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The problems O' level students face in the learning of mensuration of solid shapes. A case study of Marchwood Senior School.

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DECLARATION

I, CHIRIPAMBERI GODFREY. E, declare that this research project is my original work and has not been submitted to any other institution for the award of any degree or diploma. All sources of information used have been duly acknowledged.

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DEDICATION

This work is dedicated to my family, whose love, encouragement, and belief in my abilities have been a constant source of inspiration. I also dedicate it to all the mathematics teachers who strive daily to make complex concepts accessible to their students, and to every learner who continues to persevere despite challenges. May this research contribute in some way to making your learning journey more rewarding.

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ABSTRACT

This study investigated the challenges faced by O' Level students in learning the mensuration of solid shapes, with particular focus on misconceptions, reasoning difficulties, and the need for effective teaching strategies. A mixed-methods approach was adopted, combining quantitative data from questionnaires administered to 30 Form 4 students with qualitative insights from interviews with four mathematics teachers, classroom observations, and document analysis.

The findings revealed that 60% of students confused volume and surface area formulas, 53% misapplied slant height, and many used two-dimensional formulas in three-dimensional contexts. Spatial reasoning skills were generally weak, with learners showing low confidence in mentally visualising and manipulating 3D objects. Classroom observations indicated that teaching strategies were predominantly teacher-centred, with minimal use of visual aids, manipulatives, or technology. Teachers recognised the potential benefits of digital tools but faced barriers such as limited access, lack of training, and time constraints.

The study concludes that persistent misconceptions, underdeveloped spatial reasoning, and limited instructional resources hinder students' mastery of mensuration of solid shapes. The study recommends adopting more learner-centred and visual approaches, integrating appropriate technology, and providing targeted professional development for teachers. These measures could enhance conceptual understanding, improve student performance, and make the learning of mensuration more engaging and effective.

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CHAPTER 1 PROBLEM ORIENTATION

1.1 INTRODUCTION

This chapter introduces the background and rationale of the study, outlining the main issues secondary school students face in learning the mensuration of solid shapes. It provides a detailed statement of the problem, highlights the research objectives and questions, and explains the significance, assumptions, and scope of the study. These foundational elements establish the framework upon which the study is built.

1.2 Background of the Study

Mensuration of solid shapes is a critical component of the secondary school Mathematics curriculum, particularly under the strand of Geometry and Measurement. It equips learners with the necessary skills to calculate surface areas and volumes of three-dimensional objects such as cubes, cuboids, cylinders, cones, spheres, and pyramids. These skills are not only important for passing examinations but also for developing problem-solving abilities and logical reasoning that can be applied to real-world situations. For example, understanding mensuration is essential in careers such as architecture, engineering, surveying, and the sciences, where measurement and calculation of dimensions are fundamental. Adolphus (2011) argues that geometry and mensuration help learners develop critical and abstract thinking, which is crucial for participation in the modern technological world. Thus, conceptual understanding of mensuration is essential for both academic success and preparation for professional pathways.

Despite its significance, research consistently shows that learners struggle with this aspect of Mathematics. In Zimbabwe, mensuration has been identified as one of the topics where learners consistently underperform (ZIMSEC, 2022). Similar challenges have been reported in other African countries such as South Africa, Nigeria, and Kenya, where students often fail to demonstrate adequate understanding of geometry and measurement concepts (Alex & Mammen, 2016; Achor, 2018; Waweru, 2020). These studies highlight persistent issues such as difficulties in visualising three-dimensional objects, confusion when applying formulas, and inability to connect mathematical knowledge to real-life contexts. Through my six years of teaching experience, I have observed that a significant number of learners struggle with visualising solid shapes, applying appropriate formulae, and understanding the relationships between dimensions, units, and resulting measures. These difficulties often result in poor performance, particularly on examination questions requiring transfer of knowledge to new or unfamiliar contexts.

The Zimbabwe School Examinations Council (ZIMSEC) Chief Examiner's Report for Mathematics Paper 2 (2022) confirms this trend, noting that many candidates displayed misconceptions about basic concepts, confusion between formulae, and lack of spatial awareness. The report further noted that some students provided irrelevant calculations or mixed-up units, which indicated shallow understanding of concepts. Similar findings are echoed in studies by Siyepu (2013) and Chigonga (2017), who observed that geometry is generally perceived as a difficult area of Mathematics by learners in secondary schools. The challenge is not unique to Zimbabwe but a widespread phenomenon, reinforcing the need for focused interventions.

An additional concern is the way learners and even teachers approach mensuration in examinations. Informal discussions with fellow Ordinary Level Mathematics teachers revealed that many discourage students from attempting mensuration-related questions in Section B of Paper 2, which consists of optional long-answer problems. This reluctance is often based on past experiences of low performance and lack of confidence among learners. As a result, students miss out on opportunities to attempt questions that could potentially boost their grades, thereby reinforcing a cycle of avoidance and underachievement. Studies by Ubah and Bansilal (2019) suggest that this tendency of avoidance is linked to deep-seated anxiety towards geometry and mensuration, which reduces learners' motivation and persistence in solving challenging problems.

In the current digital age, there is an increasing need to integrate technological tools into Mathematics education to support visualisation and interactivity. Technologies such as dynamic geometry software, augmented reality (AR), and 3D modelling applications can help students visualise abstract concepts more clearly, thus improving spatial understanding and engagement (Ibáñez & Delgado-Kloos, 2018). However, the extent to which such technologies are available and effectively used in Zimbabwean classrooms remains limited, raising the need for deliberate intervention.

Research has identified a number of barriers to effective learning of mensuration. One of the major challenges is students limited spatial reasoning ability. Spatial reasoning, which refers to the ability to mentally manipulate and visualise two- and three-dimensional figures, is a key cognitive skill for success in geometry and mensuration (Uttal & Cohen, 2012). Learners with weak spatial reasoning often find it difficult to comprehend the structure of solid shapes or to correctly apply concepts such as height, radius, or slant height. Misconceptions such as confusing surface area with volume, or incorrectly substituting measurements into formulae, have also been widely reported in Mathematics education research (Ngirishi & Makoni, 2020; Duatepe-Paksu & Ubuz, 2009).

Teaching practices have also been implicated in learners' struggles with mensuration. In Zimbabwean schools, many teachers rely heavily on teacher-centred approaches and rote memorisation of formulas, with little emphasis on exploration, discovery, or use of visual aids (Mashingaidze, 2012). This often results in learners memorising formulas without understanding the concepts behind them, which contributes to errors when solving unfamiliar problems. Studies conducted in other contexts also highlight that lack of hands-on activities, absence of manipulatives such as 3D models, and minimal use of inquiry-based strategies hinder meaningful learning of geometry (Ndlovu & Moyo, 2017; Achor, Imoko, & Uloko, 2019). In contrast, student-centred approaches such as problem-based learning and use of physical manipulatives have been shown to promote conceptual understanding and long-term retention (Battista, 2007).

The challenge is further compounded by limited integration of technology in the teaching and learning of Mathematics in Zimbabwe. In today's digital era, technology offers innovative opportunities to enhance learners' understanding of abstract concepts. Dynamic geometry software, computer-assisted instruction, 3D modelling, and virtual manipulatives have been found to significantly improve spatial reasoning and learner engagement (Laborde, 2013; Ngirishi & Makoni, 2020). Studies in developed countries have shown that students who interact with visualisation tools such as GeoGebra and augmented reality applications develop stronger conceptual understanding and greater confidence in solving geometry problems (Mousoulides & Sriraman, 2014). However, in Zimbabwe, access to such technologies is limited by infrastructural challenges, inadequate teacher training, and lack of resources (Chikasha, 2019).

From this perspective, it is clear that challenges in learning mensuration are multifaceted, involving cognitive factors such as spatial reasoning, pedagogical factors such as teaching approaches, and systemic factors such as resource availability. This highlights the need for comprehensive research to better understand the specific difficulties faced by learners in Zimbabwean classrooms. Such research can provide insights into how misconceptions develop, how teachers' strategies influence learners' performance, and how technology can be effectively integrated to address gaps.

In addition to the immediate classroom challenges, difficulties in learning mensuration must be understood in the context of national curriculum reforms in Zimbabwe. The Ministry of Primary and Secondary Education (MoPSE) has emphasised the Competence-Based Curriculum (2015–2022), which encourages critical thinking, problem-solving, and application of knowledge to real-life contexts in line with the National Development Strategy 1 (NDS1). Within this framework, Mathematics is positioned as a key driver of Science, Technology, Engineering and Mathematics (STEM) education, and topics such as mensuration are expected to equip learners with skills relevant to industry and innovation. However, there remains a gap between these curriculum aspirations and classroom realities, where teacher-centred pedagogy and lack of resources continue to limit effective learning (Mashingaidze, 2012; Chikasha, 2019). This mismatch raises questions about the extent to which policy goals are being met in practice.

From a theoretical standpoint, the challenges students face in mensuration can be linked to stages of cognitive development in geometry. The van Hiele model of geometric thought, widely used in Mathematics education research, suggests that learners progress through distinct levels of geometric reasoning: visualisation, analysis, informal deduction, formal deduction, and rigour (van Hiele, 1986). Many secondary school learners in Zimbabwe appear to be stuck at the lower levels of visualisation and analysis, where they can recognise shapes but struggle to understand their properties or relationships. This theoretical lens helps explain why students can sometimes recall formulas yet fail to apply them meaningfully in problem-solving tasks. Constructivist theories of learning also emphasise that students build understanding through active engagement and connection of new knowledge with prior experiences (Piaget, 1972; Vygotsky, 1978). In contexts where learners are taught by memorisation rather than discovery, their conceptual growth in geometry is limited, reinforcing misconceptions.

Socio-economic disparities further compound the difficulties in learning mensuration. Schools in rural and low-income communities often lack adequate resources such as textbooks, geometric models, or access to digital technologies that could aid visualisation. Teachers in under-resourced schools also report larger class sizes and limited opportunities for professional development, which restricts their ability to experiment with innovative teaching strategies (Chigonga, 2017). By contrast, learners in better-resourced urban schools may have greater exposure to ICT tools, project-based learning, and supplementary tuition, which enhances their chances of mastering challenging topics like mensuration. These inequities suggest that performance gaps in Mathematics are not only cognitive but also structural, influenced by wider issues of access and opportunity within the education system.

In light of these challenges, this study seeks to investigate the core difficulties learners face in the mensuration of solid shapes, with a particular focus on misconceptions, spatial reasoning issues, and the effectiveness of current teaching strategies. It also aims to explore how technology can be leveraged to support meaningful learning and help learners overcome barriers.

1.3 Research Objectives

The primary objectives of this research are:

1. To identify the specific misconceptions that secondary school students have regarding the mensuration of solid shapes.
2. To examine how spatial reasoning difficulties affect students' understanding and performance in solving mensuration problems involving solid shapes.
3. To explore the challenges faced by both students and teachers in the teaching and learning of mensuration of solid shapes at the secondary school level.
4. To examine the teaching strategies that can be employed to enhance students' conceptual understanding and spatial reasoning in the mensuration of solid shapes, and to investigate how the integration of technology can support and strengthen these strategies.

1.4 Research Questions

1. What specific misconceptions and errors do secondary school students have regarding the mensuration of solid shapes?
2. How do spatial reasoning difficulties affect students' understanding and performance in the mensuration of solid shapes?
3. What challenges do students and teachers face in the teaching and learning of mensuration of solid shapes at the secondary school level?
4. What teaching strategies can be employed to enhance students' conceptual understanding and spatial reasoning in the mensuration of solid shapes, and how can technology be integrated to support these strategies?

1.5 Significance of the Study

This study is significant as it addresses the persistent challenges students face in understanding the mensuration of solid shapes, a key area in secondary school mathematics. By identifying specific misconceptions and examining the role of spatial reasoning, the research provides valuable insights for improving mathematics instruction. Furthermore, the exploration of technology-enhanced teaching strategies offers practical solutions that can support more effective learning experiences. For students, the research is vital as it seeks to uncover and clarify common misconceptions and cognitive difficulties, they encounter in learning the mensuration of solid shapes. By understanding these learning barriers, the study aims to inform the development of more student-centered instructional approaches that enhance conceptual understanding, boost confidence, and stimulate interest in mathematics. This can ultimately lead to improved academic performance and a more positive attitude toward the subject.

For teachers, the study offers valuable insights into the specific challenges learners face, enabling them to adjust their teaching methods accordingly. It promotes the use of evidence-based strategies, including the integration of visual aids, hands-on activities, and digital technologies to foster spatial reasoning and conceptual clarity. By equipping teachers with more effective pedagogical tools, the study supports improved delivery of mathematical concepts.

Curriculum developers also benefit from the findings, as the study highlights key areas where current instructional materials may fall short. This enables the development or revision of curricula to better match students' developmental stages, learning needs, and the cognitive demands of mensuration topics. It also supports the inclusion of diverse instructional resources that accommodate various learning styles.

Policy makers and educational planners can utilize the results to inform decisions related to teacher training, resource allocation, and curriculum support systems. By emphasizing the importance of spatial reasoning skills and conceptual understanding, the study can influence policies that support the integration of modern teaching aids, digital tools, and continuous professional development for educators.

Ultimately, this study contributes to the broader goal of improving mathematics education outcomes in Zimbabwean secondary schools. By addressing key instructional and learning challenges in mensuration, it supports the creation of a more effective, inclusive, and engaging mathematics learning environment.

1.6 Assumptions of the Study

This study assumes that students have already been introduced to the mensuration of solid shapes as part of the secondary school mathematics curriculum. It presumes that their difficulties are at least partly due to conceptual misconceptions and underdeveloped spatial reasoning abilities. The study also assumes that teachers are aware of these challenges and have attempted various strategies to address them. Furthermore, it is assumed that both teachers and students are open to the use of technology as a means to enhance the teaching and learning of mensuration. Lastly, it is assumed that participants will provide honest and thoughtful responses during data collection.

1.7 Delimitations

This study is specifically delimited to Form 4 students at Marchwood Senior Schools in Norton, who have already been introduced to the topic of mensuration of solid shapes in their mathematics curriculum. It does not include students from other levels or subjects, as the focus is on learners at a stage where this concept is expected to be understood and applied. The study concentrates solely on the mensuration of solid shapes, excluding other areas of mathematics such as algebra, statistics, or plane geometry. In addition, only the views and experiences of Mathematics teachers and students will be considered, while other stakeholders such as school heads or parents are excluded. The study will focus specifically on the concepts of mensuration of solid shapes, including calculation of surface area and volume, application of relevant formulae, and spatial reasoning related to three-dimensional visualisation. The integration of technology will be explored only in relation to specific teaching strategies such as the use of visual tools, dynamic geometry software, and interactive applications that support conceptual understanding. The study will also be conducted within a single school term, which may affect the generalisability of the findings over a longer period or in different contexts.

1.8 Limitations of the Study

This study is limited by several factors that may affect the generalisability and depth of its findings. Firstly, it only involves Form 4 students from Marchwood Senior Schools in Norton, which means the results may not fully represent the experiences of learners in other levels or schools across Zimbabwe. Secondly, the research is conducted within a single school term, limiting the amount of data collected and the opportunity to observe long-term learning progress. Additionally, the study relies on self-reported data from students and teachers, which may be influenced by personal biases or memory limitations. Access to certain technological tools may also vary across schools, potentially affecting the consistency of the findings related to technology-enhanced teaching strategies. Lastly, the study focuses only on a specific area of mathematics, mensuration of solid shapes, and does not account for how difficulties in other related topics may impact learners' overall performance.

1.9 Definition of Terms

Mensuration of solid shapes – Refers to the measurement of 3D geometric figures such as cubes, cylinders, cones, etc., including calculations of volume and surface area (Van de Walle et al., 2013).

Misconceptions – These are persistent incorrect beliefs or understandings that impede learning; they often arise from inadequate instruction or prior experiences (Smith et al., 2020; Hiebert & Grouws, 2007).

Spatial reasoning – The cognitive ability to visualise and mentally manipulate 3D shapes, crucial in understanding mensuration (Uttal & Cohen, 2012; Mix & Cheng, 2012).

Teaching strategies – Methods and approaches used by educators to convey content effectively. In this context, strategies include problem-solving, model use, and visualisation (Anthony & Walshaw, 2009).

Technology integration – The application of digital tools such as GeoGebra, simulations, or visual media in instruction to improve concept understanding (Mishra & Koehler, 2006).

Secondary school students – Refers specifically to learners in Form 4, who are expected to master mensuration skills for national examinations (ZIMSEC, 2022).

1.10 Summary of Chapter

This chapter has explored the foundational elements of the study, including the statement of the problem, research questions and objectives, significance, assumptions, delimitations, limitations, and definitions of key terms. These aspects collectively frame the scope and direction of the research on overcoming challenges in the mensuration of solid shapes among Form 4 students. The focus on addressing misconceptions, enhancing spatial reasoning, and integrating effective teaching strategies with technology sets the stage for a deeper exploration of relevant theories and previous studies. The following chapter will review existing literature on the challenges students face in mensuration and the role of teaching strategies and technology.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter presents a critical review of existing literature pertinent to the challenges faced in teaching and learning the mensuration of solid shapes. The review is organized around four key themes: misconceptions in mensuration, spatial reasoning, teaching strategies, and technology integration in mathematics education. The chapter concludes by identifying gaps in the literature that this study aims to address.

2.1.1 Understanding Misconceptions in Mathematics

Misconceptions in mathematics are deeply held yet incorrect beliefs that hinder accurate understanding of concepts. According to Smith et al. (2020), misconceptions can arise from overgeneralizations, flawed reasoning, or procedural learning without comprehension. Hiebert and Grouws (2007) explain that when students rely solely on memorisation, they are more likely to confuse concepts and fail to transfer knowledge to new problems. Addressing misconceptions requires instructional methods that focus on diagnosing misunderstandings and guiding learners to reconstruct accurate conceptions through active learning.

2.2 Misconceptions in Mensuration

Misconceptions in mathematics are persistent, incorrect understandings that hinder students' ability to grasp new concepts. In mensuration, students often confuse formulas for volume and surface area, misidentify dimensions, and struggle with unit conversions. For instance, students may mistakenly apply two-dimensional area formulas to three-dimensional contexts (Cuarto, 2024; Lowrie et al., 2016). Research indicates that these misconceptions stem from rote memorisation without conceptual understanding, inadequate instructional methods, and lack of real-world application (Sunzuma, 2016; Bicer et al., 2017). Teachers themselves may harbour misconceptions, which can inadvertently be transmitted to students (Yildiz, 2023).

Studies by Durkin et al. (2017) and Smith et al. (2020) emphasize that addressing misconceptions requires diagnostic teaching methods, formative assessment, and active learning strategies that promote conceptual clarity. Misunderstandings are often reinforced when instruction focuses excessively on procedures rather than the underlying concepts (Hiebert & Grouws, 2007). Furthermore, Mhakure and Ngara (2014) identified that learners in Zimbabwean schools tend to memorise volume and surface area formulas without truly understanding the geometric principles they represent. This results in failure to transfer knowledge to new or unfamiliar problems.

Visual representation and use of manipulatives have proven effective in helping students overcome these misconceptions. According to Van Garderen and Montague (2003), drawing diagrams and using real objects help bridge the gap between abstract formulas and concrete understanding. Learners benefit from dynamic representations that show how changes in dimensions affect volume and surface area (Boakes, 2009). In summary, misconceptions in mensuration are prevalent and must be addressed through improved pedagogical strategies, use of visual tools, and a shift from rote learning to conceptual teaching.

2.3 Spatial Reasoning and Mensuration

Spatial reasoning plays a vital role in students' understanding of mensuration, particularly with three-dimensional shapes. It involves the mental manipulation and visualisation of objects and their dimensions, which are crucial in interpreting and solving geometry problems. Students with weak spatial abilities often struggle to visualise the transformation of shapes, rotation, or the effect of altering dimensions on volume or surface area (Mix & Cheng, 2012).

Research by Wai et al. (2009) demonstrates that spatial ability strongly correlates with success in STEM fields, particularly mathematics. Learners who possess high spatial reasoning skills tend to perform better in tasks involving 3D shapes and measurement. In a Zimbabwean context, Mavuru and Bhebhe (2019) observed that students often fail to grasp concepts like height and radius in cylindrical or conical shapes because they cannot mentally rotate or visualise the objects from different angles.

Intervention studies have shown that spatial reasoning can be developed through targeted instructional methods. Uttal and Cohen (2012) found that explicit training in spatial tasks, such as mental rotation and perspective-taking, enhances students' mathematical performance. Digital tools, such as virtual manipulatives and 3D modelling software, have also been found to support spatial learning by enabling learners to interact with objects dynamically (Casey et al., 2008). Teachers play a crucial role by incorporating visualisation techniques and hands-on activities to strengthen spatial reasoning in the classroom (Sorby, 2009).

Furthermore, spatial reasoning contributes to error detection and correction. For example, students who visualise the dimensions of a cuboid are more likely to identify mistakes in the volume calculation. Enhancing this ability equips students with problem-solving strategies necessary for dealing with complex mensuration problems. Overall, spatial reasoning is a cognitive skill that, if nurtured, significantly enhances learners' comprehension and application of mensuration concepts.

2.4 Strategies for Teaching Mensuration

The teaching of mensuration requires strategies that not only transmit knowledge but also engage learners in exploration, reasoning, and application. Research has shown that effective strategies include the use of visual tools, physical manipulatives, problem-based learning, and interactive applications (Battista, 2007; Achor et al., 2019). These approaches encourage learners to move beyond rote memorisation of formulae and instead focus on conceptual understanding.

Technology can be integrated as one of these strategies to strengthen students' understanding. Tools such as dynamic geometry software (e.g., GeoGebra), 3D simulations, virtual manipulatives, and interactive whiteboards provide learners with opportunities to explore three-dimensional shapes and their measurements in interactive ways (Pierce & Stacey, 2010). For example, GeoGebra enables students to manipulate shapes and observe how changes in dimensions affect surface area and volume, fostering deeper conceptual insight (Hollebrands, 2007). Similarly, 3D simulations bridge the gap between theory and practice by presenting realistic models for measurement tasks (Kay et al., 2017).

Empirical studies support the effectiveness of such approaches. Li and Ma (2010) found that students who used educational technology tools showed greater improvement in geometry and measurement tasks compared to those taught using traditional methods. In Zimbabwe, Chikowore and Mudzamiri (2021) also reported that although access to digital tools is still limited, their use significantly enhanced learners' comprehension when available. Furthermore, technology supports differentiated instruction, allowing teachers to adapt tasks to different learning needs and levels, thereby promoting inclusivity (Florian & Black-Hawkins, 2011).

Nevertheless, the successful use of technology as a teaching strategy depends on teachers' technological pedagogical content knowledge (TPACK) and access to appropriate resources. Without adequate professional development and systemic support, the benefits of technology integration cannot be fully realised (Mishra & Koehler, 2006).

2.5 Role of Technology in Teaching Mensuration

The integration of technology in teaching mensuration has been recognised as a powerful tool for enhancing students' conceptual understanding and engagement. Technologies such as dynamic geometry software (e.g., GeoGebra), simulations, virtual manipulatives, and interactive whiteboards offer interactive and visual approaches to exploring three-dimensional shapes and their measurements (Pierce & Stacey, 2010).

GeoGebra, for example, allows students to manipulate shapes and observe how changes in dimensions affect surface area and volume. This fosters a deeper understanding of mathematical relationships through exploration and immediate feedback (Hollebrands, 2007). Similarly, 3D simulations help bridge the gap between theoretical knowledge and practical application by providing realistic models for measurement tasks (Kay et al., 2017).

Research by Li and Ma (2010) found that students who used educational technology tools showed greater improvement in geometry and measurement tasks compared to those taught using traditional methods. This is attributed to increased visualisation, interactivity, and student engagement. In a Zimbabwean study, Chikowore and Mudzamiri (2021) highlighted that limited access to digital tools remains a barrier, but where available, technology significantly enhanced learners' comprehension.

Moreover, technology facilitates differentiated instruction. Teachers can use online platforms and software to design tasks tailored to individual learner needs and pace, thus supporting inclusive education (Florian & Black-Hawkins, 2011). Video tutorials, digital assessments, and gamified learning platforms can also support practice and revision.

However, the successful integration of technology requires that teachers possess strong technological pedagogical content knowledge (TPACK) and undergo regular professional development (Mishra & Koehler, 2006). Therefore, systemic support, including training and infrastructure investment, is vital for maximising the benefits of technology in teaching mensuration.

2.6 Theoretical Framework

The theoretical framework guiding this study is rooted in constructivist learning theory, spatial intelligence theory, and the Technological Pedagogical Content Knowledge (TPACK) framework. These perspectives provide a foundation for understanding how students learn mensuration, the role of spatial reasoning, and how technology can be integrated effectively into Mathematics instruction.

Constructivist theory, primarily advanced by Jean Piaget and later expanded by Vygotsky, posits that learners build knowledge through active engagement and interaction with their environment (Piaget, 1972; Vygotsky, 1978). In the context of mensuration, constructivism emphasises hands-on learning, manipulation of 3D objects, and problem-solving in real-life contexts. This approach enables learners to develop deeper conceptual understanding and address misconceptions by constructing knowledge through experience and reflection (Fosnot & Perry, 2005). Scaffolding, where teachers provide temporary support as learners progress through their zones of proximal development, is especially relevant in guiding students through complex mensuration tasks.

Complementing constructivism is Howard Gardner’s theory of multiple intelligences, particularly spatial intelligence, which plays a critical role in geometry and mensuration. Gardner (1983) argues that individuals vary in their ability to think spatially and visually. Learners with underdeveloped spatial intelligence may struggle to mentally visualise and manipulate 3D shapes, which contributes to difficulties in understanding volume, surface area, and dimensions. This makes it important for teachers to adopt strategies that strengthen spatial reasoning, including the use of visual aids, physical manipulatives, and digital simulations (Uttal & Cohen, 2012; Mix & Cheng, 2012).

The TPACK framework (Mishra & Koehler, 2006) further provides guidance on how technology can be meaningfully integrated into subject teaching. It highlights the interplay between content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). In teaching mensuration, TPACK enables teachers to align appropriate tools with mathematical content and effective pedagogy. For instance, using GeoGebra to demonstrate how changing dimensions affect the surface area of a cylinder combines content, pedagogy, and technology in a coherent manner (Niess, 2005; Koehler & Mishra, 2009).

By drawing on these theoretical perspectives, this study seeks to explore how students can better understand mensuration through conceptually rich instruction, spatially enhanced activities, and well-integrated strategies—including the use of digital tools. Together, these theories form a comprehensive lens for analysing teacher practices, curriculum design, and interventions aimed at improving learner outcomes.

2.7 Empirical Studies

A wide range of empirical studies has examined the challenges and interventions associated with teaching and learning mensuration, especially at the secondary school level. These studies highlight common student difficulties, the effectiveness of various instructional strategies, and the role of technology and spatial reasoning in improving performance.

Sunzuma (2016) conducted a study in Zimbabwean secondary schools and found that many students exhibited shallow understanding of mensuration concepts, often relying on memorised formulas without grasping their meaning. The research revealed that the absence of practical experiences and visual aids contributed significantly to students' misconceptions. This finding is echoed in Bicer et al. (2017), who observed that students tend to confuse the dimensions of three-dimensional objects and incorrectly apply two-dimensional formulas, particularly in tasks involving volume and surface area.

In terms of spatial reasoning, Mix and Cheng (2012) demonstrated through experimental design that targeted visual-spatial training significantly improved students' geometry and measurement performance. Similarly, Uttal and Cohen (2012) showed that learners who engaged in spatial reasoning activities, such as mental rotation and 3D model manipulation, developed better conceptual understanding in mensuration. These findings underscore the importance of integrating spatial thinking into mathematics instruction.

Technology also features prominently in empirical literature. For instance, Pierce and Stacey (2010) found that students who used dynamic geometry software like Cabri and GeoGebra outperformed their peers in understanding geometric and mensuration concepts. Interactive tools helped learners visualise transformations and dimensions of shapes, making abstract ideas more concrete. In a South African context, Johnson-Glenberg (2018) explored the use of virtual reality in teaching volume and surface area, reporting higher engagement and better retention rates among students exposed to immersive environments.

Pedagogical innovations have also been tested. Boaler (2016) conducted a longitudinal study comparing traditional and inquiry-based teaching methods in mathematics. Her findings showed that students in inquiry-driven classrooms demonstrated deeper understanding, fewer misconceptions, and higher test scores in topics including mensuration. Anthony and Walshaw (2009) supported this through a meta-analysis of learner-centred strategies, indicating that activities involving real-world contexts and student collaboration were particularly effective in enhancing conceptual mastery.

In Zimbabwe, a study by Chikowore and Mudzamiri (2021) confirmed that the integration of ICT tools, though limited by resources, improved student engagement and comprehension when used effectively. However, they also highlighted challenges such as inadequate teacher training and limited access to digital infrastructure.

Collectively, these empirical studies support the notion that addressing misconceptions, enhancing spatial reasoning, adopting effective pedagogical practices, and leveraging technology are essential strategies for improving students' understanding of mensuration in secondary schools.

2.8 Summary

The literature reveals that misconceptions, inadequate spatial reasoning skills, and ineffective teaching strategies contribute to students' difficulties in mensuration. Constructivist approaches, cooperative learning, ethnomathematics, and technology integration have shown promise in addressing these challenges. However, gaps remain, particularly in the context of Zimbabwean secondary education. This study aims to fill these gaps by exploring the effectiveness of these strategies among Form 4 students in Zimbabwe.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology adopted to investigate the challenges students face in the mensuration of solid shapes and the strategies that can be used to address misconceptions, enhance spatial reasoning, and incorporate technology in teaching. The methodology provides a systematic approach to how the research was conducted, ensuring that the findings are reliable and valid. It discusses the research design, population and sample, sampling techniques, research instruments, data collection procedures, methods of data analysis, validity and reliability of instruments, as well as ethical considerations. The methods chosen align with the objectives of the study and are suitable for gathering both quantitative and qualitative data, thereby providing a comprehensive understanding of the research problem.

3.2 Research Design

This study adopted a descriptive survey research design, which is appropriate for investigating educational challenges and exploring possible solutions in real-world classroom contexts. A descriptive survey design enables the researcher to collect both quantitative and qualitative data from a relatively large group of participants, allowing for the identification of patterns, trends, and relationships among variables (Creswell & Creswell, 2018).

This design was chosen because it allows the researcher to describe the current status of students' understanding of mensuration of solid shapes, identify common misconceptions, assess spatial reasoning skills, and explore how teachers use different instructional strategies and technologies to enhance learning. It also facilitates the collection of views and experiences from both students and teachers, which is crucial for making informed conclusions and recommendations. By using this design, the researcher was able to gather in-depth information without manipulating the learning environment, thus preserving the natural classroom setting and ensuring that findings reflect actual teaching and learning practices.

3.3 Research Methods

This study employed a mixed-methods research design, integrating both quantitative and qualitative approaches to provide a comprehensive understanding of the challenges students face in the mensuration of solid shapes. Recent literature underscores the value of mixed-methods designs in educational research, particularly for addressing complex and multifaceted problems (Zhao & Xu, 2024). By combining numerical data with in-depth qualitative insights, this approach facilitates a more nuanced exploration of educational phenomena.

3.3.1 Quantitative Component

The quantitative aspect involved administering structured questionnaires to Form 4 students. These instruments were designed to assess students' conceptual understanding of mensuration, identify prevalent misconceptions, and evaluate spatial reasoning abilities. The inclusion of both closed-ended questions and Likert-scale items allowed for statistical analysis and measurement of students' attitudes and confidence levels. Descriptive statistics, such as frequencies and percentages, were employed to identify patterns and common issues. Quantitative methods are supported by recent studies highlighting their effectiveness in capturing measurable aspects of educational challenges (Watkins & Johnson, 2023).

3.3.2 Qualitative Component

The qualitative component comprised semi-structured interviews with mathematics teachers and classroom observations. Semi-structured interviews were chosen for their flexibility, enabling participants to express their perspectives on student misconceptions, instructional strategies, and the integration of technology in teaching mensuration. Classroom observations focused on teacher-student interactions and the incorporation of spatial reasoning activities. Both data sets were analyzed thematically to identify recurring themes related to teaching practices and student challenges. The qualitative approach was selected for its ability to provide rich, contextual insights into educational phenomena (Viel et al., 2023).

3.3.3 Rationale for Mixed-Methods Design

The decision to employ a mixed-methods design was driven by the complexity of the research problem, which encompasses both measurable learning outcomes and subjective experiences. Recent research emphasizes that mixed-methods approaches are particularly valuable in educational studies where understanding both the "what" and the "why" is essential (Ketsman et al., 2025). By triangulating quantitative and qualitative data, this study aimed to enhance the validity and depth of its findings, providing a holistic perspective on factors influencing student performance in mensuration.

3.4 Population of the Study

The population refers to the complete set of individuals or elements that the research seeks to study (Cohen et al., 2018). In this study, the population consisted of all Form 4 students enrolled at Marchwood Secondary School during the 2025 academic year, totaling 120 students. These students were following the Ordinary Level mathematics curriculum, which includes the topic of mensuration of solid shapes. Focusing on this population ensured that the study captured insights from students actively engaged in learning the topic and relevant to the research objectives.

3.5 Sampling

Sampling is the process of selecting a subset of individuals from the population to participate in the study, making data collection feasible while maintaining representativeness (Saunders et al., 2019). A stratified random sampling technique was used in this study. This method involves dividing the population into distinct subgroups or strata in this case, class sections and then randomly selecting participants from each subgroup. Stratified random sampling was chosen to ensure that all class sections were represented and to capture possible differences in understanding and misconceptions among students. This approach is supported by literature as an effective method for obtaining representative samples in educational research (Creswell & Creswell, 2018; Cohen et al., 2018).

For the qualitative component, purposive sampling was used to select four mathematics teachers directly involved in teaching Form 4 students. Purposive sampling allows researchers to select participants who have specific knowledge or experience relevant to the research problem (Etikan et al., 2016). These teachers provided insights into teaching strategies, student misconceptions, and the use of technology in instruction.

3.6 Research Instruments Used in the Study

The choice of data collection instruments was guided by literature on best practices in educational research. Creswell (2014) notes that the combination of questionnaires, interviews, and observations allows for comprehensive exploration of both measurable trends and personal insights. Cohen, Manion, and Morrison (2018) emphasize that using a variety of instruments enhances validity through triangulation and reduces the likelihood of data bias. This study employed a variety of research instruments to collect both quantitative and qualitative data, ensuring a comprehensive exploration of the challenges students face in mensuration and the strategies employed by teachers to address these issues. The instruments used in the study were carefully selected to align with the research objectives and to capture the perspectives of both students and teachers. The main research instruments were:

3.6.1 Questionnaires for Students

A structured questionnaire was developed for the Form 4 students to assess their understanding of mensuration of solid shapes, identify common misconceptions, and evaluate their spatial reasoning abilities. The questionnaire consisted of two main sections:

- Section 1: Demographic information, including age, gender, and academic background.
- Section 2: Questions on students' understanding of mensuration concepts (e.g., surface area, volume), common misconceptions, and attitudes towards the subject. The questions were a mix of closed-ended (multiple choice, true/false) and Likert-scale items, which allowed students to express their agreement or disagreement with statements related to their learning experiences.

The data gathered from the questionnaires were analyzed quantitatively, with frequencies and percentages calculated to identify the most common misconceptions and areas of difficulty among students.

The use of questionnaires is supported by Gay et al. (2012), who note that structured surveys are effective for collecting broad data from large groups, particularly when investigating trends like misconceptions and conceptual understanding.

3.6.2 Semi-structured Interviews with Teachers

To gain in-depth insights into the teaching strategies employed by mathematics teachers, as well as their perspectives on student misconceptions and the use of technology, semi-structured interviews were conducted with the four selected mathematics teachers. The interviews were guided by a set of pre-determined questions, but the semi-structured format allowed for flexibility and the opportunity to explore new themes that emerged during the discussions. Topics covered in the interviews included:

- Teachers' approaches to teaching mensuration concepts.
- Strategies used to address student misconceptions.
- The integration of technology in teaching mensuration.
- Challenges faced by teachers in conveying complex mensuration concepts.

The qualitative data obtained from the interviews were transcribed and analyzed thematically, identifying recurring themes related to teaching practices and instructional challenges.

As Patton (2015) argues, semi-structured interviews allow for in-depth exploration of participants' experiences while maintaining focus on specific research objectives. This method is particularly suited for uncovering the rationale behind instructional choices and identifying teacher perceptions.

3.6.3 Classroom Observations

Classroom observations were conducted to gather firsthand data on how teachers presented lessons on mensuration and how students interacted with the content. The researcher observed actual teaching sessions where mensuration topics were covered, particularly focusing on the teaching strategies used by the teachers, the instructional resources (e.g., technology, visual aids), and student participation. Observations also helped identify instances where students exhibited misconceptions or struggled with spatial reasoning. The observations were recorded using a detailed observation guide, which allowed the researcher to systematically capture key behaviors and instructional approaches during the lesson.

Classroom observations provide real-time evidence of how concepts are taught and understood. According to Merriam and Tisdell (2016), observation is critical for capturing contextual variables that might not surface during interviews or surveys.

3.6.4 Document Analysis

To complement the data gathered through the questionnaires, interviews, and observations, document analysis was conducted on relevant teaching materials used in the classroom, such as textbooks, lesson plans, and worksheets. This helped to understand the types of resources available to teachers and how they support or hinder students' understanding of mensuration. The analysis focused on identifying the clarity and accuracy of the materials in explaining mensuration concepts and whether they incorporated strategies for addressing common misconceptions.

Together, these research instruments provided a rich and comprehensive dataset, enabling the study to address the research questions from multiple angles. The combination of quantitative data from questionnaires, qualitative insights from interviews and observations, and document analysis allowed for triangulation, enhancing the validity and reliability of the findings.

Document analysis complements other instruments by offering insight into the instructional materials and official representations of the curriculum. Bowen (2009) emphasizes that such analysis allows researchers to uncover implicit assumptions and pedagogical gaps in existing teaching resources.

3.7 Data Collection Procedures

The data collection process for this study was carefully planned and executed to ensure the reliability and validity of the findings. The study employed a mix of quantitative and qualitative data collection methods, including the distribution of questionnaires, conducting semi-structured interviews, observing classroom lessons, and analyzing relevant teaching materials.

According to Creswell and Creswell (2018), systematic planning of data collection enhances the credibility and trustworthiness of a study. Using multiple methods such as questionnaires, interviews, observations, and document analysis ensures triangulation, which increases the reliability of educational research findings (Cohen, Manion, & Morrison, 2018). This approach is essential in capturing the complexity of teaching and learning practices in real classroom settings. The data collection procedures were carried out in several stages as outlined below:

3.7.1 Preparation for Data Collection

Prior to the commencement of data collection, necessary approvals were sought from the school administration, including the principal and relevant authorities, to ensure compliance with ethical guidelines. Informed consent was obtained from both the teachers and students participating in the study. Parents or guardians of the students were also required to provide written consent for their children's participation. The researcher also briefed all participants on the objectives of the study, assuring them of the confidentiality and anonymity of their responses.

3.7.2 Distribution of Questionnaires

The first step in data collection involved administering the questionnaires to the Form 4 students. Self-administered questionnaires are efficient for collecting large volumes of standardized data from students (Gay et al., 2012). The researcher visited the classes during scheduled mathematics lessons and distributed the questionnaires in a controlled setting. Students were given clear instructions on how to complete the questionnaire, and they were assured that their responses would be kept anonymous. The questionnaires took approximately 15-20 minutes to complete, and the students were encouraged to answer honestly and thoughtfully. After completion, the researcher collected the questionnaires immediately to minimize the risk of external interference and to ensure a high response rate.

3.7.3 Semi-structured Interviews with Teachers

After the questionnaires were completed, the next stage involved conducting semi-structured interviews with the four selected mathematics teachers. Semi-structured interviews, as suggested by Patton (2015), allow flexibility and depth, making them suitable for capturing educators' reflective insights. These interviews were scheduled at a time convenient for the teachers, outside of their regular teaching hours, to ensure that they could participate without time constraints. The interviews were conducted in a quiet and private location to avoid distractions and ensure confidentiality. Each interview lasted approximately 30-45 minutes, during which the researcher used a pre-prepared interview guide to direct the conversation. However, the semi-structured format allowed for flexibility, with follow-up questions being asked based on the teachers' responses to probe deeper into their experiences and perspectives. The interviews were audio-recorded with the consent of the participants, and the recordings were transcribed verbatim for analysis.

3.7.4 Classroom Observations

Classroom observations were conducted to capture the interactions between the teachers and students during lessons on mensuration. The researcher attended selected lessons where mensuration topics such as volume and surface area of solid shapes were taught. These observations were conducted unobtrusively, allowing the researcher to observe the natural flow of the lesson without influencing the teaching process. The researcher used an observation checklist to record key aspects of the lesson, including teaching strategies, the use of visual aids or technology, student participation, and moments where misconceptions or difficulties were observed. Each lesson observation lasted between 40 to 60 minutes, depending on the content covered.

3.7.5 Document Analysis

Parallel to the data collection from students and teachers, document analysis was conducted on relevant teaching resources. The researcher reviewed textbooks, lesson plans, handouts, and worksheets used by the teachers during the lessons. The goal was to analyze the content and structure of these materials to determine whether they effectively addressed the teaching of mensuration concepts and provided opportunities for addressing student misconceptions. The researcher examined how the materials presented the formulas for mensuration, the inclusion of practical examples, and whether the resources incorporated any interactive or technological elements to enhance understanding.

3.7.6 Data Collection Timeline

Data collection occurred over a period of four weeks. The first two weeks were dedicated to distributing and collecting the questionnaires from the students. Following this, interviews with teachers were conducted over the next week. Classroom observations were scheduled during the same week, ensuring that each teacher was observed during at least one lesson. Finally, document analysis was conducted throughout the data collection period, focusing on the teaching materials used by the teachers.

3.7.7 Ethical Considerations

Throughout the data collection process, ethical guidelines were strictly followed. All participants were informed about the purpose of the study and their role in it. Participation was voluntary, and participants had the right to withdraw from the study at any time without any consequences. The researcher ensured that all responses were kept confidential and that personal identifiers were removed from the data. Additionally, the audio recordings from interviews were securely stored and only accessible to the researcher.

3.8 Data Analysis and Presentation

Data analysis is a crucial step in the research process, where raw data is transformed into meaningful findings. In this study, both quantitative and qualitative data were collected, and the analysis of these data followed systematic procedures to address the research questions effectively. The analysis process was carried out using appropriate statistical methods and thematic analysis to ensure a comprehensive understanding of the challenges students face in mensuration and the strategies employed by teachers.

3.8.1 Quantitative Data Analysis

The quantitative data collected from the questionnaires were analyzed using descriptive statistics to summarize and interpret the students' responses. The following steps were followed:

- Data Entry and Cleaning: The completed questionnaires were carefully checked for completeness and consistency. Any incomplete or contradictory responses were excluded from the analysis. The remaining data were entered into a statistical software package, SPSS (Statistical Package for the Social Sciences), for analysis. Data analysis followed Creswell’s (2014) guidance on descriptive statistical procedures, using SPSS for summarizing trends, frequencies, and relationships.

- Descriptive Statistics: Descriptive statistics, including frequencies, percentages, and means, were used to summarize the data. For example, the researcher calculated the percentage of students who exhibited common misconceptions, the frequency of specific types of errors in mensuration, and the distribution of students' understanding of key concepts. This approach allowed for the identification of trends in student performance and misconceptions related to mensuration.
- Cross-tabulation: Cross-tabulation was used to examine relationships between different demographic variables (such as gender and academic performance) and the students' responses to the questionnaire items. This provided insights into whether particular groups of students struggled more with certain aspects of mensuration.
- Visualization: To enhance the presentation and interpretation of the quantitative data, the researcher used charts and graphs (e.g., bar charts, pie charts) to visually represent the findings. These visuals helped in conveying the patterns and trends in the data clearly.

3.8.2 Qualitative Data Analysis

The qualitative data collected from semi-structured interviews and classroom observations were analyzed using thematic analysis. This approach allowed the researcher to identify key themes and patterns across the responses of the teachers and observations of classroom interactions. Thematic analysis was used, consistent with Braun and Clarke (2006), involving familiarisation, coding, theme generation, and interpretation. The steps involved in the analysis were as follows:

- Transcription of Interviews: All audio recordings from the teacher interviews were transcribed verbatim. The transcription was then reviewed for accuracy, ensuring that all responses were faithfully captured.
- Coding: The transcriptions were read through multiple times to identify recurring themes, concepts, and issues. Initial open coding was done to mark significant statements related to the research questions, and a set of categories was developed. These codes were then grouped into broader themes that captured the teachers' teaching strategies, challenges, and use of technology.
- Theme Development: After the initial coding, the researcher identified broader themes that emerged across the interviews and classroom observations. Themes such as teaching strategies for mensuration, misconceptions about solid shapes, and the role of

technology in teaching were identified. These themes were used to organize and interpret the qualitative data.

- Interpretation: The final step in the qualitative analysis was interpreting the data in the context of the research questions. The researcher sought to understand the patterns in the teachers' strategies and the challenges they faced in addressing misconceptions among students. The findings were linked back to the literature reviewed in Chapter 2 to provide context and explain the significance of the results.

3.8.3 Triangulation of Data

One of the key strengths of this study is the use of triangulation, where data from multiple sources (questionnaires, interviews, classroom observations, and document analysis) were cross-checked to ensure validity and reliability. By comparing and contrasting the findings from different sources, the researcher was able to corroborate results and draw more accurate conclusions about the challenges in mensuration and the effectiveness of teaching strategies. Denzin (1978) highlights the value of triangulation in enhancing the validity of educational research by corroborating data from different sources.

3.8.4 Presentation of Data

The presentation of the data was structured to highlight the key findings in a clear and logical manner:

- Quantitative Data Presentation: The findings from the student questionnaires were presented using tables and charts, which clearly show the percentage of students who had difficulties with specific mensuration concepts, the types of misconceptions they held, and the relationships between these factors and their demographic information.
- Qualitative Data Presentation: The results from the teacher interviews and classroom observations were presented thematically. Key themes were illustrated with direct quotes from the teachers and examples from the classroom observations to provide a deeper understanding of the teaching practices and the challenges encountered in teaching mensuration.
- Synthesis of Results: A synthesis of the quantitative and qualitative findings was provided in the discussion section. This synthesis allowed for a comprehensive interpretation of how misconceptions, spatial reasoning issues, and teaching strategies interact and impact students' learning outcomes in mensuration.

3.8.5 Software and Tools Used

The study used various tools to analyze the data effectively. For quantitative data analysis, SPSS was used to compute descriptive statistics and generate charts. For qualitative data analysis, NVivo or a similar qualitative data analysis software was employed to facilitate the coding process and theme development. These tools helped streamline the analysis and ensured accuracy and consistency throughout the process.

3.9 Ethical Considerations

Ethical considerations are a fundamental aspect of any research study, ensuring that the rights, dignity, and well-being of participants are protected throughout the research process. In this study, all ethical protocols were strictly observed to guarantee responsible and respectful conduct in line with academic and institutional expectations.

First and foremost, informed consent was obtained from all participants involved in the research. Before participating, students and teachers were briefed about the purpose, objectives, and procedures of the study. They were clearly informed that their participation was voluntary and that they had the right to withdraw at any stage without facing any negative consequences. For students below the age of 18, parental or guardian consent was also sought, in addition to the students' assent.

To ensure confidentiality and anonymity, all personal identifiers were removed from the data. Participants' names, school names, and any other identifying information were replaced with codes. Data collected from questionnaires, interviews, and observations were securely stored in password-protected digital files and locked cabinets to prevent unauthorized access.

The researcher also ensured non-maleficence, meaning no harm physical, emotional, or psychological was inflicted upon participants. Questions posed during interviews and questionnaires were carefully designed to avoid discomfort or distress. In the case of classroom observations, the researcher maintained a non-intrusive presence to minimize disruption to normal teaching and learning processes.

Further, objectivity and integrity were maintained throughout the research process. The researcher avoided any form of bias or manipulation of data. All findings were reported honestly, whether favourable or unfavourable, in line with principles of academic honesty.

The study also complied with the ethical guidelines set by the researcher's institution, and permission to conduct the research was granted by the school authorities and relevant educational offices. A formal letter of approval was obtained before the commencement of data collection.

In conclusion, these ethical safeguards ensured that the study was conducted in a professional, respectful, and responsible manner, upholding the trust placed in the researcher by the participants and contributing to the credibility and reliability of the research findings.

3.10 Measures Taken to Minimize Errors

To ensure the accuracy, reliability, and validity of the research findings, several measures were taken to minimize errors during the entire research process. Errors in research can arise from data collection, instrument design, sampling, or analysis, hence deliberate steps were implemented at each stage.

Firstly, pilot testing of the research instruments (questionnaires and interview guides) was conducted with a small group of Form 4 students and teachers who were not part of the final study. The purpose of this pilot study was to identify ambiguous questions, technical issues, and inconsistencies. Feedback from the pilot informed revisions, thereby enhancing the clarity and suitability of the instruments. Pilot testing, as noted by van Teijlingen and Hundley (2001), is essential for identifying and resolving potential flaws in research instruments before full deployment. Additionally, Johnson and Christensen (2014) advocate for inter-rater verification and peer review of instruments as critical steps in improving data reliability.

Secondly, the triangulation of data collection methods including questionnaires, interviews, and classroom observations helped to cross-verify information and reduce the risk of bias or misinformation. This ensured a more comprehensive and balanced understanding of the challenges students face in mensuration of solid shapes.

In addition, clear operational definitions were used for key terms and concepts, reducing the likelihood of misinterpretation. Participants were also given clear instructions on how to respond to questions, and where necessary, clarification was provided during administration.

To minimize sampling errors, a purposive sampling technique was used to select participants who were relevant to the study objectives specifically, Form 4 students and their mathematics teachers. This ensured that data collected were directly aligned with the study focus.

During data analysis, accurate coding and categorization procedures were applied to maintain consistency. Responses were double-checked to reduce transcription and entry errors. The researcher also consulted with a research supervisor to review the methodology and results, further enhancing the credibility of the findings.

Finally, the researcher-maintained objectivity and neutrality, avoiding any personal bias during the interpretation of results. Ethical standards were strictly followed to preserve the integrity of the research process.

In summary, by employing rigorous testing of instruments, triangulating methods, careful sampling, clear communication, and thorough data handling procedures, the study minimized the risk of errors and ensured the reliability and validity of its findings.

3.11 Summary of Chapter

This chapter outlined the research methodology adopted in the study aimed at addressing the challenges students face in the mensuration of solid shapes. It began by introducing the research design, which employed a mixed-methods approach to gather both quantitative and qualitative data. The chapter also detailed the research methods used, focusing on how data were collected through questionnaires, interviews, and classroom observations.

The study sample and selection criteria were clearly defined, targeting Form 4 students and their mathematics teachers. The research instruments were described in detail, and their relevance to the objectives of the study was justified. The data collection process was explained, highlighting how ethical practices were upheld throughout the research to protect participants' rights and well-being.

Measures to ensure accurate data analysis and presentation were also discussed, along with the steps taken to minimise errors, such as piloting instruments, triangulating data sources, and maintaining objectivity. The ethical considerations observed ensured that the study was conducted responsibly and with integrity.

CHAPTER 4 DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents and interprets the data collected during the investigation into the challenges faced by Form 4 students in understanding the mensuration of solid shapes. The data were gathered through a mixed-methods approach, including structured questionnaires administered to students, semi-structured interviews with mathematics teachers, classroom observations, and document analysis. The aim is to answer the research questions by identifying misconceptions, spatial reasoning difficulties, teaching challenges, and the role of technology in enhancing learning.

The data are presented in two main sections: quantitative findings from student questionnaires and qualitative findings from teacher interviews, classroom observations, and instructional documents. Each section is organized thematically in alignment with the study's four research questions. The findings are supported by visual representations such as tables and charts for clarity, followed by interpretation that relates the results to existing literature. Where applicable, triangulation is used to confirm patterns across different data sources.

This chapter, therefore, forms the analytical core of the study and sets the foundation for drawing conclusions and proposing practical recommendations in the following chapter.

4.2 Presentation and Analysis of Quantitative Data

This section presents the quantitative data obtained from the structured questionnaires administered to 30 Form 4 students at Marchwood Secondary School. The questionnaires were designed to assess learners' understanding of mensuration concepts, identify common misconceptions, evaluate spatial reasoning abilities, and gather students' views on the use of technology in learning.

The data are organized thematically in relation to the research questions. Descriptive statistics such as frequencies and percentages are used to identify patterns in student responses. Graphs and tables are included to aid in visualizing the trends observed. This quantitative analysis provides insight into learners' conceptual challenges and serves as the basis for interpreting the broader implications discussed in later sections.

4.2.1 Demographic Data of Respondents

This subsection presents the demographic characteristics of the Form 4 students who participated in the study. Understanding students' background information—specifically their gender and age distribution—helps contextualize their learning experiences and challenges in mensuration.

Table 1: Gender Distribution of Respondents

Gender	Frequency	Percentage (%)
Male	17	56.7
Female	13	43.3
Total	30	100

The table presents the gender distribution of respondents, providing a clear breakdown of the sample population. With a total of 30 respondents, the data reveals that 17 (56.7%) are male and 13 (43.3%) are female. This indicates a slight majority of male respondents, although the difference between the two genders is not substantial.

The relatively balanced distribution between males and females suggests that the sample is fairly representative of both genders, allowing for a more comprehensive understanding of the research topic. According to UNESCO (2023), gender representation in educational research is important because it ensures that findings reflect the perspectives and experiences of both male and female learners, thereby reducing bias in interpretation. Similarly, Chinyoka and Mutambara (2022) highlight that in Zimbabwean secondary schools, although enrolment patterns sometimes differ slightly by gender due to socio-economic and cultural factors, both males and females generally have significant representation at the secondary level.

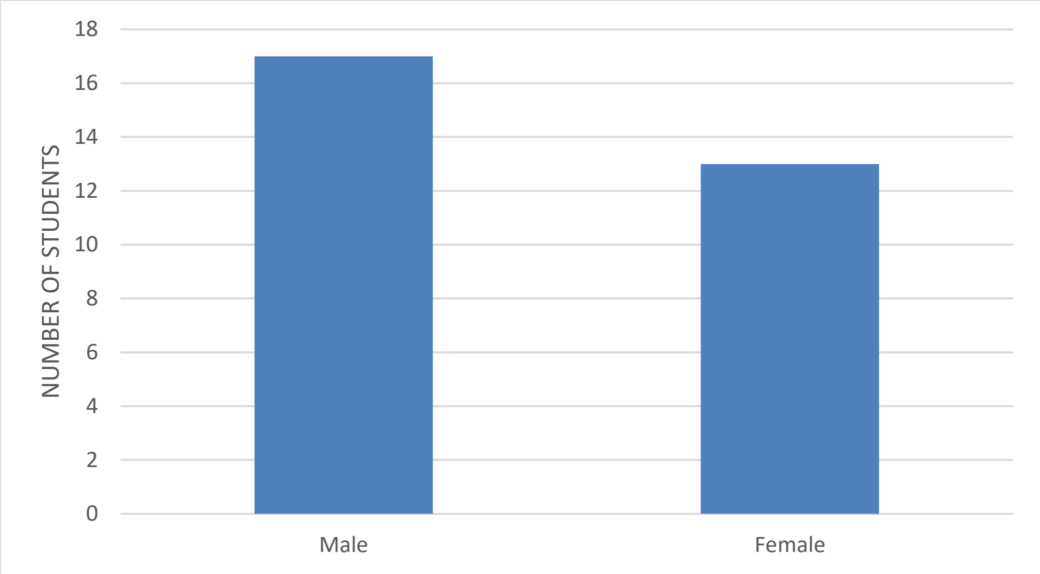

Figure 1: Gender distribution of student participants

Interpretation:

Out of 30 student participants, 56.7% were male and 43.3% were female. This balanced distribution ensures representation from both genders, allowing for diverse insights into students' understanding of mensuration concepts. Moreover, the importance of capturing both genders is supported by Sikhwari and Maphosa (2023), who note that gender differences can influence learning outcomes in mathematics and related subjects, as variations in attitudes, self-efficacy, and exposure to resources often exist. A balanced gender distribution, therefore, provides a stronger basis for drawing conclusions that apply broadly across the student population.

Table 2: Age Distribution of Respondents

Age Group	Frequency	Percentage (%)
14-15	3	10
16-17	21	70
18-19	6	20
Total	30	100

The table presents the age distribution of respondents, categorized into three age groups: 14–15, 16–17, and 18–19 years. The frequency and percentage of respondents in each age group are provided, offering insights into the demographic characteristics of the sample. Notably, the majority of respondents (70%) fall within the 16–17 age range, indicating that this age group is the most represented in the study. In contrast, the 14–15 age group constitutes the smallest proportion (10%), while the 18–19 age group accounts for 20% of the total respondents.

This age distribution is consistent with the expected enrolment age for Form 4 learners in Zimbabwe, who are typically between 16 and 17 years of age (Chinyoka & Mutambara, 2022). The presence of a smaller group of 14–15-year-olds may be attributed to early enrolment or accelerated progression, while the 18–19-year-olds could reflect delayed school entry or grade repetition, which is common in Zimbabwe due to socio-economic challenges (Mhaka, 2021).

From a developmental perspective, the predominance of learners in the 16–17 age bracket is significant, as this age coincides with Piaget's formal operational stage, where adolescents develop enhanced abstract and spatial reasoning skills, making them more capable of handling mathematical concepts such as mensuration (Papalia & Martorell, 2021). This suggests that the majority of respondents were cognitively positioned to engage effectively with the subject matter, although age-related variations in maturity and prior learning experiences may still influence performance.

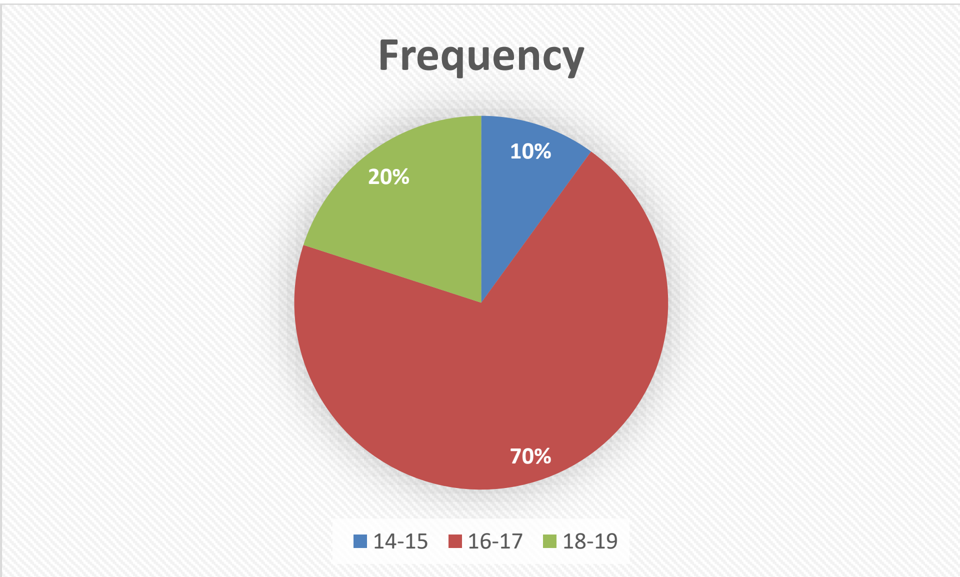

Figure 2: Age distribution of Form 4 respondents

Interpretation:

The majority of the respondents (70%) were aged between 16 and 17 years, which aligns with the expected age for Form 4 learners. A smaller proportion (10%) were slightly younger, while 20% were older, possibly due to repeating or late enrollment. Such patterns are common in sub-Saharan Africa, where educational progression is often affected by socio-economic barriers, family responsibilities, and disruptions such as school closures (UNESCO, 2023).

This age profile is particularly relevant for interpreting learners' ability to grasp mensuration, as research shows that age-related differences influence mathematical problem-solving and reasoning skills. For instance, Sikhwari and Maphosa (2023) found that older learners often display varying levels of motivation and persistence, which may affect their engagement with abstract mathematical concepts. Additionally, studies on adolescent learning emphasise that cognitive growth during this stage is closely linked to opportunities for quality instruction and exposure to problem-solving activities (Loretan et al., 2024). Therefore, the age variations within the sample are important for understanding differences in how learners comprehend and apply mensuration concepts.

4.2.2 Students' Understanding of Mensuration Concepts

This subsection presents findings on students' ability to apply correct formulas, identify appropriate measurements, and solve basic mensuration problems involving volume and surface area. The results provide insight into learners' conceptual grasp of mensuration, which directly affects their performance in mathematics.

To assess understanding, students answered 5 core questions related to solid shapes:

1. Identifying the correct formula for the volume of a cone.
2. Choosing the appropriate units for surface area.
3. Calculating volume using given dimensions.
4. Understanding the difference between lateral and total surface area.
5. Identifying the height in a composite solid diagram.

Each correct answer was awarded 1 point. A score of 4 or 5 was considered good understanding, 2 or 3 as partial understanding, and 0 or 1 as poor understanding.

Table 3: Distribution of Students' Scores on Mensuration Understanding | Understanding

Understanding level	Frequency	Percentage (%)
Good (4-5 correct)	7	23.3
Partial (2-3 correct)	13	43.3
Poor (0-1 correct)	10	33.3
Total	30	100

The table presents the distribution of students' scores on mensuration understanding, categorized into three levels: good, partial, and poor. The data reveals that 7 students (23.3%) demonstrated a good understanding, scoring 4 or 5 out of 5. In contrast, 13 students (43.3%) showed partial understanding with scores ranging from 2 to 3, while 10 students (33.3%) exhibited poor understanding, scoring 0 or 1.

This breakdown suggests that while a significant portion of students have some grasp of mensuration concepts, there is still a substantial number struggling with the subject matter. Studies have shown that mensuration and geometry are among the most challenging areas in mathematics, often due to the abstract nature of the concepts and learners' limited spatial reasoning (Ubuz, 2011; Awofala, 2011). More recent findings also indicate that post-COVID-19 learning disruptions exacerbated these difficulties, with mathematics performance in Zimbabwean secondary schools declining due to reduced instructional time and limited access to effective learning resources (UNESCO, 2023; Magocha, Munyaradzi, & Babalola, 2025).

Furthermore, research highlights that many learners fail to make connections between formulae and their geometric meaning, leading to rote memorisation rather than conceptual understanding (Loretan et al., 2024). This aligns with the high proportion of students in the partial and poor categories, suggesting a need for improved instructional strategies, such as the integration of visual models and technology-enhanced teaching, which have been shown to improve comprehension in mensuration and related topics (Sikhwari & Maphosa, 2023).

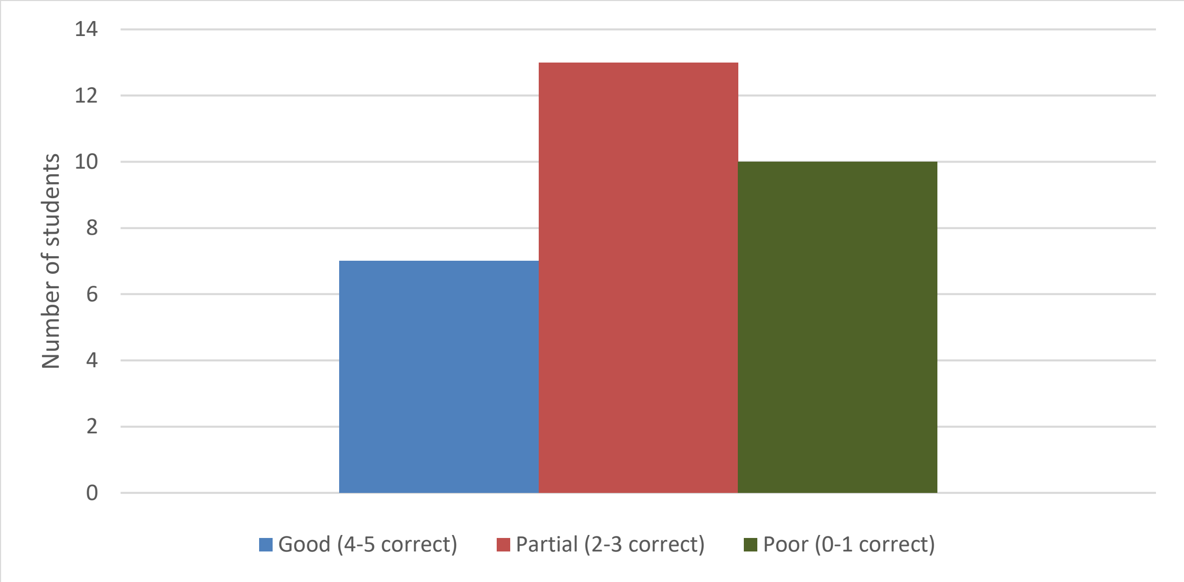

Figure 3: Students' understanding levels of mensuration concepts

Interpretation:

The results indicate that only 23.3% of students demonstrated a good understanding of the mensuration concepts assessed. The majority (43.3%) displayed partial understanding, often making minor formula or unit conversion errors. A significant proportion (33.3%) performed poorly, suggesting a deep conceptual gap. These findings align with previous studies (e.g., Sunzuma, 2016; Cuarto, 2024), which attribute poor performance in mensuration to rote memorization and lack of conceptual clarity.

- The errors observed among students included:
- Confusing surface area with volume.
- Using 2D area formulas in 3D problems.
- Selecting incorrect units (e.g., cm instead of cm^2).
- Identifying slant height as vertical height in cones.

4.2.3 Common Misconceptions

This section presents findings related to the specific misconceptions students hold regarding the mensuration of solid shapes. These misconceptions were identified through students' responses to diagnostic questions that tested their conceptual understanding of formulas, dimensions, and spatial relationships.

Misconception	Frequency	Percentage (%)
Confusing volume with surface area	18	60.0
Misapplying slant height	16	53.3
Using 2D areas formulas in 3D context	15	50.0
Incorrect unit of conversion eg cm to sqr cm	13	43.3
Inability to identify composite shapes correctly	9	30.0

Table 4: Common Misconceptions Identified in Questionnaire Responses

The table presents findings related to the specific misconceptions students hold regarding the mensuration of solid shapes. These misconceptions were identified through students' responses to diagnostic questions that tested their conceptual understanding of formulas, dimensions, and spatial relationships. The table categorizes the misconceptions into five distinct areas: confusing volume with surface area, misapplying slant height, using 2D area formulas in 3D contexts, incorrect unit conversion, and inability to identify composite shapes correctly. The frequency and percentage of each misconception are provided, offering insight into the prevalence of these misunderstandings among Form 4 students.

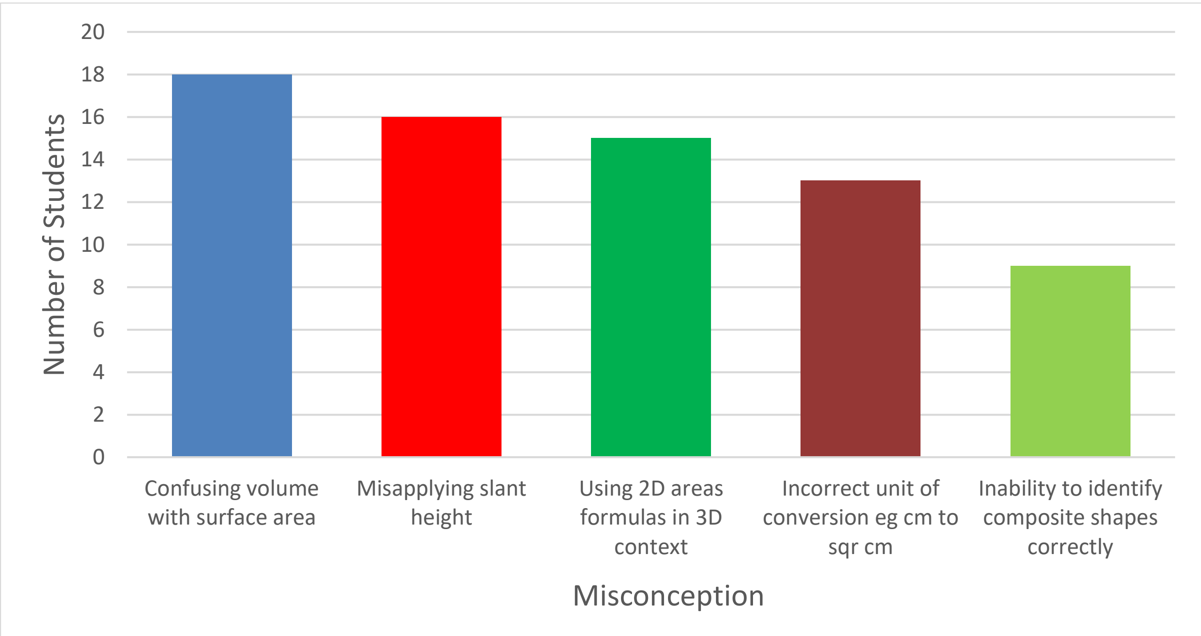

Figure 4: Frequency of common misconceptions among Form 4 students

Interpretation:

The most frequent misconception, observed in 60% of respondents, involved confusing formulas for volume and surface area, particularly in cones and cylinders. Similar findings have been reported by Awofala (2011) and Ubuz (2011), who note that many learners struggle to distinguish between 2D and 3D measurements, often applying incorrect formulas. Many students also mistook slant height for vertical height (53.3%), especially in pyramid- and cone-based questions. This aligns with Duval's (2006) argument that learners often fail to coordinate different representations of geometric objects, leading to persistent errors in distinguishing dimensions such as heights and diagonals.

Half of the respondents used area formulas meant for 2D shapes (like rectangles and circles) in problems requiring the surface area of 3D shapes. This confusion has been widely documented, with researchers highlighting that learners often overgeneralise familiar 2D rules when confronted with more complex 3D contexts (Jones, 2020). Incorrect unit conversions were also common, where students presented surface area in cm instead of cm^2. According to Papalia and Martorell (2021), such mistakes are tied to underdeveloped metacognitive skills in adolescents, which affect their attention to detail and symbolic reasoning.

A smaller but still significant portion of students (30%) could not correctly analyze composite shapes, suggesting difficulty in visualizing and deconstructing 3D figures. Research shows that visualisation and spatial reasoning are critical in understanding composite solids, and many learners struggle because they lack exposure to hands-on or technology-supported learning aids (Sikhwari & Maphosa, 2023; Loretan et al., 2024). This highlights the importance of using dynamic visual tools such as GeoGebra to strengthen students' ability to manipulate and mentally decompose 3D objects.

4.2.4 Spatial Reasoning Difficulties

Spatial reasoning is the ability to mentally visualise and manipulate 3D objects. It plays a critical role in understanding the dimensions, orientation, and measurements of solid shapes (Mix & Cheng, 2012; Uttal & Cohen, 2012). This section presents student responses to a set of Likert-scale items designed to evaluate their spatial reasoning abilities in the context of mensuration.

Students rated their confidence and ability to visualise and interpret 3D shapes using the following scale:

- 1 – Strongly Disagree
- 2 – Disagree
- 3 – Neutral
- 4 – Agree
- 5 – Strongly Agree

Five key statements were included:

- I can mentally rotate 3D shapes to view them from different angles.
- I find it easy to imagine how changing a shape's height or radius affects its volume.
- I can accurately identify dimensions (height, slant height, radius) in diagrams.
- I understand how different parts of a solid shape relate to each other in space.
- I struggle to visualize complex shapes like cones and spheres. (Negatively worded)

Table 5: Summary of Student Responses on Spatial Reasoning Skills

Statement Number	Avg. Score	Interpretation
1	2.9	Slightly below average confidence
2	2.7	Below average spatial understanding
3	3	Neutral
4	2.8	Below average
5 (negatively worded)	3.6	Above neutral agreement = difficulty present

The table presents a summary of student responses on spatial reasoning skills, with five statements related to visualizing and understanding 3D shapes. The average scores for each statement range from 2.7 to 3.6, indicating varying levels of confidence and ability among students. Statements 1, 2, and 4 received average scores below 3, suggesting that students struggle with mentally rotating 3D shapes, imagining changes in shape dimensions, and accurately identifying dimensions in diagrams. In contrast, Statement 5, which is negatively worded, received an average score above neutral agreement, indicating that students experience difficulty visualizing complex shapes like cones and spheres.

These findings align with research showing that secondary school students often face challenges in spatial reasoning, particularly in mental rotation and visualization of three-dimensional objects (Uttal et al., 2013; Loretan et al., 2024). Studies indicate that low confidence in these skills can affect students' performance in geometry and mensuration, as tasks requiring manipulation of 3D shapes depend heavily on spatial visualization (Newcombe, 2019; Takaendesa & Ndemo, 2022). Overall, the table highlights areas where students need improvement in their spatial reasoning skills, particularly in tasks requiring mental manipulation and visualization of 3D objects.

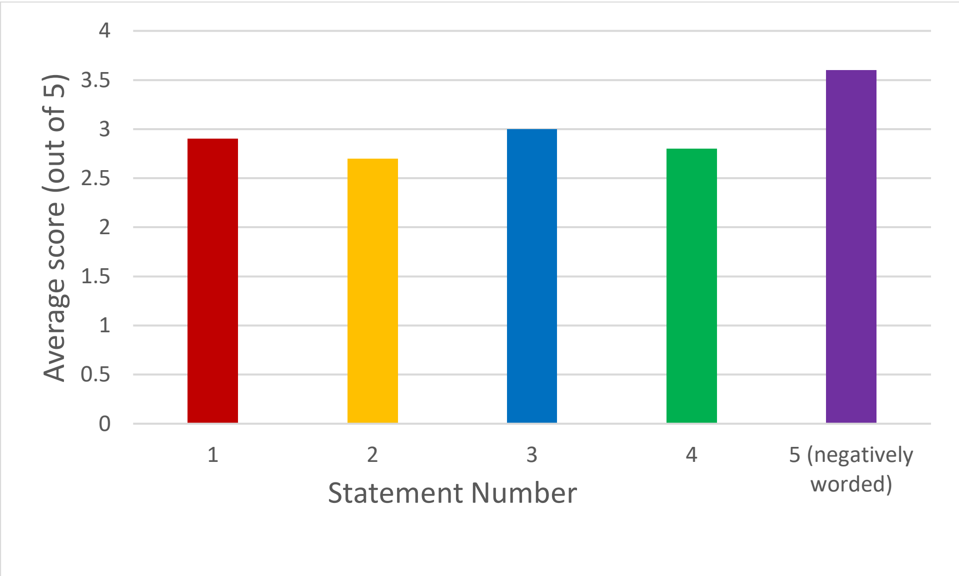

Figure 5: Average student responses to spatial reasoning statements

Interpretation:

The results show that most students expressed uncertainty or low confidence in their spatial reasoning skills. The highest average score (3.6) came from the negatively worded statement, indicating that many students admit to struggling with visualizing complex shapes such as spheres and cones. Scores for the ability to mentally rotate objects (2.9) and understand dimensional changes (2.7) were below the neutral point. Only one item—identifying correct dimensions—received a neutral average (3.0), suggesting that learners may rely on diagrams but struggle with mentally visualizing shapes in different orientations or contexts.

Research indicates that difficulties in spatial reasoning are often linked to underdeveloped mental rotation and visualization skills, which are critical for success in geometry, mensuration, and STEM-related learning (Sorby, 2023; Uttal et al., 2013). Furthermore, learners with low spatial ability are more likely to make errors in identifying dimensions, interpreting diagrams, and solving 3D geometry problems, highlighting the need for targeted instructional strategies that incorporate visual aids, hands-on models, and technology-assisted learning (Loretan et al., 2024; Takaendesa & Ndemo, 2022).

4.3 Presentation and Analysis of Qualitative Data

This section presents qualitative findings derived from semi-structured interviews with mathematics teachers, classroom observations, and document analysis. The aim is to explore how teachers experience and respond to the challenges students face in learning the mensuration of solid shapes.

Thematic analysis was used to identify patterns and recurring ideas across the qualitative data. These findings are presented under thematic categories aligned with the research objectives, including:

- Common student misconceptions
- Spatial reasoning difficulties
- Instructional challenges and practices
- Technology use in teaching mensuration

4.3.1 Teacher Interviews

Four mathematics teachers were interviewed. The analysis of their responses revealed four major themes that relate directly to the difficulties faced by students in understanding mensuration.

Theme 1: Prevalent Misconceptions All four teachers confirmed that students often confuse surface area and volume, and struggle to identify the correct dimensions when solving problems.

"Many students think surface area and volume are the same. You'll find them using the volume formula to calculate area, especially in cones or cylinders." – Teacher A "They don't understand what slant height means. They use it where the vertical height is required, especially for cones and pyramids." – Teacher C

Theme 2: Weak Spatial Reasoning Skills Teachers observed that many learners find it difficult to visualise solid shapes or understand how changes in dimensions affect measurements.

“Students can’t picture what happens when a cylinder is cut or tilted. They get confused about which side is the radius or height.” – Teacher B “Most of them can’t mentally rotate shapes or imagine how two solids fit together. That’s why they avoid composite shape questions.” – Teacher D

Theme 3: Instructional Challenges Teachers also reported facing challenges such as large class sizes, lack of teaching aids, and limited time for practical demonstrations.

“The topic requires real models or 3D diagrams, but we don’t have those. Most times we just draw shapes on the board, and learners struggle to relate.” – Teacher C “There’s too much pressure to finish the syllabus, so we don’t spend enough time on topics like this, even when students clearly don’t understand.” – Teacher A

Theme 4: Limited Use of Technology Teachers acknowledged the potential of technology but noted barriers such as lack of access and training.

“I’ve seen GeoGebra videos online that could help, but we don’t have the equipment or internet to use them in class.” – Teacher B “I would use simulations if I had a projector or even a tablet. It’s difficult to teach solids when learners can’t visualise them.” – Teacher D

Interpretation:

The interviews confirm that teachers are aware of the core challenges in mensuration: student misconceptions, spatial reasoning difficulties, and the limitations of traditional teaching approaches. While they see value in interactive methods and technology, practical constraints hinder implementation.

4.3.2 Classroom Observations

Classroom observations were conducted during four mathematics lessons focused on mensuration of solid shapes. The goal was to examine how teachers deliver instruction, how students engage with the content, and whether teaching strategies address known misconceptions and spatial reasoning challenges.

Theme 1: Predominant Use of Traditional Instruction In all observed lessons, the teachers primarily used chalk-and-talk methods to explain formulas for volume and surface area.

Observed Example: In one lesson on the surface area of a cone, the teacher wrote the formula and substituted values without explaining what the slant height physically represents.

Theme 2: Minimal Use of Manipulatives or Visual Aids None of the classrooms had access to 3D models or cut-out solids. Diagrams were hand-drawn on the board, and students struggled to interpret them.

Observed Example: During a lesson on composite solids, several students asked whether the cone was "on top" or "beside" the cylinder.

Theme 3: Limited Interaction and Diagnostic Assessment Most student responses were brief and factual. Teachers did not ask probing questions or explore the reasoning behind incorrect answers.

Observed Example: When a student gave an incorrect answer for the volume of a cylinder, the teacher corrected it without asking for explanation.

Theme 4: Absence of Technology in Teaching There was no observable use of digital tools such as projectors, simulations, or geometry software.

Observed Example: One teacher mentioned during the lesson that "if we had a projector, I would show you how this shape looks in real life."

Interpretation:

Classroom observations confirm a gap between recommended pedagogical practices and classroom realities. Lessons were largely teacher-centred, with minimal visual, tactile, or technological support. These limitations contribute to misconceptions and reduced engagement.

4.3.3 Document Analysis

Document analysis was conducted on mathematics textbooks, lesson plans, worksheets, and class handouts. The goal was to assess how mensuration is represented and whether resources support conceptual understanding, address misconceptions, and promote spatial reasoning.

Theme 1: Heavy Emphasis on Procedural Knowledge Textbooks and worksheets emphasized procedures—stating formulas and solving examples—without conceptual explanations.

Example: "Calculate the volume of a cone…" exercises lacked diagrams or context.

Theme 2: Limited Visual Support and Inconsistent Diagrams Diagrams were often 2D sketches without perspective or labels.

Observation: A pyramid diagram had no labels, but the question assumed students would identify height.

Theme 3: Lack of Real-Life or Contextualised Problems Exercises were abstract and rarely included real-world applications like estimating tank or silo volumes.

Theme 4: No Integration of Technology or Differentiation Guidelines Lesson plans and textbooks lacked any references to digital tools or scaffolding instructions.

Interpretation: The instructional documents reviewed were strongly procedural, with little support for conceptual development, visualisation, or student-centred learning. Their limitations reinforce findings from interviews and classroom observations.

4.4 Triangulation of Data

Triangulation involves comparing data from multiple sources to validate findings and deepen understanding of the research problem (Creswell & Creswell, 2018). In this study, data were collected through student questionnaires (quantitative), teacher interviews, classroom observations, and document analysis (qualitative). The integration of these sources reveals converging evidence regarding the challenges students face in learning the mensuration of solid shapes.

Table 6: Converging Themes Across Data Sources

Theme	**Questionnaire**	**Interviews**	**Observations**	**Documents**
Misconceptions	60% confused volume and surface area	Teachers noted frequent formula and dimension confusion	Students gave incorrect answers; errors not deeply probed	Emphasis on formulas; little conceptual explanation
Spatial Reasoning	DifficultiesLow confidence (avg. < 3.0 on Likert scale)	Teachers reported trouble with visualising shapes	Students struggled with diagrams and composite shapes	Poor diagrams; few spatial representations

Teaching Strategies and Challenges	Chalk-and-talk reported by students	Teachers cited lack of resources and time	Predominantly teacher-centred lessons	No differentiation or scaffolding found
Technology Integration	Students open to tech, but no exposure	Teachers saw value but lacked access/training	No observed technology use	No reference to ICT tools or methods

Interpretation: Findings from different sources consistently highlight the same core issues: conceptual misunderstandings, weak spatial reasoning, and instructional limitations. The absence of technological and visual tools is a cross-cutting theme. This triangulated evidence strengthens the validity of the study's conclusions.

4.5 Interpretation of Findings in Relation to Research Questions

This section interprets the research findings in direct relation to the four guiding research questions of the study. Drawing on the combined data from questionnaires, interviews, observations, and document analysis, this section highlights what the evidence reveals about the conceptual, pedagogical, and structural challenges students face in learning the mensuration of solid shapes

RQ1: What specific misconceptions do O' Level students have when learning the mensuration of solid shapes? Students confuse volume and surface area formulas (60%), use slant height incorrectly (53%), and apply 2D formulas in 3D contexts. These misconceptions were confirmed by teachers and aligned with textbook emphasis on rote methods.

RQ2: How do spatial reasoning difficulties affect students' understanding of solid shape mensuration? Students displayed low confidence and ability to visualise solids. Teachers observed similar struggles. Observations and documents showed limited use of visual tools, exacerbating the issue.

RQ3: What teaching strategies are being used, and how effective are they in addressing these difficulties? Chalk-and-talk dominates. Teachers rarely diagnose or address misconceptions in real-time. Observed lessons and reviewed materials lacked differentiation, interactive methods, and real-life relevance.

RQ4: What role does technology play in enhancing the teaching and learning of mensuration of solid shapes? Technology was not used in classrooms or recommended in materials. Teachers support its use but lack access and training. Students also showed interest but had minimal exposure.

Summary Interpretation:

Students' struggles with mensuration stem from conceptual, spatial, and instructional challenges. Addressing these requires systemic changes in pedagogy, teacher support, and resource provision.

4.6 Summary of Chapter

This chapter presented and analysed the data collected to explore the challenges faced by Form 4 students in learning the mensuration of solid shapes. A mixed-methods approach was employed, and findings from student questionnaires, teacher interviews, classroom observations, and document analysis were triangulated to provide a comprehensive understanding of the problem.

Quantitative data revealed that a large number of students exhibit misconceptions about core concepts such as volume and surface area, with only 23.3% demonstrating a good understanding. Common errors included formula confusion, incorrect use of dimensions, and unit misapplication. Spatial reasoning was also weak among most students, as shown by low confidence in mentally manipulating 3D figures.

Qualitative findings from teacher interviews confirmed that these misconceptions are common and persistent, and that spatial reasoning challenges are rarely addressed due to a lack of models or visual aids. Observations revealed that lessons were mostly teacher-centred, with limited student interaction, minimal probing, and no use of technology. Document analysis reinforced this picture, showing an emphasis on procedures over concepts and a lack of differentiated support or ICT integration.

Across all data sources, four dominant challenges were identified:

- Deep-seated student misconceptions,
- Poor spatial reasoning abilities,

- Limited use of interactive, visual, or learner-centred teaching strategies, and
- Minimal integration of technology in instruction.

These findings confirm that the difficulties students face is both cognitive and structural. They highlight the need for targeted interventions such as conceptual teaching, use of visual tools and manipulatives, professional development for teachers, and improved access to educational technology.

The next chapter builds on these findings to propose practical recommendations and discuss their implications for teachers, curriculum developers, and policymakers.

CHAPTER 5 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the final component of the research by discussing, interpreting, and synthesizing the findings in relation to the study's objectives and research questions. The study was conducted to investigate the challenges O' Level students face in learning the mensuration of solid shapes, with particular emphasis on the prevalence of misconceptions, the influence of spatial reasoning difficulties, the effectiveness of teaching strategies, and the role of technology in enhancing conceptual understanding.

The research employed a mixed-methods approach, combining quantitative data collected through student questionnaires with qualitative data obtained from semi-structured teacher interviews, classroom observations, and document analysis. The triangulation of these methods ensured a comprehensive understanding of the teaching and learning processes related to mensuration.

This chapter is structured into several key sections. First, the major findings of the study are discussed thematically according to the four research questions, drawing comparisons with existing literature and theoretical frameworks such as Constructivism, the Theory of Spatial Intelligence, and the Technological Pedagogical Content Knowledge (TPACK) model. Following the discussion, the chapter presents conclusions drawn from the research findings, outlining the implications for teaching practice and policy. The next section offers practical recommendations for teachers, curriculum developers, school administrators, and policymakers. It also provides suggestions for future research that could further contribute to the field of mathematics education. The chapter concludes with a reflection on the limitations of the study and a summary of the key insights gained.

Through this comprehensive analysis, the chapter seeks to provide meaningful solutions to the persistent challenges learners face in understanding the mensuration of solid shapes, and to contribute to the ongoing effort to improve mathematics instruction and outcomes at the secondary school level in Zimbabwe

5.2 Discussion of Findings

This section provides an in-depth interpretation of the research findings, organized around the study's four research questions. The discussion draws on evidence from the collected data—

student questionnaires, teacher interviews, classroom observations, and document analysis—and aligns them with the existing literature and theoretical frameworks introduced in Chapter 2. The aim is to unpack the underlying factors contributing to student difficulties in the mensuration of solid shapes and to explore how instructional approaches and technology can support improvement.

5.2.1 Misconceptions in Mensuration

One of the most prominent findings of the study was the widespread presence of misconceptions among students regarding key concepts in mensuration. Specifically, 60% of the students demonstrated confusion between the formulas for volume and surface area. Additionally, over half of the respondents misapplied the slant height when solving problems related to cones and pyramids. A significant number also incorrectly used two-dimensional area formulas in three-dimensional contexts and struggled with unit conversions, such as using cm instead of cm^2 or cm^3.

These findings echo prior studies that emphasize the persistence of misconceptions when instruction focuses heavily on rote learning rather than conceptual understanding (Smith et al., 2020; Hiebert & Grouws, 2007). The observations and interviews further revealed that most teachers emphasize procedural knowledge—teaching formulas and substitutions—without ensuring that students grasp the geometric meaning of these operations. This aligns with the work of Mhakure and Ngara (2014), who reported that Zimbabwean learners often memorize formulas but cannot transfer knowledge to novel contexts.

Teachers in the current study acknowledged these misconceptions but cited time constraints and pressure to cover the syllabus as barriers to addressing them in depth. Consequently, students develop fragmented knowledge that hinders problem-solving and long-term retention.

5.2.2 Spatial Reasoning Challenges

The findings also highlight spatial reasoning as a critical barrier to students' understanding of mensuration. Student responses on the Likert-scale questionnaire indicated low confidence in visualizing and mentally rotating 3D objects, with average scores ranging from 2.7 to 2.9 out of 5. The negatively worded item, "I struggle to visualize complex shapes like cones and spheres," had an average score of 3.6, confirming the prevalence of this difficulty.

Teachers corroborated these self-assessments, noting that students often become confused when asked to interpret diagrams, especially in composite solids. Classroom observations supported this view, as many students could not distinguish between vertical and slant height or identify the base in 3D shapes. In some lessons, learners misinterpreted hand-drawn diagrams on the chalkboard due to a lack of spatial cues like shading or perspective.

This finding supports existing literature on the cognitive demands of spatial reasoning in geometry (Mix & Cheng, 2012; Uttal & Cohen, 2012). According to Gardner's Theory of Multiple Intelligences (1983), spatial intelligence is a distinct form of cognition that not all students naturally possess but can be nurtured through visual and physical engagement with shapes. Unfortunately, the study found minimal evidence of spatial scaffolding—such as the use of models or visual simulations—in classrooms or teaching materials.

In the Zimbabwean context, as noted by Mavuru and Bhebhe (2019), the lack of emphasis on spatial reasoning in teaching contributes significantly to learners' difficulties with geometric and mensuration topics. The current study affirms the urgent need to incorporate spatial training into mathematics instruction.

5.2.3 Teaching Strategies and Instructional Practices

The study revealed that teaching strategies used in the classroom were predominantly traditional and teacher-centred. Observations showed that most lessons involved the teacher demonstrating formulas on the board while students copied and followed the steps. Opportunities for exploratory learning, peer discussion, or hands-on manipulation of models were notably absent.

This instructional approach, while efficient for syllabus coverage, is not conducive to conceptual understanding. As Anthony and Walshaw (2009) argue, effective mathematics teaching should involve active participation, real-world applications, and continuous assessment of learners' thought processes. The teacher interviews revealed that while some educators were aware of these best practices, implementation was hindered by factors such as large class sizes, limited resources, and a lack of professional development in modern pedagogical methods.

The data also showed a lack of formative assessment techniques. Teachers did not frequently probe for reasoning behind student answers, nor did they systematically address incorrect responses. This limits opportunities to uncover and address misconceptions as they arise, a critical practice for learning as highlighted by Black and Wiliam (1998).

Overall, the study confirmed findings by Chikowore and Mudzamiri (2021) that many Zimbabwean classrooms still rely on "chalk-and-talk" approaches, and that meaningful instructional innovation remains constrained by systemic challenges.

5.2.4 Role and Integration of Technology

Although students and teachers expressed interest in using technology to support the learning of mensuration, the study found no evidence of digital tools being used in the classrooms observed. Teachers cited lack of access to projectors, internet connectivity, and digital resources as major barriers. Some also indicated that they lacked training in how to effectively incorporate technology into their teaching practices.

The potential benefits of technology in teaching geometry and mensuration are well-documented. Dynamic geometry software such as GeoGebra and virtual manipulatives have been shown to enhance visualization, provide immediate feedback, and allow for interactive exploration of geometric properties (Hollebrands, 2007; Pierce & Stacey, 2010). Students can manipulate virtual 3D shapes to observe how changing dimensions affects volume and surface area—an approach that directly addresses the spatial challenges highlighted earlier.

The TPACK framework (Mishra & Koehler, 2006) emphasizes that effective technology integration requires not just access to tools, but also the knowledge of how to align them with content and pedagogy. This study's findings suggest that most teachers lacked this integration capacity due to insufficient professional development and infrastructural support.

In line with the findings of Chikowore and Mudzamiri (2021), this study concludes that while digital technology holds considerable promise for transforming mensuration instruction in Zimbabwe, its integration remains limited and underutilized in current practice.

5.3 Conclusions

This study set out to investigate the core challenges that O' Level students encounter when learning the mensuration of solid shapes, with a particular focus on misconceptions, spatial reasoning difficulties, instructional strategies, and technology integration. Drawing from a comprehensive analysis of student questionnaires, teacher interviews, classroom observations, and instructional materials, several key conclusions can be made.

First, it is evident that student misconceptions are a major barrier to understanding mensuration. Many students confuse volume and surface area formulas, misidentify dimensions like slant height and vertical height, and apply two-dimensional formulas to three-dimensional problems.

These errors are not isolated but widespread, pointing to a systemic issue in how mensuration is taught. The findings suggest that teaching in most cases emphasizes memorization and procedural recall rather than conceptual understanding, which contributes to these persistent misunderstandings. This confirms earlier research by Hiebert and Grouws (2007) and Cuarto (2024) that procedural instruction, in the absence of conceptual grounding, fails to support deep learning.

Secondly, the study concludes that spatial reasoning weaknesses significantly impair students' ability to grasp and apply mensuration concepts. Students struggle to mentally rotate shapes, imagine dimensional changes, or interpret diagrams from different perspectives. Teachers noted similar patterns during lessons and assessments. These difficulties are consistent with the theoretical underpinnings of Gardner’s (1983) spatial intelligence theory and empirical findings by Mix and Cheng (2012), which emphasize the cognitive demands involved in 3D geometry. The lack of visual and tactile resources in schools further exacerbates the issue, limiting students' opportunities to develop spatial skills.

Third, instructional practices observed in the study do not adequately support learners in overcoming these difficulties. Most teaching is teacher-centred, driven by formula delivery and problem demonstration, with little room for inquiry, discussion, or the use of real-world contexts. Teachers are aware of the challenges but are constrained by syllabus coverage pressures, large class sizes, and limited access to teaching aids. The absence of formative assessment practices—such as diagnostic questioning or feedback loops—means that misconceptions often go uncorrected. As Boaler (2016) and Anthony and Walshaw (2009) argue, traditional teaching models limit conceptual growth and engagement, which this study’s findings strongly support.

Finally, the study finds that technology integration, although recognized by both students and teachers as potentially beneficial, is largely absent in practice. Teachers expressed interest in using digital tools such as simulations or geometry software but cited barriers including inadequate infrastructure, lack of training, and limited school support. This gap between potential and practice highlights the need for systemic investment in technological resources and teacher capacity building, as outlined by the TPACK framework (Mishra & Koehler, 2006) and echoed in studies like Chikowore and Mudzamiri (2021).

In summary, the learning of mensuration at the O’ Level is hindered by a complex interplay of conceptual gaps, cognitive limitations, outdated pedagogical approaches, and structural constraints. Addressing these challenges requires a coordinated response involving changes to teaching methods, curriculum design, professional development, and technological support. Without such interventions, students are likely to continue experiencing difficulties in a topic that is not only critical for academic success but also for practical applications in science, engineering, and everyday life.

5.4 Recommendations

Based on the findings and conclusions drawn from this study, it is clear that improving students' understanding of the mensuration of solid shapes requires a multifaceted approach. The following recommendations are presented to guide interventions at the levels of classroom instruction, curriculum development, policy formulation, and further research.

5.4.1 Recommendations for Teachers

• Shift from Procedural to Conceptual Teaching

Teachers should prioritize conceptual explanations over formula memorization. Instead of simply presenting formulas, teachers should explain how and why those formulas work by connecting them to real-life contexts and geometric properties. As Van de Walle et al. (2013) suggest, understanding the reasoning behind formulas helps learners retain and apply knowledge meaningfully.

• Diagnose and Address Misconceptions

Teachers must routinely identify and correct misconceptions through diagnostic assessments, questioning strategies, and formative feedback. Smith et al. (2020) recommend using low-stakes quizzes, error analysis tasks, and think-aloud protocols to surface student thinking.

• Use of Visual Aids and Manipulatives

Incorporating 3D models (physical or digital) can significantly improve students' spatial reasoning. Teachers should use solid object cut-outs, cardboard nets, and tangible materials to help students build mental models of 3D shapes (Boakes, 2009; Van Garderen & Montague, 2003).

• Incorporate Inquiry-Based and Collaborative Learning

Active learning methods such as project-based tasks, real-world problem scenarios, and group discussions should be integrated into mensuration lessons. These approaches have been shown to improve engagement and conceptual understanding (Boaler, 2016).

• Enhance Professional Knowledge

Teachers are encouraged to pursue continuous professional development in spatial reasoning, use of digital tools like GeoGebra, and learner-centred teaching strategies. This will enhance their capacity to create more inclusive and effective learning environments (Mishra & Koehler, 2006).

5.4.2 Recommendations for Curriculum Developers

• Revise Textbooks and Syllabi

Current textbooks should be revised to include conceptual explanations, labelled diagrams with depth perspective, real-life applications of mensuration, and differentiated learning tasks that cater to learners with diverse spatial abilities.

• Include Spatial Reasoning and Visualization Tasks

Curriculum guidelines should explicitly incorporate spatial reasoning exercises such as mental rotation, diagram construction, and 3D model interpretation—skills necessary for geometry and mensuration mastery (Mix & Cheng, 2012).

• Integrate Technology Recommendations

The curriculum should encourage and guide the use of educational technologies that support visualization and interactivity. Sample lesson plans and digital resources should be made available for teachers to adapt.

5.4.3 Recommendations for School Administrators and Policy Makers

• Provide Technological Infrastructure

Schools must be equipped with projectors, tablets, reliable internet access, and educational software. These tools are critical for integrating simulations, video tutorials, and dynamic geometry applications into teaching.

• Support Teacher Training in TPACK

School leaders and education ministries should implement ongoing training programs based on the TPACK model (Technological Pedagogical Content Knowledge), enabling teachers to meaningfully combine content, pedagogy, and technology (Mishra & Koehler, 2006).

• Encourage Smaller Class Sizes or Flexible Grouping

Where possible, schools should explore strategies to reduce class sizes or use flexible grouping to provide more individualised support, particularly during spatially demanding topics like mensuration.

• Incentivize Innovation and Research-Based Practices

Policies should reward schools and teachers who adopt innovative, research-based instructional strategies. Sharing success stories and creating professional learning communities can encourage wider adoption of best practices.

5.4.4 Recommendations for Students

• Engage in Self-Assessment and Peer Learning

Students should regularly reflect on their understanding, attempt error analysis, and seek feedback from peers and teachers. This metacognitive approach can help correct misconceptions and promote active engagement.

• Utilize Digital Resources

Learners are encouraged to explore freely available digital tools such as GeoGebra, YouTube tutorials, and interactive learning apps to improve their visualization and practice skills outside class.

5.4.5 Recommendations for Future Researchers

• Conduct Intervention Studies

Future research should explore the effectiveness of specific interventions, such as the use of virtual manipulatives, augmented reality, or flipped classrooms, in improving spatial reasoning and understanding of mensuration.

• Investigate Gender and Socio-Cultural Factors

Additional research could explore how gender, language background, and socio-economic status influence students' spatial ability and conceptual understanding in geometry.

• Compare Rural and Urban School Contexts

Comparative studies can shed light on contextual differences in resources, pedagogy, and learner outcomes, offering targeted recommendations for different school settings.

• Explore Longitudinal Impacts

Long-term studies tracking students' progression in spatial reasoning and geometry performance over time could provide deeper insights into cognitive development and instructional impact.

5.5 Limitations of the Study

While this study provides valuable insights into the challenges students face in learning the mensuration of solid shapes, several limitations must be acknowledged. These limitations may have influenced the scope, depth, and generalizability of the findings.

1. Limited Sample Size and Scope

The study was conducted with a relatively small sample of 30 Form 4 students and 4 mathematics teachers from Marchwood Secondary School in Norton. While this allowed for in-depth data collection and manageable analysis, the findings may not fully represent the broader population of secondary school learners in Zimbabwe. Other schools—particularly government, rural, or lower-resourced institutions—may face additional or different challenges that were not captured in this context.

2. Single-Site Case Study Design

Because the study focused on a single school, contextual factors such as teacher experience, resource availability, school culture, and learner demographics may have influenced the results. A multi-site study would have allowed for comparative analysis and more robust conclusions across different educational environments.

3. Time Constraints

Data collection was carried out over a single school term, limiting the opportunity to observe long-term instructional practices and student progress. As a result, the study may not fully capture how students' understanding evolves over time or how sustained interventions impact learning outcomes.

4. Reliance on Self-Reported Dat

Much of the data, particularly from questionnaires and interviews, depended on self-reported responses. While efforts were made to ensure honesty and accuracy, such data may be affected by social desirability bias, recall errors, or misunderstanding of the questions.

5. Inaccessibility of Technological Resources

The absence of technology use in observed classrooms limited the study's ability to evaluate the actual impact of digital tools on teaching and learning. Although technology was discussed theoretically and teachers expressed interest in its use, its practical effects could not be measured due to a lack of infrastructure.

6. Researcher Bias and Observer Effect

As with any qualitative research involving classroom observations, there is the potential for researcher bias in data interpretation. Additionally, the presence of the researcher in the classroom may have influenced teacher behaviour (the observer effect), possibly resulting in more structured or cautious teaching than usual.

7. Focus Limited to Mensuration of Solid Shapes

The study specifically targeted the mensuration of 3D shapes and did not explore related areas such as plane geometry, trigonometry, or algebra, which might interact with students' understanding of mensuration. Broader mathematical challenges could influence performance in this topic but were beyond the scope of this study.

Despite these limitations, the study provides a strong foundation for understanding student difficulties in mensuration and offers actionable insights for teachers, curriculum developers, and policymakers. Acknowledging these constraints also strengthens the credibility of the research by encouraging cautious interpretation and future replication in diverse contexts.

5.6 Suggestions for Further Research

While this study has provided meaningful insights into the challenges students face in learning the mensuration of solid shapes, it has also raised important questions and areas that warrant further investigation. The following suggestions are proposed to build upon this research and deepen understanding in this field:

5.6.1 Intervention-Based Research

Future studies should explore the impact of specific teaching interventions on student understanding of mensuration. For example, researchers could implement and evaluate:

- The use of dynamic geometry software like GeoGebra or Cabri 3D.
- Augmented or virtual reality tools for visualizing 3D objects.
- Manipulative-based or project-based learning strategies.

Such intervention studies would provide empirical evidence on which strategies are most effective in correcting misconceptions and improving spatial reasoning.

5.6.2 Longitudinal Studies

This study was cross-sectional and captured data at a single point in time. Longitudinal studies that track students' development in mensuration and spatial reasoning across multiple school terms or grade levels could reveal:

- How conceptual understanding evolves with continued exposure and instruction.
- Whether misconceptions persist or fade over time.
- The long-term impact of specific teaching approaches.

Such research could inform curriculum sequencing and teacher support strategies.

5.6.3 Comparative Studies Between School Contexts

Future research could compare students' experiences and performance in:

- Urban vs. rural schools.
- Private vs. public schools.
- High-resource vs. low-resource environments.

These comparative studies would help identify how contextual factors—such as access to teaching materials, class size, and teacher training—impact the effectiveness of mensuration instruction.

5.6.4 Influence of Language and Terminology

- Language plays a significant role in mathematical understanding. Research could be conducted to examine:
- How students interpret mathematical vocabulary related to mensuration (e.g., radius, height, slant height, base).
- Whether language barriers or the use of local languages during instruction affect comprehension.
- Strategies for supporting language development alongside mathematics learning.

This would be especially relevant in multilingual contexts like Zimbabwe.

5.6.5 Gender and Spatial Ability

Research has shown that spatial ability may differ by gender, often influenced by societal expectations, learning experiences, and instructional exposure. Future research could:

- Investigate gender-based differences in spatial reasoning and performance in mensuration.
- Examine whether targeted strategies can reduce any observed disparities.
- Explore how teaching methods can be adapted to support all learners equitably.

5.6.6 Role of Teacher Beliefs and Knowledge

The current study highlighted the role of teacher strategies but did not extensively explore teachers' own beliefs, content knowledge, or pedagogical content knowledge in mensuration. Further studies could:

- Assess how teachers' understanding of mensuration affects their instructional choices.
- Explore the relationship between teacher confidence in spatial reasoning and classroom practices.
- Investigate how teacher training programs can better prepare educators to teach spatially demanding content.

5.6.7 Integration of Ethnomathematics

Researchers could explore how traditional or culturally relevant forms of measurement—such as those used in local crafts, construction, or farming—can be incorporated into teaching mensuration. This could:

- Enhance student engagement through contextual learning.
- Bridge abstract mathematical concepts with real-life experiences.

By pursuing these areas of research, scholars and educators can contribute to more effective, inclusive, and contextually appropriate teaching strategies in secondary mathematics. These insights would ultimately help address persistent learning gaps and promote greater mathematical success among students.

5.7 Summary of Chapter

This chapter provided a comprehensive discussion of the findings related to the challenges students face in learning the mensuration of solid shapes. The discussion was structured around the four key research questions, examining the prevalence of student misconceptions, the influence of spatial reasoning difficulties, the effectiveness of teaching strategies, and the role of technology in mathematics instruction.

The study found that misconceptions—particularly those involving formulas and dimensions—are widespread among students and are often perpetuated by rote, procedural teaching methods. Spatial reasoning emerged as a significant cognitive barrier, with students struggling to visualize and manipulate 3D shapes mentally. Instructional practices in the observed classrooms were largely teacher-centred, lacking interactive elements, real-world connections, or adequate use of formative assessment. Although both students and teachers recognized the potential value of technology in teaching mensuration, its actual use in classrooms was virtually nonexistent due to infrastructural and training limitations.

From these findings, the study drew several conclusions: students' poor understanding of mensuration is the result of interrelated cognitive, pedagogical, and structural factors. Addressing these requires targeted interventions across all levels of the education system.

The chapter presented actionable recommendations for teachers, curriculum developers, school administrators, and researchers. These included promoting conceptual teaching, integrating visual and digital tools, revising curriculum materials, and supporting professional development. The limitations of the study were also acknowledged, particularly regarding its scope and generalizability. Finally, suggestions for future research were outlined to build on this work and inform broader improvements in mathematics education.

This chapter, and the study as a whole, highlights the urgent need to rethink how mensuration is taught at the secondary level. If students are to succeed in mathematics and its applications beyond the classroom, educators and policymakers must embrace more conceptual, spatially supportive, and technology-enriched approaches to instruction.

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APPENDICES

APPENDIX A: STUDENT QUESTIONNAIRE (FORM 4 LEARNERS)

Instructions to researcher: Explain purpose briefly, reassure anonymity/confidentiality. Allow 20–30 minutes. Use printed copies or convert to Google Forms.
Title: Questionnaire — Mensuration of Solid Shapes (Form 4)

SECTION 1: DEMOGRAPHIC INFORMATION

1. Student code (for confidentiality): _______
2. Age: _______
3. Gender: ☐ Male ☐ Female ☐ Prefer not to say
4. How long have you been at this school? ______ years
5. Do you have access to a smartphone/computer at home? ☐ Yes ☐ No

SECTION 2: ATTITUDES & CONFIDENCE (LIKERT SCALE)
(1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree)

1. I feel confident solving questions on volume. 1 2 3 4 5
2. I feel confident solving questions on surface area. 1 2 3 4 5
3. I can imagine a 3D object from a 2D drawing. 1 2 3 4 5
4. I find it easy to choose the correct formula for a shape. 1 2 3 4 5
5. Using a computer or app would help me understand 3D shapes. 1 2 3 4 5

SECTION 3: MISCONCEPTION DIAGNOSTIC

1. Which of the following units is correct for volume? A. cm ☐ B. cm^2 ☐ C. cm^3 ☐ D. m ☐
2. A cylinder has radius 5 cm and height 10 cm. Which formula gives its volume? A. $\pi r^2 h$ ☐ B. $2\pi rh$ ☐ C. $4/3\pi r^3$ ☐ D. πr^2 ☐
3. A cone has slant height l and vertical height h. Which statement is true?

   A. Slant height = vertical height always ☐

   B. Slant height is used in lateral surface area, vertical height in volume ☐

   C. We use slant height for volume formula ☐

   D. Slant height and vertical height have the same units so interchangeable ☐

4. Which is the formula for the total surface area of a cube with side a?
   A. a^3 ☐ B. $6a^2$ ☐ C. $4a^2$ ☐ D. $2a^2$ ☐
5. A student uses area formula (πr^2) to find the volume of a sphere. This is:
   A. Correct ☐

   B. Incorrect — sphere volume uses $4/3\pi r^3$ ☐

   C. Sometimes correct ☐

   D. I don't know ☐

SECTION 4: SHORT APPLIED QUESTIONS (SHOW WORKING)

1. Volume of cuboid (l=6 cm, w=4 cm, h=5 cm). Show working.
2. Volume of cone (r=3 cm, h=4 cm). Show working.
3. Total surface area of cube (side=2 cm). Show working.
4. Lateral surface area of cylinder (r=7 cm, h=10 cm). Show working.
5. Total volume of composite solid (cone on top of cylinder, r=3 cm, h_cone=4 cm, h_cyl=6 cm). Show working.

SECTION 5: SHORT OPEN QUESTION

1. What part of mensuration is most difficult for you? (one sentence)

APPENDIX B: TEACHER INTERVIEW GUIDE

1. Semi-structured interview to explore misconceptions, spatial reasoning, strategies, and technology use.

   Sample questions:
2. Common misconceptions observed in mensuration?
3. How would you describe students' spatial reasoning?
4. Strategies you use to teach volume and surface area?
5. How do you address misconceptions during lessons?
6. Role of technology in your teaching?
7. Barriers to using visual/tech-based methods?
8. Example of a successful mensuration lesson and why it worked?
9. Support/training needed to teach these topics more effectively?
10. Any gender differences noticed in understanding?
11. Additional comments.

APPENDIX C: CLASSROOM OBSERVATION CHECKLIST

LESSON DETAILS

Date:___________________________________
Teacher:_________________________________
Class/Form:______________________________
Topic:__________________________________
Duration:________________________________

A. Lesson structure & pedagogy
   - Objectives stated? Yes/Partly/No
   - Conceptual explanation beyond formula? Yes/Partly/No
   - Probing questions used? Frequently/Sometimes/Rarely
B. Visual & manipulative supports
   - Use of 3D models? Yes/No
   - Clear diagrams with labels? Clear/Present but unclear/Absent
   - Use of technology? Yes/No
C. Student engagement & assessment
   - Active student participation? Many/Some/Few
   - Formative checks? Regularly/Occasionally/Not at all
   - Misconceptions addressed? Yes/No (describe)
D. Classroom climate & management
   - Adequate class size? Yes/No
   - Lesson pace: Too fast/Appropriate/Too slow

   Notes: Misconceptions observed, good practice, recommendations.