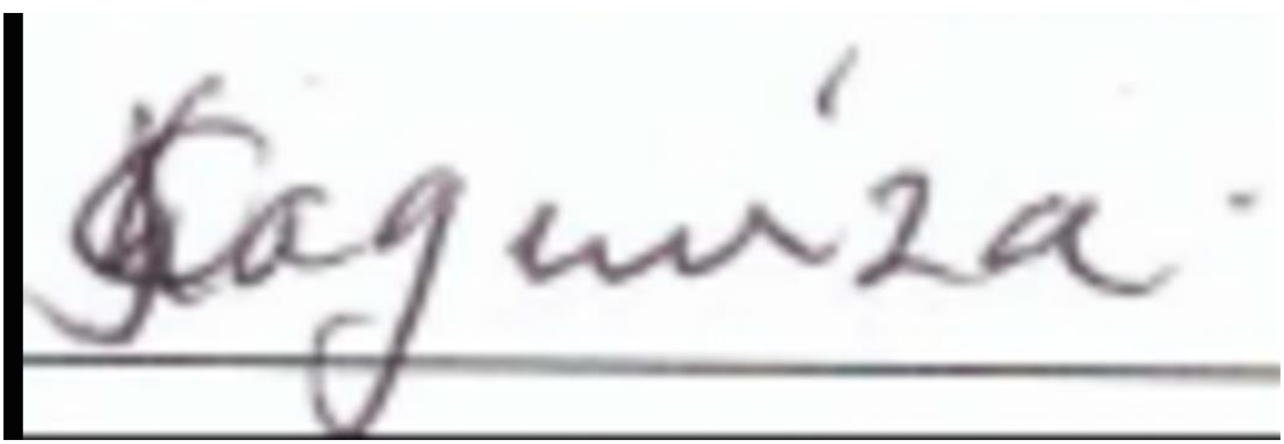

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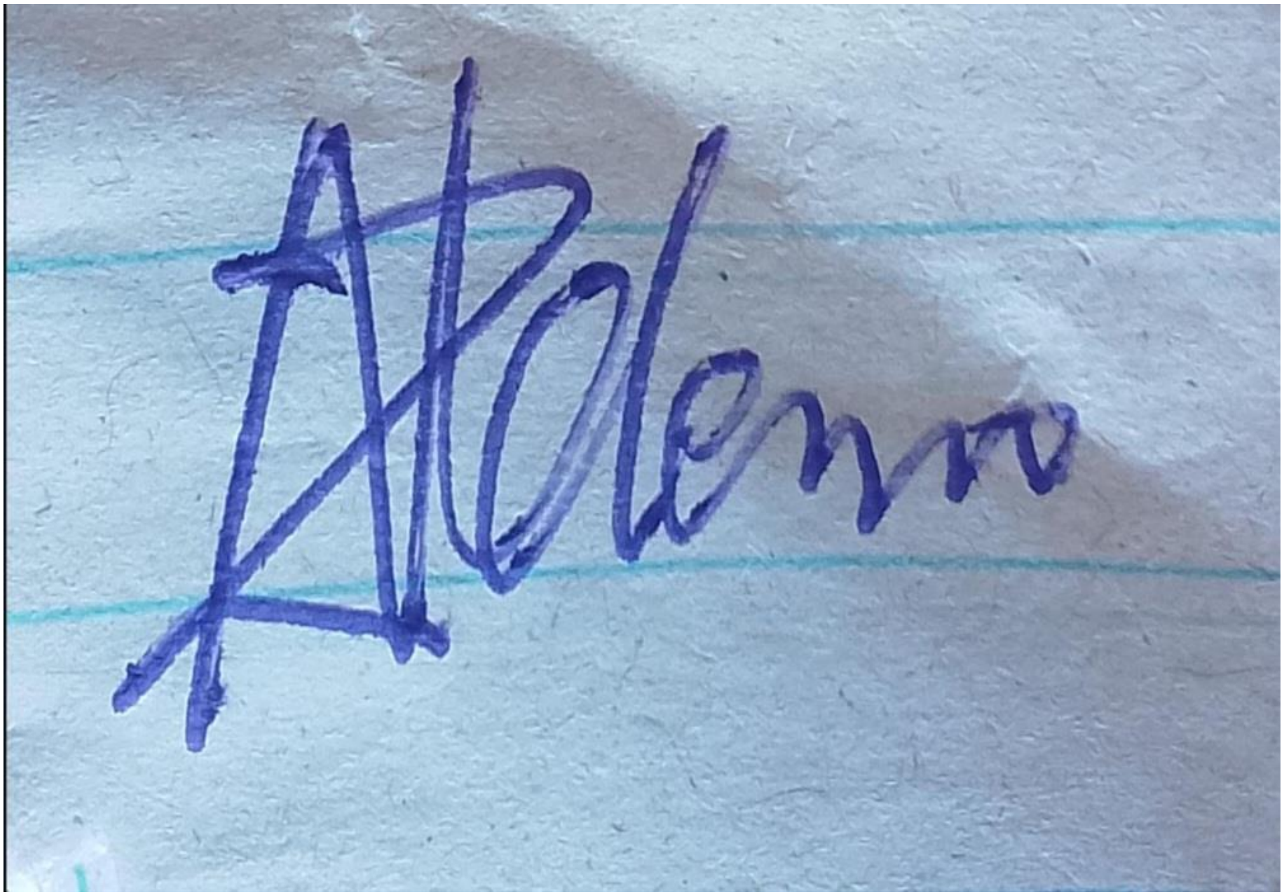

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This study is dedicated to family, my dear friends and colleagues I am thankful for all the encouragements you have given me.

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ABSTRACT

Students Mahusvu at Harare cluster have demonstrated their struggle to visualize vectors in two dimensions that find it hard to comprehend vector notations include magnitude, direction and unit vectors. This study investigated the challenges faced by learners in the learning of vectors. The study conducted the mixed method. The study is aiming to explore the aims of students and teachers' perspectives in the teaching and learning of vectors in mathematics at ordinary level at one school in Harare Metropolitan Province. Participants of the project are 70 students at a secondary school in Harare. The method used to choose students was unbiased. After the survey was conducted the findings were collected analysed. The researcher found out that in schools there are mathematics teachers who are technologically illiterate. On teacher expectation simulation-based learning can supplement traditional teaching methods. On student's expectation simulation can improve problem solving skills. The study reveals that both teachers and students have high expectations for the use of simulation in the teaching and learning of vectors. The findings suggest that simulation-based learning can enhance student engagement and motivation.

Key words: Perspectives, Simulation, Teaching and learning, Vectors, Participants

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LIST OF ANNEXURES

CHAPTER ONE: INTRODUCTION TO THE STUDY

Exploring problems faced by learners in the learning of vectors at ordinary level. A case of a secondary school in Harare metropolitan district.

1.0 Introduction to the Study

The learning of Vectors in Ordinary Level (O-Level) Mathematics in Zimbabwe present significant challenges for students. Vectors are a fundamental topic in Ordinary Level Mathematics, yet students in Zimbabwe continue to struggle with their application and conceptual understanding. Examiner reports from the Zimbabwe School Examinations Council (ZIMSEC) highlight recurring challenges. For instance, the 2020 report noted, "Many candidates failed to represent vectors correctly on diagrams" (ZIMSEC, 2020, p. 12). In 2021, examiners observed, "Students confused vector notation with coordinate geometry" (ZIMSEC, 2021, p. 15). The 2022 report emphasized, "Weakness in vector addition and subtraction was evident" (ZIMSEC, 2022, p. 10). Additionally, the 2023 report stated, "Candidates struggled with resolving vectors into components" (ZIMSEC, 2023, p. 14). Most recently, the 2024 report highlighted, "Misinterpretation of vector direction remains a major issue" (ZIMSEC, 2024, p. 11). These recurring issues suggest a need for improved learning strategies. This study explores innovative methods to enhance vector comprehension among Ordinary Level students in Zimbabwe, addressing persistent gaps identified by examiners. By identifying these challenges, educators can develop better instructional strategies. Additionally, the research aims to improve students' performance and confidence in handling vector-related problems. Understanding these difficulties is crucial for curriculum development and teacher training. Ultimately, addressing these issues can enhance the overall quality of STEM education.

1.1 Background of the Study

Vectors play a critical role in mathematics and physics, forming the basis for topics like mechanics, electromagnetism, and engineering. At the Level, students are introduced to basic vector concepts, including addition, subtraction, and resolution of vectors. However, studies indicate that many learners struggle with visualizing and manipulating vectors. Previous studies have examined challenges in teaching and learning vectors. (Chikodzi ,2020) found that students lacked visualization skills in vector problems (p. 45). (Mayo ,2020) emphasized the need for practical applications to improve understanding (p. 32). (Ndlovu ,2021) identified teacher-cantered methods as a barrier to conceptual grasp (p. 18). Meanwhile, (Dube ,2022) highlighted insufficient practice problems in textbooks (p. 27). (Makaza ,2023) recommended digital tools for interactive learning (p. 39). Despite these findings, a research gap exists in evaluating context-specific interventions for Zimbabwean classrooms. Most studies focus on general challenges rather than localized solutions. Additionally, there is limited research on integrating indigenous examples to enhance relevance. This study aims to bridge these gaps by proposing tailored instructional strategies for Ordinary Level Mathematics.

1.2 Purpose of the Study

1. To identify the key conceptual difficulties learners face in understanding vectors at O'Level.
2. To explore the role of visual aids and practical applications in enhancing vector learning.
3. To recommend strategies for improving the learning of vectors at the O'Level.

1.3 Research Questions

1. What are the challenges students encounter when learning vectors at the O'Level?

2. What strategies can be implemented to enhance the learning of vectors at the O'Level?

1.4 Statement of the Problem

Students' performance in vectors at Ordinary Level remains unsatisfactory, as evidenced by ZIMSEC reports. Despite being a core topic, misconceptions persist, affecting overall Mathematics grades. Traditional teaching methods may not address visualization and application challenges. The lack of engaging resources further exacerbates the problem. If not addressed, this issue may hinder STEM-related career paths for students.

1.5 Assumptions of The Study

This study assumes that teachers are willing to adopt new strategies. It also presumes that students have basic mathematical knowledge. Additionally, it assumes that ZIMSEC reports accurately reflect learning gaps. The study further assumes that practical examples will enhance understanding. Poor performance in Vectors is significantly influenced by inadequate teaching methods and lack of learning resources and students with access to visual and interactive learning tools perform better in Vectors.

1.6 Significant of The Study

This study is significant as it addresses a critical gap in the teaching and learning of vectors at the O'Level. By identifying key challenges, it provides insights for educators to refine their instructional approaches. The findings will help curriculum developers design more effective teaching materials tailored to students' needs. Teachers will benefit from evidence-based strategies to simplify abstract vector concepts. Students will gain from improved teaching methods, leading to better academic performance. Schools can use the recommendations to enhance STEM education and learner engagement. Examination bodies may also consider adjusting assessment techniques based on the study's outcomes. Additionally, the research contributes to existing literature on mathematics and physics education. Policymakers can use the results to inform teacher training programs. Parents and guardians will gain awareness of the difficulties their children face in learning vectors. The study also encourages the use of technology and visual aids in teaching abstract topics. Furthermore, it highlights the importance of foundational knowledge in algebra and geometry for mastering vectors. Ultimately, the research aims to reduce failure rates in vector-related exam questions. It promotes active learning and problem-solving skills among students. The long-term impact includes fostering a stronger foundation for advanced studies in engineering and physics. Overall, this study serves as a valuable resource for improving mathematics and physics education at the O'Level.

1.7 Delimitations

This study was guided by certain boundaries that were set by the researcher to make the investigation more focused and manageable. These boundaries, known as delimitations, helped to define what the study would cover and what it would not. One major delimitation was that the research focused only on Ordinary Level learners and teachers within a single educational cluster in Harare Metropolitan Province**.** This was done to keep the research specific and manageable, but it also means that the results may not apply to other regions or educational levels. It examines vectors exclusively, not other Mathematics topics. Only ZIMSEC examiner reports from 2020–2024 are analysed. Only students selected schools will be surveyed, limiting generalizability. The study examines conceptual and instructional difficulties rather than assessment or policy issues. Data collection is restricted to questionnaires, interviews, and classroom tests. The study emphasizes cognitive and pedagogical challenges rather than socio-economic factors. Another important delimitation was the focus on the topic of vectors in the mathematics curriculum. While learners may face challenges in other areas of mathematics, this study specifically explored difficulties in learning vectors. This helped the researcher to go deeper into one topic, especially in relation to the use of simulation-based learning. The study also involved only those teachers who had experience teaching vectors using simulations and learners who had been taught using such methods. Teachers and students who had not used simulations were not included. This decision was made to align with the study's main objectives but also limited the range of teaching methods explored. Lastly, the study was conducted within a specific period of time, which meant that any changes in curriculum or teaching methods after data collection were not considered. Even with these boundaries, the study aimed to give useful insights into the challenges faced by learners when studying vectors at Ordinary Level.

1.8 Limitations

Although this study was carefully designed to investigate the challenges learners face in understanding vectors at the Ordinary Level, several limitations were encountered that may have affected the scope and depth of the findings. One major limitation was the restricted sample size and geographical scope. The research was limited to one educational cluster in Harare Metropolitan Province, meaning that the results may not fully represent the experiences of all learners and teachers across Zimbabwe. This limits the generalizability of the findings to broader educational settings. Another limitation was the issue of time. The study was conducted within a limited timeframe, which made it difficult for the researcher to carry out prolonged classroom observations or follow-up interviews. This constraint may have affected the ability to capture the full range of factors influencing vector learning over time. In addition, the research relied heavily on self-reported data collected through questionnaires and interviews. While efforts were made to encourage honest responses, there is always the possibility that participants gave socially desirable answers or did not recall information accurately. Access to participants also posed a challenge. Some schools or individuals were not available for the entire duration of the study, and arranging suitable times for interviews and observations proved difficult due to academic schedules. Lastly, there were differences in how teachers applied simulation-based teaching methods. Some had more experience or training than others, which may have created inconsistencies in how vector concepts were taught and perceived by learners.

1.8.1 Definition of Terms

A vector is a quantity that has both magnitude (size) and direction, often represented as an arrow in space (Kurtz, 2019). In physics, a vector is any measurable quantity that requires both magnitude and direction for its complete description, such as force or velocity (Serway & Jewett, 2018). In O'Level education, vectors refer to mathematical and physical quantities taught in topics like mechanics, where students learn operations such as addition, subtraction, and resolution. (Cohen, 2020) defines, exploring as, "Investigating a topic systematically." (Bell, 2021, p. 22) also defines exploring as, the process of '"Examining different methodologies. Therefore, one may define exploring as analysing educational challenges. Learning is Acquiring knowledge through instruction (Hattie, 2019, p. 8). (Skinner, 2020, p. 11) Also defines learning as a, "change in behaviour due to experience". Therefore, one may define learning as a cognitive process of understanding. A secondary education certification (ZIMSEC, 2020, p. 3). A foundational exam in Zimbabwe (MoE, 2022, p. 9).

1.8.2 Organisation of the Study

The study is organised into five main chapters, each playing a specific role in guiding the reader through the research process in a clear and logical manner. Chapter One provides the foundation of the study by introducing the background to the research problem, stating the purpose, objectives, and research questions, and outlining the significance of the study. It also presents the limitations and delimitations of the study, as well as the definitions of key terms used throughout the research. Chapter Two presents a detailed review of related literature. It discusses relevant theories, past research findings, and key concepts related to the teaching and learning of vectors. This chapter also highlights gaps in existing knowledge, which this study aims to fill. Chapter Three focuses on the research methodology. It describes the research design used, the population and sampling techniques, the data collection instruments, and the procedures for both collecting and analysing the data. Ethical considerations followed during the research process are also explained in this chapter. Chapter Four deals with the presentation, analysis, and discussion of the findings. It includes results obtained from tests, questionnaires, interviews, and classroom observations. The findings are analysed and discussed in relation to the research questions and previous literature. Finally, Chapter Five presents the summary of the study, draws conclusions based on the findings, and provides recommendations for improving the teaching and learning of vectors. It also offers suggestions for future research in this area. This organisation helps to ensure that the research is systematic, coherent, and academically structured.

1.9 Chapter Summary

This chapter introduced the study, outlining its background, objectives, and significance. It highlighted the challenges in teaching and learning Vectors at O-Level in Zimbabwe and set the foundation for further investigation. The research objectives and questions were clearly defined to guide the study, aiming to explore both learners' and teachers' perspectives. The significance of the study was also discussed, emphasizing the importance of improving teaching practices and learner outcomes in vector-related topics. In addition, the chapter outlined the limitations and delimitations, which helped define the scope and boundaries of the research.

CHAPTER 2: REVIEW OF RELATED LITERATURE REVIEW

2.0 Introduction

At ordinary level, the study of vectors typically forms part of the mathematical curriculum. Vectors are mathematical entities used to represent quantities that have both magnitude and direction. In this chapter, the challenges faced by learners in the learning of vectors at a secondary school in Harare metropolitan district will be examined. The chapter will review relevant literature on the challenges faced by learners in the learning of vectors, specifically conceptual difficulties in learning vectors, role of visual aids and practical applications in enhancing vector learning at O'Level. This aim to explore strategies for improving the learning of vectors at ordinary level.

2.1 Theoretical Framework

The teaching and learning of vectors in mathematics is deeply rooted in Constructivist, Cognitive learning theories, Vygotsky's Sociocultural Theory, and the Information Processing Theory**.** The theoretical framework serves as the foundation for this study on the problems faced by learners in the learning of vectors at Ordinary Level. It draws on established educational theories that explain how students acquire mathematical concepts, process information, and overcome learning difficulties. This framework provides a lens through which the challenges experienced by learners can be analysed and understood, as these theories offer critical insights into teaching and learning practices relevant to vector concepts.

Constructivism emphasizes that learners actively construct their own understanding of mathematical concepts through experience and interaction (Piaget, 1972). When applied to vector learning, this theory suggests that learners should be provided with opportunities to manipulate vector quantities in both algebraic and geometric contexts. In the context of vector learning, this theory suggests that students should not merely memorize formulas but develop a conceptual understanding through active participation and problem-solving. Research has shown that learners struggle with vectors due to their abstract nature and lack of real-life contextualization (Kozlowski & Wirtz, 2022). When teaching relies heavily on rote methods without practical application, students fail to grasp core concepts like magnitude and direction. Simulation-based and inquiry-driven approaches are aligned with constructivist principles, promoting deeper understanding by allowing learners to experiment with vectors in real-world contexts.

Cognitive Load Theory (Sweller, 1988) also plays a critical role in understanding difficulties in learning vectors. Vectors involve both visual-spatial reasoning and abstract symbolic manipulation, which can overwhelm a learner's working memory. Vector problems often involve multiple concepts—such as component resolution, magnitude, and direction—making them cognitively demanding. If instructional strategies fail to break down complex steps, learners experience cognitive overload, leading to misconceptions and poor performance (Paas & Sweller, 2021).

Vygotsky's theory stresses the importance of social interaction and scaffolding in the learning process (Vygotsky, 1978). Learning occurs within the Zone of Proximal Development, where learners need guidance to perform tasks beyond their independent ability. In vector learning, group work, peer collaboration, and teacher support are essential for bridging gaps in understanding. Studies by Mavhunga and Moyo (2022) show that learners benefit significantly from collaborative tasks, as they allow for discussion, error correction, and shared strategies. In the absence of interactive and supportive learning environments, students often fail to overcome misconceptions about vector operations and representation.

Information Processing Theory views learning as the process of encoding, storing, and retrieving information. For students to successfully learn vectors, they must effectively transfer information from short-term to long-term memory through repeated practice and reinforcement (Atkinson & Shiffrin, 1971).When foundational vector concepts such as magnitude and direction are poorly understood, students experience difficulties in applying advanced operations like dot and cross products (Bolarinwa, 2021). Inadequate practice, insufficient use of diagrams, and lack of technological aids further contribute to weak retention.

In a nutshell, these four theories which are, Constructivism, Cognitive Load Theory, Sociocultural Theory, and Information Processing, provide a strong foundation for understanding why learners face challenges in learning vectors. Constructivism emphasizes the need for active engagement and real-life applications. Cognitive Load Theory highlights the importance of reducing instructional complexity. Sociocultural Theory points to the role of collaboration and teacher guidance, while Information Processing explains the importance of memory and reinforcement. Together, they inform the analysis and recommendations of this study

2.2 Conceptual Challenges in Learning Vectors

The teaching and learning of vectors at the Ordinary Level in Zimbabwe pose a range of conceptual challenges for students, which hinder their academic success in mathematics. While vectors form an integral part of the secondary school mathematics curriculum—encompassing operations such as vector addition, subtraction, scalar multiplication, and the determination of magnitude and direction—their abstract nature contributes significantly to learner difficulties. These challenges are rooted in a combination of misconceptions, foundational gaps in related mathematical knowledge, and cognitive overload during instruction.

2.2.1 Abstract Nature of Vectors and Operations at Ordinary Level

Moyo (2022)**,** carried out a research on the challenges faced by learners in understanding the abstract nature of vectors and their operations at the Ordinary Level. He investigated the conceptual difficulties learners encounter when dealing with vectors, particularly focusing on their abstract properties and operations such as addition, subtraction, and scalar multiplication. Moyo (2022) adopted a mixed-methods research design, integrating both quantitative and qualitative approaches. The study involved a sample of 120 Ordinary Level students and 10 mathematics teachers drawn from three secondary schools in Harare Metropolitan Province. A diagnostic test on vector concepts was administered to the students, and semi-structured interviews were conducted with the teachers. Quantitative data from the tests were analysed using descriptive statistics, while qualitative data from interviews were subjected to thematic analysis to uncover recurring conceptual difficulties and instructional challenges.

The findings revealed that most learners exhibited poor understanding of vector representation **and** operations due to their abstract nature. Specifically**,** 68% of the students struggled with visualizing vectors in two- and three-dimensional spaces**,** while 74% could not correctly apply vector addition and subtraction using geometric and algebraic methods**.** Interviews with teachers indicated that insufficient use of visual aids and practical applications in teaching contributed to these misconceptions. Additionally, the results highlighted that learners tended to memorize formulas without comprehending the underlying concepts, leading to poor problem-solving skills in vector-related questions. Based on these findings, Moyo (2022) recommended that teachers adopt multiple representations**,** including diagrams, dynamic geometry software, and real-life examples, to make abstract vector concepts more concrete. The study further suggested integrating activity-based learning approaches, such as group discussions and project-based tasks, to promote conceptual understanding rather than rote learning. Finally, teacher professional development programs were recommended to enhance instructional strategies for teaching abstract mathematical concepts effectively.

2.2.2 Misconceptions and Confusion in Vector Representation

Chirwa (2021) conducted a study titled *Misconceptions and Confusion in Vector Representation at Ordinary Level* to explore learners' conceptual challenges in representing and interpreting vectors in two-dimensional and three-dimensional spaces. Chirwa (2021) employed a qualitative case study design to gain an in-depth understanding of the misconceptions learners exhibit when dealing with vector representation. The research was carried out in two secondary schools, involving 60 Ordinary Level students and 8 mathematics teachers**.** Data collection instruments included diagnostic tests, classroom observations, and semi-structured interviews. Diagnostic tests were used to identify common misconceptions, while interviews and observations provided contextual insights into teaching practices and learner difficulties. Thematic analysis was used to interpret the qualitative data.

The study revealed significant misconceptions among learners in understanding vector representation. About 72% of students confused scalar quantities with vector quantities, often neglecting direction when representing vectors. Furthermore, 65% of learners failed to distinguish between the magnitude of a vector and its components, leading to errors in calculations. Classroom observations highlighted that teachers often relied heavily on abstract symbols and algebraic approaches, with minimal use of diagrams or real-life applications, which contributed to the confusion. Interviews with teachers indicated that time constraints and lack of teaching resources hindered the adoption of more interactive teaching methods.

Based on these findings, Chirwa (2021) recommended the integration of visual learning strategies**,** including the use of dynamic software like GeoGebra and interactive diagrams, to bridge the gap between abstract concepts and visual understanding. The study also emphasized the need for curriculum reforms that incorporate more practical examples and activities related to vectors. Additionally, Chirwa proposed teacher training workshops focusing on conceptual teaching approaches rather than procedural methods, aiming to eliminate misconceptions and foster deeper understanding among learners.

2.2.3 Lack of Foundational Understanding in Related Mathematical Concepts

In a study conducted by Mahlambi, T. (2022**)**, titled *"The Impact of Foundational Mathematical Deficiencies on Learner Performance in Secondary Schools"*, the researcher investigated how students' poor grasp of basic mathematical concepts affected their understanding of higher-level topics such as algebra, geometry, and vectors at secondary school level. The study adopted a mixed-methods approach, combining both quantitative and qualitative data collection methods. A sample of 150 students from three secondary schools in Gauteng Province, South Africa, was selected using stratified random sampling. Quantitative data were collected through diagnostic tests designed to assess understanding of basic mathematical concepts like number operations, fractions, and algebraic manipulation. Qualitative data were gathered through semi-structured interviews with mathematics teachers and classroom observations over a period of 8 weeks.

The study found that 72% of the learners lacked mastery of foundational concepts, particularly in the areas of number sense, operations with fractions, and understanding of variables. These gaps led to significant struggles when learners encountered abstract topics like solving linear equations, working with inequalities, or performing vector operations. Teachers noted that they often had to reteach foundational material, which limited time for teaching curriculum-specified topics. Learners' confidence and participation were also found to be negatively affected.

Mahlambi recommended that, Intervention Programs must be done, that is schools should implement targeted intervention programs at the lower secondary level to strengthen foundational skills before learners advance to more complex topics. Curriculum Review There is a need for curriculum designers to integrate spiral learning, where foundational concepts are revisited regularly in more complex forms. Teacher Professional Development – Teachers should receive ongoing training to diagnose foundational weaknesses and apply differentiated instruction to address varied learning needs. Use of Diagnostic Assessment – Schools should regularly administer diagnostic tests to monitor student progress and adapt instruction accordingly.

2.2.4 Instructional Approaches

Instructional approaches may further hinder learning. Traditional teacher-centred methods that emphasize memorization over understanding limit learners' ability to apply vector concepts flexibly. Interactive and inquiry-based methods are more effective but are underutilized due to curriculum constraints or lack of teacher training (Chirwa & Mhlanga, 2022).

2.2.5 Language and Symbolic Confusion.

Additionally, language and symbolic confusion plays a role. Learners often misinterpret vector symbols and direction arrows, especially when symbols are inconsistently used across subjects like mathematics and physics (Zhou, 2020). Misalignment in instructional language can cause cognitive dissonance and slow down conceptual integration.

2.2.6 Limited Resources and Lack of Visualization.

Finally, limited resources and lack of visualization tools also contribute. Many schools at the Ordinary Level do not have access to dynamic geometry software or manipulatives that can help learners visualize and experiment with vectors (Mutambara & Dube, 2021). This lack of supportive learning tools limits students' engagement and deeper understanding.

In sum, the conceptual challenges in learning vectors at the Ordinary Level in Zimbabwe are multifaceted. They stem from the abstract nature of vectors, widespread misconceptions, insufficient grounding in prerequisite mathematical skills, and high cognitive demands placed on learners. Addressing these issues requires a shift from procedural teaching to conceptual learning, enhanced teacher training, and the adoption of cognitive-load-aware instructional strategies. Without such interventions, learners will continue to struggle with a topic that is foundational not only to mathematics but also to science and technology disciplines.

2.3 Fundamental Knowledge Needed by Students to Effectively Grasp Vectors

To understand vectors effectively at the Ordinary Level, students require a solid foundation in various mathematical domains. Key among these is coordinate geometry, which provides the basis for plotting vectors, understanding direction and position, and calculating vector magnitude (Githua &

Nyabwa, 2021). Without proficiency in using the Cartesian plane, students are unlikely to interpret vectors accurately in a spatial context.

Additionally, basic algebraic skills such as manipulating expressions, solving equations, and working with variables are essential. These skills enable learners to perform vector operations such as addition, subtraction, and scalar multiplication with confidence (Mundalamo & Maphosa, 2023). Learners also need to understand how to apply the distributive and associative properties in the context of vector arithmetic.

Trigonometric knowledge is equally critical. Many vector problems, especially those involving direction and magnitude, rely heavily on sine, cosine, and tangent ratios, as well as Pythagoras' theorem, to resolve vectors into components or to determine the angle between vectors (Bansilal, 2020). A lack of understanding in this area leads to poor performance in applied vector questions.

Furthermore, spatial reasoning and visualization skills are crucial. According to Ng and Sinclair (2021), learners need to be able to mentally rotate and manipulate vectors in two-dimensional space to develop an intuitive sense of direction and magnitude. Visual literacy supports students in transitioning from abstract notation to concrete understanding.

Lastly, students need to develop conceptual understanding of quantities — distinguishing between scalar and vector quantities, identifying vector direction, and understanding the physical interpretation of vector concepts, especially in applied contexts such as physics (Zhou, 2020).

2.4 Literature gap

The literature gap in this research refers to a specific area that has not been adequately addressed or explored in previous studies. This gap consists of three main aspects. Firstly, there is a need for a comprehensive understanding of the specific errors and challenges that Form 3 learners face when solving vectors. Secondly, there is a lack of understanding of the fundamental knowledge and skills required to address these errors and improve learners' problem-solving skills in this area. Thirdly, previous research did not look the different cognitive levels of understanding among learners, such as knowledge, comprehension, application, analysis, synthesis, and evaluation, which are crucial in understanding the challenges learners face when solving vectors.

While previous studies have investigated learner errors and misconceptions in mathematics, the review enhanced the researcher's understanding of the challenges associated with insufficient knowledge of simulation in Mathematics, which is a crucial component in the study of vectors. The limited availability of Ordinary Level literature on vectors further highlights the lack of substantial research investment in this area. Additionally, some of the identified issues stem from learner carelessness, overconfidence, and gaps in teachers' content knowledge, despite efforts made to address the challenges related to simulation in vector learning.

By addressing this literature gap, the research aims to contribute meaningfully to the field of mathematics education. The study seeks to provide valuable insights into the challenges faced by Form 3 learners in solving vectors, develop targeted instructional strategies and interventions to support learners in overcoming these challenges, and enhance mathematical literacy and problem-solving skills for learners. To achieve this, the research will conduct a comprehensive analysis of learner errors and misconceptions, the fundamental knowledge and skills required to address these issues and different cognitive level of knowledge of learners. By filling this literature gap, the study aims to provide a deeper understanding of the challenges faced by Form 3 learners in solving quadratic equations using factorization and contribute to the existing body of research in mathematics education.

2.5 Chapter Summary

This chapter examined the critical challenges learners face in understanding vectors at the Ordinary Level, with a focus on the role of simulation in Mathematics. It highlighted that a lack of foundational knowledge in simulation significantly hinders learners' grasp of vector concepts, which rely heavily on spatial reasoning and mathematical modelling. The review further revealed a notable shortage of academic literature dedicated to Ordinary Level vector education, suggesting limited scholarly attention to this topic. Additionally, learner-related factors such as carelessness and overconfidence, as well as teacher content gaps, were identified as contributing to the persistent difficulties in vector instruction. Despite various interventions, these issues remain prevalent, pointing to the need for more focused research and teacher support in this area

Chapter 3: Research Methodology

3.0 Introduction

This chapter presents the methodology used to conduct the study. In this chapter, the research design for the study using problem-based learning will be discussed in the learning of vectors at ordinary level will be discussed. It will outline the instruments used to collect data, describe the target population and sample, discussing the sampling technique employed and provide an outline of procedure for collecting data.

3.1 Research Approach

This study adopted a mixed methods research design, integrating both quantitative and qualitative approaches to explore the challenges learners face when learning vectors at the Ordinary Level. A mixed methods design was selected to provide a more comprehensive understanding of the research problem by combining statistical evidence with in-depth contextual insights (Creswell & Plano Clark, 2018).

The quantitative component of the research involved the use of structured instruments, such as tests and questionnaires, to gather data on students' understanding of vectors. These tools helped identify trends, patterns, and gaps in learners' conceptual knowledge, enabling the researcher to assess the effectiveness of simulation-based learning in a measurable way (McMillan & Schumacher, 2010).

The qualitative component included interviews with learners and classroom observations. These methods allowed the researcher to gain a deeper understanding of the teaching strategies used, the learners' engagement with simulation-based activities, and the environmental factors influencing learning outcomes. Observations were conducted in natural classroom settings to enhance the authenticity and accuracy of the data collected (Patton, 2015).

Using a mixed methods design allowed for data triangulation, which increased the credibility and reliability of the findings by validating results through multiple sources and perspectives (Fetters, Curry, & Creswell, 2013). This approach not only revealed *what* challenges learners face in vector learning but also explained *why* and *how* these challenges occur in real classroom contexts.

3.1.1 The Research Design of This Study

The researcher giving learners some questionnaires. In order to ensure reliability of the questionnaires, the researcher ensured that the group was different in this case he considered all the form three classes. The researcher also made sure that the learners were given enough time to complete their questions. The researcher also made sure that the questionnaire was good enough for well the assessment. These methods of assessment were also chosen so as to ensure the validity of the assessment procedures.

3.2 Reliability

Reliability in research refers to the consistency and trustworthiness of the data collected. According to Opie (2004), reliability is closely associated with the degree to which research findings can be considered trustworthy and accurately representative of the population under study. Gertz (1973) emphasizes that reliability is achieved when the same results are obtained under consistent conditions, making it possible to replicate a study and arrive at similar conclusions. In the context of mixed methods research, reliability becomes especially important due to the integration of both quantitative and qualitative data. Bias can be introduced at various stages of research, as individual interpretations may vary depending on perspectives and experiences (Creswell & Plano Clark, 2018). As Denscombe (2014) notes, ensuring reliability requires researchers to apply consistent procedures and clear documentation, especially when dealing with different forms of data collection and analysis. Given these concerns, the researcher took deliberate steps to ensure that the data collected was dependable and credible. This included maintaining consistency in the administration of instruments, using clear protocols for observations and interviews, and carefully aligning quantitative results with qualitative insights. Such measures were essential to enhance the trustworthiness and internal consistency of the findings (Lincoln & Guba, 1985).

3.3 Validity

Validity is not an article that can be purchased with a skill; instead, validity is like nobility, character and quality to be assessed relative to purpose and circumstances (Brinberg and McGrath1985). McMillan and Schumacher (2010) defined validity as the extent to which inferences based on instrument are reasonable. It is a measure of the degree to which explanations of an event match reality. Validity can be viewed as not depending on the data but the interpretation of the data. A test can be viewed as valid if it serves its intended purpose well (Mbewe, 2013). In this study, the test questions were constructed in line with ordinary level exam papers as well as relying on common errors encountered by the researcher in the teaching/learning situation. As the researcher frequently discuss with the supervisor concerning the findings did not take for granted the existence of bias, as such, the researcher monitored beliefs, insights and preconceptions about learners' misconceptions solely based on practice.

3.4 Target Population

In this study, the target population was all ordinary level learners from one Secondary School in Harare metropolitan province.

3.4.1 Population

This study focused on a specific group of 70 Form 3 learners, which represents the target population. According to Bhandari (2020), a population refers to the entire group that you want to draw conclusions about in research. It's important to note that a population can comprise various elements, not just people. It could be a group of objects, events, organizations, countries, species, or anything else that is being studied.

3.4.2 Sample

A diverse sample of 5 learners (3 females and 2 males) was strategically selected from the test-takers based on their performance. As emphasized by Sriram (2024), including both females and males in the sample enhances the study's validity, ensuring more representative and generalizable findings that can be applied to the larger population. According to Bhandari (2020), a sample is a subset of the population, chosen to provide insights and data that can be used to make inferences about the population's characteristics. Selecting a sample allows for a more manageable group to collect and analyse data while maintaining sufficient representation, making it a crucial step in research (Bhandari, 2020).

3.4.3 Sampling Techniques to Be Used

This research employed a combination of census and purposive sampling techniques. According to Smith (2023), a sampling technique is a deliberate and systematic approach used to select a representative subset of individuals, objects, or events from a larger population. By strategically choosing participants, researchers can ensure a more accurate representation of the population, enhancing the study's validity and reliability.

3.4.4 Census Sampling Technique

The researcher administered the test to all 70 learners (the entire population) and this is an example of census sampling, where data is collected from the entire population rather than a sample. Sriram (2024) defines a census sampling method as an attempt to gather information from each and every person of interest. By testing all individuals, the researcher aimed to gather information about the errors made by the entire group of form three learners when solving quadratic equations using factorisation. This approach allows for a comprehensive understanding of the errors and patterns within the population, providing a more accurate representation of their performance and enabling meaningful analysis and conclusions about the errors in solving vectors.

3.5 Research Instruments

3.5.1 Tests

A diagnostic mathematics test focused on vector concepts was administered to learners. This instrument helped identify knowledge gaps, common errors, and performance trends among Ordinary Level students. The test items were developed based on the Ordinary Level mathematics syllabus to ensure relevance and curriculum alignment (McMillan & Schumacher, 2010).

3.5.2 Interviews

Semi-structured interviews were conducted with selected learners. After reviewing the test results, five students (3 females and 2 males) were chosen for interviews based on their varying performance levels and error types. By intentionally selecting students with diverse error patterns, the researcher aimed to gain a deeper understanding of the common mistakes made by Form Three learners when solving vectors. This targeted approach enabled the researcher to gather rich insights and contribute to the study's findings and conclusions. Interview guides were developed to ensure consistency while still allowing for open-ended responses, which helped to uncover detailed insights (Patton, 2015).

3.6 Procedures for Collecting Data

3.6.1 Procedures for Collecting Data from The Test

In this research, the researcher conducted a test to collect data on the problems faced by 70 learners in the learning of vectors. The researcher began by designing a test specifically tailored to evaluate their understanding and proficiency in this area. The test was carefully designed in line with the mathematics syllabus and focused specifically on core vector concepts such as magnitude, direction, vector operations, and application problems. Before administering the test, approval was obtained from the school authorities and relevant educational bodies. Learners and their guardians were informed about the purpose of the study, and informed consent was secured to ensure voluntary participation in line with ethical research practices (Cohen, Manion, & Morrison, 2018).Next the researcher administered the test to all 70 learners ,ensuring that each student received a copy of the test and clear instructions for completing it.Throughout the test administration , the researcher monitored the students to ensure compliance with instructions and maintain test interstater the students finished the test ,the researcher collected their answer sheet , ensuring that all papers were accounted for without any missing data. With the collected test papers from 70 learners, the researcher complied the data by organizing the responses and identify common patterns of misunderstanding, performance gaps, and overall competency levels in vector-related topics.

3.6.2 Procedures for Collecting Data from The Test *Interviews*

This study utilized purposive sampling to select participants for in-depth interviews. As defined by Nikolopoulou (2022), purposive sampling involves deliberately selecting individuals with specific characteristics that align with the research goals. In this case, the researcher administered a test on quadratic equation factorization to the entire population of 70 Form Three learners. After reviewing the test results, five students (3 females and 2 males) were chosen for interviews based on their varying performance levels and error types. By intentionally selecting students with diverse error patterns, the researcher aimed to gain a deeper understanding of the common mistakes made by Form Three learners when solving vectors. This targeted approach enabled the researcher to gather rich insights and contribute to the study's findings and conclusions.

3.7 Data Analysis Procedure

The researcher employed both quantitative and qualitative method analysis techniques to scrutinize the data, categorizing student errors and utilizing a coding and tally system to quantify specific error occurrences and opinions. In-depth content analysis was conducted to pinpoint areas of difficulty, address research questions, and identify errors and misconceptions. Visual representations of students' written work were generated, providing comprehensive and detailed data. Interviews were transcribed and analysed alongside written work, offering a holistic understanding. Focusing specifically on vector errors, the study employed audio recordings, transcription, and coding to explore student challenges in vectors. This methodology aligns with similar studies analysing diverse data sources, including test scripts and interviews (Tendere and Mutambara, 2020; Chikwanha et al., 2022; Mudavanhu et al., 2023).

3.8 Conclusion

This chapter explained the methods used to carry out the study. A mixed methods approach was used to collect both numerical data (quantitative) and descriptive information (qualitative). This was done to fully understand the challenges learners face in learning vectors at the Ordinary Level, especially when using simulations. The chapter described the research design, which combined tests, interviews, and classroom observations. It also outlined the data collection procedures, including how tests were given to learners, and how interviews with teachers were conducted. Each method was carefully chosen to make sure the data was reliable, valid, and useful for answering the research questions. Overall, this chapter laid the foundation for how the research was carried out in a clear, ethical, and structured way. The findings from this process are presented and discussed in the next chapter.

Chapter 4: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter provides an overview of data presentation, analysis and discussion. The purpose of this chapter is to address the research questions: 1. What are the challenges form three learners encounter when learning vectors at O’Level? 2. What strategies can be implemented to enhance the learning of vectors at O’Level.? This chapter is divided into six sections: introduction, methodology, results, discussion, conclusion, and limitations.

4.1 Methodology

This research used a qualitative approach to investigate how students solve vectors, giving a detailed understanding of their problem-solving methods. By using this approach, I gathered detailed information on the mistake’s students made when trying to solve vectors. Many researchers have successfully used this approach (Chikwanha et al., 2022; Johari & Shahrill, 2020; Msomi & Bansilal, 2022; Siyepu, 2015).

The study involved 70 Form 3 students from a certain High School in Harare Metropolitan Province. I created a 25-minute test using past exam papers from ZIMSEC, which ensured the test was fair and accurate in assessing students' abilities. The test had five questions on quadratic equations using factorisation, designed to test students' remembering, understanding, applying, and analysing skills. I gave the test and analysed the results to identify students' mistakes. I also interviewed five students to understand their thought processes when solving vectors. The interviews helped me understand what students need to know to solve these vectors successfully.

4.2 Results

4.2.1. What are the errors exhibited by form 3 learners when solving Vectors?

4.2.1.1 Students' response to the first question.

In the first question, a significant disparity in understanding the definition of vectors was revealed.

While 63 learners demonstrated a solid grasp of the meaning of vectors successfully, and the remaining 7

learners struggled to give a full meaning of vectors. The question that revealed this divide is presented below, highlighting the specific challenges that tripped up many learners.

1. What is a vector.?

Conceptual error for question 1

The analysis revealed that 7 students, similar to Student D exhibited the same errors that is conceptual errors when giving the meaning of vectors.

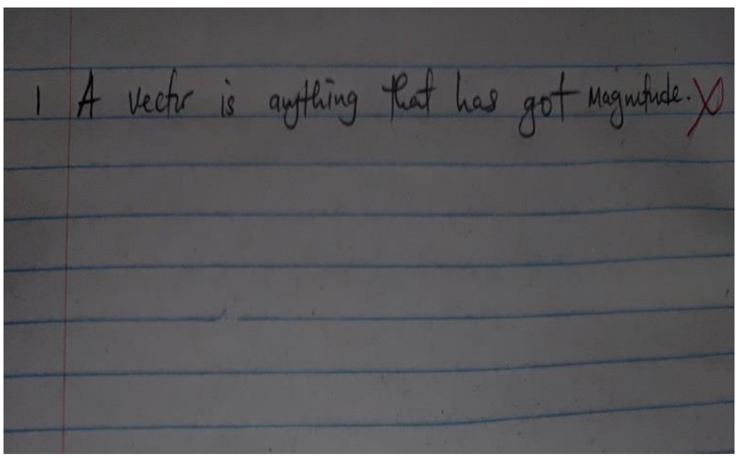

Figure 1: Student D's Problem-Definition

Snapshot - Question 1 Response

The learner was knowing that a vector has got a magnitude but he didn’t know how to define and combine the full meaning together. The learner was displaying some conceptual errors. The correct vectors definition was, ‘a vector is a magnitude with a continual quantity and direction.’. According to Bloom's Taxonomy of objectives under the cognitive domain, this error falls under the "Comprehension" level (Level 2). The learner struggles to understand the underlying concepts and relationships, despite being familiar with the procedures. A Conversation Unfolds with student D.

Researcher: How did you go about defining a Vector?

Student D: ummmm I remember that a vector has magnitude

Researcher: What was your next step?

Student D: Then I had to write.

The conversation with student D shows that the error of Student D is the conceptual error of focusing on the magnitude without remembering other aspects of vectors such as direction. This shows a misunderstanding of the direction concept, as well as vectors at large.

4.2.1.2 Students' Response to The Second Question.

Twenty learners wrote the second question correctly. The other fifty learners displayed conceptual, technical and procedural errors. Question 2 is exhibited below

2. It is given that $a = \begin{pmatrix} 3 \\ 3 \end{pmatrix} and\ b = \begin{pmatrix} -1 \\ 2 \end{pmatrix}$ find

(a) $a + b$

(b) $a - 3b$

(c) I $a - 3b$ I

Technical error for question 2

Nine learners exhibited technical errors just like student F did.

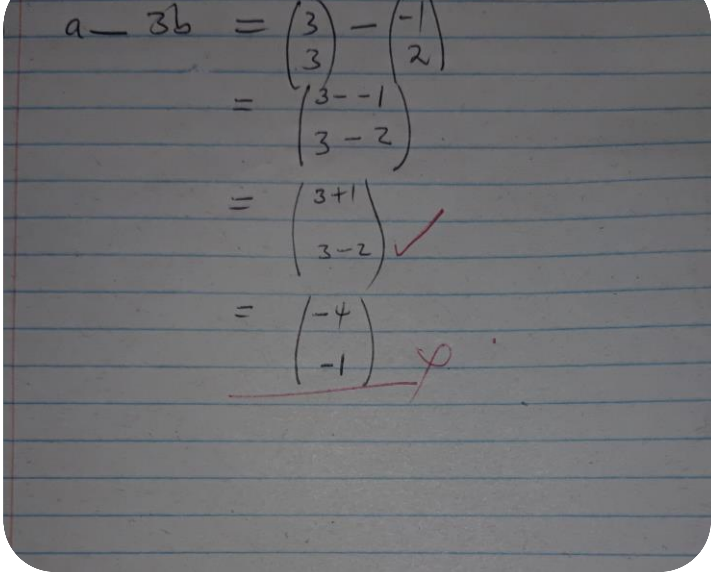

Figure 3: Student F's Problem Solving Snapshot - Question 2 Response

The learner's technical error resulted in an incorrect solution, obtaining $\begin{pmatrix}-4\\-1\end{pmatrix}$instead of the correct solutions $\begin{pmatrix}4\\1\end{pmatrix}$. This type of error is categorized as a "technical error indicating a mistake in the execution of a mathematical procedure or algorithm. In this case, the learner likely made a mistake when applying the rules of algebra, such as incorrectly handling the sign of the terms or making a calculation mistake. According to Bloom's Taxonomy of objectives under the cognitive domain, this error falls under "Application" (Level 3). This level involves the ability to apply learned concepts, procedures, and algorithms to solve problems and complete tasks. The learner has demonstrated a technical error in applying the rules of algebra, specifically in handling the sign of terms or making a calculation mistake, which is a characteristic of errors at the Application level. A conversation unfolds with student F.

Researcher: What kind of equation is this?

Student F: Column vector subtraction

Researcher: What does it mean when a vector has scalar multiplication?

Student F: It means the scalar must first multiply the bracket before subtraction.

Researcher: How did you solve this?

Student F: I first expand the vector with a scalar and then I subtract two vectors.

Researcher: How did you get $\begin{pmatrix}-4\\-1\end{pmatrix}$*?*

Student F: ummmm I made a mistake I wrote $\begin{pmatrix}-4\\-1\end{pmatrix}$ *instead of*

$\begin{pmatrix} 4 \\ 1 \end{pmatrix}$.

This conversation indicates that Student F is making a technical error, specifically a calculation error or a mistake in executing a mathematical procedure. Student F demonstrates an understanding of the concept of column vector subtraction and the correct procedure for solving column vectors, but makes a mistake in the calculation, writing $\begin{pmatrix} -4 \\ -1 \end{pmatrix}$ instead of $\begin{pmatrix} 4 \\ 1 \end{pmatrix}$. This type of error is characterized by a mistake in the execution of a mathematical procedure or algorithm, rather than a misunderstanding of the underlying concept.

Conceptual errors for question 2

Twenty-seven learners exhibited conceptual errors.

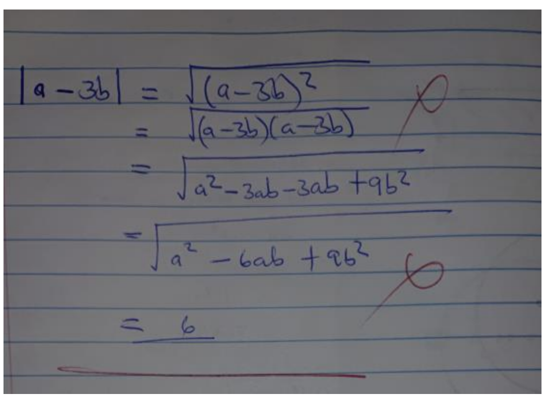

Figure 4: Student G's Problem-Solving Snapshot - Question 2 Response

The learner demonstrates a procedural understanding of finding the magnitude of a vector but displays conceptual errors and a limited understanding of solving magnitudes and algebraic concepts, failing to recognize the need to use the obtained answer from 2b to find the magnitude, thus revealing a gap in her understanding of the fundamental principles of solving magnitudes. According to Bloom's Taxonomy of objectives under the cognitive domain, this learner's errors fall under the "Understanding" level (Level 2), indicating a lack of comprehension of the underlying concepts and principles of magnitude solving, and a need to develop a deeper understanding of algebraic concepts and problem-solving strategies to progress to the "Application" level (Level 3) where they can apply their knowledge.

Procedural errors in question 2

Fourteen learners demonstrated a familiarity with the procedures for solving modulus of a vector, when tackling question 2c.

4.2.1.3 Students' Response to The Third Question.

Ten learners wrote the third question correctly. The other sixty learners exhibited conceptual errors. Question 3 is exhibited below.

3 Given that $OP = \begin{pmatrix} -2 \\ 7 \end{pmatrix} and\ OQ = \begin{pmatrix} 12 \\ -5 \end{pmatrix} where\ O\ is\ the\ origin.$

(a) Express PQ as a column vector [1]

(b) Find the coordinates of M, the midpoint of PQ [2]

Conceptual errors for question 3.

The analysis revealed that most students exhibited conceptual errors, demonstrating a fundamental misunderstanding of vectors. Specifically, sixty students struggled to find the coordinates of M the midpoint of PQ, failing to grasp the underlying mathematical concepts. As a result, they find wrong answers, highlighting a gap in their understanding of how to represent real-world scenarios mathematically.

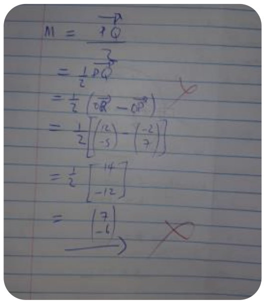

Figure 5: Student M's Problem-Solving Snapshot

- Question 3 Response

Student M exhibited conceptual error because she failed to make a diagram so as to represent her solution. It suggests that students need targeted support to develop a deeper understanding of vectors and how to apply them to solve problems, rather than just memorizing procedures. According to Bloom's Taxonomy of objectives under the cognitive domain, this type of error indicates that students are struggling to reach the "Application" level (Level 3), where they can apply their knowledge of vectors and complete tasks, revealing a need for support to move beyond mere comprehension and develop the ability to apply mathematical concepts in practical situations.
The conversation unfolds with student.

Researcher: Read the question please Student M:
He reads the question fluently.
Researcher: What is the demand of the question?
Student M: To find the coordinates of M the midpoint of PQ.
Researcher: What is the general form of a coordinates.?
Student M: ummmmm I don't know.
Researcher: How did you solve this?
Student M: I found that the midpoint needs division by 2.

The conversation with student M indicated that student M is unable to write a general coordinate given column vectors. Knowledge (Level 1) and Analysis (Level 4) under Bloom's Taxonomy of objectives in the cognitive domain. The student's lack of understanding of the question's demand indicates a deficiency in Knowledge, as they failed to recall the concept of writing general coordinates and position vectors. Furthermore, their inability to apply this knowledge of position vectors shows a challenge in Analysis, where they struggled to break down the information, identify patterns, and make connections to find coordinates in position vectors. This highlights the need for targeted instruction to address both knowledge gaps and analytical skills.

4.2.2 Fundamental Knowledge Necessary for Students to Effectively Solve Vectors While Minimizing Errors.

Through a comprehensive analysis of student responses on assessment test scripts and follow- up interviews, researchers identified five essential categories of pre-requisite knowledge crucial for learners to attain a comprehensive understanding of vectors. These categories include: directed numbers, basic algebra, coordinate geometry, linear equations and problem-solving skills.
The data showed that a solid understanding of directed numbers is essential, as seen in the following two excerpts, which highlight the importance of this concept as a prerequisite for further learning.

Researcher: Hello, what challenges do you face when solving Vectors?
Learner: directed numbers
Researcher: What are directed numbers
Learner: Directed numbers? I'm not sure what that is. I think it might have something to do with negative numbers.
Researcher: What about positive numbers? Learner: I'm quite not sure.
This conversation indicates that the learner has a partial understanding of directed numbers, associating them primarily with negative numbers but not having a clear grasp of the concept as a whole, including positive numbers. This lack of comprehensive knowledge suggests a need for further explanation and instruction on directed numbers before proceeding to more advanced topics like solving column vectors that involve directed numbers.

Secondly, the data revealed that a strong foundation in basic algebra is crucial, as evident in the following two excerpts, which highlight the importance of this concept as a prerequisite for further learning.
Researcher: What topics should be covered before learning vectors, and how can consistent practice help?
Learner: Algebra and equations.
Researcher: Can you describe the concept of basic algebra to me?

Learner: Basic algebra? I'm a bit fuzzy on that. I think it has something to do with solving for x.
Researcher: That's a good start! How about expanding and simplifying algebraic expressions?
Learner: Honestly, I'm not really sure how to do that.

This conversation indicates that the learner has a limited understanding of basic algebra, grasping the general idea of solving for a variable but struggling with more complex concepts like expression manipulation. This knowledge gap suggests a need for additional instruction and practice in basic algebra before moving on to more advanced topics like vectors.

Thirdly, the data revealed that a strong foundation in coordinate geometry is crucial, as evident in the following two excerpts, which highlight the importance of this concept as a prerequisite for further learning.

Researcher: What prior knowledge is essential for solving vectors?
learner: Coordinate
geometry
Researcher: Can you explain the process of finding coordinates from vectors?
Learner: Coordinate geometry? I'm not entirely sure... I think it involves finding two numbers of $x\ and\ y$.
Researcher: That's close! How about changing column vectors such as $\binom{3}{4}$*to coordinates?*
Learner: Hmm... I'm really not sure. I always get confused to change from column vector
to coordinates.

This conversation indicates that the learner has a partial understanding of coordinate geometry, grasping the general idea two numbers $x\ and\ y$, but struggling with more complex scenarios involving column vectors. This knowledge gap suggests a need for additional instruction and practice in coordinate geometry before moving on to more advanced topics like vectors.

Fourthly, the data revealed that a strong foundation in linear is crucial, as evident in the following two excerpts, which highlight the importance of this concept as a prerequisite for further learning.

Researcher: What prerequisite skills necessary to solve vectors.
Learner: Linear equation

Researcher: Are you able to solve linear equations

Learner: I've worked with linear equations in my math class and feel comfortable solving them.

Researcher: Excellent! Solving linear equations is a fundamental skill required to solve vectors. Can you demonstrate how you would solve a simple linear equation like 2x + 3 = 7?

Learner: Sure, I'd subtract 3 from both sides to get 2x = 4, then divide both sides by 2 to solve for x, which equals 2.

Researcher: find $x \ if$

$$\begin{pmatrix} x \\ 3 \end{pmatrix} = \frac{1}{2}\begin{pmatrix} 10 \\ 6 \end{pmatrix} + \begin{pmatrix} -1 \\ 2 \end{pmatrix}$$

Learner: I use linear equations x$=4$.

Researcher: That's good.

The learner possesses a solid understanding of linear equations, demonstrated by their ability to solve simple linear equations, such as 2x + 3 = 7, with ease and confidence. They have a strong foundation in this area, which is evident in their ability to apply linear equation skills to solve vectors, as seen in their solution to the equation above. This showcases their ability to build upon their linear equation knowledge to tackle more complex vector equations, highlighting their readiness for further learning and development in mathematics.

Fifthly, the data revealed that a strong foundation in problem-solving skills is crucial, as evident in the following two excerpts, which highlight the importance of this concept as a prerequisite for further learning.

Researcher: Can you walk me through your thought process when approaching a complex math problem?

Learner: Problem-solving? I'm not entirely sure... I usually try to find a formula or equation that fits the situation, but sometimes I get stuck.

Researcher: That's a good start! How about when the problem involves multiple steps or unknowns, like solving a system of vectors?

Learner: Hmm... I'm really not sure. I often get overwhelmed and don't know where to begin.

This conversation indicates that the learner has a partial understanding of problem-solving skills, grasping the general idea of applying formulas and equations, but struggling with more complex scenarios involving multiple steps or unknowns. This knowledge gap suggests a need for additional instruction and practice in problem-solving skills before moving on to more advanced topics like vectors.

4.3 Discussion

The purpose of this study was to investigate the errors exhibited by form three learners when solving vectors, as well as the fundamental knowledge needed for this process. The research questions that guided this study were:

1. What are the challenges students encounter when learning vectors at ordinary level?

2. What strategies can be implemented to enhance the learning of vectors at O'level?

4.3.1 Challenges Faced by Form Three Learners when Solving vectors

The findings of this study indicate that form three learners faced several challenges when attempting to solve vectors. These challenges are classified as errors they encounter and they included: procedural, conceptual and technical errors. Learners exhibited several procedural errors when solving vectors. One common error was the inability to follow correct steps when find the modulus of a vector. Additionally, mistakes were made in the actual process, such as incorrect placement of sign errors. Furthermore, learners struggled to connect the vector equations of vectors, indicating a lack of understanding of the procedural steps involved.

Conceptual errors were also prevalent, revealing a lack of understanding of the fundamental concepts underlying vectors. Many learners failed to graft the definition of vectors and this was indicated by their failure to define the definition properly. Moreover, difficulties in translating the sign of vectors into meaning such as the modulus sign. Learners also struggled to analyse complex information, identify patterns, and make connections to solve vector problems, indicating deficiencies in higher-order cognitive skills.

Technical and calculation errors were also observed, including mistakes in the execution of algebraic procedures and calculations. Learners made errors such as incorrectly handling the signs of terms or making calculation errors, demonstrating a lack of technical proficiency in algebraic manipulations. These errors highlight the need for learners to develop a strong foundation in algebraic procedures and calculations to succeed in solving vectors.

The findings of this study align with the existing literature, which highlights learners' struggles with the conceptual understanding of factorization and its relationship to solve vector related problems (Msomi and Bansilal, 2022; Tendere and Mutambara, 2020; Mutambara and Bansilal,2021). The errors which are consistent with literature review include procedural, technical, and conceptual errors, are consistent with the common challenges reported in previous research. However, this study takes it a step further by revealing that the learners' errors can be attributed to various levels of understanding according to Bloom's Taxonomy of educational objectives in the cognitive domain.

Specifically, the errors range from knowledge-level gaps (e.g., recognizing the type of equation) to higher-order analytical skills (e.g., breaking down complex information and making connections), which is a novel contribution to the existing body of research.

4.3.2 Fundamental Knowledge Needed When Solving Vector Related Problems

The findings of this study emphasize the critical importance of ensuring that learners have a strong grasp of the prerequisite knowledge necessary for developing a comprehensive understanding of vectors. The five essential categories identified- directed numbers, basic algebra, coordinate geometry, linear equations and problem-solving skills - are all fundamental building blocks that must be firmly in place for learners to successfully navigate the complexities of working with vectors.

The results regarding directed numbers reveal that learners' understanding of positive and negative numbers is often partial, with a primary association with negative numbers. This suggests that more explicit instruction and practice are needed to solidify learners' conceptual grasp of the entire directed number system. Strengthening this foundation will better equip them to work with the positive and negative numbers in vectors.

Similarly, the limitations observed in learners' basic algebra skills, particularly in manipulating algebraic expressions and solving for variables, highlight the need for additional targeted instruction and practice in these fundamental algebraic concepts. A robust understanding of basic algebra is a prerequisite for successfully applying algebraic methods to the solutions of vectors.
The findings related to coordinate geometry skills also point to the need for more comprehensive instruction and practice, as learners struggled with more complex scenarios involving coordinates. Mastering the ability to change from position vectors to coordinates systems and vice versa is a crucial step in being able to employ factorization as a problem- solving strategy.

Finally, the study's insights regarding learners' partial understanding of problem-solving skills, particularly in applying formulas and equations to multi-step or unknown-laden scenarios, underscore the importance of developing strong problem-solving abilities. These skills are essential for translating real-world vector equations into mathematical representations and then utilizing appropriate strategies to reach viable solutions.

The findings of this study align with existing literature, which highlights that solving vectors requires specific fundamental knowledge areas, including directed numbers, basic algebra, coordinate geometry, and problem-solving skills (Ly and Takuya, 2023; Tendere and Mutambara, 2020). This means that the study's results are consistent with previous research, which has also identified these knowledge areas as essential for successfully solving of vectors. However, the study also reveals that solving linear equations is another crucial fundamental knowledge area needed to solve vector equations, emphasizing the importance of a strong foundation in this skill as well.

4.3.3 Implications and Significance of the Findings

The implications and significance of this study are multifaceted. Firstly, the study provides a detailed analysis of the specific errors exhibited by form three learners when solving vectors, including procedural, conceptual, and technical errors. This taxonomy of errors can help educators better understand the areas of difficulty for students and design targeted interventions.

Secondly, the study highlights the fundamental knowledge areas that are essential for effectively solving vectors, including directed numbers, basic algebra, coordinate geometry skills, and problem-solving abilities. The findings emphasize the need to ensure students have a solid grasp of these prerequisite concepts before attempting more advanced topics.

Thirdly, the results of this study are consistent with previous research, which also identified similar challenges and knowledge gaps among students solving vectors. This reinforces the need to address these common issues in education.

Fourthly, the study goes beyond just identifying errors, by also examining them through the lens of Bloom's Taxonomy. This provides a more nuanced understanding of the cognitive skills required, ranging from basic knowledge to higher-order analytical abilities. This can inform the design of instructional strategies that target different levels of understanding Mathematics.

Fifthly, the findings can guide teachers in developing more effective instructional approaches for teaching vectors. This includes focusing on strengthening the fundamental knowledge areas, providing targeted practice, and scaffolding instruction to address the various error types and cognitive levels observed.

Lastly, by exploring the specific errors and prerequisite knowledge needed for solving quadratic equations using factorization, this study adds to the existing body of research in mathematics education. The insights generated can inform future studies and help develop a more comprehensive understanding of the challenge's students face in this domain. In summary, this study has important implications for improving mathematics instruction and student learning, particularly in the context of solving vector related problems.

4.4 Conclusion

This chapter presents the findings from a mixed method data analysis, which identified and classified errors made by Form Three learners when solving vectors. The data was collected and analysed using a systematic approach, and the errors were categorized according to Bloom's Taxonomy of objectives under the cognitive domain. The next chapter is going to look at summary, conclusions and recommendations.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter seeks to give a summary of the research, recommendations and conclusions on analysis of students' errors when solving vectors. It is going also to give us limitations which other researchers may need to take care of as they conduct their studies.

5.1 General Analyses on The Challenges Faced by Learners in The Learning of Vectors At Ordinary Level.

This study is about "analysis of students' errors when learning vectors." Chapter 1 introduces the research study on analysing learner errors in the learning of vectors. The background of the study highlights the importance of vectors in the mathematics curriculum and the challenges learners face in solving them. The purpose of the study is to identify and analyse the specific errors made by Form 3 learners in a certain school in Harare Metropolitan District when learning vectors. The research objectives include challenges students encounter when learning vectors at O'level and strategies that can be implemented to enhance the learning of vectors at O'level. The study aims to provide valuable insights for teachers, policymakers, and researchers to develop targeted instructional approaches and interventions to improve learner understanding and performance in mathematics. The chapter also outlines the significance of the study, limitations, delimitations, definition of key terms, and the organization of the study.

Chapter 2 provides a comprehensive review of the literature related to the research study on analysing learner errors in solving vectors. The theoretical framework for the study is based on Bloom's Taxonomy of objectives, which provides a hierarchical classification of learning objectives in the cognitive domain. The literature review highlights the common errors made by learners when learning vectors, including procedural, technical/foundational, computational, and conceptual errors. The study also identifies the fundamental knowledge necessary for learners to effectively solve vectors which, include a solid foundation in basic algebraic concepts, directed numbers, number sense, problem-solving strategies, and familiarity with mathematical notation and terminology. The literature review also discusses various studies that have analysed student errors in solving vectors, shedding light on the misconceptions and challenges that students face in mastering the concept. The studies highlight the importance of targeted interventions and instructional strategies to address learners' weaknesses in prerequisite skills and concepts, such as explicit instruction, guided practice, and frequent review. The chapter concludes by emphasizing the need for a comprehensive approach to address learner errors and improve student understanding and problem-solving skills in mathematics.

Chapter 3 outlines the research methodology used to analyse learner errors in solving vectors. The study adopted a mixed approach, using a test and follow-up interviews to collect data from a sample of 5 Form 3 learners (3 females and 2 males) selected from a target population of 70 learners. The research design allowed for an in-depth examination of learner errors and challenges. Data collection involved administering a test to identify error areas and conducting interviews to gather learners' thoughts and opinions. Data presentation and analysis procedures included thematic analysis, coding, and content analysis to identify recurring themes, patterns, and areas of difficulty. The study aimed to provide a comprehensive understanding of learner errors and challenges they face in solving vectors.

Chapter 4 presents the findings of a study on the errors made by Form Three learners when solving vectors, revealing various errors including procedural, technical, and conceptual mistakes. The errors were categorized according to Bloom's Taxonomy, ranging from knowledge-level gaps to higher-order analytical skills. The study identified five essential categories of pre-requisite knowledge crucial for learners to attain a comprehensive understanding of vectors: directed numbers, basic algebra, linear equations, coordinate geometry and problem-solving skills. The findings suggest targeted instruction and practice are necessary to address knowledge gaps and enhance learners' proficiency in mathematics, with limitations including a small sample size and single-school setting, highlighting the need for future research to increase generalizability and explore effective teaching strategies to reduce learners' errors. The study's main findings include: Form Three learners exhibit various errors when solving vectors; learners' errors can be attributed to different levels of understanding, ranging from knowledge- level gaps to higher-order analytical skills; solving vectors requires specific fundamental knowledge areas; and targeted instruction and practice are necessary to address knowledge gaps and enhance learners' proficiency in mathematics.

Chapter five gives summary, conclusions and recommendations of the study. A summary is for summarising the main points of each chapter, the conclusions are for giving final comments or judgements on the findings of the research and finally the recommendations which are suggestions or strategies that may be put in place in order to deal with analysis of students' errors when solving vectors.

5.2 Recommendations.

5.2.1 For Teachers

- Adopt learner-centred teaching methods that include the use of visual aids, physical demonstrations, and real-life vector applications.
- Encourage active participation through group work, discussions, and problem-solving tasks that make vector learning more interactive.
- Provide remedial lessons for learners struggling with foundational concepts like direction and magnitude.

5.2.2 For Curriculum Developers

- Revise the Ordinary Level mathematics syllabus to include more practical and context-based examples of vectors.
- Allocate more time in the syllabus to cover vector topics adequately and reinforce understanding through assessments and projects.

5.2.3 For School Administrators

- Invest in teaching resources such as vector kits, graph boards, and digital simulations.
- Provide continuous professional development programs for teachers focusing on innovative strategies for teaching abstract mathematical concepts.

5.2.4 For Learners

- Engage in peer tutoring and collaborative study to build stronger understanding.
- Use digital platforms and educational videos that simplify vector concepts and provide additional practice.

5.2.5 For Future Researchers

- Conduct similar studies on a broader scale across different regions to compare challenges and identify regional best practices.
- Explore the effectiveness of technology-based interventions such as simulations and interactive vector software in enhancing understanding.

5.3 Limitations

Mathematics books are written in English which make it a challenge to learners to translate it to meaningful instructions. Limited understanding of vector concepts that is students may struggle to grasp abstract vector ideas, making it hard to apply them in simulations. Teachers' mood is always changeable: the teacher's morale is very important to motivate students. Economic hardships have dragged the parental support into doubt especially to middle- and lower-income earners in rural and urban dwellers, subsequently students fail to buy individual laptops used for simulation which is very important in the learning of mathematics and schools are also being stricken by the same wave resulting in failing to provide sustainable pupil laptops ratio. Another challenge is from the government policy on learner teacher ratio: if the enrolment of a school does not suit the stipulated guidelines on staffing of the very school, learners can be disadvantaged by this policy ending up being deprived from accessing quality services. More often may be taught by untrained teachers in mathematics or left unattended at the end they fail mathematics. Also, there is limited engagement that is students might find simulations too abstract or disconnected from real life scenarios, leading to disengagement. The researcher cannot exhaust the list is endless but looked at a few.

5.4 Conclusion

This study found occurrence of reading, transformation, comprehension, process skill errors and other error outside these. It is therefore important to suggest that the learner and the teacher must understand the importance of the use of simulation in attention to vectors. Failure to tackle errors at the early stages, it will give pronounced impact to the students' mathematics experiences in the future. Also, this study can give information to other researchers, teachers and academic institutions on the use of simulations by tracking the findings covered in this study. The explanations of the origins of the use of simulation have been related to the existing literature in a way linking them to the broader theoretical views. In short, the role of teachers is important in enhancing the potential of students. Educators must be creative and determine appropriate approaches of delivery a topic concepts focusing on producing best quality results

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ANNEXURE 1

TEST ON VECTORS FOR ORDINARY LEVES

Answer all questions

1 What is a vector? [2]

2 It is given that $a = \begin{pmatrix} 3 \\ 3 \end{pmatrix}$ $and\ b = \begin{pmatrix} -1 \\ 2 \end{pmatrix}$ find

(a) $a + b$ [1]

(b) $a - 3b$ [2]

(c) I $a - 3b$ I [2]

4 Given that $OP = \begin{pmatrix} -2 \\ 7 \end{pmatrix}$ $and\ OQ = \begin{pmatrix} 12 \\ -5 \end{pmatrix}$ $where\ O\ is\ the\ origin.$

(c) Express PQ as a column vector [1]

(d) Find the coordinates of M, the midpoint of PQ [2]

Total [10 marks]

ANNEXURE 2

QUESTIONNAIRE FOR ORDINARY LEVEL STUDENTS.

My name is Kazhanje Peace T. I am a student at Bindura University of Science Education (BUSE), studying for a Bachelor of Sciences Degree and Honours in mathematics Education. I am currently working on a research project entitled: Exploring challenges faced by learners in the learning of vectors at ordinary level. A case of Harare Metropolitan District.I am kindly asking you to complete this questionnaire. Be assured that there is no wrong or correct answer. Your responses shall be strictly accorded the due recognition and confidentiality they so deserve

Please **do not** write **your name or that of your school** anywhere on the questionnaire.

Please indicate your answer by a tick (√) and by filling in the gaps provided.

Thank you in advance for your cooperation

1.1 Gender

Tick where applicable

Male

Female

2.0 Age

Tick where applicable

14-15 years
15-16 years
16-17 years

1. Do you think the topic on vectors will contribute much in the passing of mathematics?
   Tick where applicable

1	2	3
NO SIGNIFICANT	LESS SIGNIFICANT	SIGNIFICANT

2. Are the resources sufficient for you to do simulations?

   YES/NO……………………………

3. Did you enjoy studying vectors using simulation?

   YES/NO…………………………

5. Have you experienced any challenges while using simulations to learn vectors? (Yes/No)
   Tick where applicable

YES	NO

6. Have you used simulations to learn vectors before? (Yes/No)

YES	NO

   Tick where applicable

ANNEXURE 3: PERMISSION TO CARRY OUT THE RESEARCH INSTRUMENT FROM HARARE METROPOLITAN DISTRICT.