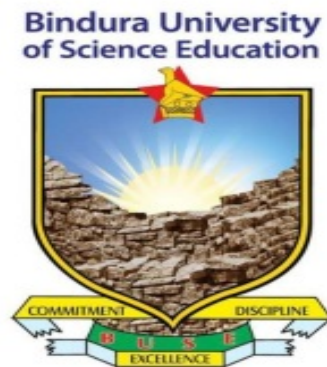


BINDURA UNIVERSITY OF SCIENCE EDUCATION
FACULTY OF SCIENCE EDUCATION
BACHELOR OF SCIENCE EDUCATION HONOURS
DEGREE IN MATHEMATICS



**STUDENTS' CHALLENGES IN LEARNING QUADRATIC EQUATIONS IN
ZIMBABWE'S SECONDARY SCHOOLS (WITH SPECIAL FOCUS ON FORM
THREE STUDENTS.)**

BY

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**A Dissertation Submitted to Bindura University of Science Education in Partial
Fulfilment of the Requirements for the Bachelor of Science Education Honours Degree
in Mathematics**

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DEDICATION

This study is dedicated to my lovely wife Andrina Mpame who encouraged me to work tirelessly hard in order to complete the dissertation. To my dear friends and colleagues, I am thankful for all the encouragement you have given me. To my lovely daughter Vanessa, and my dearest sons Claytone Jr, Cruise-Darrell and Otsile Clinton this project is for you and may it motivate you to strive for the best always using all your abilities and having trust in God.

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ABSTRACT

The purpose of this study was to investigate the students' challenges faced in learning quadratic equations in Zimbabwe's secondary schools (with special focus on form three students). Despite quadratics being a core component of the Ordinary Level mathematics curriculum, national assessment reports continue to show low pass rates and persistent learner difficulties. Using a mixed-methods approach, the researcher collected data from a student diagnostic test administered to form three students at Glen View 1 High School and semi-structured interviews with mathematics teachers in Glen View-Mufakose District. Quantitative data were analysed to determine patterns of errors in key areas such as factoring, completing the square, use of the quadratic formula, graphing quadratic functions, and solving word problems. Qualitative insights from teachers were used to explain the underlying causes of these errors.

The findings revealed that students struggled most with completing the square, interpreting and solving word problems, and applying the quadratic formula correctly. Common errors included weak algebraic manipulation, misinterpretation of mathematical symbols, limited conceptual understanding of quadratic functions, and difficulties linking real-life scenarios to appropriate mathematical models. Teachers attributed these challenges to inadequate foundational knowledge, limited exposure to multiple solution methods, overreliance on rote procedures, and insufficient teaching and learning resources.

The study concludes that improving learner performance in quadratic equations requires strengthening conceptual instruction, enhancing teacher pedagogical approaches, and increasing opportunities for practice using varied representations. It recommends targeted remedial programmes, use of diagnostic assessments, continuous professional development for mathematics teachers, and provision of more instructional materials to support learner understanding.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

This first chapter introduces this study on Students' Challenges in learning Quadratic Equations in Zimbabwe's Secondary Schools (with special focus on form three students). In addition, the chapter dwells more on the background of the research, statement of the problem, purpose of the study, research question, assumption and objectives of the study. It furthermore looks into limitations, delimitations and significance of the study on how this study has been of benefit in helping to overcome the Students' Challenges in learning Quadratic Equations in Zimbabwe's Secondary Schools.

1.1.1 Background to the Study

Quadratic equations are a central topic in the Zimbabwe secondary mathematics syllabus and underpin later study in calculus, mechanics, and several applied disciplines. The Zimbabwe syllabus explicitly requires that learners master solving quadratics by factoring, completing the square, using the quadratic formula, and interpreting quadratic graphs, making competence in these methods an expected learning outcome for forms 3–4 students. Mastery of quadratic concepts is therefore not only a curricular expectation but also foundational for success in advanced mathematics and STEM pathways.

Despite this emphasis, both examiner reports and empirical studies continue to reveal persistent weaknesses in learners' conceptual and procedural fluency in quadratic equations. ZIMSEC Chief Examiner Reports consistently highlight items where many candidates lose marks due to procedural errors, weak algebraic manipulation, and limited graphical interpretation (ZIMSEC, 2022). These challenges appear widespread and recurrent, suggesting deeper systemic issues.

Local research reinforces this concern. Studies indicate that difficulties with quadratics are not isolated individual challenges but stem from multiple interacting factors: gaps in both pre-service and in-service teacher content knowledge, teacher-centred pedagogy, resource constraints such as large class sizes, and learners' weak foundational knowledge in algebra. For instance, one study conducted in teachers' colleges identified significant gaps in pre-service teachers' understanding of quadratic functions, which limits their ability to effectively teach the topic in secondary schools.

Recent Zimbabwean studies provide further insight. Tendere and Mutambara (2020) observed that many form three students struggle to solve symbolic quadratic equations using factorisation and the quadratic formula, with a range of misconceptions being exposed. They reported that some learners attempted to factorise non-factorable quadratic expressions or guessed factors when using the cross-multiplication method. This indicates that even the standard procedural methods expected in the curriculum are poorly understood.

Likewise, Ndemo and Ndemo (2023) emphasise that students' difficulties extend beyond procedures to include conceptual gaps. They argue that errors and misconceptions persist because learners often fail to understand what quadratic equations represent, how solutions relate to graphs, or why certain methods (such as completing the square) work. Their findings reinforce the need for sustained attention to conceptual development, not merely procedural practice.

Teacher preparedness has also emerged as a crucial factor influencing learner performance in quadratics. Mutambara, Tendere and Chagwiza (2019) found that a significant proportion of pre-service mathematics teachers operated only at the action level of understanding quadratic functions, with very few progressing to the process or object level, which is essential for teaching conceptually. This limited understanding among trainee teachers potentially perpetuates instructional weaknesses in secondary classrooms. Furthermore, Mutambara et al. (2019) argued that the high failure rates in Zimbabwean mathematics examinations may partly be attributed to restricted teacher conceptual knowledge in key topics such as quadratics. Additionally to support the above assertions, Nyaumwe and Buzuzi (2017) reported that many Zimbabwean students struggle with algebraic reasoning due to instructional approaches that overemphasise procedural drills at the expense of conceptual exploration. Their study highlights that without opportunities to investigate the meaning of algebraic symbols, functions, and relationships, learners often treat quadratics as mechanical procedures rather than meaningful mathematical ideas.

International studies echo these challenges. Bush and Karp (2013) argue that students' success in algebra depends heavily on early development of relational thinking and conceptual understanding, yet many classrooms worldwide rely on rote, rule-based teaching approaches. In the context of quadratics, such pedagogy leads to learners memorising formulas without understanding why they work or when to apply them.

Similarly, Capeletti and da Silva (2021) found that students frequently display misconceptions when solving quadratic equations, particularly due to fragmented understanding of algebraic structures, limited use of visual representations, and insufficient connections between symbolic manipulation and graphical meaning. These findings align with Zimbabwean observations that students struggle to interpret quadratic graphs or connect solutions to intercepts.

Regionally, Ndlovu and Nkosi (2021) reported that many learners in Southern African classrooms lack fluency in foundational algebra concepts, which undermines their ability to engage with higher-order topics such as quadratics. Their study notes that difficulties are aggravated by teacher-centred pedagogies and lack of mathematical talk in classrooms, contributing to persistent misconceptions.

Supporting these research findings, ZIMSEC (2022) continues to report problems such as incorrect application of the quadratic formula, sign errors, poor manipulation of algebraic expressions, and failure to correctly interpret solutions. These errors suggest that the difficulties are not peripheral but central to learners' mathematical understanding.

Overall, the literature suggests that challenges in learning quadratic equations in Zimbabwe are multifaceted—arising from conceptual misunderstandings, limited teacher content mastery, insufficiently learner-centred instructional strategies, and weak connections between algebraic processes and their graphical or real-world interpretations. Given the central role of mathematics in national development and Zimbabwe's STEM education agenda (MoPSE, 2015), addressing these learning challenges is essential for improving academic performance and supporting the development of future human capital.

1.2 Purpose of the Study

The main purpose of this study is to investigate the challenges students face in learning quadratic equations in Zimbabwe's secondary schools and to identify factors that hinder or support learning in this topic. The study aims to identify the nature, causes, and extent of these difficulties, as well as explore how teachers perceive and address them in their classrooms. The study also aims to generate practical recommendations for teachers, school administrators and curriculum planners to improve teaching and learning of quadratic equations.

1.3 Statement of the Problem

Although quadratic equations are a core topic in the Zimbabwe secondary mathematics curriculum, many students continue to perform poorly in both internal assessments and national examinations on items involving quadratics. Teachers report common misconceptions (for example, errors in factoring, misuse of the quadratic formula, incorrect interpretation of graphs, and confusion between quadratic and linear behaviour), and some students exhibit low confidence and negative attitudes towards algebra, resulting in poor performance in examinations.

Studies (Tendere & Mutambara, 2020; Ndemo & Ndemo, 2023) show that conceptual and procedural errors remain widespread, while ZIMSEC reports continue to flag persistent weaknesses in algebra. These challenges undermine students' overall mathematical proficiency and hinder the attainment of national educational goals. These persistent difficulties reduce students' chances of passing mathematics at Ordinary Level and limits their access to science, technology and mathematics-related programmes at tertiary level.

There is a need to systematically investigate in depth the specific challenges students face when learning quadratic equations in Zimbabwean secondary schools, and to identify school and classroom-level factors that contribute to these difficulties. Without such evidence, interventions may remain generic, poorly-targeted, or ineffective in addressing the root causes of underperformance.

1.4 Objectives of the Study

General objective

- To investigate challenges encountered by form three students in learning quadratic equations in Zimbabwe and to recommend strategies for improvement.

Specific objectives

1. To identify the challenges that form three secondary school students in Zimbabwe face when learning quadratic equations.
2. To examine students' understanding of key concepts and procedures involved in solving quadratic equations.

3. To determine the common misconceptions and procedural errors exhibited by students when solving quadratic equations.
4. To investigate the factors contributing to students' difficulties in learning quadratic equations.
5. To explore strategies currently used by teachers to address students' challenges in learning quadratic equations and to propose practical recommendations for improving learning outcomes.

1.5 Research Questions

The study was guided by the following research questions:

1. What challenges do form three students in Zimbabwe face when learning quadratic equations?
2. To what extent do students understand the concepts and procedures involved in solving quadratic equations?
3. What are the common misconceptions and errors exhibited by students when solving quadratic equations?
4. What factors contribute to the difficulties students face in learning quadratic equations?
5. What strategies do teachers use to address students' challenges in learning quadratic equations?

1.6 Assumptions of the study

This study was guided by several underlying assumptions that shaped both the quantitative and qualitative dimensions of the research. It was assumed that students' performance on the quadratic equations test would accurately reflect their understanding of the topic and that the test items designed were valid and reliable measures of key concepts in quadratic equations. The study further assumed that the sample of students selected was representative of the wider population of secondary school learners in Zimbabwe, and that variations in student performance could be attributed to identifiable factors such as teaching methods, prior knowledge, and the learning environment. It was also presumed that data collected from

students would be free from major bias or deliberate misrepresentation. On the qualitative side, it was assumed that teachers possess valuable insights into the challenges students face when learning quadratic equations and would provide honest and reflective responses based on their classroom experiences. The study also assumed that students' learning difficulties could be better understood through teachers' explanations and classroom observations, and that the school context—including resources, curriculum, and teaching practices plays a critical role in shaping how students learn and understand quadratic equations.

According to Creswell (2014), “every study is founded on assumptions that underlie the chosen research methods and the interpretation of findings” (p. 42). Similarly, Cohen, Manion, and Morrison (2018) argue that assumptions help delimit the scope of inquiry and establish a logical basis for the study's design. Based on this, the current research proceeds under the assumption that if teachers' pedagogical approaches and learning resources are improved, students' challenges in learning quadratic equations will be reduced.

Finally, it was assumed that data obtained from teacher interviews would reveal patterns of misconceptions and teaching challenges that quantitative data alone might not capture, thereby enriching the overall understanding of students' learning difficulties in quadratic equations.

1.7 Significance of the Study

This study offers three practical contributions for the Zimbabwean context:

For teachers: aligned, evidence-based descriptions of frequent student errors and targeted classroom strategies (for example, linking symbolic manipulation to graphical representation) that teachers can use immediately. Research in Zimbabwe has shown that teacher knowledge and pedagogical choices are tightly linked to learner outcomes, so classroom-level changes can have rapid effects.

For school leaders and policy makers: evidence on resource and structural constraints (for example, large classes, shortage of manipulatives, language issues) that need administrative or policy attention to enable more effective mathematics teaching. Examiner reports and national syllabuses can be used alongside school data to prioritise interventions.

For researchers and teacher educators: empirically grounded identification of gaps (for example, at the pre-service level) to inform teacher training and continuing

professional development programmes. Previous Zimbabwean studies recommend strengthening conceptual teaching of quadratics in teacher education.

Ultimately, the study contributes to improving mathematics achievement, aligning with Zimbabwe's educational vision of producing problem-solving, innovative, and mathematically literate citizens (MoPSE, 2015).

1.8 Scope and Delimitations

The study will focus on form 3 and form 4 learners in selected urban and rural secondary schools in Zimbabwe. It will examine standard curriculum quadratics (factoring, completing the square, quadratic formula, graph interpretation, and applied word problems). The research will not attempt a national prevalence estimate nor will it examine more advanced topics (for example, non-real/complex roots beyond the ordinary curriculum) except where they appear in student misconceptions.

Limitations to note include the likely use of purposive sampling (which may limit generalisability) and potential response bias in interviews; these will be mitigated by triangulating test scores, classroom observations, and teacher interviews.

1.9 Limitations of the Study

Potential limitations include:

Sample representativeness: Due to time and resource constraints, the study may use a purposive or convenience sample of schools which may limit generalisability to all Zimbabwean secondary schools.

Self-report biases: Data from questionnaires and interviews (especially from teachers and students) may be affected by social desirability or recall bias.

Resource constraints: Limited access to some rural schools or difficulties in obtaining permission could restrict data collection.

The study will seek to mitigate these limitations by using mixed data sources to triangulate student tests with teacher interviews thereby helping to enhance the validity of findings. and by carefully documenting sampling and contextual details.

1.10 Operational Definitions of Key Terms

Quadratic equation: An algebraic equation of degree two in the form $ax^2 + bx + c = 0$, where $a \neq 0$.

Misconception: A misunderstanding of a mathematical concept or procedure.

Procedural fluency: The skill in carrying out mathematical procedures accurately and efficiently. (e.g., completing the square).

Conceptual understanding: Grasping mathematical concepts, operations, and relations — for quadratics, understanding how algebraic forms relate to their graphical representations and solutions.

Error Analysis: Examining students' solution work to categorize types of mistakes (procedural, conceptual, technical) and understand their nature.

Prior Knowledge / Prerequisite Knowledge: The algebraic skills and understanding (such as operations with exponents, variables, linear equations) students are expected to have before learning quadratic equations.

Constructivism: A theory of learning that emphasizes learners constructing their own understanding by building on prior knowledge.

1.11 Organisation of the study

This study is organized into several chapters, including an introduction, literature review, research methodology, data analysis, and conclusions. Each chapter will provide a detailed exploration of the research topic and contribute to the overall understanding of the challenges students face in learning quadratic equations in Zimbabwe's secondary schools.

1.12 Summary of Chapter

This chapter has set out the rationale, objectives and scope of a study investigating why Zimbabwean secondary school learners struggle with quadratic equations. This chapter began by outlining the background of the study, showing that despite the importance of quadratic

equations in the mathematics curriculum, many students continue to experience both procedural and conceptual difficulties. Studies by Tendere and Mutambara (2020), Ndemo and Ndemo (2023), and Mutambara et al. (2019) were cited to highlight persistent misconceptions, inadequate teacher understanding, and high failure rates reported by ZIMSEC.

The statement of the problem clarified that these challenges hinder learners' overall mathematical competence and contribute to poor examination performance. The purpose, objectives, and research questions were outlined to guide the investigation, focusing on identifying students' specific difficulties and exploring teachers' perceptions of these challenges. The significance of the study was discussed, emphasizing its potential contribution to improving mathematics teaching and learning practices in Zimbabwe.

The delimitations and limitations described the scope and possible constraints of the study, while key terms were defined to ensure conceptual clarity. The chapter also presented the hypotheses guiding the quantitative aspect of the study and the assumptions underpinning the qualitative component.

Overall, Chapter One set the foundation for the investigation by justifying the need to understand and address students' challenges in learning quadratic equations. The next chapter, will review relevant literature on students' difficulties in algebra, theoretical perspectives on learning quadratic equations, and strategies for improving mathematical understanding in secondary schools, and also identifies effective classroom strategies that are feasible within the resource constraints typical of many Zimbabwean schools.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This chapter reviews theoretical and empirical literature related to students' challenges in learning quadratic equations in Zimbabwe's Secondary Schools, with a special focus on form three learners. The review synthesises international scholarship on algebra learning and error analysis with local studies, syllabus documents, examiner reports and school-level audits. It is organised as follows: the theoretical foundations that inform the study; the curricular and assessment context in Zimbabwe; empirical evidence on student difficulties (conceptual, procedural, and application); contributory factors (teacher knowledge, pedagogy, resources, and prior preparation); a focused discussion on rural versus urban contrasts; effective teaching interventions and diagnostic design; gaps in the literature; and finally a conceptual framework that links causes to student outcomes. The chapter establishes the academic and practical rationale for the present mixed-methods investigation.

2.1 Theoretical framework

2.1.1 Constructivism and representational fluency

Constructivist learning theory asserts that learners construct meaning by building on prior knowledge and through active engagement with problems (Piaget, 1970; Vygotsky, 1978). In algebra, constructivism emphasises creating connections among multiple representations, symbolic, graphical, numerical and contextual, so learners form robust conceptual networks rather than isolated procedures (Kaput, 1999; Roschelle et al., 2016). For quadratic equations, representational fluency (the ability to shift between algebraic form, graph, table and application) is a hallmark of deep understanding; instruction that foregrounds such fluency is therefore central to overcoming persistent misconceptions.

Vygotsky's Zone of Proximal Development (ZPD) underscores the role of scaffolded instruction: learners often require guided support (teacher or peers) to internalise higher-order algebraic concepts. Zimbabwean teacher-education literature recommends scaffolding strategies — worked examples, progressive complexity, and peer collaboration — to support Form Three students transitioning from arithmetic to symbol-based algebra (Mutambara, Tendere, & Chagwiza, 2019).

2.1.2 Error Analysis and Cognitive Perspectives on Quadratic Equations

Error analysis provides a systematic framework for identifying, classifying and interpreting the types of mistakes that students make when learning mathematical concepts (Corder, 1967; Newman, 1977). In the context of quadratic equations, this analytical lens is particularly useful because solving quadratics requires the coordination of multiple algebraic skills, including factorisation, symbolic manipulation, use of the quadratic formula, completing the square, and interpreting graphs.

Research on algebra learning commonly distinguishes three broad categories of errors:

1. Conceptual errors: misunderstandings of underlying mathematical ideas;
 2. Procedural errors: incorrect execution of steps or algorithms; and
 3. Technical or surface errors: slips in signs, arithmetic, or copying (Prediger, 2010; Sfard, 1991).
- These error types manifest clearly in quadratic equations. For example, **conceptual errors** may appear when a learner interprets a quadratic equation as linear. *Example:* A student facing the equation $x^2 - 5x + 6 = 0$ may subtract 6 from both sides and attempt to “divide by x ” as if the equation were linear, showing failure to recognise the structure of a quadratic. Similarly, when solving $(x-3)(x+2) = 0$, some learners add the factors and give $x = 3 + (-2) = 1$ instead of setting each factor equal to zero.
 - Procedural errors often occur during factorisation, completing the square, or substitution into the quadratic formula, for instance in factorisation when asked to solve: $x^2 - 5x + 6 = 0$ learners often select incorrect factor pairs or reverse signs, for example writing $(x-2)(x+3)$ instead of $(x-2)(x-3)$, which indicates weak number sense and limited understanding of algebraic structure. Tall (2013) argues that such errors stem from procedural imitation without conceptual grounding, while Zimbabwean studies similarly report persistent factorisation and sign errors among secondary school learners (Mutambara & Tendere, 2020).
 - Misapplying the discriminant or reversing signs when expanding binomials. Technical errors frequently arise when students make arithmetic mistakes with negative numbers or incorrectly simplify surds when computing roots.

From a cognitive standpoint, learning quadratic equations requires students to undergo what Tall (2013) terms an “epistemic shift”. This shift involves moving from the concrete, procedural world of arithmetic to a more abstract and generalised form of symbolic reasoning. Quadratic equations demand fluency in manipulating symbolic expressions, understanding functional relationships, and visualising graphs. Thus, students must connect multiple representations:

- Symbolic (e.g., $ax^2+bx+c=0$),
- Procedural (e.g., factorisation or completing the square), and
- Graphical (e.g., vertex, axis of symmetry, direction of opening).

Failure to coordinate these representations contributes to persistent errors. For instance, learners often do not link the discriminant to the nature of roots or fail to relate factorised form to the x-intercepts of the parabola. Consider the quadratic function: $y = x^2 + x - 6$

Then the algebraic representation (factorised form): $(x-2)(x+3) = 0$ which gives

$x = 2$ or $x = -3$. Learners may correctly factorise but then fail to interpret the solutions beyond “answers to the equation.” That is, they fail to connect the roots $x=2$ and $x=-3$ with the **graphical meaning**: points where the parabola crosses the x-axis, that is they fail to understand that $x = 2$ and $x = -3$ are the x-intercepts of the graph $y = x^2 + x - 6$ thus the graph crosses the x-axis at $(2;0)$ and $(-3;0)$.

In the present study, error analysis is used as a diagnostic tool to classify the specific mistakes made by form three students when solving quadratic equations. These coded error patterns are then triangulated with teacher interview data to interpret the underlying causes whether conceptual, procedural, or cognitive. This dual-perspective approach allows for a deeper understanding of why students struggle with quadratic equations and which instructional or assessment practices may reinforce these errors.

2.2 Curricular and assessment context in Zimbabwe

Quadratic equations are central in Zimbabwe’s Ordinary Level mathematics curriculum and are formally introduced and developed in forms 3 and 4 (Zimbabwe School Examinations Council [ZIMSEC], 2022). The ZIMSEC syllabi and examiner reports (annual chief examiner commentaries) repeatedly show that candidate weakness in algebraic manipulation — including factorisation, application of the quadratic formula and graph interpretation —

contributes materially to low performance in national examinations. Examiner reports therefore serve as both summative evidence of the problem and as stimulus for localized diagnostic research and teacher CPD (ZIMSEC, 2022; ZIMSEC Examiner Reports, 2018–2023). In short, curriculum coverage alone has not eliminated conceptual and procedural gaps; systematic diagnostic work is needed at the classroom level, especially when formulating interventions for Form Three learners.

2.3 Empirical evidence: students’ conceptual and procedural difficulties

A considerable corpus of research has documented that secondary school learners experience persistent challenges when engaging with quadratic equations. These challenges appear in diverse forms; conceptual misunderstandings, procedural errors, and difficulties in modelling or applying quadratic relations to contextual problems. As Tall (2013) observes, quadratic reasoning constitutes a cognitively demanding domain because it requires learners to coordinate symbolic rules, graphical interpretations, and problem-solving strategies. In Zimbabwe, these challenges are amplified by curriculum pacing, limited exposure to exploratory tasks, and teaching approaches that emphasise procedural mastery over conceptual growth. This section synthesises empirical literature, both international and Zimbabwean, to provide a comprehensive account of students’ learning difficulties in quadratics.

2.3.1 Conceptual Misunderstandings

Conceptual challenges emerge when learners lack a deep understanding of the structure and meaning of quadratic expressions, functions, and equations. Researchers widely agree that many students manipulate quadratics mechanically without appreciating the underlying mathematical relationships. Kotsopoulos (2007) notes that a significant proportion of learners cannot articulate the function of coefficients in a quadratic expression, particularly the leading coefficient a , which governs the direction and width of the parabola. Without this understanding, students resort to memorised rules rather than reasoning about quadratic behaviour.

Similarly, Tall (2013) argues that students often fail to link the symbolic form $ax^2 + bx + c$ with its geometric representation on the Cartesian plane. Learners may correctly compute roots but remain unable to explain their significance as x -intercepts or understand how the discriminant influences the number of times a parabola crosses the horizontal axis. This

disconnect suggests that learners see algebra and graphs as separate, unrelated topics rather than as interconnected representations of the same mathematical idea.

Zimbabwean studies reveal comparable patterns. Tendere and Mutambara (2020) found that learners were often unable to explain why some quadratics factorise neatly while others require alternative methods such as completing the square or using the quadratic formula. Instead of viewing factorisation as a property dependent on the discriminant and coefficient structure, students tended to treat it as guesswork. This reliance on trial-and-error techniques reflects a limited understanding of the structural properties of quadratic functions.

Misinterpretation of the discriminant is another recurring conceptual difficulty. Tendere and Mutambara (2020) report that students frequently arrive at incorrect conclusions about the nature of roots even after substituting values correctly. They often assume that any positive discriminant yields the same type of graph, without recognising that the magnitude of the discriminant also influences the spacing of the roots and the steepness of the parabola. Such misconceptions demonstrate a fragmented understanding of quadratic relationships.

A further conceptual challenge involves the vertex form of a quadratic function, $y = a(x - h)^2 + k$. Learners often struggle to recognise that the vertex (h, k) represents the minimum or maximum point of the parabola and is essential for sketching the graph or solving optimisation problems. As Tall (2013) supports, insufficient emphasis on multiple representations limits learners' ability to transition flexibly between algebraic and graphical reasoning, thereby undermining their broader problem-solving competence.

2.3.2 Procedural Errors and Algorithmic Misuse

In addition to conceptual issues, numerous studies highlight widespread procedural errors in learners' attempts to solve quadratic equations. These errors often arise from rote learning or the mechanical application of algorithms without understanding their underlying logic. Prediger (2010) argues that when procedures are taught as isolated sequences of steps, students develop superficial competence that collapses when confronted with unfamiliar problems.

Among the most common procedural mistakes are sign errors in expansion, incorrect simplification during factorisation, and misapplication of the quadratic formula. Learners may, for instance, incorrectly evaluate the discriminant by omitting parentheses or reversing signs, resulting in drastically inaccurate solutions. Prediger (2010) notes that such errors are not

merely computational; they reveal deeper cognitive difficulties in organising and monitoring multi-step processes.

Zimbabwean studies reflect similar findings. Chinyoka and Mutambara (2022) observe that students who perform well on routine exam-style questions often fail when questions are slightly modified. This suggests an overreliance on pattern-recognition strategies rather than genuine understanding. For example, learners accustomed to factorising quadratics of the form $ax^2 + bx + c$ may struggle when the leading coefficient a is not equal to 1, even when the underlying method is the same.

A notable procedural difficulty involves selecting an appropriate method for a given quadratic. Learners may persist in attempting to factorise expressions that are not factorable, or they may incorrectly apply completing the square without understanding why the method works. Prediger (2010) argues that such rigid adherence to familiar procedures demonstrates a lack of strategic competence, a critical component of mathematical problem solving.

Zimbabwean teachers report that many learners can recite the quadratic formula but misuse it in practice. Errors include substituting $2ac$ instead of $4ac$, failing to divide the entire numerator by $2a$, or prematurely simplifying the radical expression. Chinyoka and Mutambara (2022) support the claim that procedural fluency without conceptual grounding results in brittle knowledge that does not transfer across contexts.

2.3.3 Transfer and Application Difficulties (Word Problems)

While conceptual and procedural difficulties are well-documented, learners often experience even greater challenges when required to apply quadratic concepts in real-world contexts. Modelling word problems requires abstraction, selecting relevant information, and expressing relationships algebraically. According to Nkabinde (2019), many learners find this transition from context to symbolic representation highly demanding.

International studies show that learners frequently misinterpret contextual cues or fail to recognise relationships that lead to quadratic models. Zimbabwean evidence mirrors this trend. Mtetwa and Garira (2021) report that learners struggle to translate everyday scenarios—such as motion problems, revenue optimisation tasks, and consecutive integer problems—into quadratic equations. Common challenges include omitting units, misidentifying dependent and independent variables, and assuming linear relationships where quadratic ones apply.

Furthermore, learners often resort to trial-and-error strategies when confronted with application questions, even when they possess sufficient procedural knowledge to formulate algebraic models. Mtetwa and Garira (2021) note that this behaviour reflects limited experience with problem-solving tasks in earlier secondary grades, where instruction tends to prioritise procedural drill. As a result, students may excel at symbolic manipulation but lack the ability to apply mathematical concepts to practical or unfamiliar situations.

Transfer difficulties are also linked to literacy and comprehension challenges. Word problems often require interpreting multi-step instructions, identifying constraints, and organising information, all of which demand strong reasoning skills. Nkabinde (2019) supports the view that linguistic complexity can inhibit learners' mathematical performance, particularly in multilingual contexts like Zimbabwe, where English is a second language for many students.

Consequently, empirical studies highlight the importance of integrating modelling and application tasks throughout the mathematics curriculum to strengthen students' transfer skills. Without deliberate instructional strategies that develop conceptual understanding, procedural fluency, and modelling competence simultaneously, learners' challenges with quadratic equations are likely to persist.

2.4 Causes and contributory factors

2.4.1 Teacher content knowledge and pedagogical content knowledge (PCK)

Teachers' content knowledge and PCK shape how quadratic concepts are introduced and scaffolded. Shulman (1986) emphasises that PCK, knowing how to present content so learners can understand it, is crucial. Zimbabwean studies (Mutambara et al., 2019; Chauraya, 2014) indicate that many pre-service and in-service teachers operate at an "action" level (procedural competence) rather than an "object" level (conceptual understanding). Where teacher instruction focuses on demonstrating procedures without exploring underlying concepts, students internalise algorithmic rules without grasping when or why to apply them. Strengthening teachers' PCK, particularly in linking algebraic forms to graphs and contexts is therefore critical.

2.4.2 Pedagogical approaches and classroom practices

Teacher-centred pedagogy (lecture, board demonstration, whole-class copying) persists in many Zimbabwean classrooms due to tradition, large class sizes, and syllabus pressure (Maphosa & Wadesango, 2014). Such approaches restrict opportunities for students to engage in reasoning, explore multiple representations, and receive formative feedback. Research shows that activities promoting discussion, error analysis, and representational switching improve conceptual understanding in algebra (Roschelle et al., 2016). In resource-constrained contexts, even low-tech strategies (group work, targeted worked examples, think-aloud demonstrations) can be effective if teachers are guided to use them.

2.4.3 Resource limitations and time pressures

Limited textbooks, few manipulatives, scarce access to ICT (e.g., GeoGebra), and heavy curriculum pacing compromise the depth of instruction. Studies of Zimbabwean schools (Chinyoka & Mutambara, 2022; Mtetwa, 2018) highlight that teachers in under-resourced schools often prioritise coverage over mastery, leaving students ill-prepared for the conceptual demands of quadratics. Examiner reports similarly note that insufficient classroom time devoted to algebraic reasoning contributes to superficial learning.

2.4.4 Prior knowledge and cumulative learning gaps

Algebraic competence is cumulative. Weaknesses in foundation topics, number operations, negative numbers, factorisation basics, linear equations hinder learning of quadratics. Tall (2013) and local studies (Mutambara & Bhebhe, 2021) observe that students who proceed to quadratics without secure earlier skills struggle to make the epistemic shift required. Diagnostic approaches that identify and remediate earlier gaps are therefore recommended.

2.5 Urban vs Rural contexts: a focused Zimbabwean review

2.5.1 Overview of contextual disparities

Urban–rural differences in education outcomes are well documented globally and in Zimbabwe. Urban schools typically have better access to trained teachers, textbooks, laboratories, and ICT; rural schools often face staff shortages, larger multi-grade classes, and limited resources (Garira, 2020; Mtetwa, 2018). For topics requiring multiple representations

and exploratory learning, such as quadratic equations, these disparities have direct pedagogical consequences.

2.5.2 Evidence from Zimbabwean studies

Empirical studies in Zimbabwe find consistent urban–rural performance gaps in mathematics. Chinyoka and Mutambara (2022) reported that urban students generally perform better on algebraic tasks, often due to more consistent teacher availability, smaller classes, and supplementary support (private tuition, study groups). Mtetwa (2018) documented that rural teachers face heavy workloads and multi-grade teaching, reducing opportunities for targeted feedback and diagnostic work. A case study of Mozagwa and Runde (2019) (province district report) found that rural Form Three classes were less likely to receive graphing practice and less likely to use contextual word problems—both key activities for building quadratic understanding.

2.5.3 Mechanisms producing the gap

Several mechanisms explain the urban–rural divide in quadratic learning:

Teacher distribution and expertise: Urban schools attract more experienced or specialist mathematics teachers; rural schools may rely on generalist teachers with less algebraic depth (Garira, 2020).

Resource availability: Urban schools more often have multiple textbooks per student, access to ICT and printing facilities, and private tuition networks that reinforce classroom learning (Chinyoka & Mutambara, 2022).

Parental and community support: Urban parents may have higher educational levels and can provide homework assistance or pay for tutoring, whereas rural parents may have less time and fewer resources to support study (Maphosa & Wadesango, 2014).

Professional development access: Urban teachers more readily attend CPD workshops; rural teachers face logistical and financial barriers to participation (Mutambara et al., 2019).

2.5.4 Implications for form three diagnostic interventions

Given these disparities, diagnostic instruments and remedial programmes need sensitivity to context. In rural schools, shorter, tightly-scaffolded diagnostic interventions may be more

feasible; in urban contexts, diagnostic findings can be leveraged into group remediation and technology-assisted practice. The literature suggests that one-size-fits-all curricular reforms are unlikely to succeed; instead, contextually differentiated teacher support and resource allocation are required to close the gap.

2.6 Teaching strategies and interventions that support learning quadratics

2.6.1 Multiple representations and visualisation

Teaching that explicitly links algebraic manipulation to graphical behaviour and contextual interpretation fosters deeper understanding (Roschelle et al., 2016). In Zimbabwe, practical steps include: sketching parabolas when changing coefficients, using number tables to show root behaviour, and demonstrating derivation of the quadratic formula to reveal its meaning. When ICT is available, GeoGebra and similar tools provide dynamic visualisation that helps learners explore parameter effects on vertex and shape (Chauraya, 2014).

2.6.2 Diagnostic assessment and formative feedback

Diagnostic tests identify item-level misconceptions and allow teachers to prioritise targeted remediation rather than broad revision. Tendere and Mutambara (2020) demonstrated how focused diagnostics can uncover guessing strategies in factorisation and sign misconceptions in formula substitution. Coupling diagnostics with immediate, formative feedback improves learning trajectories, particularly for formative errors that are easily remediable with short interventions (Black & Wiliam, 1998).

2.6.3 Error-analysis pedagogy and reflective practice

Teaching students to analyse errors (their own and peers') cultivates metacognitive awareness and helps convert mistakes into learning opportunities (Newman, 1977; Ndemo & Ndemo, 2023). Structured classroom routines where errors are de-personalised, discussed, and corrected collectively enhance conceptual clarity and reduce stigma around making mistakes.

2.6.4 Teacher professional development and lesson study

Teacher professional development (TPD) plays a critical role in strengthening teachers' pedagogical content knowledge (PCK), particularly in complex mathematical topics such as quadratic equations. Sustained and well-structured continuous professional development

(CPD) programmes that focus on algebraic misconceptions, representational fluency, and diagnostic interpretation of learners' errors have been shown to improve teachers' instructional effectiveness (Ball, Thames, & Phelps, 2008; Mutambara et al., 2019). Unlike once-off workshops, ongoing CPD enables teachers to deepen their understanding of how learners think about mathematical concepts and to anticipate common errors associated with factorisation, use of the quadratic formula, completing the square, and graphical interpretation.

In the context of algebra instruction, CPD that emphasises multiple representations; symbolic, graphical, and contextual; supports teachers in designing lessons that promote conceptual understanding rather than procedural memorisation. For example, professional development initiatives that train teachers to interpret learner errors diagnostically allow them to identify whether mistakes arise from weak number sense, misunderstanding of algebraic structure, or failure to coordinate representations. This diagnostic competence is particularly important in quadratic equations, where learners are required to integrate algebraic manipulation with graphical and conceptual reasoning.

Lesson study has emerged as a collaborative and practice-based model of professional development that complements traditional CPD approaches. In lesson study, teachers work collectively to plan a lesson, observe its implementation, and reflect critically on learner responses and instructional strategies. Studies conducted in Zimbabwean secondary schools suggest that lesson-study approaches are effective in generating contextually relevant pedagogical solutions, especially in resource-constrained classrooms (Mutambara et al., 2019). Through collaborative reflection, teachers are able to share strategies for addressing persistent learner misconceptions in quadratics, such as incorrect factor pairing, misinterpretation of the discriminant, and inability to link algebraic solutions to graphical features.

Furthermore, lesson study encourages reflective practice and professional dialogue, enabling teachers to move beyond syllabus coverage towards learner-centred instruction. By focusing on actual classroom evidence, teachers develop practical strategies for scaffolding abstract algebraic concepts and adapting instruction to learners' cognitive levels. This collaborative inquiry aligns well with constructivist views of learning, which emphasise the importance of social interaction and reflection in professional growth.

Overall, sustained CPD and lesson-study models contribute significantly to improving mathematics teaching by enhancing teachers' PCK, reflective capacity, and responsiveness to learner difficulties. In relation to this study, such professional development approaches are

essential for equipping teachers with the skills necessary to diagnose and address the challenges faced by Form Three learners in learning quadratic equations in Zimbabwean secondary schools.

2.7 Zimbabwean implementations and examples

Tendere and Mutambara (2020) constructed diagnostic sets that used the above principles to successfully classify student errors into thematic categories. Their approach is replicable for Form Three diagnostics: short test (30–45 minutes), mixed item types, and a marking rubric that records error types (procedural vs conceptual). Piloting in local schools and expert validation (BUSE lecturers, experienced teachers) are essential steps, as has been done in successful Zimbabwean diagnostic projects.

2.8 Gaps in the literature and justification for the study

While the Zimbabwean literature provides solid evidence of error patterns, teacher knowledge issues, and urban–rural disparities, several gaps remain:

1. **Form Three-focused empirical studies** are limited; many reports combine Form Three and Four results or focus on O-Level outcomes without early diagnostic emphasis. Early diagnostic evidence could enable timely remediation.
2. **Triangulated mixed-methods research** that links item-level diagnostic data with teacher interviews within the same schools is scarce. Such triangulation would strengthen causal inferences about how pedagogy and resources shape specific error patterns.
3. **Context-sensitive intervention studies** (especially in rural settings) that test low-cost, scalable remediation strategies for quadratics are few. Evidence on what works in resource-constrained Zimbabwean classrooms remains limited.

These gaps justify the present study’s focus on Form Three diagnostic testing combined with teacher interviews in selected urban and rural schools.

2.9 Summary of Chapter

This chapter synthesised international and Zimbabwean research on learning of quadratic equations. The evidence indicates that conceptual and procedural difficulties are widespread, shaped by teacher knowledge, pedagogy, resource constraints, and prior preparation. Urban–rural disparities further complicate the picture, requiring contextually sensitive diagnostic and remedial strategies. The literature supports employing diagnostic tests coupled with teacher interviews to triangulate the causes of student errors and to design practical classroom interventions — the exact approach adopted in the present study.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology adopted for the study titled *Students' Challenges in Learning Quadratic Equations in Zimbabwe's Secondary Schools (with special focus on Form Three Students)*. It presents the research philosophy, design, population, sampling procedures, research instruments, data collection, analysis techniques, and ethical considerations. According to Creswell (2014), a well-structured methodology provides the blueprint for conducting research, ensuring that data are collected and analysed in ways that answer the research questions reliably and validly. This study employed a mixed-methods approach that integrates both quantitative and qualitative paradigms to provide a holistic understanding of students' challenges in learning quadratic equations.

3.2 Research Philosophy / Paradigm

This study was anchored in the pragmatic research paradigm, which integrates both positivist and interpretivist perspectives to provide a more comprehensive understanding of the research problem. Pragmatism advocates for flexibility in selecting research methods that best suit the nature of the inquiry, emphasizing that the value of a method lies in its effectiveness in addressing the research objectives rather than in its philosophical purity (Tashakkori & Teddlie, 2010). In this regard, the pragmatic paradigm serves as a bridge between quantitative and qualitative approaches, acknowledging that reality can be investigated through measurable facts as well as human experiences and interpretations.

In the context of this study, pragmatism was particularly relevant because it enabled the researcher to combine quantitative methods—such as the analysis of student performance data—with qualitative methods, including interviews and observations that captured teachers' perceptions and contextual factors influencing mathematical learning. This dual approach facilitated a more holistic examination of the challenges students face in mathematics, allowing for triangulation of data to enhance the validity and reliability of the findings (Creswell & Plano Clark, 2018). The pragmatic stance thus provided the flexibility to address the complexity of educational phenomena that cannot be fully understood through a single methodological lens.

Furthermore, as Saunders, Lewis, and Thornhill (2019) observe, the pragmatic paradigm emphasizes the importance of focusing on practical outcomes and finding what works in a

specific context. This orientation made the paradigm particularly suitable for a study situated within the Zimbabwean education system, where contextual realities such as resource constraints, teacher preparedness, and learner diversity play a crucial role in shaping mathematical performance. By adopting a pragmatic approach, the researcher was able to link theoretical understanding with practical classroom realities, ensuring that the research produced actionable insights that could inform pedagogical interventions and policy formulation in mathematics education.

3.3 Research Design

The study adopted a mixed-methods approach, specifically an explanatory sequential design, which integrates both quantitative and qualitative phases to provide a comprehensive understanding of students' learning challenges in quadratic equations. As Creswell (2014) explains, the explanatory sequential design involves first collecting and analysing quantitative data to establish general patterns and relationships, followed by qualitative data to explain and elaborate on those statistical findings. This design allows the researcher to move from measuring what is happening to understanding why it is happening. Similarly, Cohen, Manion, and Morrison (2018) emphasize that combining quantitative precision with qualitative depth enhances the validity and interpretive power of educational research.

In the first phase, the study employed a student diagnostic test to collect quantitative data on learners' conceptual and procedural understanding of quadratic equations. The diagnostic assessment enabled the identification of specific areas of weakness—such as factorization, completing the square, and application of the quadratic formula. According to Kothari (2004), such quantitative instruments are essential for establishing measurable trends and providing empirical evidence of learner performance. In this study, the diagnostic test served as the foundation for detecting learning gaps and misconceptions that hinder mathematical competence among secondary school students.

The second phase of the study involved semi-structured interviews with mathematics teachers to gain qualitative insights into the causes of the challenges identified in the first phase. This phase allowed for a deeper interpretation of the test results by exploring contextual factors such as teaching methods, student attitudes, resource availability, and curriculum implementation. As Tashakkori and Teddlie (2010) note, qualitative inquiry in mixed-methods designs enriches the quantitative results by capturing participants' perspectives and experiences. Zimbabwean scholars such as Chagwiza and Mutambara (2020) have also highlighted the importance of

integrating teacher perceptions to contextualize student performance data. Therefore, the explanatory sequential design adopted in this study was ideal for uncovering not only the extent of students' challenges in quadratic equations but also the underlying pedagogical and contextual factors contributing to these difficulties within the Zimbabwean education system.

3.3.1 Quantitative Research Design

The quantitative component of this study adopted a descriptive survey design, using a student diagnostic test to identify specific learning challenges in quadratic equations. According to Creswell (2014), quantitative research seeks to quantify relationships between variables and analyse measurable data to uncover trends and patterns. In this study, the diagnostic test generated numerical data on students' performance, enabling the researcher to determine conceptual and procedural weaknesses in solving quadratic equations. Kothari (2004) supports the use of such structured instruments, noting that quantitative designs are effective when the aim is to measure levels of understanding and compare performance across groups. Thus, the design provided an empirical basis for assessing the depth and nature of students' mathematical difficulties.

In line with Cohen, Manion, and Morrison (2018), the diagnostic test was developed to evaluate learners' competencies across key areas—factorisation, completing the square, and application of the quadratic formula. The test was administered under controlled conditions to ensure objectivity and reliability of data. Quantitative analysis focused on identifying performance trends, error patterns, and the extent to which students met expected learning outcomes. Saunders, Lewis, and Thornhill (2019) emphasize that quantitative methods are particularly useful for studies seeking to generalize findings and test educational assumptions; therefore, this approach was well suited for understanding the magnitude of learners' challenges in quadratic equations.

The adoption of a diagnostic test aligns with findings by Zimbabwean scholars such as Chagwiza (2021) and Mutambara (2017), who highlight that diagnostic assessment plays a crucial role in uncovering learners' misconceptions in mathematics before remedial instruction is implemented. Similarly, research at Bindura University of Science Education (BUSE) underscores the importance of quantitative evaluation in revealing specific learning gaps among secondary school learners (Mtetwa & Marumahoko, 2020). In the present study, the

quantitative design not only identified students' weaknesses but also provided baseline evidence that informed the qualitative exploration of teacher perspectives. This integration of diagnostic testing with interpretive insights ensured a comprehensive understanding of students' difficulties in quadratic equations within the Zimbabwean educational context.

3.3.2 Qualitative Research Design

The qualitative phase of the study employed a case study design utilizing semi-structured interviews with mathematics teachers to gain an in-depth understanding of students' learning challenges and the instructional difficulties teachers encounter. According to Denzin and Lincoln (2011), qualitative research seeks to explore phenomena within their natural settings, enabling the researcher to understand the meanings individuals or groups ascribe to social or educational issues. This approach was appropriate because it provided a platform for teachers to express their personal and professional insights into why students experience particular challenges in learning quadratic equations, thus enriching the understanding derived from quantitative test results.

As Creswell (2014) notes, qualitative research emphasizes the interpretation of participants' perspectives to generate contextually grounded insights. Through semi-structured interviews, the researcher could probe deeper into the factors influencing students' mathematical performance—such as instructional strategies, classroom resources, learner motivation, and curriculum design. This flexibility allowed emerging issues to be explored while maintaining consistency with the main research questions. Similarly, Yin (2018) emphasizes that the case study design is suitable for investigating complex educational processes in real-life contexts, making it an ideal choice for understanding the interplay of factors shaping quadratic equations learning in Zimbabwean secondary schools.

Zimbabwean scholars such as Maswera (2021) and Chikasha (2020) from Bindura University of Science Education (BUSE) highlight that qualitative approaches are critical in unpacking the contextual realities of teaching and learning in developing countries. They argue that listening to teachers' voices helps reveal how socio-economic conditions, policy constraints, and learner diversity affect mathematics instruction. In line with this perspective, the present study used the qualitative phase not merely to describe but to interpret teachers' experiences, providing explanations for observed performance patterns. As Zvavahera (2020) and Mapfumo (2019) further contend, incorporating local educators' perspectives strengthens the relevance and applicability of research findings to the Zimbabwean education system. Therefore, the

qualitative design complemented the quantitative phase by offering deeper interpretive insights consistent with the pragmatic philosophy underpinning the study.

3.3.3 Specific Research Methods

This study employed specific research methods aligned with the explanatory sequential mixed-methods design, combining quantitative and qualitative approaches to provide a comprehensive understanding of students' challenges in learning quadratic equations. The quantitative method involved the administration of a Student Diagnostic Test, designed to assess learners' conceptual and procedural understanding across key areas, including factorisation, completing the square, the quadratic formula, graphing, and applied problem-solving. According to Creswell (2014), structured diagnostic tests allow researchers to quantify performance and identify patterns of strengths and weaknesses in student learning. The test provided numerical data on student performance, enabling the researcher to determine specific areas where misconceptions and procedural errors were most prevalent (Kothari, 2004; Cohen, Manion & Morrison, 2018).

The qualitative method involved semi-structured interviews with mathematics teachers, aimed at exploring their perceptions of students' difficulties and the instructional factors that influence learning. The interviews were guided by a structured interview schedule covering four domains: background information, students' challenges, instructional factors, and assessment and support needs (Appendix B). Semi-structured interviews were selected because they offer flexibility for teachers to explain and expand on their experiences while providing data that can be thematically analyzed (Denzin & Lincoln, 2018; Saunders, Lewis & Thornhill, 2019). This qualitative phase complemented the diagnostic test by providing contextual explanations for the patterns observed in students' performance.

By integrating these two methods, the study was able to triangulate findings, thereby enhancing the validity and reliability of the results. Quantitative data from the diagnostic test highlighted which aspects of quadratic equations were most problematic for learners, while qualitative insights from teacher interviews provided reasons for these difficulties, including teaching methods, learner attitudes, resource availability, and school environment factors (Chagwiza & Mutambara, 2020; Maswera, 2021). This mixed-methods approach ensured that the study not only measured students' challenges but also explained the underlying causes, yielding a comprehensive and contextually grounded understanding of learning difficulties in quadratic equations in Zimbabwean secondary schools.

3.3.4 Triangulation of Research Designs – Mixed Methods

Triangulation in this study was achieved by integrating findings from student performance tests and teacher interviews, thereby combining quantitative and qualitative perspectives to provide a more comprehensive understanding of the research problem. According to Patton (2015), triangulation enhances the validity and credibility of research by comparing and corroborating evidence from multiple sources. In this study, the quantitative data highlighted specific areas where students struggled most with quadratic equations—such as factorization, completing the square, and applying the quadratic formula—while qualitative insights from teachers’ interviews explained the underlying causes of these challenges, including instructional approaches, learner attitudes, and resource limitations.

This process allowed the study to combine numerical evidence with contextual interpretation, providing a nuanced understanding of students’ difficulties. As Creswell and Plano Clark (2018) note, mixed-methods triangulation strengthens research by integrating the objectivity of quantitative data with the depth of qualitative inquiry. In the Zimbabwean context, triangulation was particularly valuable as it captured the interaction between learner performance, teaching practices, and environmental factors affecting the mastery of quadratic equations (Maswera, 2021; Chikasha, 2020; Chagwiza, 2018). Mutambara (2019) similarly emphasizes that triangulation ensures educational research findings are both reliable and contextually relevant, enhancing the potential for evidence-based interventions.

Moreover, triangulation improved the reliability and practical applicability of the findings. By cross-validating results from multiple sources, the study minimized bias and reinforced confidence in the conclusions. As Zvavahera (2020) observes, triangulation in Zimbabwean educational research is essential for producing evidence that informs both theory and practice. By combining quantitative test results with qualitative teacher insights, this study provided a comprehensive, evidence-based, and contextually grounded understanding of the challenges students face in learning quadratic equations, fully aligned with the pragmatic paradigm that guided the research.

3.4 Study Population

According to Cohen, Manion, and Morrison (2018), a study population refers to the entire group of individuals or entities to whom the research findings are intended to generalize. Similarly, Creswell (2014) defines a population as “a group of individuals who have common characteristics that the researcher can identify and from whom data can be collected” (p. 152).

In the Zimbabwean context, Chivore (1994) explains that a population in educational research comprises all individuals within the education system who share relevant learning or teaching characteristics related to the study focus.

In this study, the target population consisted of Form Three secondary school students from a selected secondary school in Glen View, Harare, Zimbabwe and mathematics teachers from selected secondary schools in Glen View-Mufakose District, Harare, Zimbabwe. Form Three learners were chosen because they have already been introduced to quadratic equations as outlined in the *Ordinary Level Mathematics Syllabus* (Zimbabwe School Examinations Council [ZIMSEC], 2022). Including mathematics teachers who have taught Form Three or Form Four classes was vital, as their pedagogical experience provided rich insights into students' misconceptions, learning barriers, and instructional challenges related to quadratic equations.

3.5 Study Sample

A study sample refers to a smaller group of participants drawn from the target population from whom data are actually collected. According to Kothari (2004), a sample is a subset of the population selected to represent the entire group, allowing the researcher to make inferences about the population. Similarly, Cohen, Manion, and Morrison (2018) define a sample as a smaller collection of cases drawn from a larger population by a systematic procedure, enabling the researcher to study the group in detail. In the Zimbabwean context, Chivore (1994) notes that sampling allows researchers to collect manageable yet representative data from educational institutions given time and resource constraints.

In this study, a purposive and simple random sampling approach was employed. Purposive sampling was used to select secondary schools that had qualified mathematics teachers and relatively adequate teaching and learning resources. This ensured the inclusion of information-rich participants relevant to the research objectives. Thereafter, simple random sampling was applied to select forty (40) students from one school and ten (10) mathematics teachers from schools in Glen View-Mufakose District. According to Cohen et al. (2018), purposive sampling ensures that participants who are most knowledgeable about the research problem are included, while random sampling helps to reduce bias and improve the representativeness and generalizability of the findings.

3.6 Research Instruments Used in the Study

According to Creswell (2014), research instruments are the tools or devices used to collect data in order to answer the research questions of a study. Similarly, Cohen, Manion, and Morrison (2018) define a research instrument as any tool or procedure designed to obtain data from respondents in a systematic and replicable manner. In the Zimbabwean context, Chivore (1994) emphasizes that selecting appropriate research instruments in educational studies ensures the collection of valid, reliable, and contextually relevant data.

For this study, two instruments were used: a student diagnostic test and a teacher interview guide.

3.6.1 Student Diagnostic Test

A diagnostic test comprising both structured and multiple-choice items was designed to assess students' conceptual and procedural understanding of quadratic equations. The test covered major subtopics, including factorization, completing the square, and application of the quadratic formula.

The test aimed to identify students' common misconceptions, computational errors, and conceptual gaps. It was validated by Ms Munyaka and Mr Mutsoka who are mathematics teachers Glen View 1 High School to ensure content validity and alignment with the Zimbabwe School Examinations Council (ZIMSEC, 2022) Ordinary Level Mathematics syllabus. A pilot study was conducted at a nearby secondary school to evaluate clarity, reliability, and appropriateness of the test items before administering the final version to participants.

3.6.2 Teacher Interview Guide

A semi-structured interview guide was used to gather mathematics teachers' views on the challenges students face when learning quadratic equations. The guide consisted of open-ended questions focusing on students' common errors, the effectiveness of various teaching strategies, the influence of classroom resources, and the broader factors affecting learner performance.

Interviews were conducted face-to-face with the teachers' informed consent to ensure accurate data capture. This instrument allowed for deeper exploration of teachers' perceptions and provided qualitative insights that complemented the findings from the student diagnostic test.

3.7 Data Collection Procedures

Data collection refers to the systematic process of gathering information from relevant sources to answer research questions, test hypotheses, and evaluate outcomes (Creswell & Creswell, 2018). According to Kothari (2014), it involves selecting appropriate tools, identifying respondents, and ensuring that the data obtained are accurate and reliable. Cohen, Manion, and Morrison (2018) further emphasize that effective data collection requires careful planning and adherence to ethical standards to ensure validity and reliability of findings.

In this study, data were collected from both students and teachers using a mixed-methods approach, integrating quantitative and qualitative techniques. The quantitative data were gathered through a student diagnostic test, while qualitative data were obtained from semi-structured teacher interviews. This approach allowed for both numerical analysis and exploration of teachers' pedagogical insights, providing a holistic understanding of students' learning challenges in quadratic equations.

3.7.1 Administration of the Student Diagnostic Test

Before the main data collection, permission was sought from the Ministry of Primary and Secondary Education and the respective school heads. The researcher also briefed participating mathematics teachers on the purpose and procedures of the study.

The student diagnostic test was administered to students from one school in Glen View during normal school hours in a controlled classroom environment to reduce external distractions and ensure consistency. Each class was supervised by the researcher and the class teacher to maintain examination integrity. Students were given 45 minutes to complete the test, which consisted of structured questions focusing on key areas of quadratic equations—factorization, completing the square, and use of the quadratic formula, as outlined in the *Ordinary Level Mathematics Syllabus* (Zimbabwe School Examinations Council [ZIMSEC], 2022).

After collection, scripts were coded using anonymous identification numbers to protect participants' identities. According to Gay, Mills, and Airasian (2012), standardized administration procedures enhance the reliability of test results by minimizing researcher bias and ensuring uniformity in testing conditions. Chagwiza and Mutambara (2021) observed that using diagnostic testing provides valuable insights into student misconceptions and learning gaps in mathematics, especially in algebraic concepts like quadratic equations.

3.7.2 Administration of Teacher Interviews

Following the student test, interviews were conducted with mathematics teachers who had experience teaching form three or form four classes. The researcher arranged interview appointments in consultation with each teacher to minimize disruption of teaching schedules.

The interviews were conducted face-to-face in a quiet and private space within the school premises. Each session lasted approximately 20 to 30 minutes and was guided by a semi-structured interview schedule. With participants' informed consent, the discussions were audio-recorded to ensure accuracy and later transcribed verbatim for analysis.

McMillan and Schumacher (2014) note that semi-structured interviews allow for both structure and flexibility, enabling the researcher to probe deeper into emerging issues while maintaining focus on the study objectives. Similarly, Chagwiza and Mutambara (2021) highlight that open-ended interviews with teachers in Zimbabwean schools provide richer contextual data on the pedagogical and environmental factors affecting students' understanding of mathematical concepts.

3.8 Data Analysis and Presentation

Data analysis refers to the systematic process of organizing, interpreting, and presenting data to provide meaningful insights that address the research questions (Creswell & Creswell, 2018). According to Cohen, Manion, and Morrison (2018), data analysis transforms raw data into useful information by identifying patterns, relationships, and trends. In a mixed-methods study, both quantitative and qualitative data are analysed separately and then integrated to enhance the validity and comprehensiveness of findings (Patton, 2015).

In this study, the quantitative data obtained from the student diagnostic test were analysed using descriptive statistics, while the qualitative data from teacher interviews were analysed through thematic analysis. The integration of these findings allowed for triangulation, providing a holistic understanding of students' challenges in learning quadratic equations.

3.8.1 Quantitative Data Analysis

The student diagnostic test results were coded and entered into Microsoft Excel and SPSS (Statistical Package for the Social Sciences) for analysis. Descriptive statistics such as means, frequencies, and percentages were computed to identify areas of strength and weakness in

students' understanding of quadratic equations. The test items focused on key areas, including factorization, completing the square, and the quadratic formula.

According to Gay, Mills, and Airasian (2012), descriptive statistics provide a summary of data patterns that help researchers understand general trends without necessarily inferring causation. In this study, the analysis aimed to reveal the extent of students' conceptual understanding and procedural fluency in solving quadratic equations.

Results were presented using tables, bar graphs, and pie charts for clarity and easy comparison across different question categories. This visual representation enhanced interpretation and allowed the researcher to highlight specific concepts where students exhibited high error rates or misconceptions.

3.8.2 Qualitative Data Analysis

Qualitative data from the semi-structured teacher interviews were analyzed using thematic analysis, following the steps proposed by Braun and Clarke (2006). First, all interview recordings were transcribed verbatim. The researcher then read and re-read the transcripts to familiarize themselves with the content, after which **codes** were generated to identify recurring ideas. These codes were grouped into **themes** representing major categories such as:

1. Students' conceptual misunderstandings in quadratic equations
2. Teaching and learning strategies used by teachers
3. Resource limitations and curriculum pressures
4. Attitudes and motivation toward mathematics

As McMillan and Schumacher (2014) assert, thematic analysis allows researchers to organize qualitative data into coherent patterns that explain social or educational phenomena. Emerging themes were supported by direct quotations from teachers to preserve authenticity and illustrate their lived experiences.

3.8.3 Integration and Presentation of Findings

After separate analyses, the quantitative and qualitative results were compared and integrated. This triangulation process provided a more comprehensive understanding of students' learning difficulties. For instance, where the test results showed low performance in completing the

square, teacher interviews helped explain this weakness by pointing to conceptual gaps and inadequate time allocation for practice.

Findings were presented in both narrative and visual forms. Tables and graphs illustrated statistical patterns, while qualitative excerpts provided explanatory depth. According to Patton (2015), such integration strengthens the credibility of findings and enhances their applicability in educational policy and classroom practice.

3.9 Ethical Considerations

Ethical considerations are a critical component of any research study, ensuring the protection of participants' rights, dignity, and well-being (Creswell & Creswell, 2018). According to Cohen, Manion, and Morrison (2018), ethical research practice involves obtaining informed consent, ensuring confidentiality, avoiding harm, and maintaining integrity throughout the research process. In the Zimbabwean educational context, ethical clearance from relevant authorities is also required to conduct research within schools (Chagwiza & Mutambara, 2021).

The researcher adhered to ethical principles throughout the study. Informed consent was obtained from all participants, and parental permission was sought for students under 18 years. Confidentiality and anonymity were maintained by using pseudonyms. The study complied with the ethical standards of the Bindura University of Science Education Research Ethics Committee and the Ministry of Primary and Secondary Education (2019) guidelines.

The researcher ensured that all ethical standards for educational research were followed. Participants were informed of the study's purpose and their right to withdraw at any stage. Anonymity was maintained by using pseudonyms, and all collected data were securely stored and used solely for academic purposes.

3.10 Measures Taken to Minimise Errors, Validity, and Reliability

To ensure the reliability and validity of the study, several measures were implemented throughout the research process. According to Cohen, Manion, and Morrison (2018), systematic checks and triangulation of data sources enhance the credibility and trustworthiness of research findings.

Pilot Testing: The student diagnostic test was piloted at a nearby secondary school before full administration. This allowed the researcher to identify ambiguous or misleading questions and revise them to ensure clarity and appropriateness (Gay, Mills, & Airasian, 2012).

Expert Validation (Content Validity): Content validity was ensured through expert review by mathematics lecturers and experienced teachers. They confirmed that the test items and interview questions were aligned with the learning objectives of the Zimbabwean O-Level Mathematics syllabus (ZIMSEC, 2022). This process guaranteed that the instruments accurately measured the intended constructs and topics.

Reliability of Instruments:

For the quantitative instrument (student diagnostic test), reliability was assessed using Cronbach's alpha, which measures internal consistency of test items. A reliability coefficient of 0.75 or higher was considered acceptable (Tavakol & Dennick, 2011).

For the qualitative component (teacher interviews), reliability was enhanced through member checking, where participants reviewed summaries of their interviews to verify the accuracy of interpretations and ensure that their views were correctly captured.

Triangulation: A mixed-methods approach allowed triangulation of data. Quantitative results from the student test were cross-checked with qualitative insights from teacher interviews to confirm patterns of student challenges and misconceptions (Patton, 2015).

Consistent Data Collection Procedures: Standardized administration protocols were followed for both the test and interviews to reduce researcher bias and ensure uniformity across participants.

Careful Data Management: All data were coded, stored securely, and double-checked for accuracy before analysis. Audio recordings were transcribed verbatim, and transcripts were reviewed to prevent misinterpretation.

By implementing these strategies, the study minimized errors, enhanced instrument validity and reliability, and ensured that the findings were trustworthy and reflective of the reality in Zimbabwean secondary schools.

3.11 Anonymity, Confidentiality, and Use of Pseudonyms

To protect participants' privacy and comply with ethical research standards, strict measures were taken to ensure **anonymity and confidentiality**:

- **Pseudonyms** were assigned to all teacher and student participants. Real names, school names, or any other identifying details were removed or replaced during transcription and reporting.
- All data were stored securely, accessible only to the researcher, ensuring that no unauthorized person could link responses to individuals or schools.
- In the final report and subsequent publications, findings were presented in a way that prevents identification of participants, schools, or districts.
- Interview recordings and raw data will be securely deleted after the completion of the study, in line with institutional ethical guidelines.

These measures ensured that participants' identities were protected and that they could contribute freely and honestly without fear of negative consequences.

3.12 Summary of Chapter

Chapter Three (3) has outlined the research methodology employed in this study, including the philosophical underpinnings, research design, population and sampling, instruments, data collection procedures, and ethical considerations.

The study adopted a mixed-methods design, which allowed for triangulation of quantitative and qualitative data, integrating a student diagnostic test (quantitative) and teacher interviews (qualitative) to examine the challenges students face when learning quadratic equations. The population comprised Form Three students and mathematics teachers from selected secondary schools in Zimbabwe. Purposive and simple random sampling ensured that the participants were both relevant and representative.

Research instruments were validated and piloted, and ethical procedures, including informed consent and confidentiality, were strictly observed. Data analysis employed descriptive statistics for quantitative results and thematic analysis for qualitative findings. Measures to minimize errors and enhance reliability, such as pilot testing, expert validation, and triangulation, were implemented to strengthen the credibility of the study.

Overall, the chapter provides a robust methodological framework to guide the investigation of student learning challenges in quadratic equations, ensuring that the findings are both valid and applicable within the Zimbabwean educational context.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents, analyses, and interprets the data collected using a student diagnostic test and teacher interviews. Quantitative results from the diagnostic test administered to forty (40) form three learners at a selected secondary school in Glen View, Harare are presented first, followed by qualitative insights obtained from teacher interviews. The analysis seeks to answer the research questions outlined in Chapter 1, focusing on students' common errors, instructional challenges, and support needs.

4.2 Quantitative Results: Student Diagnostic Test

The diagnostic test was administered to 40 Form Three students and comprised five major areas of quadratic equations: factoring, completing the square, quadratic formula, graphing, and word problems. The purpose of the test was to identify the specific areas in which learners experience conceptual or procedural challenges.

4.2.1 Students' Performance by Question

The table below presents the performance of students on various questions that were administered to them

Table 4.1

Question	Topic	Correct	Partially correct	Incorrect
1	Factoring	17	8	15
2	Factoring	11	5	24
3	Completing the Square	0	3	37
4	Quadratic formula	7	8	25
5	Graphs	1	4	35
6	Word problem	0	0	40

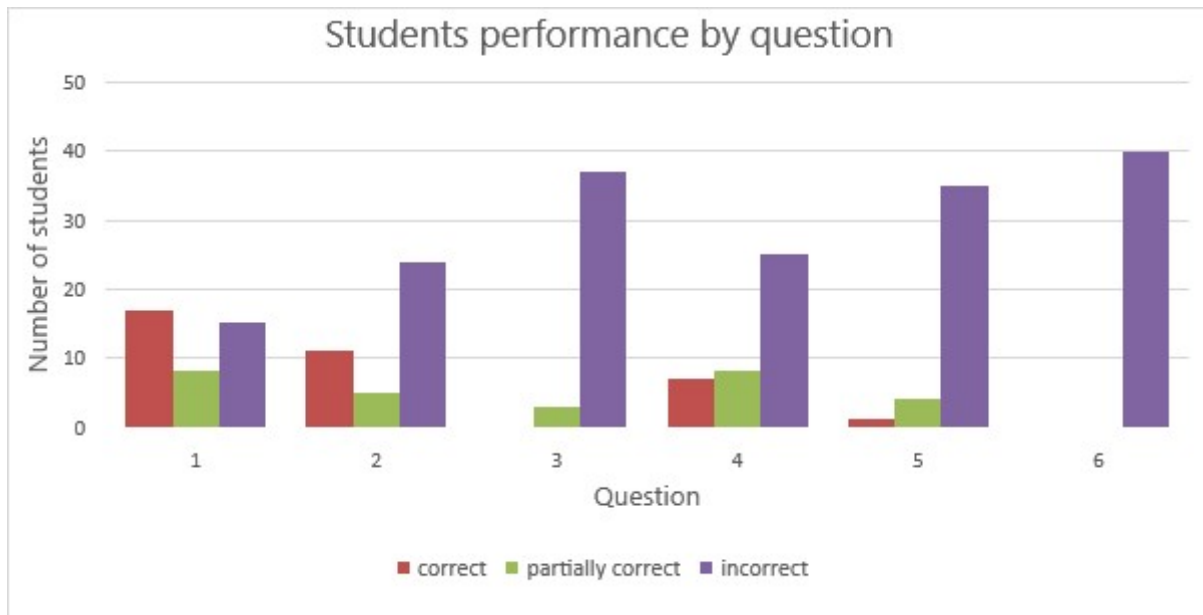


Figure 4.1: Students' performance by question

4.2.2 Performance Overview

As shown **Figure 4.1**, students generally performed poorly across most sections of the diagnostic test. While a few students demonstrated partial understanding in certain areas, particularly factoring and the quadratic formula, the majority struggled significantly with completing the square, graphing quadratic functions, and solving quadratic word problems. These patterns highlight critical gaps in both conceptual understanding and procedural fluency.

Table 4.2 Frequency of Common Student Errors (n = 40)

Error Type	Frequency	% of Students
Incorrect factorisation on Q1	15	37.5
Incorrect factorisation on Q2	24	60
Misunderstanding completing the square	37	92.5
Failure to use quadratic formula	25	62.5
Failure to use the graph	35	87.5
Failure to form equation from word problem	40	100

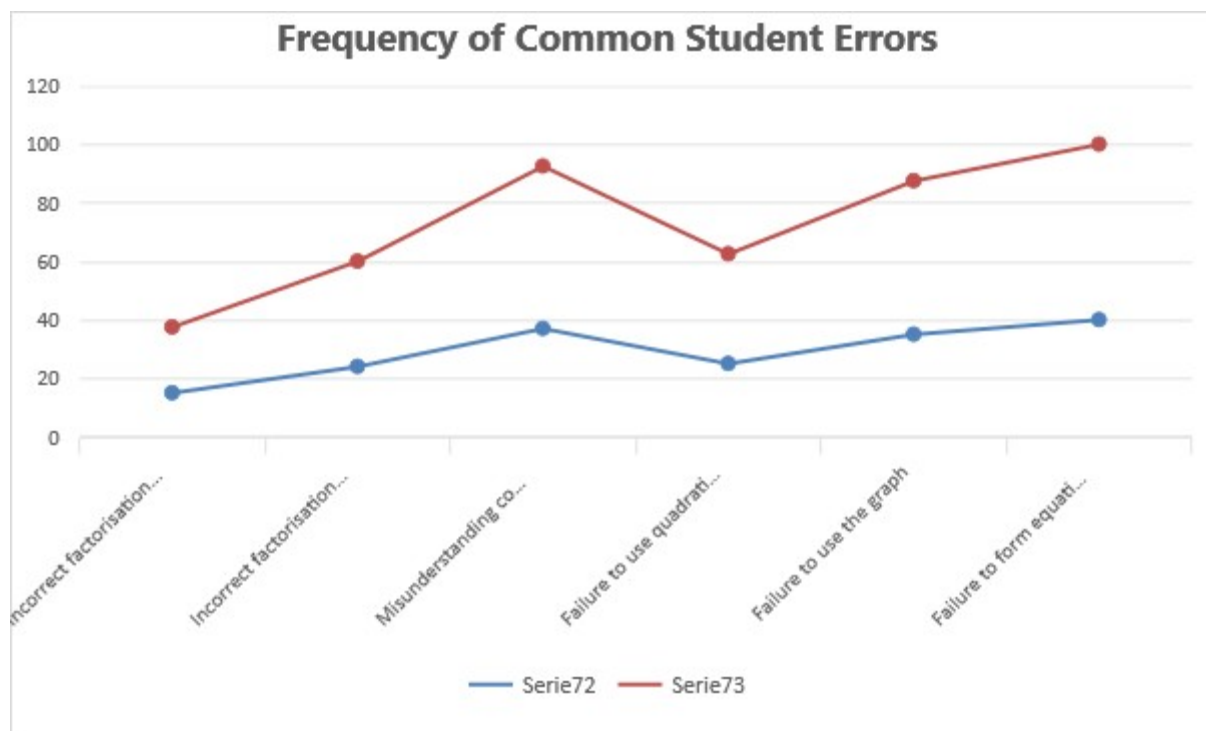


Figure 4.2: Frequency of Common Student Errors (n = 40)

Overall, as shown in **Figure 4.2**, the error-frequency patterns reveal a clear gradient: the more conceptually demanding or representationally complex the task, the higher the likelihood of errors. Tasks requiring deep algebraic reasoning (completing the square), multi-representational coordination (graphing), or linguistic-to-symbolic translation (word problems) recorded the highest error rates. By contrast, more procedural tasks such as factorisation and applying the quadratic formula produced slightly lower error frequencies, though still substantial.

When triangulated with teacher interview data, these findings indicate that students' challenges stem from a combination of conceptual gaps, procedural weaknesses, affective factors, and limited exposure to resources. The error-analysis results therefore provide strong empirical evidence of the specific areas where learners struggle and offer valuable guidance for targeted instructional intervention.

4.2.3 Analysis of Students' Performance by question

1. Factoring (Questions 1–2)

Factoring was the best-performed section, although error rates remained high. For Question 1, fewer than half (17 out of 40) answered correctly, showing familiarity with simple factorable quadratics. As question tested basic factoring, it recorded the highest number of correct responses.

$$\begin{aligned} 1) \quad & x^2 + 5x + 6 = 0 \\ & x^2 + 3x + 2x + 6 = 0 \\ & x^2 + 3x + 2x + 6 \\ & x(x + 3) + 2(2 + 3) \end{aligned}$$

Student A01-Question 1

Student A01 knows the *procedure* of splitting the middle term: $5x = 3x + 2x$. This shows awareness of the steps in factorisation by grouping but also shows that the procedure is partially known. The learner also does not understand why terms are grouped and factored. They combine numbers because they *add to 5* rather than identifying common factors; writing $x(2+3) + 2(2+3)$ shows a misunderstanding of the distributive law, and the structure of algebraic expressions. This indicates weak understanding of algebraic meaning, not just steps.

Performance dropped even further in Question 2. Many responses reflected common errors such as incorrect sign selection, wrong factor pairs, and attempts to factor non-factorable quadratics.

Handwritten student work on lined paper showing three equations:

$$2) 2x^2 - 3x - 5 = 0$$

$$5x^2 - 5 = 0$$

$$\underline{x^2 = 0}$$

Student A02

The error reflects a serious conceptual misunderstanding of equation equivalence, accompanied by a procedural failure to apply any recognised method for solving quadratic equations.

This pattern aligns with Tendere and Mutambara (2020), who observed that Zimbabwean secondary learners frequently display *conceptual, procedural and technical errors* when solving symbolic quadratic equations. Their study highlights that “trial-and-error” factor guessing, sign confusion, and poor algebraic foundations are typical sources of error—patterns clearly reflected in my sample. Thus, my findings confirm that difficulties in factoring remain a persistent challenge in Zimbabwean classrooms.

2. Completing the Square (Question 3)

Only three students showed partial understanding, while none answered the question fully correctly. This makes completing the square one of the weakest areas in the entire test.

Qn Number	
3.	$x^2 + 6x + 5 = 0$
	$x^2 + 6x + 3^2 - 3^2 + 5 = 0$ ✓
	$x + 6x + 9 - 9 + 5 = 0$ (2)
	$x + 6x + 9 - 9 + 5 = 0$
	$(x+3)^2 - 4 = 0$
	$(x+3)^2 = 4$ ✓
	~~$x = 4 - 3$~~
	<u>$x = 1$</u>

Student A03

Student A03's response revealed an attempt to apply the completing-the-square procedure; however, the method was executed incorrectly. The learner altered coefficients and omitted terms without performing valid algebraic operations, resulting in a non-equivalent equation. Although there was evidence of procedural awareness such as trying to isolate the quadratic and constant terms, the learner failed to maintain equality throughout the transformation process.

This error reflects a conceptual misunderstanding of equation equivalence, compounded by procedural weaknesses in manipulating algebraic expressions. Specifically, Student A03 appeared to treat completing the square as a set of mechanical steps rather than as a process grounded in the distributive property and balance principle.

$x+6=0$ or $x-1=0$
 $x = -6$ or $x = 1$

Section B: Completing the Square

3. Solve $x^2 + 6x + 5 = 0$ Use method of completing the square

$x^2 + 6x + 12 + 5 = 0$
 $x(x+3) + 1(x+5) = 0$

Section C: Quadratic Formulae

4. Solve $3x^2 + 2x - 1 = 0$

$a = 3$
 $b = +2$
 $c = -1$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Student A04

Student A04's response reflects a conceptual misunderstanding of the completing-the-square method, accompanied by procedural errors in algebraic manipulation. The learner incorrectly reverted to factorisation and failed to apply the defining steps of completing the square.

The high error rate is consistent with the observation by Kazunga, Sunzuma, Chiromo and Zezekwa (2025), who argue that Zimbabwean students often struggle with algebra due to its abstract nature and the cognitive demands of symbolic manipulation. Completing the square requires multiple sequential steps and a firm grasp of basic algebraic operations, skills which many students in my study demonstrated inadequate mastery of.

Teacher interview responses in my qualitative section further reinforce this finding. Several teachers indicated that learners "do not understand why the method works," suggesting deep-rooted conceptual weaknesses. These results therefore echo challenges already highlighted in local mathematics education research.

3. Quadratic Formula (Question 4)

Only seven (7) students answered this question correctly, while eight (8) gave partially correct responses. The remaining twenty-five (25) students made errors ranging from mis-substitution to incorrect handling of positive and negative signs.

4. $3x^2 + 2x + 1 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-2 \pm \sqrt{(2)^2 - 4(3)(1)}}{2(3)}$$

$$x = \frac{-2 \pm \sqrt{4 - 12(-1)}}{2(3)}$$

$$x = \frac{-2 \pm \sqrt{-8-1}}{6}$$

$$x = \frac{-2 \pm \sqrt{-9}}{6}$$

$$x = \frac{-2 + -3}{6} \quad \text{or} \quad x = \frac{-2 - -3}{6}$$

$$x = \frac{-5}{6} \quad x = \frac{1}{6}$$

Student A05

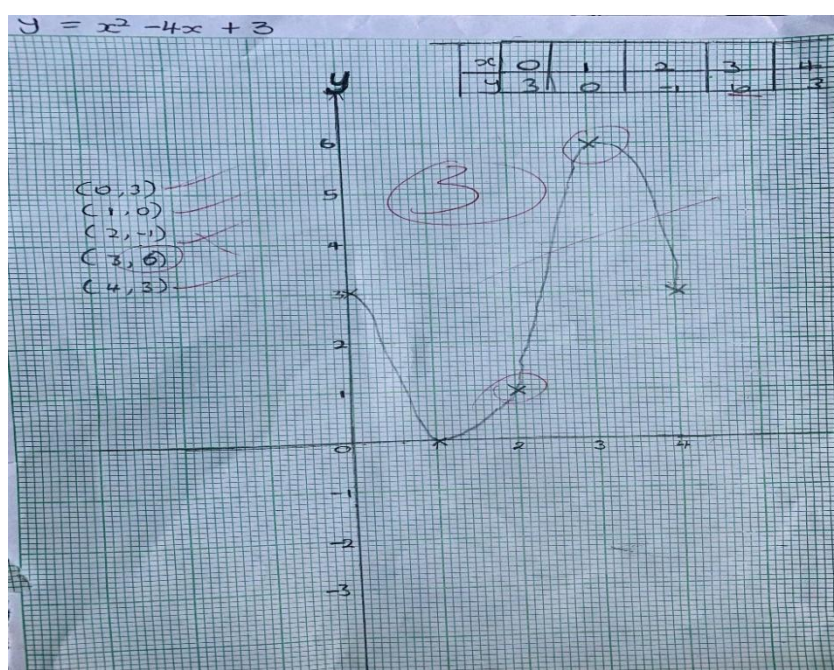
Student A05 correctly recalled the quadratic formula but struggled in simplifying $b^2 - 4ac$. This led to an incorrect discriminant and, consequently, wrong solutions. Such errors indicate difficulty in identifying coefficients from a standard quadratic equation and confusion regarding sign conventions, a common challenge reported in quadratic problem-solving literature.

This is consistent with the findings of Tendere and Mutambara (2020), who reported that many students apply the quadratic formula mechanically without understanding the underlying

structure. As a result, even minor arithmetic mistakes lead to completely incorrect solutions. My data therefore confirm that reliance on procedural knowledge alone—without adequate conceptual grounding—continues to undermine learner performance.

4. Graphing Quadratic Functions (Question 5)

Performance in graphing was extremely low: only one student produced a correct graph, while 35 students were entirely incorrect. Most errors reflected difficulties in identifying key features such as the vertex, axis of symmetry, and intercepts.



Student A06

Student A06 made some errors in substituting values of x into the equation resulting in getting wrong values of y as shown above. The student ended up failing to draw the correct graph, finding the axis of symmetry as well as failing to get the correct intercepts.

This challenge is consistent with the study by Sunzuma and Luneta (2023), who found that many Zimbabwean mathematics textbooks provide limited scaffolding for graph interpretation and visualization. They argue that inadequate visual and practical support contributes to weak graphical understanding among learners—exactly what my diagnostic test revealed. Additionally, teachers in my interviews frequently cited a lack of resources (e.g., graph paper, visual aids) as a major contributor to learners' challenges.

5. Word Problems (Question 6)

All 40 students answered the quadratic word problem incorrectly. This was the lowest-performing section of the entire diagnostic test. The complete lack of correct responses suggests that students struggle not only with algebraic manipulation but also with *mathematical modelling*—that is, converting a real-life scenario into a quadratic equation and solving it.

Student A07

Student A07 attempted to solve the problem without first defining variables or forming a quadratic equation from the given context. As a

The image shows a piece of lined paper with handwritten work in blue ink. On the left margin, the number '6' is written. The first equation is $n^2 = 132$, underlined in red. The second equation is $n = \sqrt{132}$, also underlined in red. The third equation is $n = ?$, underlined in red. The paper is slightly wrinkled and has horizontal lines.

result, the solution lacked logical connection to the problem situation and produced an invalid answer. Similar responses showed that many learners either failed to identify relevant information from the word problem or were unable to express relationships algebraically.

My findings reflect the concerns raised by Chirinda (2025), who argues that Zimbabwean mathematics education has become heavily procedural and examination-driven, leaving little room for genuine problem-solving. As a result, learners often fail when required to apply their knowledge in unfamiliar or non-routine contexts. The pattern in my study mirrors this broader national trend.

4.2.4 Summary of Quantitative Findings

The diagnostic test revealed several key patterns:

- The greatest challenges lie in completing the square, graphing quadratic functions, and solving word problems, with almost all students performing poorly.
- Factoring and the quadratic formula showed slightly better performance, but error rates remain high and indicate gaps in foundational algebraic skills.
- These results closely mirror trends reported in Zimbabwean mathematics education literature, suggesting that the difficulties observed in my sample are not isolated but reflect systemic, long-standing challenges in the teaching and learning of quadratic equations.

Overall, the diagnostic test confirms that most learners lack the conceptual understanding required to manipulate, interpret, and apply quadratic equations effectively.

4.3 Qualitative Results: Teacher Interviews

4.3.1 Teacher Background

The teacher interviews involved ten (10) mathematics teachers drawn from a local secondary school Glen View under Glen View-Mufakose District in Harare, Harare. Table 4.3.1 summarizes their professional profiles: years of teaching experience, the Forms in which they teach quadratic equations, and their typical class sizes.

Table 4.3.1: Teacher background (n = 10)

Teacher	Years Teaching	Forms Taught	Class Size
A	20 yrs	3 & 4	62
B	14 yrs	3	65
C	20 yrs	3, 4 & 5	60

Teacher	Years Teaching	Forms Taught	Class Size
D	21 yrs	2 & 3	42
E	21 yrs	2, 3, 4	61
F	12 yrs	3	60
G	18 yrs	3 & 4	58
H	34 yrs	3, 5, 6	63
I	10 yrs	2 & 3	60
J	15 yrs	2, 3, 4	55

Description of Table 4.3.1

Table 4.3.1 summarises the demographic and professional characteristics of the ten teachers who participated in the study. The data show that the teaching experience of respondents ranged widely from 10 to 34 years, indicating that the sample comprised predominantly seasoned practitioners. This diversity in experience is critical, as teachers with extensive classroom exposure often develop deeper insights into learners' difficulties and effective instructional strategies.

Furthermore, the table reveals that most teachers were responsible for teaching Form Three classes, either exclusively or in combination with other levels such as Forms Two, Four, or Five. This is significant because the study focuses on Form Three learners' challenges in quadratic equations; therefore, the teachers who contributed data were directly involved with the target group.

Class sizes recorded in the table also show a pattern of large enrolments, with numbers ranging from 42 to 65 learners per class. Such high enrolments are characteristic of many Zimbabwean secondary schools and have potential implications for instructional quality, individualised attention, and error diagnosis in mathematics. Teachers managing classes above 60 learners, as seen in several cases (Teachers A, B, E, F, H, and I), are likely to encounter difficulties

implementing learner-centred approaches or providing adequate remediation for struggling students.

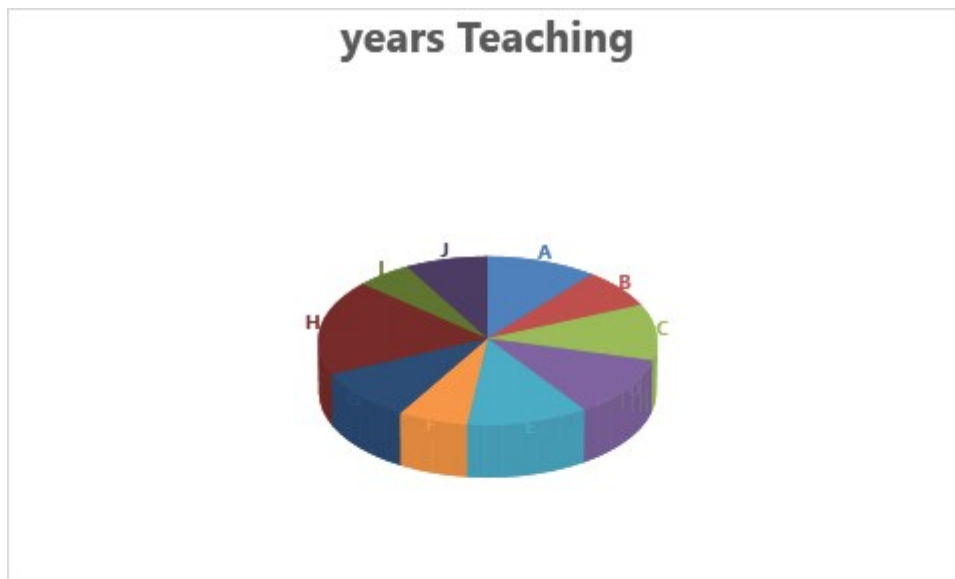


Fig. 4.3 Teacher teaching experience

Description of the Pie Chart

Figure 4.3 presents a pie chart illustrating the distribution of the participating teachers according to their years of teaching experience. The chart shows a wide spread across the groups, with each teacher represented as an individual segment. Notably, the largest portions of the pie correspond to Teachers H, D, and E, who have 34, 21, and 21 years of experience respectively. This reflects that a substantial share of the respondents are highly experienced educators. Teachers A and C, each with 20 years, also occupy significant segments, further emphasising the dominance of long-serving professionals in the sample. In contrast, the smallest slices of the chart represent Teachers I and F, who have 10 and 12 years of experience, indicating the presence of relatively fewer mid-career teachers. Overall, the pie chart makes it visually clear that the sample is skewed towards teachers with more than 15 years of service, highlighting that the insights gathered in the study are grounded in extensive teaching experience.

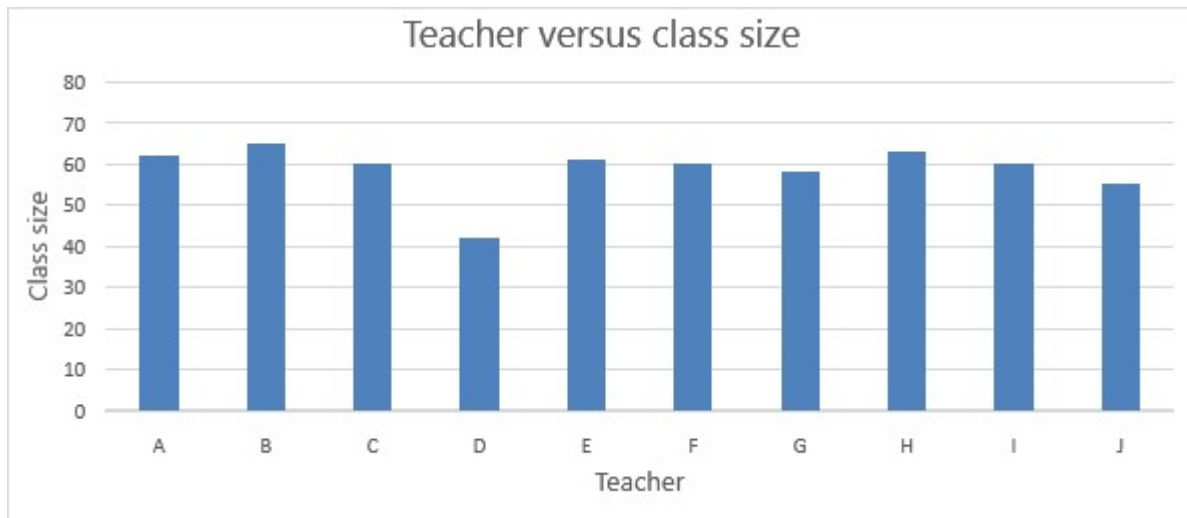


Fig. 4.4 Teacher versus class size

3. The bar graph above shows the comparison between teacher and the class size indicating that large class sizes with mean class sizes near 59 and several classes above 60, individualised instruction and remedial support are likely constrained. Such large classes are important contextual factors when interpreting reported student difficulties and teachers' method choices.

These contextual features (high teacher experience but large class sizes and multi-form teaching, where a single teacher is responsible for teaching several forms) shaped the interview data and provide an essential frame for interpreting the challenges teachers later describe in Section 4.3.2.

4.3.2 Students' Challenges (Teacher Perspectives)

The teacher interviews revealed a range of persistent challenges that students face in learning quadratic equations. These difficulties centred on factorisation, algebraic manipulation, sign handling, correct application of the quadratic formula, and learners' attitudes towards the topic. The challenges identified align strongly with patterns documented in Zimbabwean mathematics education literature.

A major challenge reported by the teachers was learners' difficulty with factorisation. Teachers G, F, B, A, E, and H cited frequent errors in determining correct factor pairs, handling negative signs, and identifying factors of negative numbers. For example, Teacher E described "complete failure to factorise," while Teacher H noted that some learners "do not even know how to factorise." These observations mirror findings by Tendere and Mutambara (2020), who

found that Zimbabwean learners frequently make conceptual, procedural, and technical errors in factorisation due to weak algebraic foundations and inadequate scaffolding.

Teachers also highlighted widespread weaknesses in algebraic manipulation, with Teacher J pointing to “poor algebraic manipulation” as a major barrier, and Teacher A noting that many learners provide incomplete solutions even when they start correctly. This is consistent with Kazunga, Sunzuma, Chiromo, and Zezekwa (2025), who argue that difficulties in algebra stem from limited conceptual understanding, abstraction, and insufficient early preparation in symbolic manipulation.

Another area of concern was learners’ difficulty with the quadratic formula. Teachers C, G, B, and I noted that students frequently fail to recall the formula accurately or apply it correctly. Teacher C mentioned “failure to state the correct formula,” while Teacher I referred to “formula misapplication.” These challenges echo Tendere and Mutambara’s (2020) findings, which show that learners often memorise the quadratic formula without understanding how it works or when it is appropriate, resulting in consistent substitution and arithmetic errors.

In addition, sign errors were frequently mentioned. Teachers F, D, and H pointed out that students often mishandle positive and negative signs, particularly when dealing with factors of negative numbers. This corroborates Sunzuma and Luneta (2023), who found that sign manipulation is one of the most common algebraic stumbling blocks for Zimbabwean learners due to weak arithmetic foundations and limited individualised support, especially in large classes.

i) Methods Students Find Most Difficult

Teachers were asked which solving method; factoring, completing the square, using the quadratic formula, or graphing; students find most difficult. Clear patterns emerged:

- Method of completing the square was identified as the most difficult by most teachers (Teachers A, C, D, E, I, and others).
- Teacher B believed the quadratic formula posed the greatest challenge for his learners.
- Teacher C noted that factorisation remains the most difficult for some learners.

Overall, method of completing the square emerged as the method most learners struggle with. This method is multistep and requires precision in algebraic manipulation, which many learners lack. The findings are consistent with Kazunga et al. (2025), who noted that students struggle

significantly with abstract, multi-procedural algebraic tasks that require strong foundational understanding.

ii) Rural–Urban Differences in Performance

Teachers were asked if they have taught in both rural and urban schools and if the answer was yes, then they were asked about the differences they have observed.

Seven teachers reported having taught in both rural and urban schools. A dominant view was that urban learners generally perform better in solving quadratic equations than rural learners. Teachers attributed this difference to:

- better access to textbooks and teaching materials,
- more stable teaching staff,
- greater parental support or supervision, and
- exposure to environments that encourage study.

These observations align with Chirinda (2015), who notes that disparities in instructional resources and school environments between rural and urban areas significantly influence learners' mathematical achievement. Rural classrooms, often characterised by large class sizes and limited resources, may not offer the necessary support for mastering abstract concepts such as quadratics.

iii) Learners' Attitudes and Beliefs

Teachers A, G, and J further highlighted that negative learner attitudes significantly contribute to poor performance. Some students approach quadratics with the belief that the topic is inherently difficult, which lowers their motivation and engagement. Teacher J noted that many learners display “lack of confidence,” while Teacher A observed a “negative attitude” towards the topic even before instruction begins.

This aligns with the literature, as Chirinda (2015) emphasises that affective factors such as learners' confidence, anxieties, and beliefs about mathematics play a significant role in shaping performance. When learners perceive a topic as difficult, they are less likely to participate actively, practice consistently, or seek help, thereby reinforcing poor outcomes. Research in

Zimbabwean classrooms has repeatedly shown that negative beliefs compound conceptual weaknesses, making it harder for learners to acquire and retain algebraic skills.

Overall Synthesis

The combined interview data paint a comprehensive picture of learners' difficulties with quadratic equations. Students struggle with factorisation, algebraic manipulation, formula application, and sign handling, challenges widely reported in Zimbabwean literature. The method of completing the square stands out as the most difficult method due to its abstract, multistep nature. Rural–urban differences underline structural inequalities that affect learners' progression. Finally, negative attitudes and low confidence further hinder students' ability to engage meaningfully with quadratic equations. These findings collectively suggest that learners' challenges are systemic, multifaceted, and deeply rooted in both cognitive and contextual factors.

4.3.3 Instructional Factors Influencing the Teaching of Quadratic Equations

This section examines how instructional methods, classroom conditions, and remedial strategies affect the teaching and learning of quadratic equations. Teachers described the strategies they use, the challenges they face, and the interventions they have attempted to support learners. Their responses highlight both pedagogical strengths and systemic limitations within the instructional environment.

Teaching Strategies and Resources Used

Teachers reported using a variety of strategies and resources when introducing quadratic equations. Several teachers (G, A, and C) indicated that they rely on a combination of lecture-based instruction and group work. Group work was emphasised by Teachers A, C, and F as a means of promoting peer interaction and allowing learners to collaboratively solve quadratic problems. Teacher C additionally uses worksheets and instructional videos to demonstrate different solving methods and to provide visual representations of quadratic functions. Teacher F mentioned using the parabola as a visual tool to help learners connect algebraic processes with graphical interpretations. Teacher C also noted that he starts by revising linear equations before progressing to quadratics, as a way of building conceptual continuity.

These strategies are consistent with recommendations in the literature. According to Sunzuma and Luneta (2023), the integration of visual aids such as graphs and videos can enhance

conceptual understanding by providing multiple representations of algebraic ideas. Similarly, Chirinda (2015) emphasises that varied instructional strategies, including collaborative learning and visual methods, help to deepen learners' engagement and support problem-solving development.

Impact of Classroom Challenges on Teaching Quadratics

Teachers highlighted several instructional constraints that hinder effective teaching. Large class sizes were commonly mentioned as a barrier. Teachers A and C explained that slow learners are often left behind, as whole-class instruction makes it difficult to provide individualised support. Teachers E, F, G, and J echoed this view, noting that large classes make it “difficult to cater for individual problems,” especially when learners struggle at different levels.

Shortages of teaching aids also affected instruction. Teacher B reported that the use of instructional videos is limited due to unreliable or nonexistent school Wi-Fi, which restricts access to digital resources that could support visual learning. This mirrors findings by Kazunga et al. (2025), who argue that limited teaching resources and overcrowded classrooms reduce opportunities for differentiated and interactive instruction, especially in abstract topics like algebra.

Challenges with the language of instruction were also implied in several responses, as some learners struggle to follow explanations delivered at a pace suitable for more proficient students. Research by Tendere and Mutambara (2020) similarly notes that linguistic challenges can compound conceptual difficulties, leading to misunderstandings in algebraic procedures.

Overall, the constraints described by teachers reflect broader systemic issues in Zimbabwean secondary schools, where large classes, resource shortages, and infrastructure limitations directly affect instructional quality.

Strategies for Addressing Learner Difficulties

Teachers also shared interventions they use to help learners overcome difficulties in quadratic equations. Teacher B incorporates quadratic-related questions into other topics to reinforce continuous engagement with the concept. Teachers A and D rely heavily on group work, homework, and work cards, which allow learners to practice collaboratively and receive peer support. Teacher C emphasised extensive practice, including the use of past examination papers to familiarise learners with common question formats and improve procedural fluency.

These strategies align with research recommending regular, structured practice to strengthen procedural skills in mathematics. Chirinda (2015) notes that repeated exposure to problem-solving tasks enhances learners' confidence and conceptual retention. Similarly, Kazunga et al. (2025) emphasise the importance of scaffolding through practice and guided exercises to help learners develop deeper understanding in algebra.

Teachers generally viewed these interventions as partially effective. While group work and practice help learners improve procedural fluency, they are limited by large class sizes and the wide range of learner abilities. Consequently, struggling learners may still lag behind despite the teachers' use of diverse instructional approaches.

Overall Interpretation

The instructional factors described by teachers reveal a teaching environment characterised by dedicated effort but constrained by systemic challenges. Teachers employ varied strategies, that is lecture, group work, worksheets, videos, and extensive practice to support learning. However, these efforts are limited by large class sizes, inadequate resources, and restricted access to technology. The effectiveness of remediation strategies such as group work, homework, and repeated practice is therefore shaped by broader structural realities that impact the teaching and learning of quadratic equations in Zimbabwe.

4.3.4 Assessment and Support

4.3.4.1 Difficult Areas in Assessment of Quadratic Equations

Teachers highlighted that certain types of examination and test questions consistently present greater difficulty for students. Most teachers (A, D, I, J) reported that learners struggle the most with items requiring application of the quadratic formula, noting that students frequently misapply the formula, substitute values incorrectly, or make computational errors. Teachers D and E added that questions requiring method of completing the square are particularly challenging because many students lack foundational algebraic manipulation skills and often find the procedure too lengthy or abstract.

Graph-related questions were also identified as troublesome (Teachers D and E), especially tasks requiring students to sketch parabolas, identify turning points, or interpret graphs. Similarly, Teachers F and B observed that learners find word problems involving quadratic

equations difficult, mainly because they struggle to translate contextual scenarios into mathematical expressions. Teacher B further noted challenges with difference of two squares and questions that require learners to determine which method of solving is most appropriate.

These findings are strongly supported by literature. Smith (2021) notes that completing the square is globally recognized as the least understood method due to its multi-step nature and cognitive load. Kapfunde (2019) also found that Zimbabwean learners often struggle with contextual quadratic problems because they require both linguistic and mathematical interpretation. Similarly, Nyaruwata & Musingafi (2020) argue that poor algebraic foundations contribute to the persistent difficulties students encounter in graph interpretation and formula-based questions.

4.3.4.2 Teacher Support needs

Teachers identified several areas where support is needed to enhance instruction. Teacher B emphasised the need for diversified teaching methodologies to accommodate different learner needs. Teacher C noted that some teachers avoid the completing-the-square method, preferring factorisation or the quadratic formula; thus, training is required to ensure that all methods are taught effectively and confidently.

Several teachers (F, D, G) emphasised the need for professional development workshops, especially in ICT-enhanced teaching, audio-visual tools, and updated pedagogy. Teacher D suggested that some curriculum components such as area under a curve, which relate directly to quadratic functions, should be revisited for alignment. Teachers J, E, F, and G stressed the need for better instructional resources to address individual learning difficulties, especially in large, mixed-ability classes.

Literature supports these insights. Mpofu and Shumba (2022) argue that continuous professional development is essential for improving mathematics instruction in Zimbabwe, particularly where ICT integration is required. Chikodzi (2020) emphasises that workshops empower teachers with practical strategies for diverse learners. Mavhunga (2019) similarly notes that teacher mastery of all solution methods—including completing the square—enhances learners’ conceptual understanding and reduces misconceptions.

4.4 Summary of Qualitative Findings

Qualitative findings revealed several interconnected learner, instructional, and contextual challenges in teaching and learning quadratic equations.

Learners demonstrated significant misconceptions and procedural errors, including incorrect factorisation, mishandling of signs, misapplication of the quadratic formula, incomplete working, and weak algebraic manipulation. These findings are consistent with earlier studies reporting deficiencies in algebra readiness among Zimbabwean learners (Kapfunde, 2019; Ncube & Mutambara, 2021).

Teachers also indicated that the method completing the square is the most difficult method for learners, followed by graphing and contextual word problems. Those with experience in both settings stated that urban learners outperform rural learners, largely due to better resources and greater exposure to ICT tools. This supports studies highlighting persistent rural–urban inequalities in mathematics instruction (Musingafi & Mafugu, 2020).

Instructional challenges such as large class sizes, limited technology, lack of teaching aids, and inability to provide individualised support affect teaching effectiveness. Teachers employ strategies such as group work, worksheets, past exam papers, work-cards, and repeated practice, though these strategies are often constrained by contextual limitations. Similar observations are made by Shizha (2019), who argues that resource shortages in Zimbabwean schools hinder effective mathematics pedagogy.

Teachers expressed strong need for support, including ICT resources, professional development workshops, and policy reinforcement to ensure comprehensive coverage of all quadratic methods. These needs align with Mpofu and Shumba’s (2022) recommendation that systematic teacher support is essential for improving mathematics learning outcomes.

Overall, the qualitative findings show that challenges in quadratic equations stem from intertwined learner factors, instructional constraints, and environmental conditions, echoing the broader literature on mathematics education in Zimbabwe and the region.

4.5 Triangulation of Student and Teacher Data

Triangulating the diagnostic test results with teacher interview data provides a comprehensive understanding of the challenges faced by Form Three students in learning quadratic equations. The convergence of evidence from both sources shows that learners’ difficulties are neither

random nor isolated, but instead reflect deeper cognitive, pedagogical, and contextual issues. These findings align with existing literature on mathematics learning both in Zimbabwe and internationally.

A key area of challenge involves factoring quadratic expressions, where student work revealed moderate error rates. Teachers noted that learners often struggle with sign manipulation and selecting correct factor pairs—an observation supported by research showing that factoring is difficult for many secondary learners because it requires conceptual understanding of equivalence and multiplicative structure (Alemu, 2019). Zimbabwean studies (Ncube & Mpofu, 2016) similarly report that students tend to memorise mechanical procedures without grasping the underlying relationships between coefficients and factors, leading to persistent mistakes. The triangulated data confirms these trends, indicating that learners possess fragmented procedural knowledge with limited conceptual grounding.

The most pronounced challenge emerged in completing the square, where 37 of the 40 students produced incorrect solutions. Teachers consistently described this technique as the most demanding for learners, largely because it requires symbolic manipulation and transformation of expressions. This is consistent with Tall's (2013) view that completing the square represents a major cognitive hurdle as students move from arithmetic operations to structural algebraic thinking. Local studies (Chagwiza, 2020) have also shown that Zimbabwean learners often lack the algebraic fluency needed for this method, resulting in high error rates similar to those found in the present study.

Difficulties with the quadratic formula—with 25 out of 40 student errors—also align with teacher reports that learners commonly misapply signs, misinterpret the discriminant, or perform incorrect arithmetic. These findings reflect broader literature highlighting that, while the quadratic formula is often taught as a procedural shortcut, students frequently lack understanding of the meaning of the discriminant and the structure of the formula (Zaslavsky, 2010). In Zimbabwe, Mutodi and Nyikahadzoyi (2018) observed that many students rely on rote substitution, which increases the likelihood of procedural slips—precisely what the triangulated findings show.

The triangulation also highlights serious challenges in graphing quadratic functions, where 35 out of 40 students performed poorly. Teachers attributed this to learners' inability to identify key features such as the vertex, axis of symmetry, and intercepts. International research supports this pattern: according to Duval (2006), students often struggle to connect algebraic

and graphical representations due to limited representational fluency. Zimbabwean research by Gatawa (2019) similarly reports that learners seldom receive adequate instructional exposure to graphs, especially in resource-constrained schools, resulting in weak conceptual links between symbolic expressions and their graphical interpretations.

The most severe challenge was found in quadratic word problems, where all students (40/40) answered incorrectly. Teachers confirmed that learners have major difficulties translating contextual information into algebraic expressions, a finding consistent with global literature on problem-solving barriers. Newman (1977) notes that translation from language to algebra represents a critical cognitive bottleneck where many learners fail. Zimbabwean evidence (Kadyamatimba, 2021) further shows that linguistic difficulties, weak reading comprehension, and limited experience with mathematical modelling contribute to poor performance on such tasks. The complete failure rate in this study is therefore consistent with broader patterns reported elsewhere.

Affective factors also emerged through triangulation. Student scripts showed low attempt rates on complex items, while teachers indicated that learners fear making mistakes and often hold negative attitudes towards algebra. Such findings echo the work of Mutodi and Ngirande (2014), who demonstrated that mathematics anxiety and low confidence significantly hinder Zimbabwean students' performance. Internationally, Hannula (2011) argues that emotional factors shape learners' willingness to engage with challenging symbolic tasks—an insight mirrored in the current study.

Finally, triangulation revealed critical issues related to instructional resources and learning conditions. While student test performance indirectly suggested limited exposure to manipulatives or visual aids, teachers explicitly highlighted shortages of teaching resources, large class sizes, and constrained instructional time. These observations are supported by MoPSE (2024), which acknowledges persistent resource disparities between schools. Studies by Zvobgo (2019) and Mundangepfupfu (2022) similarly point out that overcrowded classrooms and inadequate learning materials significantly impair effective teaching of abstract topics such as quadratic equations.

Overall, triangulating student and teacher data with existing literature confirms that difficulties in learning quadratic equations stem from intertwined conceptual gaps, procedural weaknesses, representational challenges, affective barriers, and structural limitations. Teacher explanations help clarify why specific errors recur, while student performance provides concrete evidence

of the magnitude of these challenges. Together, these findings offer a holistic picture of the learning difficulties faced by Zimbabwean learners and point to several areas where targeted pedagogical support is urgently needed.

4.6 Interpretation of Findings

4.6.1 Persistent Conceptual Gaps:

The high error rates in completing the square and word problems suggest students struggle not just with procedure but with *understanding*. This supports Kazunga et al. (2025) who emphasize the need for conceptual frameworks rather than rote procedural instruction.

Tendere & Mutambara's (2020) classification of errors (conceptual, procedural, technical) helps explain the patterns seen in your data, reinforcing that these are not isolated mistakes but predictable misunderstanding types.

4.6.2 Resource and Instructional Constraints:

Teachers' reports of large class sizes and lack of teaching aids correspond with barriers identified in local studies. For example, Mangwende & Maharaj (2019) examine how teachers' knowledge of students' learning styles is limited by structural constraints.

The limited use of visual representation tools (i.e., graphing aids, dynamic geometry) further compounds the problem, as highlighted by Sunzuma & Luneta (2023), who argue that textbooks need to provide more scaffolding.

4.6.3 Affective and Pedagogical Dimensions:

The lack of confidence and negative attitudes among students is not surprising in light of the exam-driven nature of mathematics education in Zimbabwe. Chirinda (2015) highlights that many teachers stick to procedural tasks under exam pressure, which discourages reasoning and risk-taking.

Furthermore, the implementation of socio-mathematical norms such as argumentation (as advocated by Chitera, Mudavanhu & Dziva, 2025) could help improve students' reasoning, collaboration, and confidence in algebra.

4.6.4 Teacher Professional Development Needs:

The call from teachers for more training, especially in conceptual and visual pedagogies, is well supported by the literature. Mangwende & Maharaj (2019) recommend in-service training so that teachers can better align instruction with students' learning styles.

Similarly, promoting reasoning and argumentation in mathematics through structured norms (Chitera et al., 2025) could be a powerful professional development focus.

4.7 Summary

This chapter presented and analysed both quantitative and qualitative data to illuminate the challenges faced by Form Three students in learning quadratic equations. The results revealed that topics such as completing the square, graphing quadratic functions, and interpreting word problems posed the greatest difficulties, leading to persistent misconceptions and consistently high error rates. These challenges were closely linked to gaps in learners' foundational algebraic understanding, which manifested in procedural errors, weak symbolic manipulation, and an inability to translate contextual scenarios into appropriate quadratic models. As argued by Ncube (2018), such weaknesses are common in Zimbabwean classrooms where learners often progress to advanced algebra without having mastered basic mathematical operations.

The study further demonstrated that these learner-related challenges were intensified by several instructional and contextual constraints. Large class sizes, limited access to teaching aids, and the continued dominance of traditional teacher-centred approaches were frequently cited by participating teachers as key barriers to effective instruction. This aligns with Mutambara's (2020) observation that resource shortages and rigid pedagogical practices remain persistent obstacles to quality mathematics teaching in Zimbabwean secondary schools. Teachers in the study underscored the need for enhanced professional development, increased use of visual and hands-on resources, reduced class sizes, and structured remedial programmes to support learners who struggle with algebraic concepts.

Overall, the chapter's findings corroborate a growing body of Zimbabwean scholarship which indicates that learners' difficulties with quadratic equations are rooted not only in cognitive and conceptual gaps but also in systemic issues within the schooling environment. As Maposa (2019) notes, the intersection of learner-level challenges, pedagogical limitations, and institutional resource constraints continues to shape mathematics performance across the

country. Therefore, the evidence presented in this chapter highlights the need for holistic interventions that address both instructional practices and broader structural conditions within secondary schools

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter presents a discussion of the findings from the study on students' challenges in learning quadratic equations in Zimbabwean secondary schools, particularly focusing on form three students. The discussion interprets the results of the student diagnostic test and teacher interviews in light of existing literature. Based on these findings, implications for teaching, learning, and curriculum implementation are outlined, followed by practical recommendations.

5.1 Summary of the study

This study investigated the students' challenges in learning quadratic equations in Zimbabwean secondary schools (with special focus on form three students). The main focus was to identify specific areas of difficulty and to explore teachers' perspectives on factors contributing to students' poor performance in quadratic equations. Both quantitative and qualitative approaches were adopted to provide a comprehensive understanding of the problem.

Data was collected using a student diagnostic test and teacher interviews. The diagnostic test was used to assess students' procedural and conceptual understanding of quadratic equations, while teacher interviews provided insights into classroom practices, learner difficulties, and instructional challenges. The findings from the diagnostic test revealed that most students experienced serious difficulties in factoring quadratic expressions, particularly those with non-monic coefficients. The method of completing the square was also poorly understood, with many students failing to manipulate algebraic expressions correctly. Although some students could recall the quadratic formula, frequent errors were observed in substitution and calculation of the discriminant. Quadratic word problems emerged as the most challenging area, as students struggled to translate real-life situations into mathematical equations.

Teacher interviews corroborated these findings, indicating that students lack strong foundational algebraic skills, rely heavily on memorization, and have limited exposure to problem-solving activities. Teachers also highlighted time constraints, large class sizes, and inadequate teaching resources as contributing factors to the challenges faced by learners.

Overall, the study established that students' difficulties with quadratic equations are rooted in weak algebraic foundations, limited conceptual understanding, and insufficient emphasis on problem-solving and contextualized learning.

5.2 Discussion of Findings

5.2.1 Challenges with Factoring

The student diagnostic test revealed that a significant proportion of form three students struggled with factoring quadratic equations, particularly those involving non-monic coefficients, (for example $2x^2 - 3x - 5 = 0$ the non -monic coefficient is 2). This confirms earlier findings by Chikoko and Khan (2019), who noted that insufficient foundational knowledge in algebra often hinders students' ability to manipulate complex expressions. The difficulty with factoring also echoes findings from Smith (1985), emphasizing that procedural knowledge without conceptual understanding leads to rote learning and low problem-solving ability. Teachers indicated that students frequently confuse factor pairs and fail to identify common factors, leading to errors in solving quadratic equations.

These findings align with Maswera (2021), who emphasized that procedural knowledge without conceptual understanding can result in rote learning, where students memorize steps without comprehending underlying principles. The difficulty with factoring suggests a gap in earlier algebra instruction, highlighting the need for targeted reinforcement of basic algebraic concepts.

5.2.2 Completing the Square

Completing the square was identified as another challenging area. Students often made errors in transforming equations into the form $(x+p)^2=q$, with common mistakes including incorrect manipulation of constants and coefficients. Teachers reported that students rarely attempt this method unless explicitly instructed, often opting for the quadratic formula instead (MoPSE, 2024).

These results support Smith's (1985) observation that more abstract algebraic methods, such as completing the square, are difficult for learners who lack strong foundational skills and confidence in manipulating algebraic expressions. The difficulty with this technique may limit students' ability to solve quadratic equations efficiently, particularly in examination contexts.

5.2.3 Quadratic Formula

While some students could apply the quadratic formula correctly, errors were frequent in substituting values into $ax^2+bx+c=0$ and in calculating the discriminant (b^2-4ac). Teachers noted that students often rely on memorization without understanding the derivation or application of the formula.

This mirrors findings by Kelly (2009), who argued that overemphasis on formulaic approaches can impede problem-solving skills and conceptual understanding. The observed errors indicate that students may benefit from guided practice emphasizing both procedural fluency and conceptual reasoning.

5.2.4 Word Problems

Word problems were consistently the most challenging for students. Many students could manipulate equations but struggled to translate real-life scenarios into quadratic equations. Teachers observed misinterpretation of key terms and difficulty identifying unknowns (Chikoko & Khan, 2019; MoPSE, 2024).

This confirms that students' inability to connect abstract mathematics to real-world contexts undermines problem-solving skills, a challenge highlighted in Zimbabwean curriculum studies (Chikoko & Khan, 2019). Effective strategies for teaching word problems should include contextualized examples and stepwise problem-solving guidance.

5.3 Conclusion

The study established that Form Three students in Zimbabwe face significant challenges in learning quadratic equations, particularly in factoring, completing the square, applying the quadratic formula, and solving word problems. These difficulties stem from gaps in foundational knowledge, overreliance on memorized procedures, and limited problem-solving practice. Addressing these challenges requires coordinated efforts from teachers, schools, curriculum developers, and policymakers to strengthen conceptual understanding, improve teaching practices, and enhance students' ability to apply mathematics in real-life contexts.

5.4 Implications of Findings

The findings of this study have important implications for mathematics education practice and policy in Zimbabwean secondary schools. The persistent errors identified in learners' responses

to quadratic equations, particularly in factorisation, sign selection, representation, and interpretation of word problems, indicate that the challenges extend beyond individual learner weaknesses to broader issues related to teaching approaches, curriculum sequencing, and assessment practices. Consequently, the implications of these findings are discussed under three key areas: teaching and learning, curriculum design, and assessment practices.

1. Teaching and Learning:

The results underscore the need for teaching strategies that develop conceptual understanding alongside procedural fluency. Approaches such as guided practice, peer instruction, and use of visual aids can enhance student comprehension of quadratic equations (Maswera, 2021).

2. Curriculum Design:

The findings indicate gaps in scaffolding prior algebra knowledge before introducing complex quadratic methods. Curriculum developers should ensure mastery of foundational topics, such as factorization and linear equations, before progressing to abstract methods like completing the square and quadratic formula (MoPSE, 2024).

3. Assessment

Practices:

The prevalence of errors in word problems suggests that assessment should include formative tasks integrating real-life contexts. Continuous assessment focusing on problem interpretation can improve students' ability to apply mathematical concepts (Chikoko & Khan, 2019).

5.5 Recommendations

Based on the study's findings, several recommendations are proposed to improve learners' mastery of quadratic equations in Zimbabwean secondary schools. Teachers are encouraged to strengthen learners' foundational algebraic skills before progressing to more complex quadratic procedures, as a strong algebraic base reduces both conceptual and procedural errors. In addition, teachers should incorporate guided problem-solving approaches, particularly for word problems, and make greater use of visual aids, manipulatives, and real-life applications to enhance conceptual understanding, as suggested by Maswera (2021). Schools should invest in continuous professional development programmes to equip teachers with innovative

strategies for teaching quadratic equations, in line with the expectations of the MoPSE (2024) curriculum reforms. Establishing peer tutoring structures and remedial classes would also help support learners who struggle with algebraic foundations. For curriculum developers, it is recommended that the sequencing and pacing of algebra topics be reviewed to ensure that concepts are appropriately scaffolded, thereby reducing learner overload. Furthermore, the curriculum should integrate contextualised and culturally relevant mathematical problems to strengthen learners' problem-solving skills, consistent with the perspectives advanced by Chikoko and Khan (2019). At a broader level, policymakers should promote teaching and assessment policies that balance procedural fluency with conceptual understanding, ensuring that examinations do not overemphasise rote methods. Finally, adequate resources must be allocated to support teacher training and the provision of mathematics teaching and learning materials, as advocated in the MoPSE (2024) policy framework.

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APPENDICES

Appendix A: Student Diagnostic Test

Instructions: Answer all questions. Show all your working clearly.

Section A: Factoring (6 marks)

1. Solve $x^2 + 5x + 6 = 0$. (2 marks)
2. Solve $2x^2 - 3x - 5 = 0$. (4 marks)

Section B: Completing the Square (4 marks)

3. Solve $x^2 + 6x + 5 = 0$ by completing the square. (4 marks)

Section C: Quadratic Formula (4 marks)

4. Solve $3x^2 + 2x - 1 = 0$ using the quadratic formula. (4 marks)

Section D: Graphs (6 marks)

5. Sketch the graph of $y = x^2 - 4x + 3$. Use the graphical method to solve for x. Label the intercepts and the turning point. (6 marks)

Section E: Word Problem (5 marks)

6. The product of two consecutive positive integers is 132. Form and solve a quadratic equation to find the integers. (5 marks)

Appendix B:

Dear Sir or Madam,

My name is Claytone Mpame (Reg. No. B232919B), a student studying for a Bachelor of Science Education Honours Degree in Mathematics at Bindura University of Science Education. As part of my professional studies, I am required to submit a completed dissertation. I am therefore conducting a study titled “*Students’ Challenges in learning Quadratic Equations in Zimbabwe’s Secondary Schools (with special focus on Form Three Students)*.” You have been identified as a respondent for this study, and I kindly request your participation by responding to the interview questions. Please note that this research is purely for academic purposes and all ethical considerations, including confidentiality and voluntary participation, will be strictly observed.

Thank you for your cooperation and valuable contribution to this study.

Yours sincerely,

Claytone Mpame

Interview Guide for Teachers

Purpose: To gather insights from mathematics teachers on the challenges students face in learning quadratic equations in Zimbabwean secondary schools.

Section 1: Background Information

1. How many years have you been teaching mathematics at the secondary level?

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2. Which Forms do you currently teach quadratic equations to?

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3. What is the typical class size in your school for mathematics lessons?

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Section 2: Students' Challenges

4. What common errors or misconceptions do your students show when solving quadratic equations?

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5. Which method of solving quadratics (factoring, completing the square, quadratic formula, or graphing) do students find most difficult, and why?

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6. Have you taught in both rural and urban schools? If yes, what differences have you observed?

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7. How do students' attitudes and levels of confidence in mathematics affect their learning of quadratics?

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Section 3: Instructional Factors

8. What teaching strategies and resources do you usually use when introducing quadratic equations?

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9. How do challenges such as large class sizes, language of instruction, or shortage of teaching aids affect your teaching of quadratics?

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10. What strategies have you tried to help students overcome difficulties in quadratic equations, and how effective were they?

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Section 4: Assessment and Support

11. From your experience, which types of exam/test questions on quadratics cause the most difficulty for students?

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12. What support (training, resources, or policy changes) do you think teachers need to improve the teaching and learning of quadratics?

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