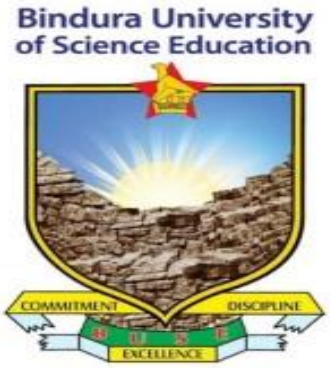

INVESTIGATING ERRORS AND MISCONCEPTIONS IN LEARNERS WHEN SOLVING SIMULTANEOUS LINEAR EQUATIONS AT ORDINARY LEVEL: ***A CASE STUDY OF A SECONDARY SCHOOL IN MOUNT DARWIN DISTRICT.***

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONORS DEGREE IN MATHEMATICS EDUCATION

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RELEASE FORM

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DEDICATION

The work is heartily dedicated to my wife, Mlema Ashlee for her steadfast backing towards the production of this paper. Also, the research is dedicated to my brother, Chidimu Wellington whose unyielding encouragement has been the foundation of my academic journey

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ABSTRACT

This research investigates the pervasive errors and misconceptions that learners encounter when solving simultaneous linear equations at Ordinary Level, with a specific focus on students at Kapiripiri Secondary School in Mount Darwin District of Mashonaland Central Province in Zimbabwe.

The research employs a mixed-methods approach for data collection, utilizing pre-tests and post-tests to measure learning outcomes, alongside questionnaires and focus group discussions to gather qualitative insights. A sample of ten (10) participants was selected through simple random sampling, while purposive sampling was utilized to engage eleven (11) mathematics teachers selected from five secondary schools in the same cluster in questionnaire responses.

Through a detailed analysis of students' responses in the pre-test, the researcher identified common pitfalls such as incorrect application of elimination and substitution methods, misinterpretation of variables, failing to make variables subject of formula and incorrect sign handling among others. Additionally, misconceptions of thinking that simultaneous linear equations have only one unknown variable have been highlighted. The research proposed several strategies to mitigate these errors, such as the use of learner-centered approaches, the use of Cognitive Load Theory, Constructivism theory and Error analysis theory and the implementation of peer tutoring systems that encourage collaborative problem-solving.

Data presentation is meticulously structured, utilizing tables, graphs, pictures, and bar graphs to enhance clarity and visual comprehension of findings. Analysis of the data employs both descriptive statistics and qualitative techniques, revealing significant trends and patterns in learners' understanding. The results indicate that traditional teaching methods negatively impact learner performance. Notably, there was a significant improvement in learner outcomes as evidenced by post-test results, confirmed through hypothesis testing during data analysis.

The study concludes that teacher-centered methods are more effective for facilitating learners' grasp of mathematical concepts, while traditional pedagogical approaches often exacerbate misconceptions and hinder performance. Considering these findings, the research advocates for

educators to adopt learner-centered approaches, which have demonstrated potential in reducing errors and enhancing comprehension. Further studies are recommended to explore similar issues within other mathematical concepts, aiming to broaden the understanding of errors and improve educational strategies in mathematics education.

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CT	CONSTRUCTIVISMTHEORY

CHAPTER ONE

1.0 Introduction

In this chapter the researcher pre-empts his findings on the background of the study supported by relevant literature. The Statement of the problem, research objectives, research questions, significance of the study and its justification to the learners, educators and the nation at large will be expounded. The delimitations and limitation of the study will be clearly elaborated. Lastly, the definition of key terms and summary to this chapter will be outlined.

1.1: Background of the study

Simultaneous linear equations are fundamental algebraic mathematical concepts taught at the Ordinary Level in Zimbabwe. It is of paramount importance for learners to master these equations since they form the basis for advanced mathematical problem-solving in various fields. This algebraic principle acts as a base to accommodate more complex thoughts to be laid in learners. Educators are guided by our curriculum which advocates for imparting mathematical skills and knowledge which will act as a solid foundation for learners to pursue in mathematical related studies. However, the situation prevailing at Kapiripiri secondary school in Mount Darwin, is totally diverging from this requirement from our curriculum. Most students are lagging in these skills which will often lead to learners encountering difficulties, making errors, and developing misconceptions and perceptions when solving simultaneous linear equations. As a result, the researcher delves into unpacking these challenges by carrying out research, investigating the strategies that can minimize or eradicate errors and misconceptions in solving simultaneous linear equations at Ordinary level.

At Kapiripiri secondary school in Mount Darwin, substantial learners are exhibiting negative perceptions towards the subject of mathematics. A considerable number of learners end up dropping out of school while others develop negative attitudes towards the subject. After going through some findings on why learners display this deviant behavior towards mathematical concepts, the researcher posits that persistent errors and misconceptions learners have in solving

algebraic concepts are a huge contributing factor for all these misfortunes. The above assumption is endorsed by the previous research done by Ndemo and Ndemo (2018), on 'Secondary schools students' errors and misconceptions in learning Algebra', where the study clearly amplified that there exist errors and misconceptions in learners in solving simultaneous linear equations. In buttressing Ndemo and Ndemo's (2018) findings, Chikwanha et al (2022), Mudavanhu et al, (2023), and Chaudhary, (2022), concur on the existence of errors and misconceptions in learners when solving simultaneous linear equations. However, their revelations did not proffer possible solutions to eradicate or minimize these errors. The researcher further asserts that the root cause of these errors and misconceptions in learners emanate from the use of traditional teaching methods which most educators are employing when teaching these mathematical abstractions. Some of the traditional methods include role memorization of formulas without understanding underlying principles, overemphasis on procedural fluency rather than conceptual understanding and lack of interactive teaching methods where learners will be actively participating. Chibayo and Wematangari (2016) criticized the above traditional methods, exerting emphasis on the adoption of learner-centered strategies in teaching algebraic concepts. Based on the research carried out by Mawarire and Chirume (2020) on teaching methods and their influence on poor performance, the two advocate for teachers to make their lessons interactive and actively involve learners in the teaching and learning activities. This may result in minimizing errors and misconceptions in learners. In the researcher's journal, 'Factors contributing to poor performance in Mathematics' by Kamau et al (2020) the discoveries sustained that teachers and learners' attitude contribute to poor performance which may be the results of errors and misconceptions by learners. Hence, the need for this research to investigate strategies that can unpack or minimize these errors and misconceptions by students in solving simultaneous linear equations. The common errors that learners have according to some insights by Smith (2019) and Johnson and Wang (2018) include failure to apply proper techniques, that is using elimination methods instead of using the most suitable substitution method. Additionally, misunderstanding of algebraic notation is another error exhibited by learners whereby students may misinterpret the notation leading to mixing up variables or coefficients that can also lead to incorrect solutions. For example, when solving systems of equations given by: $2x+3y= 7$; $4x-2y = 8$, learners may mistakenly identify $3y$ as $-3y$, which is a common error in learners. In addition, Brown and Davis (2020) identify some algebraic errors where learners may forget to distribute a negative sign

correctly. For example, learners may simplify 3x+2y =5 as 3x=2y+5. Learners may also fail to combine like-terms correctly. Furthermore, inconsistent elimination methods are other errors learners may have where they may use different elimination methods (adding or subtracting equations) inconsistently across multiple steps leading to incorrect result (error). For instance, when eliminating the variable of 'y' in the following systems of equations: 2x +3y =5; 3x - 3y =8 Instead of adding the two systems of equations to eliminate 'y', they end up subtracting the equations leading to errors.

There are also several misconceptions learners have in solving simultaneous linear equations. To begin with, learners think that equating coefficients of variables automatically solves the system. In addition, most learners have a misunderstanding that only one solution exists for a system of simultaneous equations. Smith, (2019) says some learners think that adding or subtracting equations is the only valid method for eliminating variables. In addition, the above scholar further elucidates that learners are also of the idea that variables represent specific values, not unknown quantities. Smith, (2019) further opines that learners have a false impression that solving simultaneous equations requires memorizing a set of procedures.

If the above observed and identified errors and faulty assumptions are not addressed, learners will end up losing interest and having negative attitudes towards the subject, hence this research is critical in investigating strategies to minimize those errors and misunderstandings learners have in solving simultaneous linear equations at Ordinary level. Driven by the previous investigation which pointed out the existence of these errors and misconceptions but lacking possible solutions to overcome the errors and misconceptions in learners when solving simultaneous linear equations, the researcher considered carrying out this inquiry with the intention to minimize those errors and misconceptions learners have.

An inspection carried out by the researcher in Mt Darwin at Kapiripiri secondary school indicates that the number of learners who will be enrolled at this school at Ordinary level tend to decrease when it comes to registering the mathematics subject for examinations. The data also show that the number of learners who passed the subject for the past five years is gradually declining yearly. The findings clearly indicate that there are several dropouts. And the few

learners who would have passed the subject will struggle to pursue mathematics in related areas. These discoveries are a motivating factor to carry out this study. The findings on table 1.1 below show the trend over a 5yr period.

Figure 1: A Research from Kapiripiri Secondary School in Mount Darwin District in Mashonaland Central province of Zimbabwe

Year	No of learners enrolled	No of learners registered for ZIMSEC exams	No of learners passed	No of learners who pursue mathematical related studies
2019	36	18	9	0
2020	39	31	7	0
2021	33	24	4	0
2022	29	18	1	0
2023	31	20	0	0
	Total: 168	Average %: 111/168= 66%	Average %: 21/111= 18.9%	Average %: 0/21= 0%

The above evidence motivated the researcher. As a result, there is need for this probe in: Investigating strategies to minimize errors and misconceptions in solving simultaneous linear equations in learners at Ordinary level at Kapiripiri secondary school in Mount Darwin under Mashonaland Central Province of Zimbabwe.

1.2 Statement of the Problem

Simultaneous equations are a fundamental concept in mathematics that involves solving systems of equations. In the teaching of mathematics at Ordinary level education, the study of simultaneous equations holds significant importance. According to Larson and Edwards (2019) simultaneous equations require students to develop critical thinking and problem-solving skills. Simultaneous equations also serve as a foundation for more advanced topics in algebra and calculus at large. Despite their fundamental nature, students at Kapiripiri secondary school often

encounter difficulties, mistakes, and misunderstandings while solving simultaneous equations. Common issues include misunderstanding concepts, incorrectly applying elimination or substitution methods, and mishandling signs. The investigations reviewed did not proffer solutions to this challenge. Hence this instalment sought to contribute to the body of literature to this vastly disregarded area on Investigating strategies to minimize errors and misconceptions in solving simultaneous linear equations in learners at Ordinary level with Kapiripiri secondary school in Mount Darwin in Mashonaland Central Province of Zimbabwe as a case study.

1.3 Research Objectives

a) To identify common errors and misconceptions made by learners when solving simultaneous linear equations at Ordinary level.

b) To investigate the underlying causes of errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level

c) To analyze the possible negative effects of traditional teaching methods towards learners' performance in solving simultaneous linear equations

d) To examine the negative effects of learners' negative attitude on performance in solving simultaneous linear equations.

e) To assess strategies that can help minimize errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level.

1.4 Research questions

The research seeks to answer the following questions

a) What are the common errors and misconceptions students have when solving simultaneous linear equations?

b) What are the possible causes of errors and misconceptions in learners when solving simultaneous linear equations?

c) How do traditional teaching strategies affect learners' performance?

d) What are the effects of learners' negative attitude on performance in Mathematics?

e) What strategies can help minimize errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level?

1.5 Significance of the study.

This research is important to learners, educators and the nation at large.

1.5. 1 Significance to Learners

The study is very important as it aims to minimise errors and misconceptions in learners when solving algebraic concepts. By minimizing these errors and misconceptions, it then leads to learners having an improved positive attitude towards Mathematics which will in turn improve their performance. Exposing learners to strategies that minimize their errors and misconceptions, by allowing them to actively participate will help them develop positive perception towards the subject. Learners are likely to grow into productive beings as they can apply algebraic skills, knowledge and competencies in the real world. The research will also widen the learners' career opportunities as they can pursue further mathematics studies. Algebra therefore stands as a solid base or foundation to support future studies leading to coherent mastery of mathematical concepts one after the other.

1.5.2 Significance to Educators

The significance of this research is anchored on its potential to improve the quality of mathematics education in Zimbabwe. By identifying common errors and misconceptions, educators can develop targeted instructional approaches that address these challenges. Furthermore, this is beneficial to educators as it aims at improving teachers' teaching methodologies and strategies and relations with learners. The research also acts as an appetizer to help other educators carry out studies and improve the learning process. After reading this research, educators can also acquire skills and knowledge that will enable them to impart those knowledge and skills to learners without any hindrances to learners' grasping of concepts. This is so because this research is trying to diverge from traditional teaching methods while advocating for the hybridization of teaching strategies.

1.5.3 Significance to Nation

The research will also play a pivotal role to the nation at large. Curriculum designers can also take into consideration the findings of this research into developing learning methodologies, approaches and strategies to be included in the curriculum framework. Different stakeholders in the country are likely to benefit. Once the schools can produce learners who can apply the learnt algebraic skills, knowledge and competencies, there is hope that they will be productive beings in the industrial sector especially in the banking sectors where application of algebraic concepts are highly recognized.

1.6 Research Assumptions

These are statements of what the researcher believes to be factual but cannot be verified.

The study therefore holds the following key assumptions:

Assumption of prior knowledge where the researcher assumes that learners have been introduced to basic algebraic concepts and have received instruction on solving linear equations. The researcher assumes that the research will be conducted in a typical classroom setting, with the researcher present to guide the learning process.

It is also presumed that learners have sufficient language skills to comprehend the mathematical terminology and instructions related to solving simultaneous linear equations for example be able to comprehend these words: elimination method, substitution method and others.

Assumption of learner motivation: Learners are motivated to engage in the learning process and show effort in solving simultaneous linear equations if exposed to learner centered approaches. Lastly the researcher assumes that hybridization of strategies will minimize errors and misconceptions. It will presuppose that respondents would cooperate.

1.7 Delimitations of the Study

Delimitations of a study refers to the boundaries that are intentionally imposed to focus on the research and define its scope. In this study one of the major delimitations is the geographical scope. The study is limited to one rural school in Zimbabwe, excluding the other schools in the region. In addition, the research had delimitation on variables since the study was based on errors

and misconceptions only in solving simultaneous linear equations excluding errors in other algebraic concepts. Furthermore, the results may not be generalized to other schools.

1.8 Limitations of the study

Limitations of the study refer to constraints or weaknesses that may impact the validity, reliability or generalizability of the research findings. The inquiry has the following impediments:

1.8.1 Experience: The researcher's lack of experience will adversely affect the results. However, the researcher will seek assistance from supervisors and consult studies that were previously done.

1.8.2 Limited Resources: One of the limitations to this research was limited resources. The study lacked adequate funding. There was also limited time resource since this research was carried out under the block release program where the researcher would be committed to other educational duties. As a result, the researcher had to utilize weekends and little spare time during the week.

1.8.3 Internet Connectivity: Limited access to technology or internet connectivity was also a limitation to this study since the research was carried out in rural areas where internet connectivity is a challenge. The researcher had to struggle to connect to the internet in search of relevant literature to support the research findings.

1.8.4 Research Participants: The researcher encountered some challenges in recruiting participants using the random sampling method. This was because it was the first time in history for that school to be included in a research sample and this posed some resistance in participants. The researcher had to seek parental consent.

The above noted delimitations and limitations should be considered and acknowledged when designing and conducting any research especially in rural areas where this research was conducted. Researchers should strive to address these challenges and make appropriate

justifications and adaptations for the potential impact on the overall validity and generalizability of the study. By taking the above into account, researchers will be diverging from possible threats to internal and external validity of their research.

1.9 Definition of Terms

The following are definitions of key terms and concepts that will be used during the study.

1.9.1 Errors in mathematics:

Errors in mathematics refer to mistakes or inaccuracies made during mathematical calculations, problem-solving, or reasoning processes (Lee, 2017).

1.9.2 Misconceptions in mathematics

Smith, (2019) views misconceptions in mathematics as erroneous beliefs or misunderstandings that individuals, particularly students, may have about mathematical concepts, procedures, or principles.

1.9.3 Algebra:

Johnson, (2018) views algebra as a branch of mathematics that deals with mathematical symbols, as well as the rules for manipulating these symbols to solve equations and represent relationships between quantities. It involves the study of structures, relations, and quantities.

1.9.4 Deviant behaviors:

According to Brown, (2015) deviant behaviors are actions or conducts that divert from societal norms, values, or expectations. These behaviors are often perceived as outside the boundaries of accepted or conventional behavior within a particular society or culture.

1.9.5 Simultaneous linear equations

Simultaneous linear equations are a set of two or more equations that contain linear terms (i.e., variables raised to the power of 1) and are solved simultaneously to find the values of the variables that satisfy all the equations (Larson and Edwards, 2017).

1.9.6 Teaching Strategies:

Ormrod (2015) is of the view that teaching strategies refer to the methods, approaches, techniques, or instructional practices that educators employ to facilitate student learning and achieve desired educational outcomes.

1.9.7 Interest:

Interest refers to the level of attention, curiosity, or engagement a person has towards a particular topic, activity, or subject (Williams, 2016). It encompasses feelings of enthusiasm, motivation, and involvement.

1.9.8 Attitude:

In his view, Davis (2014) defines attitude as a person's evaluation, feelings, beliefs, or behavioral tendencies towards a particular object, person, group, or situation. Attitudes can influence behaviors and decision-making processes.

1.10. Summary

Chapter one of the study has highlighted the background of the study and stated the problem that has inspired the research, where learners at Kapiripiri secondary school in Mount Darwin are exhibiting negative attitudes and deviant behaviors towards Mathematics. Literature from previous research was acknowledged to support this background of the problem. The chapter also outlined the statement of the problem which is an investigation on strategies to minimize errors and misconceptions in learners when solving simultaneous linear equations. Some findings to establish the problem were clearly captured and recorded in the form of a table to support the statement of the problem. Objectives of this research were also outlined. The research questions were also addressed. The significance of this research to learners, educators and to the nation was also attended to. Several assumptions to the research, delimitations and limitations of the study were articulated. Lastly, scholarly definitions of key terms such as errors, misconceptions, algebra and many others were raised. The next chapter will explore the literature review related to this study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The review of empirical literature sets forth a deep insight and clear view of the overall field and all relevant material that has a bearing on the topic. Substantial studies were conducted especially in the teaching and learning of algebraic concepts in mathematics at different levels in Zimbabwean schools and beyond our borders and region. An attempt has been made to briefly review the previous studies around teaching mathematical algebraic concepts. Despite numerous approaches and strategies being used to teach mathematical algebraic concepts, most learners still exhibit errors and misconceptions especially when solving simultaneous linear equations at Ordinary level. This chapter presents a review of related literature under the errors and misconceptions learners have when solving simultaneous linear equations. Before delving into the relevant literature, the following terms commonly used in the context of this study such as errors, misconceptions, theories and simultaneous equations will be explained.

2.1 Errors and Misconceptions

According to Hooke and Baird (2018) and Roh (2015) errors refer to mistakes or inaccuracies made by individuals when attempting to find the solution to a system of equations that are linear and interconnected. In supporting the above definitions Sullivan (2018) says mathematical errors are deviations from accuracy in mathematical work, often categorized into different types, including computational mistakes or misapplications of concepts, affecting the ultimate interpretation of results. From these elucidations, errors in mathematics can be described as systematic or random inaccuracies made in the processes of mathematical thought, that lead to incorrect results. According to Sullivan (2018) misconceptions in mathematics are deeply rooted beliefs or ideas that conflict with established mathematical concepts, leading students to draw incorrect conclusions or solve problems inappropriately. Adair (2019) and Czerwinski and Carnes (2018) are of the same view that misconceptions are erroneous beliefs about mathematical principles and operations that can significantly hinder students' ability to learn and apply mathematical concepts correctly. Therefore, it can be deduced that misconceptions in

simultaneous linear equations are incorrect or flawed understanding that students may develop when working with systems of equations. In other words, misconceptions in mathematics are incorrect understandings of mathematical concepts that can occur due to insufficient experiences or applications, often persisting despite formal teaching.

2.2 Importance of literature review in research

Literature review aims to identify the research gaps, building a theoretical framework, refining research questions and objectives, providing evidence for arguments and discussions, and avoiding duplication of effort. Literature review also informs methodology and research design, providing researchers with insights into various research methodologies and designs used in previous studies. Therefore, reviewing related literature is of great importance to researchers. Related literature to this research's questions (outlined in chapter one) have been reviewed as follows.

2.3 Theories on errors and misconceptions in solving simultaneous linear equations

Several educational theories were discovered to address errors and misconceptions in learners when solving simultaneous linear equations. Among these theories are Cognitive Load Theory (CLT), Constructivism theory and Error analysis theory. Conceptual Change Theory was also discovered to address errors and misconceptions in learners when solving simultaneous linear equations.

Cognitive Load Theory (CLT) is a theoretical framework that explores how the human cognitive system processes and retains information. It was developed by John Sweller, who proposed that the working memory has limited capacity, and that learning is influenced by the cognitive load imposed on the learner. The major tenets of Cognitive Load theory (CLT) include Cognitive Load which refers to the amount of mental effort required to process information. This cognitive load can be divided into three types namely: intrinsic load, extraneous load and germane load. CLT is also characterized by working which is the limited cognitive capacity that holds and processes information in the short term. According to CLT, working memory has a limited capacity for processing information, and cognitive load affects the efficiency of learning. CLT emphasizes the importance of constructing schemas, which are mental frameworks that organize and integrate knowledge. Learning is more effective when learners can relate new information to

existing schemas, reducing cognitive load and facilitating the acquisition and retention of knowledge. This theory suggests that there should be reduction of cognitive load where several strategies can be employed to reduce cognitive load and promote effective learning. So, it is of great importance for educators to provide explicit guidance. This guidance offers clear instructions and explanations to help learners understand complex tasks or concepts. By doing so, it results in minimizing errors and misconceptions in learners. Explicit guidance is crucial because it helps learners focus their attention on the essential elements of the problem, reducing the cognitive load associated with searching for relevant information. By providing clear and direct instructions, the teacher can draw the learner's attention to the critical aspects of the algebraic concepts, reducing the chances of cognitive overload. By combining explicit guidance and schema-based instruction, teachers can effectively manage the cognitive load of learners, enabling them to focus on the essential aspects of algebraic concepts and build a robust understanding that can be applied in various contexts.

In addition, the CLT advocates for sequencing and segmenting of concepts where educators have to break down complex tasks into smaller, manageable segments to reduce cognitive load. Hence there will be a reduction in errors and in learners. VanPatten and Williams (2015) opine that worked examples, providing scaffolding and fostering of self-explanation play a vital role in learners to minimize errors and misconceptions. Therefore, this research will explore how CLT can be utilized to address errors and misconceptions in learners when solving simultaneous linear equations.

Constructivism Theory is one of the theories which talks much on how errors and misconceptions can be minimized in learners. Constructivism Theory (CT) emphasizes the importance of social interactions and collaborative learning. This theory puts much emphasis on the use of interactive teaching methods or learner centered approaches to minimize errors and misconceptions in learners. Driven by this accession, the researcher pondered incorporating peer tutoring and focus groups to teach algebraic concepts as a way of minimizing errors and misconceptions in learners when solving simultaneous linear equations.

However, there may be a gap in its explicit application to addressing errors and misconceptions in solving simultaneous linear equations. Therefore, in this research one will try to explore how

CL approaches can effectively minimize errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level.

Finally, Error Analysis Theory (EAT) also propounds on errors and misconceptions in learners. The EAT provides insights into understanding general learners' errors. According to VanPatten and Williams, (2015) ETA is a valuable approach in language learning and teaching, aiming to identify and address errors made by learners. By analyzing and understanding the nature of errors, educators can design appropriate strategies to minimize them. This research could explore how this theory can be effectively applied to address misconceptions in this mathematical domain of errors and misconceptions in learners when solving simultaneous linear equations.

2.4 Possible causes of errors and misconceptions in learners

Understanding the possible causes of errors and misconceptions in learners when solving simultaneous linear equations is crucial for effective teaching and learning, Brown and White, (2018) are of the view that the major cause of errors and misconceptions in learners when solving simultaneous linear equations is the confusion when applying elimination or substitution methods. The two further explore that difficulty in identifying the correct operations to perform on both equations simultaneously is one root cause for these errors and misconceptions in learners. In addition, Johnson and Lee, (2019) suggest that misunderstanding the concept of equality and maintaining equivalence during the solving process is another cause of learners having these errors and misconceptions when solving simultaneous linear equations. Error propagation when simplifying expressions during the solution process was pointed out by Smith and Johnson (2018) as one of the causes to learners exhibiting errors and misconceptions when solving simultaneous linear equations. From the above findings, the researcher can clearly say that these studies lack the impact of different instructional and learner centered approaches on students' understanding of simultaneous linear equations. Hence as one of these research questions, the researcher has this question in mind, 'How can learner centered approaches (peer tutoring and focus groups) minimize errors and misconceptions in learners when solving simultaneous linear equations?' From the researcher's view, if well employed, learner centered approaches can minimize errors and misconceptions by learners when solving simultaneous

linear equations. Under the exhausted possible causes of errors and misconceptions in learners, these lack the role of technology in facilitating the learning and problem solving in solving simultaneous linear equations. It then knocked sense into the researcher's mind that technology has a role to play in minimizing errors and misconceptions in learners when solving simultaneous linear equations. Brown and White, (2018) suggest that there is a need to examine the role of technology in facilitating the learning and teaching of algebraic concepts. However, in this research, the researcher will not take into consideration the above suggestion due to unavailability of resources such as PowerPoint presentation to support the use of technology in the teaching and learning of simultaneous linear equations. In this research the researcher will try to unpack those errors and misconceptions learners have in solving simultaneous linear equations by making use of interactive learning among learners.

2.5 Common errors and misconceptions in learners when solving simultaneous linear equations

Solving simultaneous linear equations proved to be a challenging topic for learners, especially if learners are not exposed to proper teaching strategies or methodologies. In this research, the researcher had sleepless nights on what are the common errors and misconceptions in learners when solving simultaneous linear equations? This question prompted the researcher to review relevant literature to unpack this question. Research by Ndemo and Ndemo (2018) on 'Secondary school students' errors and misconceptions in learning Algebra', clearly pointed out that learners have an error of adding instead of subtracting to eliminate an unknown. For example, Ndemo and Ndemo, (2018) noted that learners make errors when they want to eliminate unknown in these two equations: $-a - b = 7$; $-a + 3b = 10$

Instead of subtracting first equation from last equation to eliminate **a** learners end up adding the two equations which will result in error on their solution. These arithmetic errors were also noted by Smith, (2019) saying learners make arithmetic errors when performing operations such as addition, subtraction, multiplication, or division.

In their research, on 'Students' errors and misconceptions in Algebra', Saqid et al, (2023) noted that learners have an error which is a result of failure to apply the correct method to eliminate an

unknown. Smith, (2019) and Johnson and Wang, (2018) further explain the above error saying learners will fail to apply the proper technique, they tend to use elimination method instead of using the most suitable substitution method. Davis, (2014) identify an error in learners in which they will have a misunderstanding of algebraic notation. Learners misinterpret the notation leading to mixing up variables of coefficients that can lead to incorrect solutions. For example, given: $3x + 5y = 11$; $4x - 3y = 8$, learners may mistakenly identify $5y$ as $-5y$ which is a common error. Another error in learners as per research done by Mudavanhu et al, (2023) learners may combine like terms incorrectly especially when using the substitution method. For example, incorrectly simplifying $x + 4y = 10$ as $x = 4y + 10$. Incorrectly combining like terms or misusing the distributive property is an error learners have (Smith and Johnson, 2018)

However, in their findings, Smith and Johnson (2018) clearly indicated that, it is impossible to avoid errors and misconceptions as we teach since students will always make errors and incorrect generalizations. Therefore, teachers must develop an open eye and mind to identify and curb these errors and misconceptions. The above quote motivated the researcher to carry out this research to identify potential errors and misconceptions in learners when solving simultaneous linear equations. As a result, the researcher thought that the application of Cognitive Load Theory, Constructivism theory and Error analysis theory can lead to reduced errors and misconceptions in learners.

Some gaps were identified in some previous studies. The above reviewed literature from previous literature failed to investigate the effectiveness of different teaching methods in helping learners understand and solve simultaneous linear equations. This identified gap was recommended for further exploration to investigate the effectiveness of different teaching methods in helping students understand and solve simultaneous linear equations by Smith and Johnson, (2018). The researcher identified the gap where previous research also lacked the impact of technology, such as graphing calculators or online tools, on students' ability to grasp the concept of solving simultaneous linear equations. By reviewing this literature, it helped the researcher to carry out his research trying to address those gaps by trying to accommodate theories of errors in the teaching and learning of simultaneous linear equations. The above literature review also set drawbacks on the effectiveness of collaborative learning strategies in addressing common errors and misconceptions in simultaneous linear equation solving. This gap

triggered the researcher to incorporate collaborative learning through peer tutoring and focus groups on his research as a way of trying to minimize errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level. Patel and Chen, (2021) suggest the use of collaborative learning as a strategy for addressing misconceptions and errors in simultaneous linear equations. Lack of the connection between students' spatial reasoning skills and their success in solving simultaneous equations graphically is another gap identified by the researcher in which Patel and Chen, (2021) clearly indicate that this is the major gap in research conducted before in errors and misconceptions learners have when solving simultaneous linear equations. However, the research recommended further exploration of this gap by future researchers since the researcher is not able to close the identified gap due to limitations surrounding this research.

2.6 Effects of traditional teaching strategies and negative attitudes on learners' performance in Mathematics.

Traditional teaching methods are commonly used in the day-to-day teaching and learning process in mathematics. According to the National Council of Teachers of Mathematics, (2014) there are several traditional teaching methods educators use which are acting as a stumbling block to the fully understanding of concepts by learners. Some of these methods include lecture-based instruction, textbook exercises, memorization, and many others. Under lecture- based methods, the teacher presents the algebraic concepts through lectures, explaining definitions, procedures, and examples. It is also a norm for most educators to use textbook exercises to teach learners. According to the National Council of Teachers of Mathematics. (2014) traditional teaching methods hinder learners' understanding of concepts where learners work through exercises and problems in a textbook, often with limited guidance or explanation. Some existing literature states that some educators use memorization methods which is an obstacle to learners' grasping of concepts. Chibayo and Wematangari (2016) say this method places emphasis on memorizing formulas, rules, and procedures without necessarily understanding their underlying concepts. This will affect learners in several ways. Learners may end up exhibiting errors and misconceptions.

Most of these traditional teaching methods will result in passive learning where learners may become passive recipients of knowledge, with limited opportunities for active engagement and critical thinking. Hence this will lead to learners developing negative attitudes towards the subject. Learners may also develop deviant behaviors which will retard excelling in their performances.

According to Brown and Johnson, (2018) traditional teaching methods will also result in limited understanding by learners. Rote memorization and procedural focus may hinder learners' deeper understanding of algebraic concepts and their applications. It also leads to a lack of motivation in learners. These monotonous drill and practice activities can lead to disengagement and reduced motivation among learners. In addition, traditional teaching methods will result in difficulty in transfer by learners where learners may struggle to apply algebraic concepts in real-world contexts or to solve unfamiliar problems outside the structured exercises. These findings from this reviewed literature undoubtedly indicate that traditional teaching methods are a contributing factor to a quite number of challenges learners are facing when solving simultaneous linear equations. Hence the need for this research to be carried out where the researcher will diverge from these traditional teaching methods to minimize errors and misconceptions in learners when solving simultaneous linear equations.

Once learners develop negative attitudes towards the subject it will automatically lead to reduced performance. In his view, Smith (2019) a negative attitude will result in reduced motivation. Negative attitudes towards the subject can result in decreased motivation to learn and engage with mathematical topics, which can hinder performance in solving equations like simultaneous linear equations. It also leads to increased anxiety. Negative attitudes can contribute to Mathematics anxiety, which may impair students' abilities to focus, problem-solve and perform well on mathematical tasks. All these can lead to poor performance which will be a result of errors and misconceptions by learners which could have been emanating from the negative attitude learners possess. With confidence, Smith, (2019) argues that learners with negative attitudes may be affected by their self-fulfilling prophecy. These students may have lower expectations of their own abilities, leading to a self-fulfilling prophecy where they underperform in the subject due to their beliefs about their capabilities.

Therefore, based on this reviewed related literature, the researcher can suggest that negative attitudes in learners needs to be dealt with so that learners will not exhibit errors and misconceptions which could result in learners' negativity towards the subject. Traditional teaching methods also proved to be problematic to most learners where most learners will be negatively affected by these methods. Guided by relevant literature, the researcher suggests employing interactive and collaborative learning methods in learners so that negative attitudes towards the subject will be a thing of the past.

2.7 Impact of learner-centered approaches in minimizing errors and misconceptions in learners when solving simultaneous linear equations.

Learner-centered approaches, such as peer tutoring and focus groups, can play a significant role in minimizing errors and misconceptions among learners when solving simultaneous linear equations. These approaches actively engage students in the learning process and promote collaboration, discussion, and critical thinking. By doing so, they address common sources of errors and misconceptions and enhance students' understanding of the topic.

Peer tutoring is one of the learner-centered approaches. Peer tutoring involves pairing students to work together in a collaborative learning environment. Krueger Casey (2015) argues that peer tutoring encourages active learning, where students actively participate in problem-solving, ask questions, and explain concepts to each other. This process helps identify and correct errors or misconceptions as students engage in meaningful discussions. In other words, peer tutoring encourages active participation and engagement from both the tutor and the tutee. The tutor's explanations and demonstrations require them to articulate their understanding, which can help identify any errors or misconceptions in their own knowledge. Similarly, the tutees' active involvement in the learning process allows them to ask questions, seek clarifications, and receive immediate feedback, reducing the likelihood of errors or misconceptions being reinforced.

Some research done before clearly pointed out that there is increased confidence in learners through peer tutoring since it can boost learners' confidence in their abilities. As tutors, students gain confidence in their knowledge and communication skills by assisting others. Tutees, on the other hand, experience personalized support and guidance, which can enhance their self-

confidence and belief in their learning capabilities. This increased confidence can promote a positive attitude towards learning. This in turn can contribute to minimizing errors and misconceptions by fostering a positive and proactive learning environment.

Focus groups are another learner centered approach. They are a qualitative research method that involves a structured and moderated discussion among a small group of individuals. The purpose of focus groups is to gather in-depth insights, opinions, and experiences on a specific topic by encouraging participants to freely express their thoughts and engage in group interactions. Some previous researchers advocate for it as a way of reducing errors and misconceptions due to its numerous advantages. Krueger and Casey, (2015) say focus groups involve small groups of students coming together to discuss and solve problems collaboratively. If correctly administered, focus groups contribute to minimizing errors and misconceptions in solving simultaneous linear equations. Firstly, it promotes collaborative problem-solving. There is also peer support in focus groups. Another point raised by Krueger and Casey, (2015) says focus groups leverage group dynamics to encourage participants to challenge and elaborate on each other's ideas. In addition, focus groups allow participants to reflect on their own thoughts and ideas in relation to those expressed by others. This reflexivity can help individuals recognize and rectify errors or misconceptions they may have. By engaging in open discussions and considering alternative viewpoints, participants are more likely to identify and correct any inaccuracies in their understanding. In their research, Mawarire and Chirume, (2020) titled: *Teaching Methods and their Influence on Poor Performance in Ordinary Level Math*, they put much emphasis on the use of Constructivism theory which they say, Constructivism theory is concerned about the learner as the one to get the knowledge and it stresses that learning should be hands on. This quote clearly shows that peer tutoring and group discussions are important teaching strategies to employ when trying to minimize errors and misconceptions. From their findings after interviewing the school's heads, Mawarire and Chirume (2020) say most secondary school's heads indicated the need for variation of teaching methods when teaching Mathematics at Ordinary level. These findings show that teaching methods are a contributing factor to learners' understanding or poor performance in Mathematics. From this researcher's view, most learners are exhibiting errors and misconceptions in solving simultaneous linear equations due to poor administering of these learner centered approaches. In this research the

researcher will try his level best to effectively incorporate peer tutoring and focus groups to minimize errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level.

2.8 Summary

In summary, literature review is of great importance to researchers as it aims to acknowledge existing literature, identify research gaps and build a theoretical framework. With relevant literature review, researchers will avoid duplication of efforts. Literature review also helps researchers refine research questions and objectives of their research. In this chapter, literature related to all research questions raised in Chapter one was clearly reviewed. Major views and tenets of CLT, CT and EAT were reviewed supported by relevant references. Their possible gaps were identified, and the researcher raised his views to incorporate in his research to minimize errors and misconceptions in learners when solving simultaneous linear equations. Related literature on possible causes of errors and misconceptions, common errors and misconceptions and effects of traditional teaching methods were not left unattended. The above components' relevant literature was reviewed, their possible gaps were identified, areas of similarities and differences were also exhausted, supported by existing literature. The next chapter will pay attention to the research methodologies the researcher used in coming up with this research finding.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

For research to be successfully carried out, researchers should take into consideration the appropriate and relevant research methodologies to employ in their research. The proper use of appropriate methodologies will help researchers to deviate from possible internal and external threats that will act as barriers to the validity of the research. Therefore, this chapter will explore the research design, target population, sample size and sampling processes, ethical considerations and research instruments that the researcher used in this research. Data collection procedures used, and data analysis techniques will also be discussed in this chapter supported by their pros from different scholars.

3.1 Research design

Qualitative and quantitative research designs are two distinct approaches employed in research methodology. In this research, the researcher employed both qualitative and quantitative research designs. Denzin and Lincoln (2018) and Patton, (2015) both define qualitative research design as an exploratory method that aims to understand and interpret social phenomena through the collection and analysis of non-numerical data. It focuses on capturing the richness and complexity of human experiences, perspectives, and behaviors. Qualitative research often uses techniques such as interviews, observations, and focus groups to gather data. In this research the researcher used observations, interviews and focus groups to gather data. The researcher chose this research design due to its numerous advantages. The major advantage of qualitative research according to Denzin and Lincoln, (2018) is that it provides an in-depth understanding. It allows researchers to gain a deep and nuanced understanding of complex phenomena by exploring participants' perspectives and experiences in detail. In addition to the above, Patton (2015) says qualitative research design research offers flexibility in data collection methods, allowing researchers to adapt their approach based on emerging insights and new questions that arise during the study.

If correctly employed, qualitative research design often contributes to theory development by generating new concepts or refining existing theories based on empirical observations and participant perspectives.

However, this research design has its drawbacks. Creswell and Creswell, (2017) say that there is limited generalizability. Due to the small sample sizes and specific contexts inherent in qualitative research, findings may not be easily generalized to larger populations. In addition, qualitative research design is subjective. It involves subjective interpretation and analysis, which may introduce bias and affect the reliability of the findings (Sekaran and Bougie, 2016). Creswell and Creswell, (2017) define quantitative research as a design that employs systematic and objective methods to gather numerical data for statistical analysis and generalization. It focuses on measuring relationships, patterns, and trends within a population or sample. This approach often utilizes surveys, experiments, questionnaires, use of tests and statistical techniques to collect and analyze data.

3.2 Target Population

In any research, the target population refers to the specific group of individuals or objects that the researcher wants to study and generalize the findings. It is the population to which the research questions and conclusions are intended to apply. The target population is defined based on specific characteristics, such as age, gender, location, occupation, or any other relevant attributes. It is important for researchers to clearly define their target population to ensure that results can be generalized to the broader population with confidence. This research targeted the form four learners at Kapiripiri secondary school in Mount Darwin District of Mashonaland Central Province in Zimbabwe. The school has a total population of twenty-seven Form four learners, nine males and eighteen females. The research also targeted eleven Mathematics teachers from the neighboring secondary schools of Kapiripiri namely*:* Katarira Secondary school, Mukumbura secondary school, Kamutsenzere secondary school and Chiswiti secondary school. The above-mentioned five schools have eleven mathematics teachers who teach Ordinary level. The targeted teachers were the respondents to the questionnaire which were designed to investigate if these teachers were noticing some errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level.

3.3 Sample Size and sampling technique

Researchers use sampling in their studies to select a subset of individuals or objects from a larger population. Sampling allows researchers to study a manageable and representative portion of the population rather than attempting to collect data from everyone in the target population which could be impossible. Babbie (2016) defines sampling as the process of selecting a subset of individuals from a larger population to conduct research or gather information. In this research the researcher used simple random sampling which is a type of sampling method where every individual in the population has an equal chance of being selected. The researcher chose simple random sampling because of its advantages over other sampling techniques. Firstly, it leads to unbiased selection since every individual has an equal chance of being chosen, hence it reduces the potential for bias in the selection process. In addition, the above-chosen technique is easy to use. It is straight forward and easy to implement, making it a cost-effective sampling method. It also enables generalizability since it allows for the results of the study to be more easily generalized to the larger population.

In this research the researcher chose a sample of eleven mathematics teachers from five different secondary schools. A sample of ten form four learners from Kapiripiri secondary school were selected through simple random sampling. The ten learners were six girls and four boys. This sample size can be summarized on the table 3.1 below together with the target population. The sample size will be expressed as a percentage of the target population.

Figure 1: Population and sample size

Category	**Target population**	**Sample size**	**Percentage of sample size**
Ordinary Mathematics Teachers	11	11	100%
Form Four learners (Boys)	9	4	44.4%
Form Four learners (Girls)	18	6	33.3%

3.4 Research Instruments

Since the researcher chose to employ both qualitative and quantitative research designs in this research, questionnaires, focus groups, pre-test and post-test were used to collect data under quantitative research design. Under qualitative research design, the researcher used focus groups for students and interviews to collect data.

According to Smith and Johnson (2018) a questionnaire in research refers to a set of questions designed to gather information from individuals about a particular topic of interest. Fink (2020) says questionnaires are commonly used in research to collect data from a large group of people in a standardized and structured way. As an advantage, questionnaires can be distributed to a large number of participants, making data collection efficient. However, in this research the population was not large. Wright (2021) adds on saying questionnaires allow for anonymity, which may yield more honest responses. Furthermore, questionnaires facilitate quantitative analysis of data, allowing for statistical comparisons and conclusions. Questionnaires are efficient when collecting data from a large or small sample. Smith and Johnson (2018) further assert that questionnaires provide standardization of responses for easy comparison. Due to its anonymity, it can encourage more honest responses. It is also cost-effective as compared to other data collection methods

In this research, focus groups were used to collect data from selected sample of ten students. Brown and Wilson (2019) reiterate that focus groups on research involve a small group of individuals who participate in a guided discussion facilitated by a moderator. In this context the moderator is the researcher. Krueger and Casey (2020) say focus groups are structured discussions with a small group of participants led by a facilitator (researcher). Focus groups are a nobble instrument since they provide in-depth insight into participants' thoughts and feelings, allowing for richer qualitative data. It also encourages interaction among participants, which can lead to the emergence of new ideas and viewpoints. Focus groups are used in research since they allow researchers to explore complex topics in a dynamic environment. As an advantage, focus groups provide an opportunity for in-depth exploration of topics. In addition, interaction among participants can generate new ideas and perspectives (Brown and Wilson, 2019). Furthermore,

there is real-time observation of group dynamics and there exists an ability to capture non-verbal cues and reactions.

Pre-test and post-tests were also part of the research instruments used to collect data in this research. Fink (2020) defines pre-test as an assessment conducted before a program or intervention is implemented. It helps to measure the participants' existing knowledge, attitudes or behaviors regarding the subject matter. Fink (2020) further avers post-test as an assessment administered after the intervention or program to evaluate its effectiveness by measuring any changes in knowledge, attitudes, or behaviors that occurred as a result of the program. According to Johnson and Smith (2020) pre-test and post-test are assessments conducted before and after an intervention or treatment to measure changes or outcomes. Pre-tests establish a baseline, while post-tests evaluate the impact of the intervention. This tool is advantageous to the researcher due to its ability to measure the effectiveness of interventions. It also provides evidence of causal relationships between interventions and outcomes. Pre-test and post-tests help identify areas of improvement or strengths in the participants' knowledge or skills. The two tests also allow for comparisons over time, enabling researchers to track changes and outcomes. (Johnson and Smith, 2020). Pre-test and post-test provide measurable data to assess the effectiveness of an intervention.

3.5 Data collection procedures

In this research, the researcher visited the five selected schools namely: Kapiripiri secondary, Mukumbura secondary, Katarira secondary, Chiswiti secondary and Kamutsenzere secondary schools and sought permission from the school administrators to engage all mathematics teachers in this research. At Kapiripiri secondary school, the researcher also sought permission to engage learners who were to be selected through simple random sampling. After being granted permission by the schools' administrators, the researcher introduced himself to the mathematics teachers, clearly stating the reason(s) why he visited them, while putting emphasis on rapport. Ethical considerations were clearly explained by the researcher to the mathematics teachers as a way of safeguarding privacy and confidentiality of the intended findings. Questionnaires were issued to all eleven mathematics teachers for them to complete. This was done to find out if those

teachers were also experiencing some errors and misconceptions in learners when solving simultaneous linear equations. If they were facing the same problem, the questionnaire clearly requested them to clearly state some major errors and misconceptions they were facing. The researcher left questionnaires to give these mathematics teachers enough and ample time to respond to them.

On a booked and agreed date, the researcher returned and collected the questionnaires. Then the researcher administered a pre-test of six items to ten participants from Kapiripiri secondary school only after a simple random sampling was done to select participants. It was administered to establish whether there exist errors and misconceptions in learners when solving simultaneous linear equations. The researcher had to find out and make sure that learners were once introduced to the concept under certain traditional teaching methods. Participants wrote the pre-test, and the researcher marked the scripts and kept them as evidence. After marking them, it was noted that learners had errors and misconceptions when solving simultaneous linear equations.

After being granted permission, the researcher visited again the school on an agreed and booked date. The researcher taught the concept of solving simultaneous linear equations using strategies recommended by the three theories namely: Cognitive Load theory, Constructivism theory and Error analysis theory. The methods of elimination and substitution were employed, guided by the above theories. During group discussions and peer interactions, data was captured where the researcher observed, listened to contributions by learners and recorded the attitudes of participants during their discussions. Pictures during peer interactions were also captured. During peer tutoring as a way of feedback from group interactions, the researcher also captured images of learners presenting in front of others. The researcher also interviewed participants as a way of analyzing errors.

Thereafter, the post-test was administered to the same participants on a separate day. It was a way of assessing the effectiveness of the employed strategies in minimizing or eradicating errors and misconceptions in learners when solving simultaneous linear equations. The posttest consisted of six items.

3.6 Data Presentation and Analysis Techniques

According to Smith and Johnson, (2018) data analysis techniques refer to the methods and approaches used to examine, interpret, and draw meaningful conclusions from data to gain insights and make informed decisions. These techniques differ depending on the nature of the data, research objectives, and the specific field of study. Some commonly used data analysis techniques include statistical analysis, qualitative analysis, exploratory data analysis, inferential analysis, and data visualization.

After the research was conducted, the pre-test, post-test, focus groups, peer tutoring and questionnaires were analyzed to ascertain the accuracy and effectiveness of research instruments and data collection procedures used to collect data. Descriptive statistics, quantitative analysis techniques together with qualitative analysis techniques were used to analyze data collected. The research findings were presented in the form of tables, pictures (captured during focus groups and peer tutoring), graphs and prose on objectives of the research accompanied by its research questions.

Data collected on focus groups was analyzed using thematic analysis, where the researcher identified and categorized themes and patterns in the participants' responses. Data from peer interactions was analyzed using qualitative content analysis, where the researcher identified and categorized key themes and patterns in the interactions.

On data collected through pre-test and post-test, the researcher used statistical analysis techniques of paired t-tests. The researcher clearly stated the null and alternative hypothesis. The researcher defined the null hypothesis as: There is no significant difference in performance by learners in both pre-test and post-test. The null hypothesis was clearly stated as: There is significant difference in learners' performance in both pre and posttests. The hypothesis was calculated at 5% significance. However, the researcher investigated consideration if there exists type 1 error when using statistical analysis. This error occurs when we fail to reject the null hypothesis when it is true that there will be difference in performance by learners in pre-test and

post-test. The researcher also compared the performance of participants in both pre-test and post-test by comparing the means and standard deviation. The higher the mean the better the learners performed. Then the lower the standard deviation the better the performance. Quantitative analysis techniques were used to analyze data collected from questionnaires. The return rate of questionnaires was expressed as a percentage. The researcher brought on board descriptive statistics techniques such as calculating frequencies and percentages.

3.7 Ethical Considerations

When carrying out research, especially in rural areas where this research was conducted, there are several possible ethical considerations to keep in mind. The researcher put in mind the following ethical considerations. The researcher sought and obtained informed consent and ensured that all participants, such as students and teachers, fully understood the purpose, nature, and potential risks and benefits of the research project. The issue of privacy and confidentiality was also in the researcher's mind. The researcher promised to protect the privacy and confidentiality of the participants by ensuring that any personal information collected is anonymized and stored securely. No real names were used in this research to maintain confidentiality. Instead, the researcher used codes in the form of letters (A, B, C, D, E, F, G, H, I and J) to refer to individual participants. In addition to that, the researcher considered cultural sensitivity since the research was carried out in rural areas where different norms and values are to be respected. In other words, the researcher respected the cultural norms, values, and traditions of the community. The researcher was aware of potential cultural differences and sensitivities to avoid committing offense or causing discomfort. Therefore, the researcher sought guidance from school administrators to ensure that the research was culturally appropriate. Furthermore, power imbalances were addressed. The researcher recognized and addressed any power imbalances that might exist between the researcher and the participants, such as differences in age, education, or social status. To achieve this the researcher ensured that participants were treated with respect and that their voices were heard and valued. Equity and inclusion were also looked at where the researcher ensured equal opportunity and inclusion for all participants, regardless of gender, ethnicity, socio-economic background, or any other characteristic. The technique of simple random sampling addressed this ethical consideration. The researcher avoided any form of discrimination or bias in the selection and treatment of participants.

3.8 Summary

In a nutshell, this chapter investigated the research designs used by the researcher which are qualitative and quantitative research designs. Advantages to both designs were also articulated. This research also targeted the population of form three learners at Kapiripiri secondary school which has a population of twenty-seven learners. Ordinary level teachers from five schools namely: Kapiripiri, Katarira, Mukumbura, Chiswiti and Kamutsenzere and were also part of the targeted population under study. Out of the above targeted population, the researcher used a simple random sampling technique to select ten learners from Kapiripiri secondary school. The researcher selected all eleven teachers from the respective five scholars as the sample size under study. Questionnaires, focus groups and pre-test and post-test were used as research instruments to gather data. The researcher also put into consideration the ethical considerations where privacy and confidentiality were clearly communicated to the participants. No real names were used, instead the researcher used codes of letters. Under the data collection procedures, the researcher visited the selected schools and sought permission from the school's administrators as well as teachers. Thereafter the researcher administered questionnaires to mathematics teachers. Pre-test and post-test were administered to ten learners who were selected under simple random sampling. Data collected was then analyzed to ascertain the accuracy and effectiveness of research instruments. Descriptive statistics, quantitative analysis, and qualitative analysis were also part of data analysis techniques used to analyze data. Next chapter will deal with data analysis, presentation and interpretation.

CHAPTER FOUR

DATA PRESENTATION, INTERPRETATION AND ANALYSIS

4.0 Introduction

In the realm of mathematics education, understanding the complexities of learners' thought processes is vital, particularly when addressing simultaneous linear equations at Ordinary level. This chapter delves into the heart of this investigation, focusing on errors and misconceptions that students grapple with in this critical area of study. The research problem centers on identifying the specific challenges faced by learners, as well as the underlying misconceptions that hinder their problem-solving abilities. The chapter is therefore going to present and analyze data collected using questionnaires, pre-tests, post-tests and focus groups. Tables, pictures, figures and graphs were used to present data. Descriptive statistics, quantitative analysis and qualitative analysis are the key data analysis techniques employed in this research. It will begin by presenting the quantitative data derived from questionnaires, pre-test and post-test providing statistical insights into learner performance before and after intervention. A comprehensive summary will be outlined at the end of this chapter.

4.1 Data presentation

Data collected using questionnaires, pre-test and post-test was presented in the form of tables, figures, charts, pictures and graphs.

4.1.1: Common errors and misconceptions learners have when solving simultaneous linear equations.

Questionnaires and pre-test were used to identify common errors and misconceptions in learners when solving simultaneous linear equations from mathematics teachers and selected learners respectively. The findings were presented in the form of the table below.

Figure 2 showing errors identified in questionnaires administered to selected mathematics teachers from selected secondary school

Error Type	Frequency	Percentage (%)
Incorrect application of method	9	36
Error on sign handling	5	20
Failing to make a variable subject of formula	5	20
Forgetting to multiply whole equation by a constant	2	8
Forgetting to find another variable	1	4
Other errors	3	12

The above table exhibit errors observed by selected mathematics mentors at Ordinary level when solving simultaneous linear equations. A staggering 36% of academic staff detected that students often misapply methods for solving simultaneous equations such as using elimination when substitution would be more appropriate, or vice versa. The error of incorrect application of methods constitutes the highest percentage (36%) when compared to all other errors recorded.

Studies indicate that learners frequently struggled with conceptual underpinnings of mathematical methods. For instance, a study by Kocak and Cakiroglu (2022) emphasizes the importance of guided discovery approaches in helping students to comprehend when to apply specific methods effectively.

The error on sign handling was also cited by mathematics tutors in their reactions to questionnaires. Errors in handling signs, such as failing to change the sign when moving terms

across the equation and omitting especially negative sign, are prevalent among learners. This can lead to significant errors in their final answers. About 20% of the instructors acknowledged the above error. To justify the above findings, literature infers those misconceptions about the rules of arithmetic operations, particularly with negative numbers are common among students. According to an investigation by de Oliveira and Lopes (2022) many students do not fully comprehend the implications of sign changes in equations, which then lead to persistent errors. However recent studies have reinforced this finding, indicating that targeted instructions on sign handling can improve student performance in algebra.

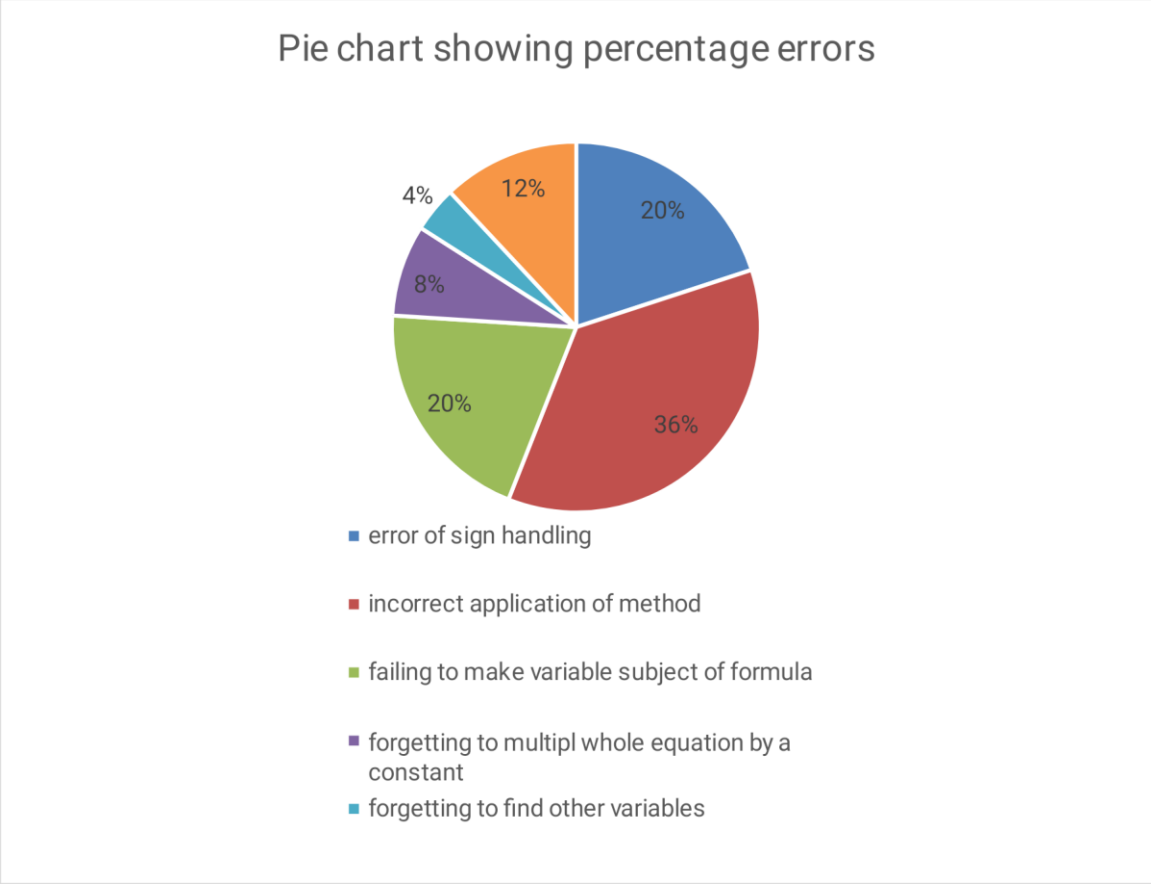
The revelations above also evaluates that many students struggle with isolating variables, which is a critical skill in algebra, particularly when solving simultaneous linear equations. Twenty percent (20%) of teachers highlighted the above error in their responses. The error in handling signs can prevent learners from effectively manipulating equations to find solutions, leading to errors in their final answers. To buttress the above insights, some inquiry by Chen and Pajares (2022) highlights that students often lack the necessary skills to rearrange equations, which is essential for solving simultaneous equations.

Forgetting to find other variable was also discovered, with 4% of mathematics teachers observing that error. About 8% of coaches upheld that some learners forget to multiply whole equation by a constant, which is also another error when solving simultaneous linear equations.

In a nutshell the errors identified by mathematics educators reflect broader issues in mathematics education that have been documented in recent literature, which the inquirer acknowledged in the literature review to this research. The investigator endeavored to address these errors using learner-centered approaches that can help minimize or eradicate errors in learners when solving simultaneous linear equations.

The above information was also presented in the form of a pie chart. A pie chart is effective for showing the proportion of each error type relative to the whole. The key was designed for easy interpretation of the findings. Below is a pie chart for errors identified in learners by mathematics educators when solving simultaneous linear equations at Ordinary level.

Figure 3 showing errors identified in questionnaires administered to selected mathematics teachers from selected secondary schools



4.1.2 Common errors identified in pre-test by learners

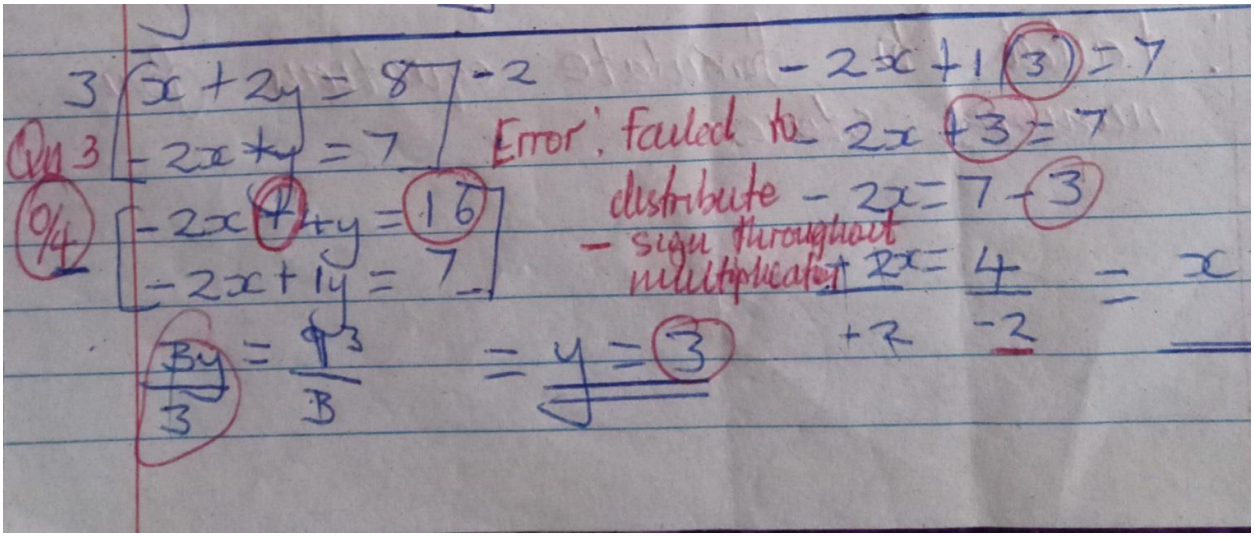
Learners were given a pre-test before the intervention of using learner-centered approaches by the researcher. Below is a presentation of errors exhibited by learners in the pre-test. The findings were presented in the form of a table, Figure 5 below. Afterwards some key errors by learners were displayed in form of scanned pictures presented below Figure 5, from figures 6a – 6e.

Figure 4 showing frequencies of errors identified in learners in the pre-test

Error type	**Frequency**	**Percentage (%)**
Calculations mistakes	8	20
Incorrect sign handling	12	30
Misinterpretation of question (word problems)	7	17.5
Incorrect application of method	4	10
Not multiplying whole equation by a constant	2	5
Failing to make variable subject of formula	3	7.5
Failing to find Common denominator	2	5
Other	2	5

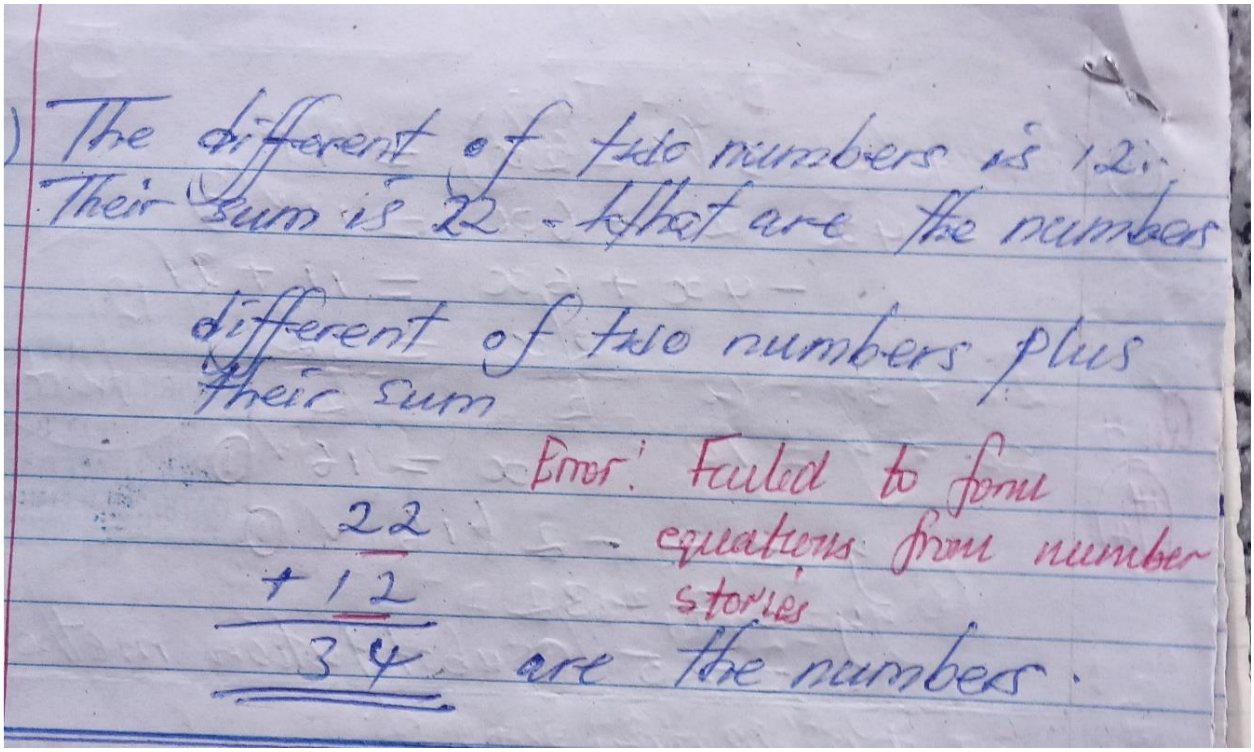
Some of the errors identified were presented in form of pictures as shown below

Figure 6a showing an error of sign handling



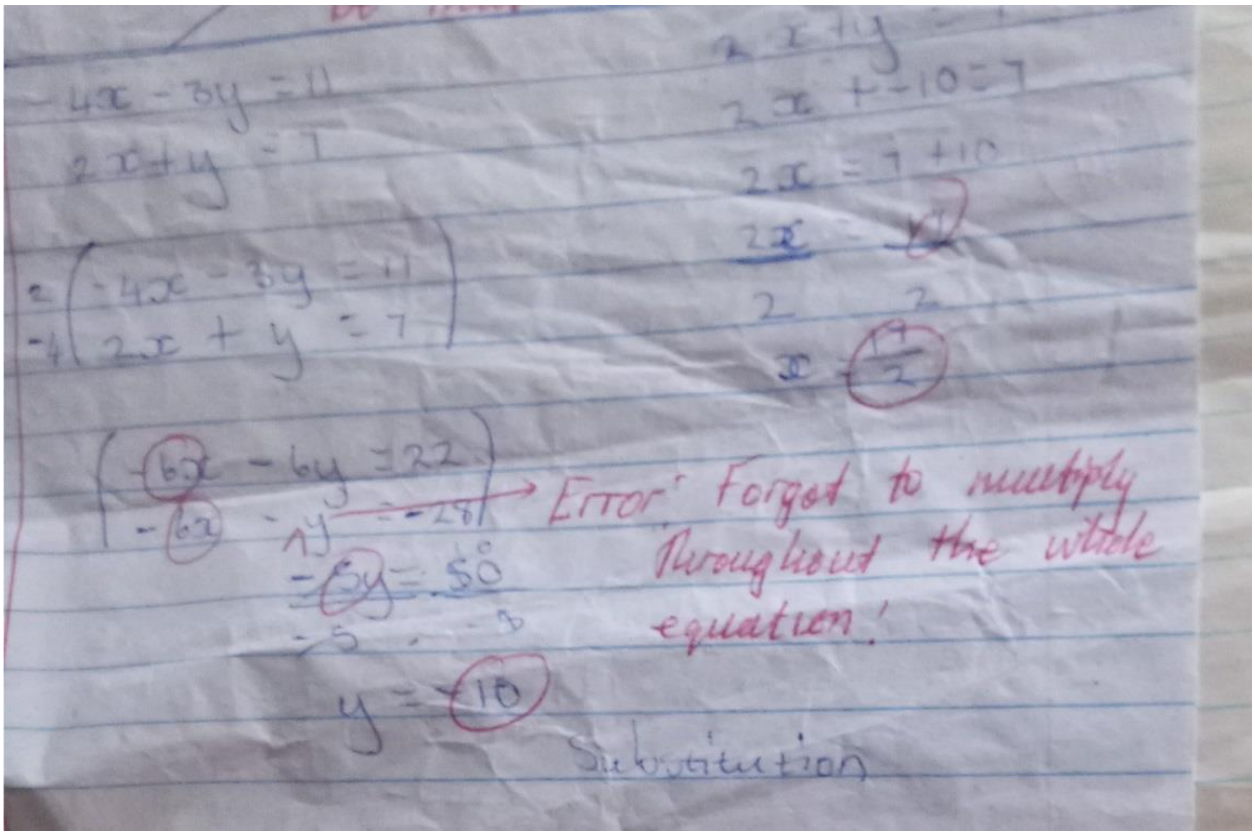
The figure above shows an error exhibited by a learner where a learner failed to distribute the sign correctly. The learner failed to put the negative sign on 6 to become -6. This kind of error was noted in the questionnaires by most mathematics teachers under this study. The error of sign handling has more frequencies as shown in figure 5 above. Kogut and Pappas (2023) support the above findings saying mismanagement of signs, such as overlooking negative signs or incorrectly applying them during calculations, is a frequent issue that can distort the solution process.

Figure 6b showing error of misinterpretation of question



The above figure shows an error of misinterpretation of question. Most learners showed this type of Error in the pre-test where most of them failed to formulate simultaneous linear equations from given word problems. The above error was also noted by Jansen and van der Sandt (2021) saying learners often misinterpret the structure of equations, leading to incorrect operations or assumptions.

Figure 6c showing an error of failing to multiply whole equation by a constant



The above error is on failing to multiply the whole equation by a constant. Firstly, the learner failed to find common multiple of 4 and 2 as 8, 12, 16, etc. Instead, the learner chose 6, which is also an error. Thereafter choosing 6, the learner failed to multiply the whole equation which resulted in an error shown above. In their findings, Gacheche and Rachon (2022) conclude that students often overlook the importance of multiplying the entire equation by a constant, which can lead to incorrect solutions, especially when attempting to align coefficients for elimination.

Figure 6d showing error of failing to make variable subject of formula

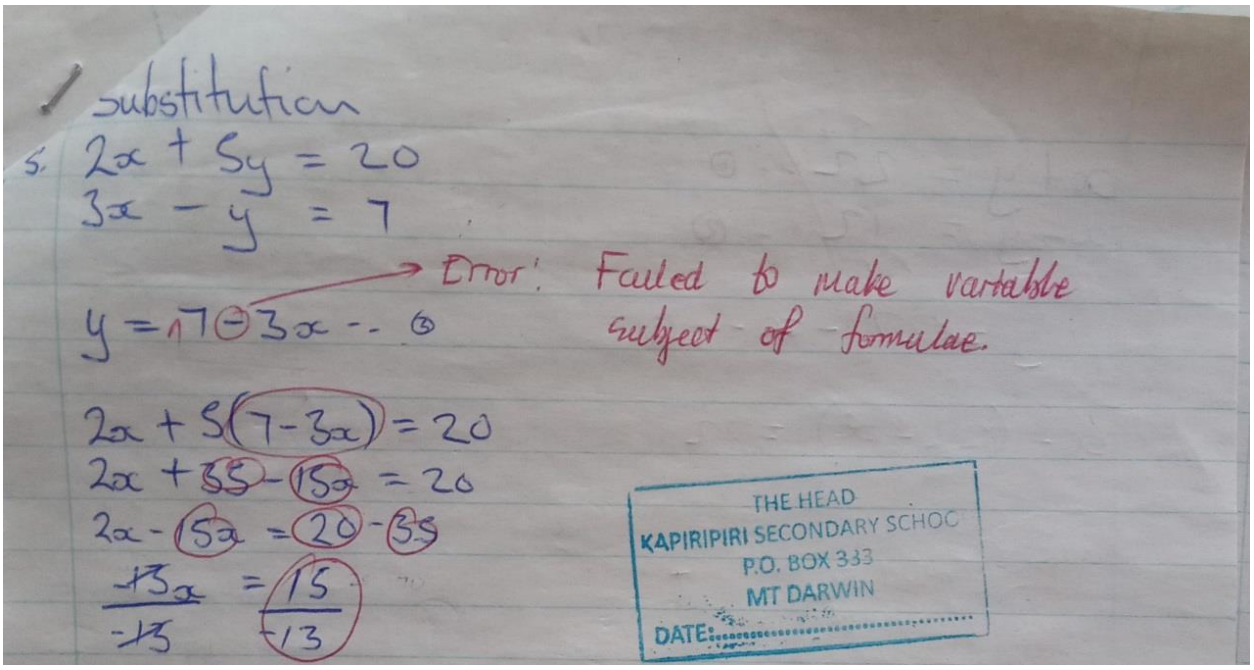
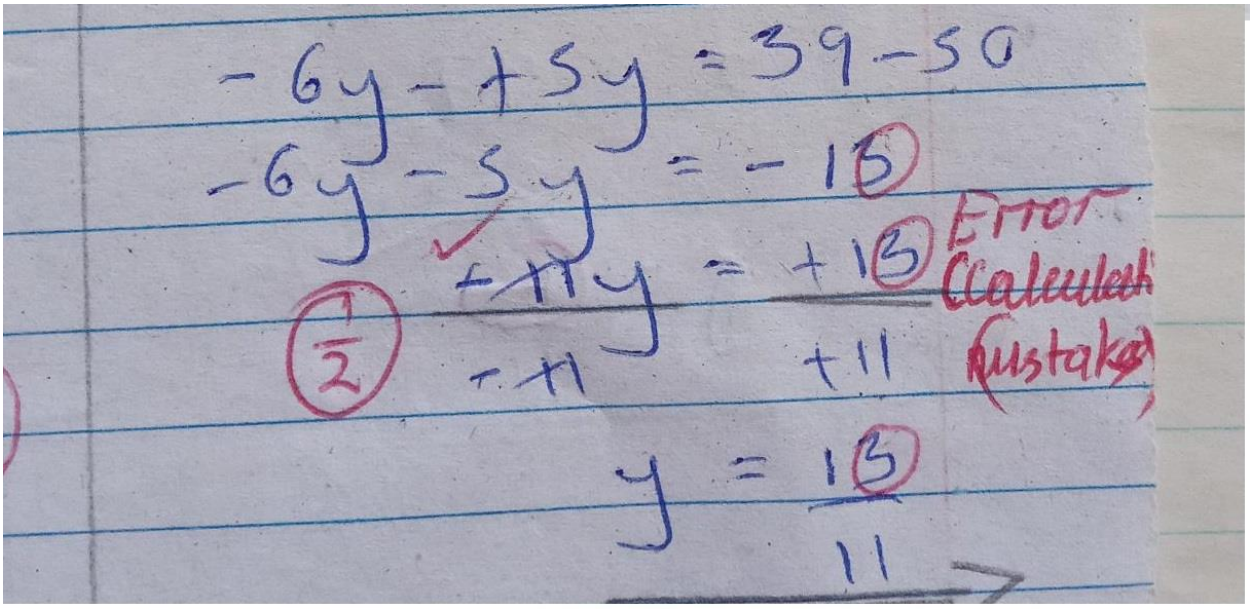


Figure 6d above shows an error of failing to make variable subject of formula. Several learners showed this error in their pre-test marked scripts. The findings are also supported by Mudavanhu et al (2023) where they clearly outline the existence of such type of Error in learners when solving simultaneous linear equations Hsu and Hwang (2021) are of the view that many learners struggle with isolating a variable or making it the subject of the formula. This inability can lead to confusion and errors in subsequent steps when solving equations as evidenced in the error above.

Figure 6e Fig showing an error of calculation mistakes



In the above figure a learner showed calculation mistakes where a learner failed to subtract 50 from 39. The learner mistakenly got -13 instead of -11 These arithmetic errors is one of the errors pointed out by Anwar and Hussain (2020). They said these arithmetic mistakes are prevalent, particularly during the addition or subtraction of terms. In other words, learners will fail to eliminate a variable when using elimination method. Such errors can lead to incorrect solutions that are based on faulty calculations.

4.1.3: A combined collection of pre-test and post-test data

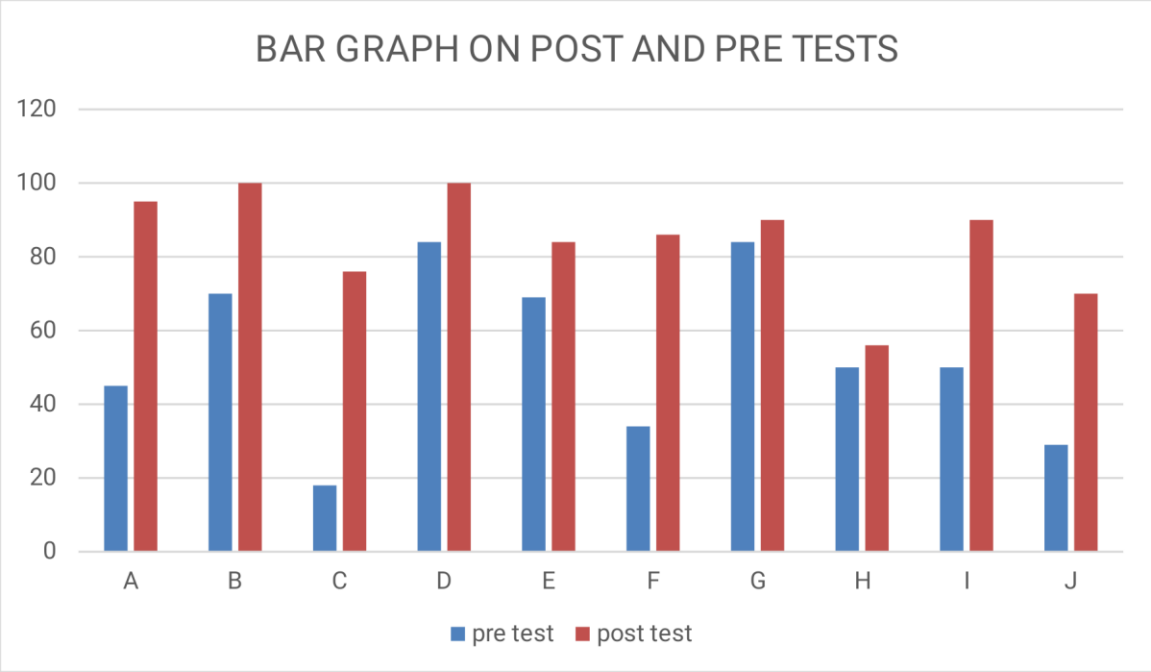
Data collected from pre-test and post-test was presented in the form of a table. It was also presented on the bar graph to ascertain a comprehensive comparison on the students' performance. The findings are shown in table 4.3 and figure 4.2 below.

Figure 7 showing learners' marks in the pre-test and post-test

Student	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Pre-test (%)	44	71	17	83	69	33	83	50	50	29
Post-test (%)	96	100	76	100	84	86	90	56	90	70

Figure 7 showing a comprehensive comparison of each student's marks in both pre-test and post-test

The results from the study as shown in figure 7 above indicate a significant improvement in students' performance after the implementation of learner-centered approaches and the use of focus groups and peer tutoring. The results show that learner-centered approaches typically foster engagement among students. By allowing them to take an active role in their learning, students may feel more motivated and interested in their academics. Baird and O'Connell (2021) say the improvement in post-test results in a research serve as evidence that pedagogical techniques tailored to student involvement yield positive outcomes. Hence learner-centered approaches, focus groups and peer tutoring are contributing factors to learners' improvement in post-test. Fadel and Lemke (2020) further support that focus groups specially support foster collaboration and peer learning, allowing students articulate their understanding and clarify errors as evidenced in the reduction of errors in post-test results.



The bar graph above illustrating the pre-test and post-test scores of ten students highlights a significant improvement in performance following the implementation of learner-centered approaches and focus groups. The stark contrasts between the pre-test scores, which were notably low, and the post-test scores indicates a positive shift in students' understanding and retention of material. This result not only demonstrates that the strategies employed were effective but also underscores the potential for meaningful learning transformations in a relatively short period. Hasegawa and Olivares (2022) support the effective use of focus groups as one of the strategies that educators can employ to minimize errors in learners. Under this investigation, the researcher selected participants into three small manageable groups of three participants from each group and the third group consisted of four participants. The researcher then created a discussion guide in form of questions.

Questions included were:

a) Which teaching strategies are more effective?

b) Is peer tutoring beneficial to most learners?

c). Are traditional teaching methods a contributing factor to the existence of errors in learners?

d). How has focus group affected your understanding of simultaneous linear equations?

After formulating the above questions, the researcher facilitated the discussion from each group while recording the learners' responses in form of themes as shown on figure 8 below.

4.1.4: Presentation of data collected from focus groups by learners

Data collected from focus groups was presented in the form of the table. Since the researcher asked learners some questions during the group discussions, learners' responses were coded based on the questions asked. Codes and themes were formulated based on responses which occurred most. Below is a table of findings from focus groups.

Figure 5 showing data collected from focus groups by learners

Theme based on question asked	Possible Frequency outcomes	Actual Frequency outcomes	Percentage Frequency (%)
Learner centered approaches are more effective than traditional teaching methods	10	10	100
Instructional methods have a positive impact on learners' grasping of concepts	10	7	70
Traditional teaching methods contribute significantly to the existence of errors in learners	10	10	100
Peer interaction is beneficial to most learners	10	8	80

The above data shows that most learners support the use of learner-centered approaches to reduce errors and misconceptions in learners. The overall appreciation expressed by the students that learner-centered approaches effectively engage them in the learning process. This aligns with research suggesting that such approaches promote higher levels of student motivation and involvement, leading to enhanced learning experiences. A study by Prince (2021) emphasizes that learner-centered approaches lead to increased engagement and can significantly reduce errors and misconceptions that students may develop through traditional instructional methods.

Some pictures below show learners interacting in their focus group.

Figure 6 Pictures showing learners in their focus groups

In addition, students in their focus groups blamed traditional teaching methods. The students' conclusions that traditional teaching methods contribute to errors in learning reflects a growing body of literature that critiques these methods for being overly focused on rote memorization and passive reception of information. Traditional methods typically do not accommodate diverse learning styles, which can hinder some students' understanding. A systematic review by Alavi and Leidner (2020) highlighted that traditional teaching methods often fail to provide the deep learning experiences necessary for transferring knowledge to new contexts, which aligns with the students' observations of errors stemming from such practices. On the other hand, Gokhale (2020) says peer tutoring and collaborative learning environments have been shown to improve not only academic performance but also interpersonal skills, making learning a more holistic experience.

4.2 Data analysis

Data collected was analyzed using descriptive statistics, quantitative analysis technique and qualitative analysis technique.

4.2.1: Comparisons of the pre-test and post-test

The researcher gave learners a pre-test before interventions. After intervention, the researcher then gave learners a post-test to find out if the interventions employed were effective.

Measures of central tendency and dispersion were used to analyze data collected from pre-test and post-test after the researcher's intervention methods for the post test. After the researcher noted errors in the pre-test, learner centered approaches were employed before the administration of the post-test. Learner centered approaches used include focus groups and peer tutoring. Cognitive Load Theory, Constructivism theory and Error analysis theory were part of interventions used for the post-test. The results from pre-test and post-test were gathered and recorded. The mean, median, mode, range and standard deviation of both pre-test and post-test were calculated and used to analyze data as below.

a) Mean for pre-test

(44+71+17+83+69+33+83+50+50+29)/10

=529/10

=52.9

Mean for post-test

(96+100+76+100+84+86+90+56+90+70)/10

=848/10

=84.8

I) Mean improvement

Pre-test mean = 52.9

Post-test mean = 84.8

Improvement = 84.8 - 52.9

=31.9

The increase in mean score indicates a substantial overall improvement in learner performance from pre-test to the post-test. This shows that pedagogical approaches employed during intervention are more effective in reducing errors and misconceptions in learners.

b) Median for pre-test

Ordered scores: 17,29,33,44,50,50,69,71,83,83

Median= (50+50)/2

=50

Median for post test

Ordered scores

56,70,76,84,86,90,90,96,100,100

Median = (86+90)/2

=88

Median improvement

Pre-test Median = 50

Post-test Median = 88

Improvement = 88 - 50

=38

The rise in median also signifies a shift in the center of the distribution towards higher performance, suggesting that more learners scored closer to the higher end of the scale in the post-test.

c) Mode for pre-test

The modes are 50 and 83. (Multimodal data)

Mode for post-test

Modes are 90 and 100 (Multimodal data)

The change in modes reflects a shift in the most frequently occurring scores. The pre-test modes of 50 and 83 are much lower than those of the post-test, indicating that high scores (90 and 100) emerged as common results. This shows an improvement in learners' performance in the post-test as compared to pre-test.

d) Range for pre-test

Range =maximum-minimum

=83-17

=66

Range for post-test

Range =Maximum-minimum

=100-56

=44

A decrease in range suggests a reduction in score variability among learners in the post-test. This means the scores clustered more closely together, possibly indicating that learners performed uniformly at a high level. Hence there was an improvement in learners' performance in post-test as compared to pre-test.

e) Standard deviation for pre-test

It is given by the square root of the summation of the difference of each score from the mean squared

= 22.9

Standard deviation for post-test= 14.02

The decrease in Standard deviation shows that the scores are clustered more closely around the mean of post intervention meaning to say learners performed better in post-test than in pre-test.

4.2.2 Conclusion of the findings from pre-test and post-test

The data indicates a clear improvement in learners' performance from the pre-test to the post-test, showcased by increasing mean, median and modes, alongside reduced range and standard deviation. These trends suggest that the interventions or teaching methods employed between the tests effectively helped the learners enhance their understanding and performance in solving simultaneous linear equations.

4.3 Qualitative data analysis for data collected from focus groups

Data collected from focus groups was analyzed using thematic qualitative data analysis technique. Themes were formulated based on the responses to questions asked by the researcher. Below are themes and their responses from the students

4.3.1 Effectiveness of learner-centered approaches

Most learners expressed agreement that learner-centered approaches were more effective than traditional teacher centered approaches. They highlighted that these methods allowed them to actively engage in problem-solving and fostered a deeper understanding of concepts.

Quote example: *When we worked together, I felt like I understood the equations better because we could explain things to each other,* said student D.

4.3.2 Impact of instructional methods on understanding the concepts

Most learners identified collaborative learning, hands-on activities, and guided discovery as the instructional methods that significantly help them grasp simultaneous linear equations. They appreciated the opportunity to explore problems collaboratively rather than passively receiving information.

Quote example: *Working in groups helped me see different ways to solve the same equation,* said student B.

4.3.3 Causes of Errors in problem-solving

Learners noted several factors contributing to their errors including a lack of foundational knowledge, misinterpretation of questions and anxiety during assessments. Most blamed the

traditional methods as key factors contributing to them exhibiting errors in problem-solving. More than 70% of learners attributed their previous misconceptions to insufficient guidance and practice.

Quote example *I often incorrectly applied the substitution or elimination method because I had no foundational knowledge,* said student G. These traditional methods, often characterized by lecture-based instruction, rote memorization, and a one-size-fits-all approach, can have several negative effects on learners particularly when solving simultaneous linear equations. There is limited engagement and motivation. According to Bhuasiri et al (2022) this passive learning can lead to decreased motivation and interest in mathematics. Research by Abed et al (2022) emphasizes that students exposed to traditional approaches may experience Mathematics anxiety, which affects their confidence in tackling challenges like simultaneous linear equations. In addition, these traditional teaching methods may not cater to diverse learning styles and paces, leaving some students behind. According to Cheung and Wong (2022), this can create disparities in understanding and performance among students, particularly in collaborative problem-solving scenarios.

4.3.4 Value of peer interaction in learning

Peer interactions were deemed beneficial by all participants. They reported that discussions with classmates clarified doubts and provided alternative perspectives on problem-solving approaches. Thus, collaborations were seen as a crucial factor in reducing misconceptions. **Quote example** *Talking to my group mates helped me see where I was going wrong. It boosted my confidence,* said student D.

Conclusions of findings from focus groups

The analysis of focus group data indicates a clear preference for learner-centered approaches, highlighting their effectiveness in promoting understanding of simultaneous linear equations. The study reviews that collaborative learning and peer interactions significantly contribute to reducing errors and misconceptions. These findings suggest that incorporating more interactive and student-centered methods could enhance learning outcomes.

4.4 Analysis of data using inferential statistics technique

The selected ten learners were given both the pre-test and post-test as a way of gathering data. Post-test was given after the researcher' interventions of employing learner-centered approaches to the learners.

Data collected from pre-test and post-test were also analyzed using the inferential statistics technique (hypothesis testing). This was done to find out if there was a significant difference in learners' performance after the researcher's interventions. The researcher used the paired t-tests as the researcher had two related samples (students' scores before and after intervention).

4.4.1 Hypothesis Testing (two tail paired t-tests)

Hypothesis testing is a statistical procedure used to make decisions or inferences about population parameters based on sample data (Freeman et al, 2020). The researcher chose this hypothesis testing due to its advantages. It is useful in evaluation of intervention effectiveness (Hattie, 2020; Freeman et al., 2020). It provides a structured method to quantitatively assess whether an intervention (like leaner centered approaches) led to significant improvement in learning outcomes. In addition, a two tailed hypothesis allows researchers to assess both directions of effect-whether post test scores are significantly higher or lower than pre-test scores, providing a comprehensive view of learner performance. According to GeeksforGeeks (2020), hypothesis testing establishes statistical significance. By using hypothesis testing, researchers can determine if the observed changes in test scores are due to the intervention rather than random chance. This leads to more robust conclusions about the effectiveness of the interventions. Hypothesis testing involves formulating two competing hypotheses:

Null hypothesis (H0): This represents a statement of no effect or no difference. It serves as a default position that there is no relationship or that a particular treatment has no effect. In this research the researcher formulated this null hypothesis as: There is no significant difference in performance before and after intervention (mean difference =0)

Alternative hypothesis (H1): This statement suggests that there is an effect, a difference or a relationship between variables. The researcher formulated this alternative hypothesis as: There is a significant difference in performance before and after the intervention (mean difference is not equal 0). After formulating the null and alternative hypotheses, the researcher chose 0.05 as the

significance level. The researcher then gathered data as shown on the table below. The data was then used to calculate the t-calculated and the t-critical values.

Significant level = 5%

Rejection criteria: After calculating the t-calculated and the t-critical values, we reject H0 if t-calculated value is greater than t-critical value.

Figure 7 showing Data obtained from pre-test and post-test

Student	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Pre-test	**44**	**71**	**17**	**83**	**69**	**33**	**83**	**50**	**50**	**29**
Post-test	**96**	**100**	**76**	**100**	**84**	**86**	**90**	**56**	**90**	**70**
Post -pre (d)	**52**	**29**	**59**	**17**	**15**	**53**	**7**	**6**	**40**	**41**
Mean	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**	**31.9**
Score-mean	**20.1**	**-2.9**	**27.1**	**-14.9**	**-16.9**	**21.1**	**-24.9**	**-25.9**	**8.1**	**9.1**
(d)^2	**404.01**	**8.41**	**734.4**	**222.01**	**285.61**	**445.21**	**620.01**	**670.81**	**65.61**	**82.81**

Mean of differences

(52+29+59+17+15+53+7+6+40+41)/10

=319/10

=31.9

Standard deviation = 19.83

T calculated value = 5.1

T critical value = 2.262(from t value tables)

Conclusion

Since t calculated value (5.1) > t critical value (2.262), we reject the null hypothesis (H0) and conclude that there is significant difference in performance before and after the intervention at the 5% significant level.

Justification of the results from the hypothesis testing

Based on the scenario where learners showed improvement in their post-test scores following the implementation of learner-centered approaches and considering error analysis theory alongside cognitive load theory and constructivism theory, several conclusions and remarks can be made. The hypothesis testing results indicate a significant difference between pre-test and post-test scores. It can be concluded that the intervention was effective in enhancing students learning outcomes. The positive changes in learner performance can be attributed to the application of learner-centered approaches, which focused on active engagement, fostering deeper understanding and retention of knowledge (Freeman et al, 2020). In supporting the above findings, Hattie (2020) says the observed improvements can be attributed to the engagement and active participation encouraged by learner-centered approaches, which have been shown to facilitate deeper learning and critical thinking skills among students. This also aligns with the literature indicating that active learning strategies foster better understanding and retention of material, ultimately leading to improved academic performance (Hattie, 2020; Freeman et al., 2020)

In essence, the integration of effective teaching methodologies (learner-centered) informed by theory not only enhances immediate learning outcomes but also supports lasting educational improvements.

4.5: Summary

In this chapter, the researcher explored the findings from an investigation into errors and misconceptions faced by learners at the Ordinary level when solving simultaneous linear equations. Utilizing a mixed-methods approach, the researcher gathered data through questionnaires, pre-tests, post-tests, and focus group discussions. This comprehensive data collection allowed for a nuanced understanding of student challenges and misconceptions.

The results were systematically presented through tables, charts, and bar graphs, illustrating key patterns and trends. The researcher’s analysis employed both quantitative and qualitative

techniques, enabling him to capture the breadth of student experiences and the depth of their understanding. Key findings reveal that learner-centered methods and collaborative focus groups significantly enhance students' comprehension of simultaneous linear equations. Students who participated in focus groups demonstrated a notable improvement in their problem-solving abilities, as indicated by their post-test scores compared to the pre-test results. The qualitative data from focus group discussions further highlighted that peer interaction played a crucial role in clarifying concepts and reducing misconceptions. Descriptive statistics were also employed where the researcher calculated measures of central tendency for both pre-test and post-test marks. These mean, mode, median, standard deviation and the range were used to compare the marks for both pre-test and post-test. The results show that learners performed better in post-test than in pre-test. Findings also reveal that traditional teaching methods are a contributing factor to the exhibition of errors and misconceptions in learners when solving simultaneous linear equations.

Overally, this chapter underscores the importance of adopting interactive teaching strategies. The evidence suggests that engaging students in collaborative learning environments can effectively address common errors and foster a deeper understanding of mathematical concepts. These insights not only contribute to the existing literature on mathematics education but also suggest practical implications for educators seeking to improve instructional practices in solving simultaneous linear equations.

CHAPTER 5

Summary, Discussions, Conclusion and Recommendations

5.1 Introduction

In this chapter, the researcher presents a comprehensive overview of the research conducted on the errors and misconceptions learners experience when solving simultaneous linear equations at the Ordinary level. The findings from this investigation are crucial for understanding the underlying challenges faced by students in mastering this fundamental mathematical concept.

The chapter begins with a summary of findings, which encapsulates the key results derived from the data collection, including pre-test and post-test evaluations, focus group. Following the summary, the researcher will also give a thorough discussion, highlighting the effectiveness of teacher-centered approaches, focus groups, and peer tutoring in addressing the identified misconceptions based on the findings obtained from the research instruments used to gather data. This chapter will provide a succinct conclusion that reiterates the significance of the research findings and their contribution to the field of mathematics education. The researcher will also provide recommendations for educators and future researchers, suggesting strategies to enhance teaching practices and further areas of study that could build upon our findings.

Finally, this chapter will include a list of references cited throughout the research, along with appendices that contain supplementary materials, such as the instruments used and additional data analyses. This structured approach aims to ensure that the insights gained from this research are both actionable and informative for stakeholders in mathematics education.

5.2 Summary of Findings

Below are the findings of a study on examining errors and misconceptions that learners face when solving simultaneous linear equations at the Ordinary level. The research utilized multiple data collection methods, including questionnaires, pre-tests, post-tests, and focus group

discussions. As a result, a summary of findings from each instrument will be given separately below.

5.2.1 Summary of findings from Questionnaires

The analysis of questionnaires revealed that learners commonly encounter errors in solving simultaneous linear equations. Key insights include:

Prevalent errors were noted. Questionnaire respondents (eleven selected mathematics teachers) noted that learners frequently made mistakes in basic algebraic processes, such as simplification and sign management. Methodological confusion (incorrect application of method) was the major error noted by mathematics teachers with highest frequency as shown on figure 3. Many students struggled to choose the correct method (substitution vs. elimination), which often led to incorrect solutions. In addition, misinterpretation of problems was also noted. A significant number of learners misinterpreted the problems, resulting in poorly set-up equations, especially on questions involving word problems. Learners also exhibited errors on sign handling. The majority also failed to make variables subject of formula which resulted in errors. These findings indicate that foundational misconceptions play a critical role in hindering learners' problem-solving abilities.

5.2.2 Summary of Pre-Test Results

The findings from the pre-test, administered to 10 participants, confirmed most of the issues identified in the questionnaires: There were error patterns in learners. Most participants exhibited a range of errors, reflecting a lack of understanding and confidence in solving simultaneous equations. The common error with the highest frequencies was sign handling. Ineffective application of knowledge, calculation mistakes and failing to make variables subject of formula were part of errors identified. Participants struggled to effectively apply their knowledge to practical problems, indicating a gap between theoretical understanding and practical execution. This suggests an urgent need for targeted instructional strategies to address these challenges.

5.2.3 Summary of Post-Test Outcomes

Post-test results indicated a significant improvement among the same group of learners following researcher's interventions:

There was a reduction in errors. There was a marked decrease in errors, demonstrating that learners had gained a better understanding of the content. There were also improved problem-solving skills. Students displayed enhanced abilities in applying various methods correctly, leading to more accurate solutions. Mean improvement, median improvement, decrease in the range and decrease in standard deviation shows a significant improvement in the post test.

These outcomes highlight the effectiveness of targeted teaching interventions in addressing prior misconceptions and errors.

5.2.4 Summary of Findings on Focus Group Discussions

Focus group discussions provided deeper insights into learners' preferences regarding teaching methods. Preference for student-centered approaches were highlighted during focus groups. The majority of learners expressed a strong preference for student-centered methods, such as group work and interactive learning, which they found to be more engaging and effective. Learners blamed lack of foundational knowledge as a key factor contributing to their errors. Traditional teaching methods were also to blame by learners. Most learners valued peer interaction and instructional methods in learning. Few learners advocated for the need for practical applications. Learners emphasized the importance of connecting mathematical concepts to real-world scenarios, which they felt improved understanding and retention. This feedback underscores the necessity of adopting teaching strategies that align with learners' preferences to foster a more effective learning environment.

The findings from this research reveal that learners struggle with significant errors and misconceptions when solving simultaneous linear equations. However, the implementation of focused teacher interventions can lead to notable improvements in learners' problem-solving abilities. Additionally, incorporating student-centered teaching methods can enhance engagement and understanding. Future instructional practices should prioritize these strategies to further reduce errors and support learner success. Discussions, and insights from mathematics teachers.

5.3 Discussion of Findings

The findings from the research investigating errors and misconceptions in learners when solving simultaneous linear equations reveal a significant improvement in student performance from the pre-test to the post-test. This improvement underscores the effectiveness of learner-centered approaches, focus groups, and peer tutoring in reducing errors in solving simultaneous linear equations at Ordinary level.

5.3.1 Improvement in Performance

The data collected during the study indicated that students demonstrated a marked increase in their understanding and application of simultaneous linear equations after engaging in targeted instructional strategies. The pre-test results highlighted prevalent misconceptions and errors, which were effectively addressed through the implementation of learner-centered methodologies. The post-test results showed that students not only retained the information better but also applied it more accurately in problem-solving scenarios.

5.3.2 Effectiveness of Learner-Centered Approaches

Learner-centered approaches emphasize active participation and engagement, allowing students to take ownership of their learning. Research has consistently shown that such approaches lead to deeper understanding and retention of mathematical concepts. For instance, a study by Johnson and Wang, (2018) found that student-centered learning environments significantly enhance student achievement in mathematics. By focusing on the learners' needs and encouraging them to explore concepts collaboratively, these approaches help to clarify misunderstandings and foster a more profound grasp of algebraic principles. In contrast traditional teaching methods proved to be the root cause of learners' errors and misconceptions in solving simultaneous linear equations. Mawarire and Chirume (2020) support the above view saying most educators prefer traditional teaching methods (teacher centered approaches) which are a contributing factor to poor performance by learners in schools.

5.3.3 Role of Focus Groups

Focus groups played a crucial role in identifying specific errors and misconceptions among students. By facilitating discussions, educators were able to pinpoint common areas of confusion and tailor their instruction accordingly. This collaborative environment not only allowed students to express their thought processes but also encouraged peer learning, which has been shown to enhance understanding in mathematics (Johnson and Wang, 2018). The findings suggest that when students articulate their reasoning and engage in dialogue with peers, they are more likely to confront and rectify their misconceptions.

5.3 4 Impact of Peer Tutoring

Peer tutoring emerged as a particularly effective strategy in the study. The findings indicated that students who participated in peer tutoring sessions showed greater improvement in their ability to solve simultaneous linear equations compared to those who did not. Research supports this, indicating that peer tutoring not only reinforces the tutor's understanding but also provides the tutee with alternative explanations that can clarify complex concepts (Patel and Chen 2021). This reciprocal teaching model fosters a supportive learning environment where students can learn from one another, thereby reducing errors in algebraic concepts.

In summary, the findings from this research highlight the effectiveness of learner-centered approaches, focus groups, and peer tutoring in improving student performance in solving simultaneous linear equations. The significant improvement observed in the post-test results compared to the pre-test underscores the importance of these instructional strategies in addressing errors and misconceptions in algebra. By fostering an engaging and collaborative learning environment, educators can enhance students' understanding and mastery of mathematical concepts.

5.4 Conclusion

In conclusion, the investigation into errors and misconceptions in learners when solving simultaneous linear equations at the Ordinary level highlights the superiority of learner-centered methods in fostering conceptual understanding. The findings underscore the importance of Error analysis theory, Constructivism theory and Cognitive Load theory in mitigating mistakes,

suggesting that a deeper awareness of these theories can significantly enhance learning outcomes. Furthermore, the study reveals that traditional pedagogical approaches contribute to persistent errors, emphasizing the need for educators to adopt more effective, student-focused teaching strategies. By prioritizing these methods, we can better support learners in overcoming challenges in mathematics especially under this concept of research. Therefore, without any hesitation and doubt, the researcher can conclude that if well implemented, learner-centered approaches, accompanied by error analysis theories can unpack and reduce errors and misconceptions learners have in solving simultaneous linear equations.

5.5 Recommendations

Based on the outcomes of this research, the researcher can make the following recommendations:

5.5.1 Adoption of learner-centered pedagogies.

Educators should implement learner-centered teaching strategies, such as collaborative problem-solving and inquiry-based learning, and focus groups to enhance students' understanding of simultaneous linear equations. These methods encourage active participation and facilitate deeper conceptual grasp.

5.5.2 Integrate Error Analysis in Teaching

It is critical to incorporate error theory into the curriculum to help students recognize, analyze, and learn from their mistakes. Workshops or sessions focused on common errors can empower learners to develop strategies for avoiding similar misconceptions in the future.

5.5.3 Professional Development for Educators

The Ministry of Primary and Secondary Education in conjunction with relevant stakeholders should provide ongoing training for teachers on effective pedagogical practices and learner-centered approaches. This professional development should also emphasize the importance of understanding and addressing students' misconceptions.

5.5.4 Utilize Technology and Interactive Tools

Since this research was carried out in rural areas where technological tools for supporting learning are scarce resources, the researcher therefore recommends employment of educational technologies and interactive resources that allow students to visualize and manipulate equations. Tools such as graphing calculators or online simulations can enhance engagement and understanding of the concepts involved in solving simultaneous linear equations.

5.5.5 Continuous Assessment and Feedback

Recommendation on implementing regular formative assessments to gauge student understanding and misconceptions is hereby made. Providing timely, constructive feedback by educators will help learners identify areas for improvement and reinforce their understanding of the material.

5.5.6 Further studies

Since this research was mainly based on errors and misconceptions in learners when solving simultaneous linear equations at Ordinary level, the researcher recommends further research at different levels under different concepts. Further research on this concept can be done using graphical and matrix methods since this research centered on elimination and substitution methods only. Varying methods help learners to tackle the same problems from different angles.

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Appendix A: Questionnaire for Mathematics educators

Introduction

I am Chidimu Tendai doing my studies at Bindura University. I am currently doing my research in mathematics where I am gathering information to come up with my research. This questionnaire will help me to gather data. Privacy and confidentiality will be taken into consideration. No need to write your names since I will use codes instead of real names. Your responses will be used for the purpose of this research only.

Choose your answer by ticking/circling your answer

1. What is your gender? Male/Female
2. Are you a Mathematics teacher? Yes/No
3. Which level do you teach? O level/A level
4. What is your experience in teaching mathematics at your current level?

   2 years and below/ Above 2years

5.	Are you experiencing dropouts in mathematics at your current school?	Yes	No
6.	Have ever experienced lack of interest and negative attitudes towards Mathematics by your learners?	Yes	No
7.	Some research done before show that some learners tend to develop deviant behaviors when it comes to teaching and learning of mathematical concepts especially simultaneous linear equations. Do you agree?	Yes	No
8.	According to your experience, which teaching methods are more effective for learners to grasp mathematical concepts?	Leaner centered methods	Teacher centered methods
9	Did you experience some errors and misconceptions in your learners when solving simultaneous linear equations?	Yes	No
10.	Are these errors affecting learners' performance at their assessment tests?	Yes	No

11. If your answer is **yes,** on question 9, state any common errors and misconceptions you noticed in your learners when solving simultaneous linear equations

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

12. Leaners should attempt questions on simultaneous in their examinations. What are your views?

Strongly agree b. agree c. disagree d. strongly disagree

13. What challenges have you come across in the teaching of simultaneous linear equations?

_____

_____

_____

_____

_____

_____

14. What are your suggestions that teachers can adopt to improve learners' performance in the learning of Mathematical concepts especially simultaneous equations?

_____

_____

_____

_____

Conclusion

Thank you so much for the time you spared to complete my questionnaire based on your teaching experience. I believe and understand that your contribution to my research will help me to produce authentic research.

Appendix B: Pre-Test wrote by learners

KAPIRIPIRI SECONDARY SCHOOL

PRE-TEST FOR FORM 4

TOPIC: ALGEBRA

DATE: 04/07/24

Instructions

Answer all questions

Solve the following simultaneous linear equations using either a) elimination or b) substitution methods

1. $2x + 3y = 12$.
   $3x + y = 10$.

2. $5x - 2y = 13$
   $3x + y = 10$

3. $x + 2y = 8$.
   $-2x + y = 7$.

4. $-4x - 3y = 11$
   $2x + y = 7$

5. $2x + 5y = 20$.
   $3x - y = 7$

6. The difference of two numbers is 12. Their sum is 22. What are the numbers?

Appendix C: Post Test wrote by learners

KAPIRIPIRI SECONDARY SCHOOL

POST TEST FOR FORM 4

TOPIC: ALGEBRA

DATE: 12/07/24

Answer all questions.

Use either elimination or substitution method to solve the following simultaneous linear equations

1. $4x - 3y = 11$.
   $2x + y = 7$.

2). $5m - 2n = 8$
   $3m + n = 13$

3). $y = 3x$.
   $3y - x = 0$.

4). $r - 2s = ½$
   $3r + s = 5$

5). $2z + 3y + 8 = 0$
   $z + y + 3 = 0$

6. The sum of two numbers, r and s is 20, and their difference is 3. Find the two numbers. (Hint: Take r as the bigger number and s be the smaller number).

Appendix D: Questions asked during focus groups

FOCUS GROUPS

Below are the questions asked by the researcher to participants during focus groups by the participants.

1. Peer influence: Did you benefit from group discussions with your peers?

a. Agree. b. Strongly agrees. c. Disagree. d. Strongly disagrees

2. **Problem solving strategies:** When solving simultaneous linear equations what methods do you typically use? Have you encountered any specific methods that seem to lead to mistakes?

3. **Understanding the concepts:** What do you find more challenging about the concept involved in simultaneous linear equations? Can you describe any specific terms or ideas that confuse you?

4. **Error identification:** Did you make some errors before when solving simultaneous linear equations? What do you think led to those errors or mistakes?

5. **Instructional support:** What type of support or instructional methods have helped you understand the concept of solving simultaneous linear equations?

6. Leaner centered methods are more effective than teacher centered approaches when solving simultaneous linear equations. Do you agree?

a. Agree. b. Strongly agree c. Disagree. d. Strongly disagrees

Appendix E: Photos captured during focus groups

SAMED

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Tel: 0271 - 7531 ext 1038
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BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: 12-12-2024

TO WHOM IT MAY CONCERN

NAME: CHIDIMU TENDAI REGISTRATION NUMBER: B225986A

PROGRAMME: HBScEd Mathematics PART: 22

This memo serves to confirm that the above is a bona fide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present a Research Project in partial fulfillment of the HBScEd Mathematics programme. The research topic is:

Investigating errors and misconceptions in learners when solving simultaneous linear equations at Ordinary Level. A case study of a secondary school in Mt Darwin District.

In this regard, the department kindly requests your permission to allow the student to carry out his/her research in your institutions.

Your co-operation and assistance is greatly appreciated.

Thank you

BINDURA UNIVERSITY OF SCIENCE EDUCATION
DEPARTMENT OF EDUCATIONAL FOUNDATIONS
OCT 2024
P. BAG 1020
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Z Ndemo (Dr.)
CHAIRPERSON - SAMED