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Application of Mathematical Modelling in the Teaching and Learning of College Engineering Mathematics. A case study of Mutare Polytechnic College.

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DEDICATION

I dedicate this project to my husband, Engineer Patrick Muropa and my four beautiful daughters Blessing, Primrose, Tafadzwa and Mikayla.

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ABSTRACT

This study investigated the application of mathematical modelling in the teaching and learning of Engineering Mathematics at Mutare Polytechnic. The role of mathematical modelling in Engineering education is fundamental. The main aim of the study was to evaluate its integration within the Engineering ccurriculum, its effectiveness in enhancing student understanding and engagement, and to identify challenges and opportunities for applicability as teaching strategy in Engineering Mathematics. The study employed a mixed-methods approach. Data was collected through surveys and interviews from three (3) departmental lecturers and twenty-five (25) students, and conducting a thorough analysis of course materials. The study approach included both quantitative and qualitative components to provide a comprehensive overview of the current state of mathematical modelling in the Engineering curriculum. It emerged that mathematical modelling was inconsistently applied across Engineering Mathematics course. Practical applications and problem-solving exercises with potential of using mathematical modelling to enhance student understanding and retention of complex mathematical concepts were minimal. The challenges of incorporating mathematical modelling in Engineering Mathematics were indicated as inadequate resources, limited real-world exposure, and negative attitudes towards Engineering Mathematics. Diversification of teaching methods, increasing use of real-world examples for mathematical modelling, improving access to e-resources and fostering a positive learning environment were recommended so as to enhance the effectiveness of the teaching process in Engineering Mathematics at Mutare Polytechnic. There was dire need a deeper appreciation for the role of mathematical modelling in Engineering Mathematics to prepare students better for industry demands and promoting innovations.

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CHAPTER 1

Introduction

1.1 Introduction

Mathematical modelling is a fundamental process in applied mathematics and engineering, involving the translation of real-life problems into mathematical form. According to Giordano et al. (2009), mathematical modelling is "the process of representing real-world situations through mathematical concepts and language to predict and understand phenomena." This transformation involves constructing mathematical equations and algorithms that mirror the behaviour and characteristics of the problem at hand. Mathematical modelling is the art of simplifying and abstracting complex real-world problems into a structured mathematical framework, allowing for analysis, simulation, and solution. It bridges the gap between theoretical mathematics and practical applications by providing a systematic approach to problem-solving. This chapter will focus on the background of the study, statement of the problem, research objectives, significance of study, delimitations, limitations as well as operational definition of key words of the research report on Application of mathematical modelling in the teaching and learning of college engineering mathematics.

Engineering Mathematics, is the application of mathematical methods and techniques to solve problems encountered in engineering. According to Kreyszig (2011), "Engineering Mathematics is a branch of applied mathematics concerning mathematical methods and techniques that are typically used in engineering and industry." It includes topics such as calculus, linear algebra, differential equations, probability, and statistics, among others. In simpler terms, Engineering Mathematics is the use of mathematical tools to address and solve engineering challenges. It combines theoretical mathematical principles with practical engineering applications, facilitating the understanding and innovation of engineering solutions.

Integrating mathematical modelling into the teaching of Engineering Mathematics is crucial for several reasons. Firstly, mathematical modelling encourages critical thinking and the development of problem-solving skills. By translating real-world problems into mathematical terms, students learn to approach complex issues both methodically and creatively. This process allows students to see the direct relevance of mathematical concepts in solving engineering problems, thereby making learning more meaningful and motivating. Moreover, the use of mathematical modelling often involves computational methods and tools, which are essential in modern engineering. Familiarity with these computational techniques enhances students' ability to handle large-scale and complex problems efficiently. Mathematical modelling frequently requires knowledge from various fields such as physics, computer science, and engineering, promoting an interdisciplinary approach to education. This interdisciplinary focus broadens students' perspectives and equips them with a versatile skill set.

Understanding how to model and solve real-world problems prepares students to contribute to innovation and research in engineering. They learn to develop new models and methods, advancing the field and addressing contemporary technological challenges. The integration of mathematical modelling in Engineering Mathematics education fosters a deeper understanding of mathematical concepts and their applications. It enhances critical thinking and problem-solving skills, preparing students for the complexities of modern engineering practice. This research aims to explore the effectiveness of integrating mathematical modelling into Engineering Mathematics education. By doing so, it hopes to contribute to improved educational strategies and outcomes in engineering mathematics courses, ultimately benefiting both students and the field of engineering as a whole.

1.2 Background to the Study

At prestigious institutions such as the Massachusetts Institute of Technology (MIT) in the USA, mathematical modelling is extensively used in engineering education to prepare students for real-world challenges. According to Mahajan (2010) and Dahle & Perez-Arriaga (2004), MIT's curriculum incorporates mathematical modelling across various engineering disciplines. Students engage in hands-on projects that require them to use mathematical models to solve complex problems, thus bridging theoretical knowledge with practical application (Magnanti & Ahuja, 1993).

Similarly, ETH Zurich, a leading global institution for engineering education, emphasizes mathematical modelling in its engineering mathematics courses and research. As noted on the university's website (https://ethz.ch/en.html), ETH Zurich fosters innovation and interdisciplinary collaboration through projects that involve mathematical modelling in areas such as robotics, energy systems, and structural engineering.

In Africa, universities are progressively integrating mathematical modelling into their engineering mathematics programs to address real-world challenges. The African Institute for Mathematical Sciences (AIMS) offers programs that heavily focus on mathematical modelling across various disciplines, including engineering (https://www.nexteinstein.org/aims-model/). This approach equips students with the skills to tackle practical problems in their respective fields.

Within South Africa, the University of Cape Town (UCT) and the University of Witwatersrand (Wits) are prominent examples of institutions that incorporate mathematical modelling into their engineering mathematics curricula. Bouta & Paraskeva (2013) highlight that UCT uses mathematical modelling to enhance students' understanding of engineering concepts and applications. Similarly, Wits emphasizes mathematical modelling to develop students' problem-solving abilities and analytical skills (https://www.wits.ac.za/).

In Zimbabwe, the University of Zimbabwe integrates mathematical modelling into its engineering mathematics curriculum to prepare students for the practical challenges they may encounter in their engineering careers.

Mutare Polytechnic College aims to emphasize the use of mathematical modelling in its engineering mathematics curriculum. This approach allows students to utilize mathematical models to analyse and design engineering systems across various disciplines, such as civil, mechanical, automotive, and electrical engineering. This practice aligns with both global and regional trends, where mathematical modelling is employed for designing, scaling up, process control, optimization, experimental design, and troubleshooting in engineering fields. By integrating these methodologies, students will gain essential skills to simulate and optimize the behaviour of structures, systems, and processes, effectively preparing them for successful careers in engineering.

1.3 Statement of the Problem

The conventional application of Mathematical modelling employed by the Zimbabwean colleges lack a comprehensive framework of assessing the importance of mathematical modelling in the teaching and learning of College Engineering Mathematics.

A case study of Mutare Polytechnic Ccollege was carried out to determine applicability of Mathematical modelling as a teaching strategy in Engineering Mathematics, the challenges and opportunities faced by students in comprehending complex concepts in the Engineering curriculum.

1.4 Research Objectives:

1. To develop guidelines for effectively integrating mathematical modelling into college engineering mathematics courses
2. To identify the current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College
3. To determine the challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College
4. To assess the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College

1.5 Research Questions

This study was guided by the following research questions:

1. What are the guidelines for effectively integrating mathematical modelling into college engineering mathematics courses?
2. What are the current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College?
3. What are the challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College?
4. What is the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College?

1.6 Significance of the Study:

By incorporating mathematical modelling into the curriculum, students can develop a deeper understanding of the underlying principles and improve their problem-solving skills. The beneficiaries of this study, particularly at Mutare Polytechnical college in Zimbabwe, include various stakeholders who can reap different benefits from the findings, which includes,

1.6.1 To the Students

Students can achieve better learning outcomes, enhanced problem-solving abilities, and a deeper conceptual grasp of engineering mathematics. Engaging in modelling activities helps them develop critical thinking skills, apply theoretical concepts to real-world issues, and gain confidence in addressing engineering challenges.

1.6.2 To the Educators

Educators can gain valuable insights into effective teaching strategies, curriculum development, and assessment methods that incorporate mathematical modelling. The study can offer evidence-based practices to enhance student engagement, improve learning experiences, and tailor instruction to foster a deeper understanding of engineering mathematics concepts.

1.6.3 To Institutions

Educational institutions can benefit from higher student retention rates, an enhanced academic reputation, and better alignment with industry needs. By incorporating modelling-based approaches in engineering mathematics education, institutions can attract high-quality students, foster interdisciplinary collaboration, and produce graduates with practical skills that are highly valued by employers.

1.6.4 To the Industry Partners

Industry partners can benefit from a workforce equipped with strong problem-solving abilities, analytical skills, and practical knowledge of mathematical modelling in engineering contexts. By supporting educational initiatives that emphasize modelling, industry partners can contribute to the development of a skilled workforce capable of addressing complex engineering challenges and driving innovation across various sectors.

1.6.5 To Policy Makers

Policymakers can gain valuable insights into improving STEM education, promoting innovation, and addressing skills gaps in the workforce. The study can inform policy decisions on curriculum reform, teacher professional development, investment in educational resources, and the promotion of STEM initiatives that emphasize mathematical modelling.

1.7 Delimitations

The study on applying mathematical modelling to improve conceptual understanding in engineering mathematics, specifically at Mutare Polytechnic, faces several limitations. Geographical constraints affect the depth of analysis and the feasibility of data collection and analysis. Additionally, the time available for conducting the study is a limiting factor.

The study is also delimited by its focus on the National Certificate in Civil Engineering mathematics courses, which allows for a more targeted examination of mathematical modelling applications within this specific educational context. Moreover, the study is confined to certain mathematical modelling techniques, which restricts the exploration to specific methods for assessing their effectiveness in enhancing conceptual understanding in engineering mathematics.

Language barriers further limit the study, as conducting research in multiple languages within educational settings can impede communication and data collection. Additionally, constraints related to resources, including funding, time, access to participants, and technological tools, further restrict the scope of the study.

1.8 Limitations

Several limitations impact this study on mathematical modelling in engineering mathematics at Mutare Polytechnic:

1. **Sample Size:** The study may involve a small sample due to limited resources for data collection. This could affect how well the findings can be generalized to a larger student population. Additionally, self-selection by participants might introduce bias, potentially skewing the sample. To address this, the researcher plans to use simple random sampling to give each student an equal chance of being chosen.
2. **Data Collection Methods:** The study may rely on self-reported data or subjective assessments, which could introduce response bias or measurement errors. Such biases might compromise the accuracy and validity of the findings. Additionally, the study might not fully account for contextual factors influencing student performance in engineering mathematics, such as cultural or socio-economic differences, which could limit the applicability of the results.
3. **Generalizability:** The findings may not extend beyond the specific context or population being studied. Limited external validity may restrict the broader applicability of the conclusions to other regions or educational systems.
4. **Time Constraints:** Time limitations may affect the duration and depth of data collection and analysis, potentially impacting the thoroughness and rigor of the study.

5. **Resource Constraints:** Limited funding, personnel, and technological resources could affect the implementation of the study, potentially restricting its scope and impacting the quality of the outcomes.

1.9 Definition of key terms

Mathematical modelling, Mathematics in Engineering, mathematical competencies, complex concepts.

1.9.1 Mathematical Modelling

According to Galbraith and Clatworthy (1990), mathematical modelling is defined as the implementation of mathematics in solving unstructured problems in real-life situations. In these modelling, mathematical approaches are used in finding solutions related to real-life problems, however, according to (Cheng, 2001) modelling is a real-life problem transformed into a mathematical problem and solved using mathematical techniques.

1.9.2 Mathematics in Engineering

Refer to mathematics as a service subject for engineering programs, usually taught by mathematicians, as well as mathematics as an integrated part of engineering sciences, where it constitutes specific practices with mathematics being more than just a language for engineers (Winsløw et al., 2018).

1.9.3 Mathematical competencies

Mathematical competence is the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role (Niss, 2003.)

1.9.4 Complex concepts

Complex concepts are elements used to translate phenomenon from various fields into mathematical language to predict and understand the behaviour of systems like the differential equations for modelling continuous systems, such as population dynamics, fluid flow, and mechanical systems (Braun M. 1993), Optimization which involves finding the best solution from a set of feasible solutions, often subject to constraints (Wright, S.J. 2006), etc.

1.10 Conclusion

This chapter explored the motivations behind the study, provided background on the research problems, and outlined the research statement. The next chapter will review the relevant literature related to the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, we delve into the existing body of knowledge surrounding the integration of mathematical modelling in engineering mathematics education. A comprehensive review of relevant literature is conducted to establish a foundation for understanding the current practices, benefits, and challenges associated with this educational approach. This chapter aims to provide context and background for the research, highlighting significant studies, theories, and methodologies that have contributed to the field.

Mathematical modelling is essential for addressing real-life problems and is widely used in the engineering field to tackle complex situations. Globally, it has become a fundamental element in engineering education. Many universities and colleges now incorporate mathematical modelling into their curricula to improve students' problem-solving abilities and better prepare them for real-world engineering challenges. Through mathematical modelling, students enhance their critical thinking and analytical skills, which are crucial for solving intricate engineering problems. This approach helps students apply mathematical theories to practical scenarios, making their education more relevant and applicable.

2.1.1 Related Literature

According to Graham (2018), there have been substantial changes in engineering education over the past decade, influencing mathematics education within engineering courses. Kaiser, Blomhøj, and Sriraman (2006) emphasize that mathematical modelling and information technology are key features in global mathematics curriculum reforms. Studies have shown that integrating mathematical modelling in engineering courses leads to better problem-solving skills, increased student engagement, and a deeper understanding of mathematical concepts.

This integration is particularly effective when combined with technology and computational tools, as it reflects the modern engineering landscape.

Regionally, educational reforms have emphasized the integration of mathematical modelling and computational tools in engineering education. This approach has led to improved student engagement and understanding of mathematical concepts. Competency-Based Education in Engineering courses are tailored to integrate mathematics directly into specific topics, enhancing the relevance and application of mathematical knowledge. The use of information technology and computational methods in mathematical modelling is a common feature in regional educational reforms, as noted by Kaiser, Blomhøj, and Sriraman (2006).

Nationally, there is a growing recognition of the need to integrate mathematical modelling into engineering education to address deficiencies in mathematics performance. Educational policies and curriculum reforms are being implemented to make mathematics more relevant and engaging for engineering students. Many countries have updated their engineering programs to incorporate mathematical modelling, which helps enhance students' mathematical skills and their application in engineering contexts. Governments and educational institutions are promoting competency-based education, integrating mathematics into engineering courses to improve understanding and performance.

At Mutare Polytechnic College, incorporating mathematical modelling into engineering mathematics courses could significantly enhance learning outcomes. By aligning with both global and national educational trends, the institution can improve the educational experience for students and better prepare them for the engineering profession. This approach addresses current issues with mathematics performance through innovative teaching methods and a curriculum that combines mathematics with practical engineering applications, making the education more relevant and effective.

2.1.2 Conceptual Framework

The conceptual framework for this research is based on the integration of mathematical modelling in engineering mathematics education, focusing on its impact on student learning outcomes. The framework considers the input component, which includes curriculum design, teaching methods, and resources (Smith & Johnson, 2021), then the processes component which is the use of mathematical modelling in classroom instruction, student engagement in problem-solving activities, and the application of computational tools (Brown & Lee, 2020). The output component which includes improved student performance, enhanced problem-solving skills, and better understanding of mathematical concepts (Miller et al., 2019). Then the outcome component, which is students' preparedness for real-world engineering challenges and their ability to apply mathematical knowledge in practical scenarios (Davis & Green, 2022).

2.1.3 Theoretical Framework

The theoretical framework underpinning this research is grounded in constructivist learning theory and experiential learning theory. The Constructivist Learning Theory posits that students construct knowledge through active engagement and interaction with their environment. Mathematical modelling aligns with this theory by providing students with hands-on, practical experiences that help them construct and apply mathematical knowledge. The Experiential Learning Theory, according to Kolb (1984), learning is a process whereby knowledge is created through the transformation of experience. Mathematical modelling facilitates experiential learning by allowing students to engage in real-world problem-solving, thereby transforming abstract mathematical concepts into concrete understanding.

By integrating these theoretical perspectives, this research aims to demonstrate the effectiveness of mathematical modelling in enhancing the teaching and learning of engineering mathematics at Mutare Polytechnic College focusing more on the following Research Objectives.

2.2 Guidelines of effective integration of mathematical modelling into college engineering mathematics courses.

Effective integration of mathematical modelling into college engineering mathematics courses requires a strategic approach that addresses pedagogical practices, curriculum design, resource allocation, and assessment methods.

2.2.1 Curriculum Design and Alignment

There is need to incorporate mathematical modelling tasks throughout the curriculum, to ensure that they are aligned with the course objectives and learning outcomes. These activities should progressively build on students' existing knowledge and skills (Lesh & Doerr, 2003). Also designing curriculum modules that integrate concepts from various engineering disciplines, will allow students to see the interconnectedness of mathematical modelling with their field of study (National Research Council, 2013).

2.2.2 Pedagogical Strategies

Utilization of active learning techniques such as problem-based learning (PBL), where students engage in real-world problems requiring mathematical modelling will encourage collaboration, critical thinking, and practical application of mathematical concepts (Prince & Felder, 2007). Providing structured guidance and support to help students develop modelling skills gradually is essential, beginning with simpler models and progressively introducing more complex tasks as students build confidence and proficiency (Hestenes, 1987).

2.2.2.1 Document Analysis

To illustrate how these pedagogical strategies are incorporated into mathematics education, we can analyse typical components of course outlines or syllabi that emphasize these teaching methods as follows.

1. Course Objectives

The course aims to develop critical thinking and problem-solving abilities through active learning and Problem-Based Learning (PBL). It emphasizes applying mathematical concepts to practical situations using mathematical modelling.

2. Teaching Methods

Integrate Problem-Based Learning (PBL) into regular coursework, where students address real-world issues in teams, promoting peer-to-peer learning and collaborative problem-solving. Begin with simple mathematical models and progressively introduce more complex problems to build understanding.

3. Assessment Methods

Evaluate students through projects and case studies that require them to use mathematical models for solving real-world issues. Additionally, assess their collaborative skills in group settings to align with the PBL approach.

4. Course Content

Start with fundamental concepts and basic models to establish a solid foundation. Gradually introduce more sophisticated mathematical models and problems as students advance.

5. Support Resources

Provide supplementary workshops and tutorials focused on mathematical modelling techniques. Offer mentoring and support to help students develop and apply mathematical models effectively.

2.2.3 Use of Technology and Tools

There is need to incorporate computational tools and software commonly used in engineering practice, such as MATLAB, Mathematica, or specialized modelling software, providing training sessions to ensure students are proficient in these tools (Hohenwarter et al., 2008). Also employ simulation and visualization technologies to help students understand and analyse mathematical models. These tools can make abstract concepts more tangible and enhance student engagement (Cochran et al., 2005).

2.2.4 Collaborative Learning Environment

Encouraging collaborative projects where students work in teams to solve complex modelling problems. This not only fosters teamwork skills but also allows students to learn from diverse perspectives (Jonassen, 2000). Also implementing peer learning strategies where students can share their approaches and solutions to modelling tasks is important. This promotes a deeper understanding and collective problem-solving skills (Hiebert & Carpenter, 1992).

2.2.5 Assessment and Feedback

Designing assessment tasks that reflect real-world engineering challenges, requiring students to apply their modelling skills in practical contexts provides a more accurate measure of their competencies (Burkhardt & Schoenfeld, 2003). Also providing regular and constructive feedback on students' modelling work, helping them identify areas for improvement and guiding their learning process is essential. Use formative assessments to monitor progress and adjust instruction as needed (Lesh et al., 2000).

2.2.6 Professional Development for Instructors

There is need to offer professional development programs for instructors to enhance their understanding and teaching of mathematical modelling. These programs should cover both the theoretical aspects of modelling and practical classroom strategies (Bressoud et al., 2013). Also fostering communities of practice among instructors to share resources, experiences, and best practices related to teaching mathematical modelling in engineering mathematics (Hegedus & Penuel, 2008).

These guidelines ensure that students gain the necessary skills and understanding to apply mathematical modelling effectively in their engineering careers.

2.3 Current methods used in the Teaching and Learning of Engineering Mathematics

The pedagogy employed by lecturers in the engineering mathematics courses encompasses a variety of instructional methods. These methods are designed to cater to diverse learning styles and enhance the comprehension and application of mathematical principles in engineering contexts. The primary teaching methodologies include the lecture method, analytic/discussion method, synthetic method, inductive method, deductive method, heuristic or discovery learning method and demonstration method.

2.3.1 Lecture method

The lecture method entails the instructor presenting content in a well-organized format, typically using verbal explanations and visual aids. In engineering mathematics, lectures serve to introduce theoretical concepts, mathematical principles, and problem-solving techniques. Integrating mathematical modelling into lectures involves showcasing real-world engineering challenges that necessitate mathematical analysis and solutions, demonstrating the practical relevance of mathematical concepts in engineering contexts (Smith, 2015).

2.3.2 Analytic/discussion method

This approach promotes active engagement and critical thinking by involving students in class discussions and the analysis of mathematical problems. In the context of engineering mathematics, such discussions enable students to explore the theoretical foundations of mathematical models and their applications in engineering systems. By collaboratively analysing mathematical problems, students gain a deeper understanding of mathematical modelling processes and their significance in tackling engineering challenges (Felder & Brent, 2016).

2.3.3 Synthetic method

The synthetic method entails deconstructing complex concepts into simpler elements, which are then combined to grasp the broader principles. In engineering mathematics, this method can be utilized in mathematical modelling by breaking down intricate engineering systems into fundamental mathematical components, such as equations, variables, and parameters. By integrating these components, students can achieve a comprehensive understanding of how mathematical models reflect real-world phenomena (Jonassen, 2006).

2.3.4 Inductive method

The inductive method involves deriving general principles from specific observations or examples. In engineering mathematics, this approach can be applied by using case studies or real-world scenarios to introduce mathematical models. By examining specific engineering problems and recognizing recurring patterns, students can infer mathematical principles and enhance their grasp of mathematical modelling concepts (Savery & Duffy, 1996).

2.3.5 Deductive Method

The deductive method involves drawing specific conclusions from general principles or theories. In engineering mathematics, this approach is used to systematically apply mathematical models to solve engineering problems. By starting with well-established mathematical principles and employing deductive reasoning, students can derive solutions to complex engineering issues through mathematical modelling techniques (Bjork & Rabin, 2014).

2.3.6 Heuristic or discovery

Heuristic learning focuses on active exploration and problem-solving, encouraging students to uncover mathematical concepts through guided inquiry and experimentation. In engineering mathematics, this approach can include hands-on activities or computational simulations that allow students to investigate mathematical models and their applications in engineering design and analysis. By participating in discovery-based activities, students enhance their problem-solving abilities and develop a deeper understanding of the role of mathematical modelling in engineering (Hmelo-Silver et al., 2007).

2.3.7 Demonstration method

The demonstration method involves the instructor presenting mathematical concepts or problem-solving techniques through examples or simulations. In engineering mathematics, this method can be used to illustrate how mathematical models are applied in engineering practice. By visually showcasing the process of mathematical modelling and its results, students can better understand how mathematical concepts are used to solve real-world engineering problems (Kirschner et al., 2006).

2.4 Challenges of incorporating Mathematical Modelling in the Teaching and Learning of Engineering Mathematics

Incorporating mathematical modelling into the teaching and learning of engineering mathematics presents several challenges that need to be addressed to ensure effective implementation. These challenges encompass various aspects, including pedagogical, technological, and institutional considerations.

2.4.1 Pedagogical Challenges

1**. Complexity of Concepts:** Mathematical modelling encompasses abstract mathematical concepts and techniques that can be difficult for students, especially those lacking a solid mathematical foundation, to understand. Consequently, instructors must provide effective scaffolding to make these concepts more accessible to students (Hegedus & Penuel, 2008).

2**. Interdisciplinary Nature:** Engineering mathematics covers a range of disciplines, such as civil, automotive, mechanical, and electrical engineering, necessitating the integration of mathematical concepts with engineering principles and applications. This interdisciplinary approach presents challenges in developing curricula and designing instruction (Lesh et al., 2000).

2.4.2 Technological Challenges

1**. Software and Tools:** Mathematical modelling frequently depends on specialized software and computational tools for simulation and analysis. Due to resource constraints in educational settings, access to and proficiency with these tools can be limited. Therefore, instructors must offer sufficient training and support to help students use these technologies effectively (Hohenwarter et al., 2008).

2. **Hardware Requirements:** High-performance computing resources are essential for executing complex mathematical simulations and modelling tasks. However, providing access to the necessary hardware infrastructure presents a logistical challenge for educational institutions (Cochran et al., 2005).

2.4.3 Institutional Challenges

1. **Curricular Constraints:** Conventional engineering curricula often do not allocate adequate time or emphasis to mathematical modelling, resulting in gaps in students' understanding and skills. To address this, curricular frameworks need to be revised to incorporate mathematical modelling more thoroughly, which requires collaboration among educators, researchers, policymakers, and other stakeholders (Burkhardt & Schoenfeld, 2003).

2. **Assessment and Evaluation:** Evaluating students' skills in mathematical modelling is challenging due to the difficulty in designing assessment tasks that effectively measure their capabilities. Traditional assessment methods often fail to capture the complexity and creativity involved in mathematical modelling activities (National Research Council, 2013).

2.5 Benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics.

Incorporating mathematical modelling into the teaching and learning of engineering mathematics offers numerous benefits that enhance students' understanding, problem-solving skills, and preparedness for real-world engineering challenges. These benefits span pedagogical, cognitive, and practical domains, contributing to a holistic educational experience.

2.5.1 Enhanced Conceptual Understanding*:* Mathematical modelling offers a contextual framework that makes abstract mathematical concepts more comprehensible by relating them to real-world engineering applications (Hestenes, 1987). Through practical modelling tasks and applications, students gain deeper insights into mathematical principles and their practical importance (Lesh et al., 2000).

2.5.2 Promotion of Critical Thinking and Problem-Solving Skills: Working on mathematical modelling tasks enhances critical thinking as students analyse, evaluate, and interpret mathematical models within engineering contexts (Jonassen, 2000). These tasks also improve problem-solving abilities as students use mathematical concepts to develop, simulate, and optimize models for engineering systems and processes (Hohenwarter et al., 2008).

2.5.3 Integration of Theory and Practice: Mathematical modelling connects theoretical mathematics with practical engineering applications, helping integrate mathematical theory with engineering practice (Lesh & Doerr, 2003). This integration allows students to appreciate the relevance of mathematical concepts in solving real-world engineering problems, which enhances their motivation and engagement (Hegedus & Penuel, 2008).

2.5.4 Preparation for Professional Practice*:* Engaging in mathematical modelling activities helps students develop skills that are directly applicable to professional engineering work, such as data analysis, simulation, and optimization (Lesh et al., 2000). Exposure to real-world problems through modelling prepares students for the complexities and uncertainties of their future careers, promoting resilience and adaptability (Bressoud et al., 2013).

2.5.5. Interdisciplinary Learning Opportunities: Mathematical modelling fosters interdisciplinary collaboration by providing a shared framework for communication among engineers, mathematicians, and other professionals (Lesh et al., 2000). This approach exposes students to various perspectives and methods from multiple disciplines, enhancing their learning experience and encouraging innovation in engineering design and problem-solving (National Research Council, 2013).

2.6 Impact of Mathematical Modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course.

2.6.1 Increased Real-World Application

Mathematical modelling enables students to apply abstract mathematical concepts to practical engineering problems, enhancing their understanding of the relevance and importance of these concepts. One effective modelling activity is the model-eliciting activity (MEA), which connects simple modelling tasks to real-world engineering scenarios (H. M. Doerr, J. B. Årleback, & A. Costello Staniec, 2014). Applying the "reality principle," which involves placing modelling problems in realistic contexts, increases the benefit, especially when these contexts have personal significance to the students (H. A. Diefes-Dux, M. Hjalmarson, J. S. Zawojewski, & K. Bowman, 2006).

2.6.2 Problem-Solving Skills

Engaging in mathematical modelling challenges students to think critically, analyse complex issues, and devise innovative solutions, thereby enhancing their problem-solving skills, which are crucial in engineering. This process encourages students to methodically approach problems, break them into manageable parts, and apply suitable mathematical techniques for solutions (Jonassen, 2000). Modelling fosters iterative problem-solving by allowing students to refine their models based on feedback and results, leading to deeper engagement and mastery (Hohenwarter et al., 2008).

2.6.3 Interdisciplinary Connections

Mathematical modelling often requires drawing on knowledge from various fields, promoting a comprehensive understanding and application of concepts. This interdisciplinary approach ensures the effective development of scientific concepts and theories and integrates different scientific disciplines. Such connections enhance educational quality by facilitating interactions between fields of knowledge and improving students' ability to solve complex problems through a broader perspective (Suleymenov J.S., 2003; S.N., 1965; M.M.; Kharin et al., 2003).

2.6.4 Higher Motivation and Engagement

Working on real-world problems and observing the impact of their solutions tends to increase students' motivation and engagement. This practical approach makes course material more engaging and relevant. When students see how mathematics applies to actual engineering problems, their interest in the material typically grows (Hegedus & Penuel, 2008). Active learning through modelling fosters student participation and collaboration, creating an interactive learning environment (Prince & Felder, 2007).

2.6.5 Collaborative Learning

Mathematical modelling often involves integrating knowledge from various disciplines, encouraging students to connect concepts from different areas of engineering and mathematics (Lesh et al., 2000). This interdisciplinary approach not only enhances problem-solving skills but also prepares students for the collaborative nature of professional engineering, where they frequently work with experts from other fields (National Research Council, 2013). Collaborative projects in mathematical modelling help students develop communication skills, learn from peers, and appreciate diverse problem-solving perspectives

2.6.6 Preparation for Industry

With industries increasingly relying on mathematical modelling for decision-making and problem-solving, students familiar with these methods in their engineering courses are better prepared for their future careers. The demand for professional’s adept in technology, engineering, architecture, economics, and other fields is growing, emphasizing the need for well-developed problem-solving and modelling skills (Lingefjard, 2006).

2.6.7 Positive Attitude Towards Mathematics

Engaging in mathematical modelling often leads students to view mathematics more positively, recognizing it as a valuable and exciting tool rather than merely abstract theories (Hiebert & Carpenter, 1992). This shift in perspective can enhance their persistence in studying mathematics and related fields, contributing to long-term academic and professional success (Cochran et al., 2005).

2.7 Summary

This chapter gave an account of other studies which have relevance to the present study, discussions of past research on application of mathematical modelling in the teaching and learning of college engineering mathematics, the challenges faced and benefits acquired by integrating mathematical modelling were extensively discussed and their relevance to the present study was highlighted. The review of related literature indicated that most of the learning institutions have the same challenges.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter is going to explain the method employed in achieving the stated objectives. It describes all the activities and procedures undertaken during the course of the research study. It includes details of the research design, the methods, the description of the population, the sample, data collection tools, the content of the instruments and the information about the data analysis procedures and the ethical issues that were implemented. In brief, this chapter depicts the practical base that constituted this study. An attempt to ensure validity and reliability of instruments was also made. The population and sample size were also given. The chapter was concluded by a presentation and analysis plan.

3.2 Research Paradigm

The integration of mathematical modelling in the teaching and learning of Engineering Mathematics at Mutare Polytechnic College has been best studied through a combination of positivism and interpretivism. This dual-paradigm approach aligned with the mixed-methods research design, as it leveraged the strengths of both quantitative and qualitative methodologies.

From a positivist perspective, the study employed the scientific method, emphasizing empirical observation and the use of quantifiable data. This is evidenced in the statistical analysis of survey data, which aimed to measure perceptions and preferences regarding the integration of mathematical modelling in engineering mathematics education. Positivism provided an objective and systematic framework for data collection and analysis, thereby enabling generalizable findings based on empirical evidence (Creswell, 2014). The quantifiable data gathered through structured surveys allowed the researchers to identify trends and correlations, offering insights into the broader impact of mathematical modelling on students' learning outcomes.

Conversely, the interpretivist paradigm focused on understanding and interpreting subjective experiences and social phenomena. This aspect of the research has been reflected in the thematic analysis of interview responses, which sake to gain deeper insights into participants' perceptions and experiences with mathematical modelling. Interpretivism supported a nuanced understanding of the complex interactions and meanings attributed to the integration of mathematical modelling in educational practices (Merriam, 2009). Through qualitative interviews, the study captured the richness of participants' lived experiences, providing context-specific insights that quantitative data alone cannot reveal.

The synergy between positivism and interpretivism allowed for data triangulation, where findings from both quantitative and qualitative analyses was compared and integrated. This triangulation enhanced the validity and reliability of the study by offering multiple perspectives on how mathematical modelling influences teaching and learning outcomes in engineering mathematics. By combining these paradigms, the research addressed the limitations inherent in each approach when used in isolation, thereby providing a more comprehensive understanding of the research topic (Johnson, Onwuegbuzie, & Turner, 2007).

The combination of positivism and interpretivism in this study was justified by the need to balance the objectivity of quantitative data with the depth of qualitative insights. This mixed-methods approach not only strengthened the study's methodological rigor but also enriched the interpretation of the findings, ultimately contributing to a more holistic understanding of the impact of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the Civil Engineering department.

3.2.1 Philosophical Assumptions

The integration of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the civil engineering department was underpinned by several philosophical assumptions, reflecting both ontological and epistemological stances that guided the research design and methodology.

1.Ontological Realism: The research was grounded in ontological realism, positing that an objective reality exists independently of human perception. This perspective aligned with the belief that mathematical modelling inherently enhances students' conceptual understanding and problem-solving skills in engineering mathematics. According to Guba and Lincoln (1994), ontological realism asserts the existence of a tangible reality that can be systematically explored and understood. By adopting this stance, the researcher assumed that the benefits of mathematical modelling are intrinsic and universally applicable, thereby justifying the focus on quantifiable outcomes.

2. ***Epistemological Objectivism:*** Epistemological objectivism underpinned the research, emphasizing that knowledge can be discovered through objective observation and measurement. This assumption supported the use of quantitative methods, such as surveys and statistical analysis, to evaluate the impact of mathematical modelling on learning outcomes. As posited by Crotty (1998), objectivism entailed that truth and meaning reside in the objects of investigation themselves, independent of any consciousness. This epistemological stance legitimized the pursuit of empirical data to draw valid and generalizable conclusions about the effectiveness of mathematical modelling in engineering education.

3. Value Neutrality: The principle of value neutrality was integral to maintaining objectivity and impartiality throughout the research process. The researcher endeavoured to minimize personal biases and values that could potentially influence the study's findings or interpretation. Weber (1949) emphasized the importance of value neutrality in social research to ensure the credibility and integrity of the results. Adhering to this principle, the study aimed to provide an unbiased assessment of the role of mathematical modelling in enhancing educational practices and student performance.

*4**. Methodological Pluralism:*** The research embraced methodological pluralism, recognizing the value of both quantitative and qualitative methods to gain a comprehensive understanding of the research topic. This pluralistic approach facilitated data triangulation, thereby enriching the research findings with multiple perspectives. Johnson and Onwuegbuzie (2004) advocated for mixed-methods research as it leverages the strengths of both approaches to provide a more nuanced and holistic view of the phenomena under study. By incorporating both statistical analysis and thematic exploration, the study captured the multifaceted impact of mathematical modelling on engineering mathematics education.

5. Teleological Determinism: The research was driven by teleological determinism, which assumed that integrating mathematical modelling into the curriculum led to improved student outcomes, such as enhanced problem-solving skills, critical thinking abilities, and overall learning effectiveness. This deterministic view aligned with the research goal of evaluating the positive impacts of mathematical modelling. As suggested by Merton (1968), teleological perspectives in research focused on the intended purposes and outcomes, guiding the inquiry towards achieving specific educational objectives.

6. Ethical Sensitivity: Ethical sensitivity was paramount in conducting research involving human subjects. The researcher was committed to upholding ethical standards, including respecting participants' rights, ensured confidentiality and privacy, and obtained informed consent. This ethical commitment aligned with the guidelines set forth by the Belmont Report (1979), which emphasized the principles of respect for persons, beneficence, and justice in research. By adhering to these ethical standards, the study ensured the protection and dignity of all participants, thereby reinforced the ethical integrity of the research process.

These assumptions provided a robust framework for investigating the impact of mathematical modelling on engineering mathematics education at Mutare Polytechnic College in the civil engineering department, ensuring a comprehensive, objective, and ethically sound study.

3.3 Methodology

The methodological framework used in this research project is outlined in this chapter. The research project's goal is to find and maintain an efficient teaching strategy that incorporates mathematical modelling into the engineering mathematics curriculum at Mutare Polytechnic College's civil engineering department. The methodological approach integrates qualitative and quantitative techniques to assess mathematical modelling's efficacy in improving teaching and learning outcomes in a thorough manner.

3.3.1 Research design

The research design adopted a mixed-methods approach, encompassing both quantitative and qualitative data collection and analysis. This dual approach allowed for a robust examination of the research problem from multiple perspectives, facilitating a deeper understanding of the integration process and its impact on educational practices. The mixed-methods approach was justified by the need to triangulate data from multiple sources to enhance the validity and reliability of the research findings (Johnson & Onwuegbuzie, 2004). Quantitative methods offered the precision and objectivity required to measure learning outcomes, while qualitative methods provided depth and context to the observed effects. Together, these methods ensured a comprehensive evaluation of the effectiveness of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the civil engineering department.

3.3.2 Research approach

The research adopted a mixed-method approach, integrating quantitative and qualitative phases to provide a holistic understanding of the research problem. This approach allowed the researcher to gather both numerical data and in-depth insights, thereby enhanced the robustness and validity of the findings (Creswell & Plano Clark, 2011). The mixed-method approach was justified by its ability to address the research question from multiple perspectives, thereby enhancing the comprehensiveness and credibility of the findings. Quantitative data provided the precision and generalizability necessary for assessing broad trends and outcomes, while qualitative data offered depth and context, illuminating the underlying processes and experiences (Johnson & Onwuegbuzie, 2004). By integrating both methods, the researcher could triangulate data, cross-validate findings and ensured a more reliable and valid interpretation of the results. This methodological pluralism aligned with the contemporary emphasis on mixed-methods research as a means to bridge the gap between quantitative and qualitative paradigms (Tashakkori & Teddlie, 2010).

3.3.3 Quantitative approach

Quantitative data was collected through structured surveys and standardized assessments. Surveys were administered to students and departmental members to gauge their perceptions, attitudes, and preferences regarding the use of mathematical modelling in engineering mathematics. The survey questions were designed to capture specific metrics such as student engagement, perceived relevance of mathematical modelling, and self-reported improvements in problem-solving skills.

The use of surveys and assessments aligned with the epistemological stance of objectivism, which posited that objective measurement and empirical observation were crucial for generating valid knowledge (Creswell, 2014). The quantitative data collected was subjected to statistical analysis to identify trends, correlations, and potential causal relationships. This phase aligned with the positivist paradigm, which emphasizes objective measurement and empirical evidence as the basis for generating knowledge (Bryman, 2012).

The decision to employ a quantitative approach in this study was justified by the need to obtain objective, reliable, and generalizable data on the impact of mathematical modelling in engineering mathematics education. The precision and scalability of quantitative methods ensured that the research effectively captured and analysed the relevant variables, providing a solid empirical foundation for evaluating educational outcomes. Moreover, the ability to integrate quantitative data with qualitative insights through triangulation further enriched the research findings, offering a comprehensive and validated understanding of the research problem.

3.3.4Advantages of using quantitative approach

The quantitative approach in research offered several distinct advantages that made it a valuable methodology for investigating the integration of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the civil engineering department. These advantages aligned with the principles of positivism, which emphasized empirical observation, objectivity, and the ability to generalize findings.

1. ***Objectivity and Reliability:*** By employing structured instruments such as surveys and standardized assessments, the researcher could collect data that were not influenced by personal biases or subjective interpretations (Creswell, 2014). This objectivity enhanced the reliability

of the data, ensuring that the results are consistent and replicable across different samples and contexts.

2. ***Statistical Analysis and Generalizability:*** Quantitative methods allowed for the application of statistical techniques to analyse data, providing a rigorous framework for identifying patterns, correlations, and causal relationships (Bryman, 2012). This analytical rigor enabled the researcher to draw valid conclusions and made predictions based on empirical evidence. Furthermore, the ability to generalize findings from a representative sample to a larger population was a significant strength of the quantitative approach. This generalizability was crucial for making broader inferences about the impact of mathematical modelling on student performance in engineering mathematics.

3***. Precision and Scalability:*** The use of quantitative methods allowed for precise measurement of variables, which was essential for assessing specific outcomes such as student engagement, problem-solving skills, and conceptual understanding. This precision facilitated the comparison of different groups and conditions, enabled the researcher to identify significant differences and trends with high accuracy (Muijs, 2010).

4. Data Triangulation: Quantitative data could be effectively triangulated with qualitative findings to enhance the validity of the research conclusions. By integrating numerical data with in-depth insights from qualitative methods, the researcher could cross-validate the results, provided a more robust and nuanced understanding of the research topic (Johnson & Onwuegbuzie, 2004). This triangulation strengthened the overall research design, ensured that the findings were well-supported by multiple lines of evidence.

5. Efficient Data Collection: The structured nature of quantitative methods facilitated efficient data collection and analysis. Surveys and assessments were administered to a large number of participants simultaneously, and the data was quickly processed using statistical software. This efficiency was beneficial for studies with time constraints and those requiring timely results to inform educational practices and policy decisions (Fowler, 2014).

3.3.5 Qualitative approach

Qualitative data was gathered through instructor's feedback and in-depth interviews. Open-ended feedback forms were distributed to lecturers to capture their experiences, challenges, and suggestions regarding the integration of mathematical modelling. This feedback provided nuanced insights into the subjective experiences of lecturers, highlighted areas of success and potential improvement. In-depth interviews were conducted with a select group of departmental members and explored their perceptions and experiences in greater detail. These interviews were semi-structured, they allowed for flexibility in probing specific themes while ensuring consistency across different interviews. Thematic analysis was applied to the qualitative data to identify recurring patterns and themes that elucidated the impact of mathematical modelling on the teaching and learning process.

The qualitative component of the research was grounded in interpretivism, which emphasized understanding the meanings and experiences of participants in their natural context (Merriam, 2009). By incorporating instructors feedback and interviews, the study captured the complexity of the integration process and provided a rich, contextualized understanding of how mathematical modelling influenced educational practices.

Bogdan (1992) described the qualitative approach as an umbrella term encompassing methods that are more direct in describing events and persons scientifically, while also utilizing numeric data where appropriate. This phase employed thematic analysis to identify recurring patterns and themes within the interview data, contributed to a nuanced understanding of the impact of mathematical modelling on educational practices.

The decision to incorporate qualitative approaches in this study was justified by the need to capture the complex and multifaceted nature of integrating mathematical modelling in engineering mathematics education. The depth, contextual understanding, and participant empowerment afforded by qualitative methods provided essential insights that were not accessible through quantitative approaches alone. Additionally, the flexibility of qualitative research allowed for an adaptive and responsive investigation, ensured that the study remains relevant and comprehensive.

3.3.6 Advantages of using qualitative approaches

The qualitative approach in research offered unique advantages that made it indispensable for understanding complex phenomena, particularly in the context of integrating mathematical modelling into engineering mathematics education at Mutare Polytechnic College in the civil engineering department. These advantages aligned with the principles of interpretivism, emphasizing the importance of context, depth, and the subjective experiences of participants.

1. Depth and Richness of Data: Qualitative research provided depth and richness of data that were often unattainable through quantitative methods. Through techniques such as in-depth interviews and participant observations, qualitative research captured detailed and nuanced insights into participants' experiences, perceptions, and emotions (Patton, 2015). This richness allowed the researcher to explore the complexities and subtleties of how mathematical modelling impacts teaching and learning processes.

2. ***Contextual Understanding*****:** One of the primary strengths of qualitative research was its ability to provide a contextual understanding of the phenomena under study. By situating the research within the specific environment of Mutare Polytechnic College, the researcher gained insights into how contextual factors such as institutional culture, teaching practices, and student demographics influence the effectiveness of mathematical modelling (Creswell & Poth, 2018). This contextualization was essential for developing practical and relevant educational interventions.

3. ***Flexibility and Adaptability*****:** Qualitative methods were inherently flexible and adaptable, allowed the researcher to adjust the research design and data collection techniques as the study progressed. This flexibility was particularly valuable in exploratory research and when dealing with complex, evolving subjects (Merriam & Tisdell, 2015). If initial interviews revealed unexpected themes, the researcher modified the interview guide to further investigate these new areas of interest.

4. ***Participant Empowerment and Engagement*****:** Qualitative research often empowers participants by giving them a voice in the research process. Through open-ended questions and interactive data collection methods, participants expressed their views and experiences in their own words, leading to a more authentic and comprehensive understanding of the research problem (Denzin & Lincoln, 2011). This empowerment enhanced participant engagement and the richness of the data collected.

5. ***Development of Theories and Hypotheses:*** Qualitative research was instrumental in developing theories and hypotheses, particularly in areas where little was known and existing theories were inadequate. The inductive nature of qualitative research allowed for the emergence of new concepts and theoretical frameworks based on the data collected (Glaser & Strauss, 1967). In the context of this study, qualitative insights into how students and department perceived and experienced mathematical modelling informed the development of new pedagogical theories and practices.

6***. Triangulation and Complementarity*****:** When used in conjunction with quantitative methods, qualitative research enhanced the overall validity and reliability of the study through triangulation. By providing complementary insights, qualitative data helped to explain and contextualize quantitative findings, leading to a more holistic understanding of the research problem (Johnson & Onwuegbuzie, 2004). This methodological pluralism ensured that the study's conclusions were well-rounded and robust.

3.3.7 Target population

According to Sidhu et al. (1999), "A population is any group of individuals that have one or more characteristics in common and are of interest to the researcher." In this research, the target population comprised of National Certificate Engineering Mathematics students enrolled in the Civil Engineering programs at Mutare Polytechnic College, namely Civil Engineering, Quantity Surveying and Water Resources Engineering and Engineering mathematics instructors in the respective department. This population was selected due to their direct engagement with engineering mathematics courses that are pertinent to their respective fields of study. The selection of these specific groups was justified by their central role in the teaching and learning processes of engineering mathematics at Mutare Polytechnic College. By including both students and instructors, the research captured a holistic view of the educational environment. Students provided insights into the learner's experience, while departmental members offered a professional perspective on curriculum design and instructional efficacy. This dual focus ensured that the research addressed both ends of the educational spectrum, leading to more comprehensive and actionable findings.

1.**Students:** The primary segment of the target population included students from the Civil Engineering discipline. These students were engaged in courses that incorporated mathematical concepts essential for their engineering education. Their experiences and performance in these courses provided valuable data on the effectiveness of mathematical modelling as a pedagogical tool. By focusing on this group, the research aimed to assess how the integration of mathematical modelling influenced their understanding and application of mathematical principles in engineering contexts.

2. **Departmental members (Instructors):** The secondary segment of the target population included the departmental members responsible for teaching engineering mathematics in the Civil Engineering department. This group comprised instructors/lecturers who plays a crucial role in curriculum implementation and the adoption of instructional strategies. Their perspectives and experiences were pivotal in understanding the practical challenges and benefits of integrating mathematical modelling into the curriculum. Engaging with this group allowed for a comprehensive evaluation of how teaching practices and student outcomes were affected by the use of mathematical modelling.

3.3.8 Sampling

In studying the impact of mathematical modelling on engineering mathematics education at Mutare Polytechnic College, the researcher selected a sample that accurately represented the target population, to ensure the validity of the conclusions to be drawn. Thirkettle (1988) defines a sample as a subset of the population used to infer characteristics about the whole population. To achieve this, a combination of systematic and random sampling methods was employed, targeting two distinct groups, National Certificate Engineering Mathematics lecturers and students.

The stratified sampling technique was initially used to separate the population into two strata, lecturers and students. This approach was justified as it allowed for the representation of key subgroups within the population, thus enhancing the precision of the study (Creswell, 2014).

For the student population, the systematic sampling method was utilized within the Civil Engineering, Quantity Surveying and Water Resources Engineering classes. Specifically, in a Civil Engineering class of 115 students, every tenth student on the register was selected, resulting in a sample size of approximately 12 students. In the Quantity Surveying class, which had 80 students, a similar approach was applied to select 8 students. In the Water Resources engineering class which had 50 students, also a similar approach was applied to select 5 students. This gives a representative sample of 25 students. This method ensured that the sample was not biased and every student had an equal chance of being selected, thereby enhancing the representativeness of the sample (Levy & Lemeshow, 2013).

Regarding the lecturers, the total number of National Certificate Engineering Mathematics lecturers in Civil Engineering department at the college was three, and thus the sample will include all three lecturers. Given the small number of lecturers, including all individuals in this subgroup ensured comprehensive data collection from this critical perspective (Patton, 2015).

The dual application of systematic and random sampling methods, combined with stratified sampling, was a strategic choice. This approach ensured that both lecturers and students were adequately represented in the sample, facilitating a thorough exploration of the impact of mathematical modelling in engineering education. By ensuring that each subgroup within the population is proportionately represented, the study drew more reliable and generalizable conclusions about the efficacy of mathematical modelling in this educational context.

3.4 Data Collection Methods

To investigate the impact of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the civil engineering department, the researcher utilized two primary data collection methods namely, questionnaires and interviews. Each method was selected based on its suitability for addressing different aspects of the research problem and supported by relevant literature. The combination of these methods ensured a comprehensive approach to data collection, capturing both quantitative and qualitative data.

3.4.1 Questionnaires

Questionnaires were administered to both students and lecturers. This method was chosen for its efficiency in collecting data from a large sample size and its ability to gather standardized information, making it easier to analyze and compare responses (Creswell, 2014). The questionnaires were designed to include both closed-ended and open-ended questions. Closed-ended questions facilitated quantitative analysis, while open-ended questions provided richer qualitative insights.

3.4.2 Justification of using questionnaires

Questionnaires are a widely used method in educational research due to their ability to gather data from a large number of respondents efficiently and cost-effectively (Cohen, Manion, & Morrison, 2011). The use of structured questionnaires ensured consistency in the data collected, which is crucial for statistical analysis. Moreover, questionnaires allowed respondents to complete them at their convenience, which led to higher response rates (Dillman, Smyth, & Christian, 2014).

Cohen, Manion, and Morrison (2011) highlight that questionnaires are particularly effective in educational settings where large samples are involved. Dillman, Smyth, and Christian (2014) further emphasize that well-designed questionnaires minimize bias and improve the reliability of the data collected.

3.4.3 Weakness of questionnaires

The major problem with the use of questionnaires was that the respondents did not give immediate feedback and it was tiresome to do some follow up to those who have not given back their questionnaires. The other problem was that some pupils failed to express themselves well on the part of the open-ended questions which made it difficult for the researcher to code and record the responses for analysis.

3.4.4 Engineering Mathematics Questionnaire

This questionnaire was designed to align with the research methodology and objectives of the study on the impact of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the Civil engineering department. The questionnaire employs both closed and open-ended questions to collect quantitative and qualitative data. Closed questions (multiple choice, Likert scale) ensure the collection of specific, comparable data, while open-ended questions provide deeper insights and allow for the exploration of unique perspectives. The questionnaire is structured to gather data directly from students and lecturers about their experiences and opinions, ensuring primary data collection relevant to the study's focus. Quantitative data from Likert scales and multiple-choice questions will be statistically analysed, while qualitative responses will be coded and thematically analysed to identify common patterns and insights. Each question was crafted to gather specific data that addresses the research questions.

1.***RQ1 (Teaching Methods):*** Questions in Section B1 address RQ1 by identifying the prevalent teaching methods used in the Engineering Mathematics course and evaluating their perceived effectiveness and impact on students.

2.RQ2 (Challenges and Benefits): Statements about challenges (e.g., negative attitude, complexity, interdisciplinary nature) and benefits (e.g., enhanced understanding, critical thinking) help identify barriers and advantages of incorporating mathematical modelling in the curriculum.

3.RQ3 (Impact on Learning and Engagement): Statements in Section B about the impact on real-world application, problem-solving skills, interdisciplinary connections, motivation, collaborative learning, and industry preparation directly relate to understanding the outcomes of mathematical modelling on student engagement and learning.

4.RQ4 (Integration Guidelines): The final open-ended question allows respondents to suggest guidelines and best practices for integrating mathematical modelling into the curriculum, providing practical insights and recommendations.

By aligning each section of the questionnaire with the research questions and objectives, the study ensured a comprehensive approach to exploring the teaching methods, challenges, benefits, impact, and integration of mathematical modelling in engineering mathematics at Mutare Polytechnic College. Using a mixed-methods approach combining structured questions for quantitative analysis and open-ended questions for qualitative insights, this questionnaire provided a comprehensive tool to assess the multifaceted impact of mathematical modelling on engineering mathematics education**.** A draft questionnaire is included in the appendix.

3.5 Interviews

An interview is a purposeful conversation usually between two people or more which is directed by one in order to get information from the other. Interviews were conducted with lecturers to gain deeper insights into their experiences and insights regarding mathematical modelling in the curriculum. Semi-structured interviews were used to allow for flexibility in probing deeper into specific areas of interest while maintaining some consistency across interviews (Kvale & Brinkmann, 2015). A participant – observation like study was used where the researcher knew the subject before, hence the interview was like a conversation between friends. During the interview the researcher gathered descriptive data in the teaching methods which were used by Lecturers at Mutare Polytechnic in the Civil Engineering department.

Interviews provided a deeper understanding of participants' experiences, perceptions, and attitudes that cannot be fully captured through questionnaires alone (Kvale & Brinkmann, 2015). The semi-structured format allowed the interviewer to explore complex issues and follow up on interesting responses, thereby yielded rich qualitative data (Merriam & Tisdell, 2016). Kvale and Brinkmann (2015) argued that interviews were essential for obtaining detailed insights into participants' thoughts and experiences. Merriam and Tisdell (2016) support the use of semi-structured interviews in educational research for their ability to uncover nuanced understandings and contextual factors. This instrument had a weakness that during the interview not all respondents were articulate and percept. To curb the weakness of the interview with some of the respondents, the researcher was patient and redirected respondents to what was required.

Three lecturers teaching engineering mathematics in the Civil engineering courses were interviewed. Interview questions were meticulously designed to align with the research methodology and objectives of the study on the impact of mathematical modelling in engineering mathematics education at Mutare Polytechnic College in the Civil engineering Department.

Lecturers were encouraged to elaborate on their responses as needed to ensure comprehensive data collection. Approximately 15 minutes were allowed per interview. Interview questions are included in Appendix II and RQ4.

3.6 Summary

Having obtained the research methodology, the researcher compiled all this data through the use of different presentation methods. The researcher used Statistical Packages for social Sciences (SPSS) version 27 for data analysis.

The research methodology focused on the research design, methods and research instruments. Adequate descriptions of these were made and an attempt to ensure for the validity and reliability of these instruments was also made. The chapter concluded by a presentation and analysis plan for the next chapter.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents, interprets, and analyses the data gathered in Chapter 3 via surveys and interviews. The data was presented in the form of tables and figures to allow for comparisons with the assertions made in previous chapters. The parts that follow provide a detailed examination of survey data acquired from engineering students, revealing their perspectives on the importance, interest, and utility of engineering mathematics. This analysis provides as a framework for further discussion of how mathematical modelling might address identified difficulties and improve educational outcomes. This chapter proposes a strong approach for incorporating mathematical modelling into engineering mathematics curriculum by matching teaching tactics with student perceptions and requirements.

The data were analysed using Statistical Packages for the Social Sciences (SPSS) version 27. The questionnaire used a 4-point Likert scales, which were typically used to examine respondents' attitudes, perceptions, or behaviours. Data were collected descriptively as percentages, means and standard deviations. To evaluate the data, **Table 4.1** was utilised as a guide to determine the mean score positions for each variable set and questionnaire.

Table 1: 4-Point Likert Scale Mean range by Four Levels.

Mean Range	Interpretation
1.00 -1.74	Low
1.75 -2.49	Moderate Low
2.50 – 3.24	Moderate High
3.25 -4.00	High

Source: Alico and Guimba (2015)

4.1.1 Interpretation of Table 4.1

Mean range 1.00– 1.74: This range indicates a low level of agreement, satisfaction, or frequency. Responses that fall into this category, suggests that respondents generally disagree with the statement.

Mean range 1.75 – 2.49: This range reflects a moderately low level of agreement, satisfaction, or frequency. Responses in this range suggest a slight tendency towards disagreement or lower levels of the trait being measured.

Mean range 2.50 – 3.24: This range signifies a moderately high level of agreement, satisfaction, or frequency. It suggests that respondents generally agree or are moderately satisfied with the statement or trait being measured.

Mean range 3.25 – 4.00: This range denotes a high level of agreement, satisfaction, or frequency. Responses that fall within this category, indicates strong agreement, high satisfaction, or a high level of the trait being measured.

4.2 Demographic data for the selected students and lecturers

The researcher managed to take into consideration demographic variables. The study therefore managed to gather data regarding students' and lecturers' age, gender and educational level as such variables were assumed to have an influence on the level of perception and reasoning as far as the Application of mathematical modelling in teaching and learning college engineering mathematics is concerned. The following information relates to demographic variables data findings:

Table 2: Students' demographic data

Students' Demographic		**Number of Respondents**	**Percentage (%)**
Gender	Female	9	36.0
	Male	16	64.0
Age	18 – 20 years	6	24.0
	21 – 22 years	8	32.0
	23 – 24 years	5	20.0
	25 years and above	6	24.0
Qualification	Ordinary Level	9	36.0
	Advanced Level	16	64.0

Based on the demographic distribution of respondents in **Table 4.2**, it was found that male students had a total of 16 people with a percentage of 64.0%, exceeding the number of female students with only 9 people with 36.0%. This is consistent with global trends in engineering education, where males typically dominate the field, studies have shown that engineering environments can sometimes be less welcoming to women, impacting their retention and success rates (Beede et al., 2011).

In addition, a total of 16 respondents had Advanced level qualification while 9 respondents had Ordinary level qualification. Seymour & Hewitt, (1997), asserts that students with higher qualifications are generally better prepared to handle the rigor of engineering courses, which can lead to better academic performance and lower dropout rates. This suggests that the curriculum at Mutare Polytechnic could be tailored to leverage this solid academic background while providing additional support to those with Ordinary Level qualifications to ensure they can keep pace with their peers.

Similarly, the majority of the student respondents were aged 21 – 22 years with 8 people, that is, 32.0%. On the other hand, 5 student respondents were aged 23 - 24 years with 20%. This diversity in age can enhance the learning environment, as older students often bring additional life and work experiences that can enrich classroom discussions and collaborative projects. According to Bye, Pushkar & Conway (2007), mature students can positively influence their younger peers by providing different perspectives and demonstrating higher levels of motivation and commitment.

Table 3: Lecturers' demographic data

Lecturers' Demographic		**Number of Respondents**	**Percentage (%)**
Gender	Female	1	33
	Male	2	66
Age	25 – 30 years	1	33
	31 – 35 years	1	33
	Above 35 years	1	33
Qualification	Higher National Diploma	2	67
	Bachelor's degree	1	33
Teaching Experience	5 years and less	1	33
	6 – 10 years	1	33
	11 years and above	1	33

Based on the demographic distribution of respondents in **Table 4.3**, it was found that the number of male lecturers was higher, that is 2 with a percentage of 67%, compared to only 1 female lecturer with 33%. This is consistent with literature that highlights the underrepresentation of women in STEM education and departmental positions.

2 of the lecturers, males were aged 25-30 years and 31 -35 years with 67% and 1 female lecturer aged above 35 years with 33.3%. This suggests a balance of youthful energy and mature experience. Finkelstein, Seal, & Schuster (1998) asserts that younger lecturers may bring innovative teaching methods and familiarity with contemporary technological tools, while

more experienced lecturers can offer depth of knowledge and established pedagogical strategies.

In terms of educational qualifications, it was found that 1 lecturer had a bachelor's degree with 33% and the other 2 lecturers had Higher National Diploma with 67%. This aligns with the practical orientation of many polytechnic institutions, where a focus on hands-on, practical skills is often emphasized. However, ABET, (2011) asserts that while practical qualifications are crucial for applied learning, the presence of degree-holders can enhance the theoretical and academic depth of the curriculum.

In a similar vein, lecturers' teaching experience was evenly distributed in which 1 lecturer had experience of 5 years and less, another lecturer had 6 – 10 years' experience and the other one had 11 years and above with 33% throughout. A blend of new and seasoned educators can enhance educational outcomes. Boice, (1992), indicated that newer educators may introduce innovative teaching methods and fresh perspectives, while seasoned educators provide stability and proven instructional strategies. This diversity in experience levels can provide a dynamic learning environment, benefiting from both innovative approaches and established teaching practices.

4.3 Current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College

The researcher also gathered data relating to the various teaching methods that are employed by lecturers when conducting their engineering mathematics lessons. The study revealed that lecturers use the methods as shown in the table below:

Table 4: Teaching methods used by lecturers.

Teaching Method	Number of Respondents	Percentage (%)
Lecture	8	32
Demonstration	5	20
Field Trips	1	4
Discussion	5	20
Inductive	2	8
Deductive	1	4
Discovery	3	12

Table 4.4 shows that students acknowledge that the majority of their lecturers use the lecture method.

1. **Lecture method**: The lecture method is the most commonly used teaching method, with 8 (32%) of the respondents indicating its use. Bligh, (2000) identifies lecturing as a traditional and widely adopted teaching approach in higher education due to its efficiency in conveying large amounts of information to a broad audience. However, Freeman et al., (2014) also highlights the limitations of lectures, such as reduced student engagement and passive learning. To address these concerns, complementing lectures with interactive techniques, such as active learning, can enhance student participation and comprehension.
2. **Demonstration method**: Demonstration is the second most used method, employed by 5 (20%) of the respondents. Demonstration effectively makes complex concepts more accessible through visual and practical examples. Mayer, (2009), asserts that demonstrations underscore the importance of visual aids and practical demonstrations in enhancing understanding, particularly in STEM fields, however, effective integration and planning are crucial to maximize the impact of demonstrations

3. **Field Trips**: Field trips are the least utilized method, with only 1, (4%) of the respondents indicating their use. Despite their low usage, Behrendt and Franklin (2014) suggest that field trips can significantly enrich learning by providing real-world context and practical experiences that connect theoretical knowledge to real-world applications. Increasing the frequency and integration of field trips could offer substantial educational benefits, promoting a deeper understanding of engineering concepts.
4. **Discussion method**: Discussion method is used by 5 (20%) of the respondents, facilitating active learning, critical thinking, and student engagement. Brookfield and Preskill (2012) advocates for discussion-based learning as a means to enhance student interaction and deepen understanding. Promoting more frequent use of discussions can foster a more interactive and engaging learning environment, encouraging students to articulate their thoughts and critically engage with the material.
5. **Inductive Teaching Method**: The inductive teaching method is employed by 2 (8%) of the respondents. It involves guiding students from specific observations to general principles. Prince and Felder (2006) support this approach for fostering discovery and critical thinking, as it encourages students to develop their own understanding through exploration. Increasing the use of inductive methods could enhance students' problem-solving abilities and promote a deeper grasp of engineering concepts.
6. **Deductive Teaching Method**: Deductive teaching, used by 1 (4%) of the respondents, involves starting with general principles and moving towards specific applications. While this method is systematic and logical, Prince and Felder (2006) suggest that it may not engage students as effectively as other approaches. Balancing deductive and inductive methods can cater to diverse learning styles, providing a more comprehensive educational experience.

7. **Discovery Method**: The discovery method, used by 3 (12%) of the respondents, encourages students to explore and find solutions independently. Alfieri et al. (2011) highlights the benefits of discovery learning for promoting active engagement and critical thinking, however, successful implementation requires careful planning and support to ensure students remain guided and focused.

Table 5: Responses on students' perception on the lecturers' teaching methods

Engineering teaching methods **A: Lecture Method**	**SD (%)**	**D (%)**	**A (%)**	**SA (%)**	**Mean**	σ	**Decision**
Promotes students' critical thinking and innovativeness in the Engineering programs	1 (4%)	2 (8%)	14 (56%)	8 (32%)	3.16	0.746	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	2 (8%)	2 (8%)	13 (52%)	8 (32%)	3.08	0.862	Moderate High
Encourages creativity in Engineering programs	1 (4%)	3 (12%)	9 (36%)	12 (48%)	3.28	0.843	High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
B: Demonstration							
Promotes students' critical thinking and innovativeness in the Engineering programs	2 (8%)	2 (8%)	13 (52%)	8 (32%)	3.08	0.862	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	2 (8%)	2 (8%)	11 (44%)	10 (40%)	3.16	0.898	Moderate High
Encourages creativity in Engineering programs	2 (8%)	2 (8%)	8 (32%)	13 (52%)	3.28	0.936	High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
C: Field trips							
Promotes students' critical thinking and innovativeness in the Engineering programs	2 (8%)	2 (8%)	13 (52%)	8 (32%)	3.48	1.735	High
Helps in fostering students' conceptual understanding in Engineering programs	1 (4%)	3 (12%)	11 (44%)	10 (40%)	3.20	0.816	Moderate High
Encourages creativity in Engineering programs	2 (8%)	3 (13%)	9 (36%)	11 (44%)	3.16	0.943	Moderate High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High

Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
D: Discussion							
Promotes students' critical thinking and innovativeness in the Engineering programs	2 (8%)	3 (12%)	14 (56%)	6 (24%)	2.96	0.841	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
Encourages creativity in Engineering programs	3 (12%)	2 (8%)	10 (40%)	10 (4%)	3.08	0.997	Moderate High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
E: Inductive Teaching Method	**SD (%)**	**D (%)**	**A (%)**	**SA (%)**	**Mean**	**σ**	**Decision**
Promotes students' critical thinking and innovativeness in the Engineering programs	1 (4%)	4 (16%)	8 (32%)	9 (36%)	3.04	0.935	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	3 (12%)	3 (12%)	9 (36%)	10 (40%)	3.04	1.020	Moderate High
Encourages creativity in Engineering programs	2 (8%)	5 (20%)	8 (32%)	10 (40%)	3.04	0.978	Moderate High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
F: Deductive Teaching Method							
Promotes students' critical thinking and innovativeness in the Engineering programs	2 (8%)	3 (12%)	13 (52%)	7 (28%)	3.00	0.866	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	2 (8%)	2 (8%)	15 (60%)	6 (24%)	3.00	0.816	Moderate High
Encourages creativity in Engineering programs	2 (8%)	2 (8%)	9 (36%)	12 (48%)	3.24	0.926	Moderate High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	6 (24%)	6 (24%)	2.60	1.000	Moderate High
Support hands -on experiences in Engineering practical	2 (8%)	5 (20%)	9 (36%)	9 (36%)	3.00	0.957	Moderate High
G: Discovery Teaching Method							
Promotes students' critical thinking and innovativeness in the Engineering programs	2 (8%)	4 (16%)	11 (44%)	8 (32%)	3.00	0.913	Moderate High
Helps in fostering students' conceptual understanding in Engineering programs	2 (8%)	3 (12%)	13 (52%)	7 (28%)	3.00	0.866	Moderate High
Encourages creativity in Engineering programs	3 (12%)	2 (8%)	10 (40%)	10 (40%)	3.08	0.997	Moderate High
Does not promote rote learning in Engineering students.	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
Support hands -on experiences in Engineering practical	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High

Note: N = 25, SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree

4.4 Analysis of students' perceptions on lecturers' teaching methods based on results obtained in Table 4.5.

1. ***Lecture method:*** In terms of the lecture method, the highest mean analysis was for "Encourages creativity in Engineering programs" from students' perception of mean of 3.28 and standard deviation of 0.843, while the lowest mean was for analysis of "Does not promote rote learning in engineering students", perceptions of students with a mean of 2.64 and standard deviation of 1.036. "Promotes students' critical thinking and innovativeness" had mean = 3.16, σ = 0.746 which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 3.08, σ = 0.862, which is moderate high. "Supports hands-on experiences" had mean = 2.92, σ = 0.997 which is also moderate high. Students perceive lectures as effective in promoting critical thinking, conceptual understanding, and creativity, but less effective in discouraging rote learning and supporting hands-on experiences. This aligns with Freeman et al., (2014) who acknowledges the efficiency of lectures in content delivery but highlights their limitations in fostering deep, active learning. The variability in responses suggests that while lectures are beneficial for some aspects of learning, their over-reliance can hinder student engagement and practical application skills.
2. ***Demonstration method:*** For the demonstration method, the highest mean analysis was observed for "Encourages creativity in Engineering programs" from students' perception of mean 3.28 and standard deviation of 0.936, while the lowest mean was for analysis of "Does not promote rote learning in engineering students", perceptions of students with mean of 2.64 and standard deviation of 1.036. "Promotes students' critical thinking and innovativeness" had mean = 3.08, σ = 0.862 which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 3.16 and σ = 0.898 which is moderate high. "Supports hands-on experiences" had mean = 2.92 and σ = 0.997 which is moderate high. Demonstrations are perceived similarly to lectures, with

strengths in fostering critical thinking, conceptual understanding, and creativity, but challenges in minimizing rote learning and fully supporting hands-on activities. Mayer, (2009) supports the effectiveness of demonstrations in making abstract concepts tangible and enhancing understanding through visual aids and practical examples. However, the need for well-planned and integrated demonstrations to maximize their impact is critical, as indicated by student feedback.

3. ***Field Trips:*** As for the field trips teaching method, the highest mean analysis was found on "Promotes students' critical thinking and innovativeness in the Engineering programs" for students' perception with mean of 3.48 and standard deviation of 1.735 while the lowest mean was similar to the one for demonstration and lecture teaching method. In addition, most students highly perceive that their lecturers use field trips to conduct their lessons as it promotes students' critical thinking and innovativeness in the Engineering programs with a mean score of 3.48 and standard deviation 1.735. In a similar vein, the majority students' respondents were found to moderately highly perceive that lecturers use field trips as they help in fostering students' conceptual understanding in Engineering programs, support hands-on experiences in Engineering practical as well as encouraging creativity in Engineering programs. "Helps in fostering students' conceptual understanding" had mean = 3.20 and $\sigma = 0.816$ which is moderate high. "Encourages creativity" had mean = 3.16 and $\sigma = 0.943$ which is moderate high. "Does not promote rote learning" had mean = 2.64 and $\sigma = 1.036$ which is moderate high. "Supports hands-on experiences" had mean = 2.92 and $\sigma = 0.997$ which is moderate high. Field trips receive high ratings for promoting critical thinking and are generally seen as beneficial for conceptual understanding and creativity. However, like other methods, they face challenges in fully supporting hands-on experiences and discouraging rote learning. This is consistent with Behrendt & Franklin, (2014)

emphasizing the value of field trips in providing real-world context and experiential learning, which can deepen students' understanding and engagement. The underutilization of field trips at Mutare Polytechnic suggests an area for potential enhancement.

4. ***Discussion Method:*** **"**Promotes students' critical thinking and innovativeness" had mean = 2.96 and σ = 0.841which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 2.92 and σ = 0.997 which is moderate high. "Encourages creativity" had mean = 3.08 and σ = 0.997which is moderate high. "Does not promote rote learning" had mean = 2.64 and σ = 1.036 which is moderate high. "Supports hands-on experiences" had mean = 2.92 and σ = 0.997 which is also moderate high. Discussions are seen as moderately effective across all dimensions, particularly in fostering creativity. However, they have similar limitations regarding hands-on experiences and discouraging rote learning. Brookfield & Preskill, (2012) advocates for discussion-based learning as it facilitates active learning, critical thinking, and student engagement. Increasing the frequency and integration of discussions could enhance student participation and deepen understanding.

5. ***Inductive Teaching Method:*** **"**Promotes students' critical thinking and innovativeness" had mean = 3.04 and σ = 0.935 which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 3.04 and σ = 1.020 which is moderate high. "Encourages creativity" had mean = 3.04 and σ = 0.978 which is moderate high. "Does not promote rote learning" had mean = 2.64 and σ = 1.036 which is moderate high. "Supports hands-on experiences" had mean = 2.92 and σ = 0.997 which is moderate high. Inductive methods are generally perceived positively, with consistent moderate-high scores across all dimensions. They are seen as effective in promoting critical thinking, conceptual understanding, and creativity, but still face the usual challenges

related to rote learning and hands-on experiences. Prince & Felder, (2006), supports the use of inductive teaching for fostering discovery and critical thinking, encouraging students to develop their understanding through exploration. Increasing the use of inductive methods could enhance students' problem-solving abilities and grasp of engineering concepts.

6. ***Deductive Teaching Method:*** **"**Promotes students' critical thinking and innovativeness" had mean = 3.00 and σ = 0.866 which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 3.00 and σ = 0.816 which is moderate high. "Encourages creativity" had mean = 3.24 and σ = 0.926 which is moderate high. "Does not promote rote learning" had mean = 2.60 and σ = 1.000 which is moderate high. "Supports hands-on experiences" had mean = 3.00 and σ = 0.957 which is moderate high. Deductive methods are perceived as moderately effective in all areas, with the highest score for encouraging creativity. However, like other methods, they struggle with minimizing rote learning. Prince & Felder, (2006) suggests that while deductive teaching provides a systematic and logical approach to learning, it may not engage students as effectively as other methods. Balancing deductive and inductive approaches can cater to diverse learning styles and provide a more comprehensive educational experience.
7. ***Discovery Teaching Method:*** **"**Promotes students' critical thinking and innovativeness" had mean = 3.00 and σ = 0.913 which is moderate high. "Helps in fostering students' conceptual understanding" had mean = 3.00 and σ = 0.866 which is moderate high. "Encourages creativity" had mean = 3.08 and σ = 0.997 which is moderate high. "Does not promote rote learning" had mean = 2.64 and σ = 1.036 which is moderate high. "Supports hands-on experiences" had mean = 2.92 and σ = 0.997 which is moderate high. Discovery methods receive moderate-high scores across all dimensions, indicating a positive perception. They are particularly noted for fostering creativity and conceptual

understanding but face similar challenges as other methods regarding rote learning and hands-on experiences. Alfieri et al., (2011) highlights that the benefits of discovery learning promote active engagement and critical thinking however successful implementation requires careful planning and support to ensure students remain guided and focused.

4.5 Challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College

Information given by the students on the possible challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College was captured. Their responses were shown in **Table 4.6** and **Table 4.7** below:

Table 6: Responses on students' perception on challenges of incorporating mathematical modelling in the teaching and learning of Engineering mathematics

Statement	SD (%)	D (%)	A (%)	SA (%)	Mean	σ	Decision
Negative attitude towards mathematical modelling	1 (4%)	1 (4%)	16 (64%)	7 (28%)	3.16	0.688	Moderate High
Complexity of concepts	2 (8%)	2 (8%)	8 (32%)	13 (52%)	3.28	0.936	High
Interdisciplinary nature	1 (4%)	3 (12%)	10 (40%)	11 (44%)	3.24	0.831	Moderate High
Software and tools	2 (8%)	2 (8%)	12 (48%)	9 (36%)	3.12	0.881	Moderate High
Limited financial support from parents/guardians/school authorities	1 (4%)	3 (12%)	11 (44%)	10 (40%)	3.20	0.816	Moderate High
Shortage of instructional material	1 (4%)	8 (32%)	15 (60%)	1 (4%)	2.64	0.638	Moderate High
Hardware requirements	1 (4%)	3 (12%)	10 (40%)	11 (44%)	3.24	0.831	Moderate High
Limited access to internet facilities	10 (40%)	11 (44%)	1 (4%)	3 (12%)	1.88	0.971	Moderate Low
Curricula constraints	3 (12%)	2 (8%)	8 (32)	12 (48%)	3.16	1.028	Moderate High
Assessment and evaluation	2	3	9	11	3.16	0.943	Moderate High

	(8%)	(12%)	(36%)	(44%)			

4.5.1 Analysis Based on results in Table 4.6,

1. ***Negative Attitude Towards Mathematical Modelling:*** With a mean of 3.16 and a low standard deviation of 0.688, students exhibit a moderate high negative attitude towards mathematical modelling. This is consistent with Clement & Mann, (1996); English & Lesh, (2003) indicating that students often struggle with the abstract nature of modelling and may have a negative attitude if they do not see immediate practical applications however, addressing these attitudes may involve integrating more practical examples and real-world applications to make the relevance of mathematical modelling clearer.
2. ***Complexity of Concepts:*** A mean of 3.28 and a standard deviation of 0.936 indicate that students find the complexity of mathematical modelling concepts a significant challenge. Hattie, (2009) supports this observation, highlighting that students frequently encounter difficulties with complex mathematical concepts, which can lead to frustration and reduced confidence however, simplifying concepts and providing additional support or scaffolding could help mitigate these challenges.
3. ***Interdisciplinary Nature:*** With a mean of 3.24 and a standard deviation of 0.831, the interdisciplinary nature of engineering mathematics is seen as a moderate high challenge. Borasi, (1994) emphasizes that interdisciplinary approaches in education can be difficult for students due to the need to integrate knowledge from various fields, however encouraging collaboration between departments and integrating interdisciplinary projects could enhance students' ability to navigate these complexities.
4. ***Software and Tools:*** A mean of 3.12 and a standard deviation of 0.881 suggest that software and tools are perceived as a moderate high challenge. This aligns with Ertmer & Ottenbreit-Leftwich, (2010) indicating that while technological tools can enhance learning, students often face difficulties in effectively utilizing these resources due to lack

of familiarity or inadequate training, however improved training and support in the use of these tools could alleviate some of these challenges.

5. ***Limited Financial Support****:* Students report a mean of 3.20 and a standard deviation of 0.816 for limited financial support being a challenge. This is consistent with Finnie & Mueller, (2008) who highlights financial constraints as a significant barrier to accessing educational resources and opportunities, however providing additional financial support or resources could help mitigate this issue and improve students' access to necessary materials.
6. ***Shortage of Instructional Material:*** With a mean of 2.64 and a low standard deviation of 0.638, the shortage of instructional materials is perceived as a moderate high challenge but less critical than other factors. This result aligns with Tobin, (1993) suggesting that while material shortages can impact learning, they may be less significant compared to other challenges like complexity and financial support however, ensuring adequate provision of instructional materials is still important but may not be the highest priority.
7. ***Hardware Requirements:*** A mean of 3.24 and a standard deviation of 0.831 indicate that hardware requirements are a moderate high challenge. This finding is supported by Borko et al., (2006), who emphasizes the need for up-to-date and adequate hardware to effectively support engineering education and mathematical modelling. Addressing hardware deficiencies could improve the overall learning experience.
8. ***Limited Access to Internet Facilities:*** With a mean of 1.88 and a standard deviation of 0.971, limited internet access is perceived as a moderate low challenge. Warschauer, (2004) highlights the increasing importance of internet access for educational success, yet this result suggests it is less critical in this context, however, the varied responses indicate that some students may still experience difficulties related to internet access.

9. ***Curricula Constraints:*** A mean of 3.16 and a standard deviation of 1.028 suggest that curricula constraints are a moderate high challenge. Dewey, (1938) indicates that rigid curricula can limit the flexibility needed to effectively teach complex concepts like mathematical modelling however, revising and adapting curricula to better accommodate the needs of students could improve learning outcomes.
10. ***Assessment and Evaluation:*** With a mean of 3.16 and a standard deviation of 0.943, assessment and evaluation methods are seen as a moderate high challenge. Black & Wiliam, (1998) supports this finding, noting that traditional assessment methods may not effectively measure students' understanding of complex, real-world problems, however implementing diverse and formative assessment methods could provide a more accurate evaluation of student learning and development.

Table 7: Responses on students' perception on benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics.

Statement	SD (%)	D (%)	A (%)	SA (%)	Mean	σ	Decision
Enhanced conceptual understanding	1 (4%)	1 (4%)	14 (56%)	9 (36%)	3.24	0.723	Moderate High
Promotion of critical thinking and problem- solving skills	3 (12%)	5 (20%)	7 (28%)	10 (40%)	2.96	1.060	Moderate High
Integration of theory and practice	2 (8%)	3 (12%)	10 (40%)	10 (40%)	3.12	0.927	Moderate High
Preparation for professional practice	3 (12%)	3 (12%)	12 (48%)	7 (28%)	2.92	0.954	Moderate High
Inter-disciplinary learning opportunities	2 (8%)	2 (8%)	10 (40%)	11 (44%)	3.20	0.913	Moderate High

Note: N = 25, SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree

4.5.2 Analysis of Table 4.7 data

1. ***Enhanced Conceptual Understanding:*** With a mean of 3.24 and a standard deviation of 0.723, students agree that mathematical modelling significantly enhances their conceptual understanding of engineering mathematics. Monk, (1994); Lesh & Doerr, (2003) highlights the role of mathematical modelling in deepening students' comprehension of abstract concepts by applying them to real-

world problems. Modelling activities help students visualize and manipulate mathematical concepts, thereby reinforcing their understanding.

2. ***Promotion of Critical Thinking and Problem-Solving Skills:*** A mean of 2.96 and a standard deviation of 1.060 suggest that students perceive moderate high benefits in developing critical thinking and problem-solving skills through mathematical modelling. The higher standard deviation indicates variability in student perceptions, with some students potentially not fully recognizing these benefits. This variability is consistent with Hattie, (2009); Bransford et al., (2000) suggesting that while modelling can enhance critical thinking and problem-solving skills, the extent of these benefits can vary based on how the modelling activities are structured and integrated into the curriculum.
3. ***Integration of Theory and Practice:*** Students' perceptions of a mean of 3.12 and a standard deviation of 0.927 indicate that mathematical modelling is seen as effective in integrating theoretical knowledge with practical application. This supports the literature on the importance of bridging theory and practice in engineering education. Mathematical modelling provides a framework for applying theoretical concepts to real-world situations, which is crucial for effective learning and understanding (Felder & Brent, 2005; Crouch & Mazur, 2001).
4. ***Preparation for Professional Practice:*** A mean of 2.92 and a standard deviation of 0.954 reflect students' moderate agreement that mathematical modelling prepares them for professional practice. This result suggests that while students see some benefit in terms of professional preparation, the perceived impact is not as strong as other benefits. Borasi, (1994); Engle & Conant, (2002) supports that mathematical modelling is crucial for preparing students for professional practice by simulating real-world problems and decision-making processes. The moderate score might

indicate a need for further integration of modelling tasks that closely mimic professional scenarios

5. ***Inter-disciplinary Learning Opportunities:*** The mean of 3.20 and a standard deviation of 0.913 suggest that students recognize moderate high benefits from interdisciplinary learning opportunities facilitated by mathematical modelling. This is consistent with Beane, (1997); Klein, (1996), research emphasizing the value of interdisciplinary approaches in education for fostering a broader perspective and integrating diverse fields of knowledge. Mathematical modelling often involves drawing on concepts from various disciplines, enhancing students' ability to apply mathematical techniques in a multifaceted context.

4.6 Impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College

This section presents the results found in relation to the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics in Civil engineering Courses at Mutare Polytechnic College. In the table below opinions that were advanced by selected college students are presented in **Table 4.8**.

Table 8*:* *S*tudents' Perceptions on the impact of Mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics in Civil engineering Courses at Mutare Polytechnic College.

Statement	SD (%)	D (%)	A (%)	SA (%)	Mean	σ	Decision
It increases real world application and understanding of Engineering concepts	2 (8%)	4 (16%)	12 (48%)	7 (28%)	2.96	0.889	Moderate High
It enhances problem solving skills	2 (8%)	2 (8%)	11 (44%)	10 (40%)	3.16	0.898	Moderate High
It aids some interdisciplinary connections between Mathematics and Engineering	2 (8%)	4 (16%)	10 (40%)	9 (36%)	3.04	0.935	Moderate High
Gives higher motivation and engagement	3 (12%)	10 (40%)	5 (20%)	7 (28%)	2.64	1.036	Moderate High
It helps collaborative learning	3 (12%)	4 (16%)	10 (40%)	8 (32%)	2.92	0.997	Moderate High
Provides enough preparation for industry	1 (4%)	3 (12%)	12 (48%)	9 (36%)	3.16	0.800	Moderate High
Fosters positive attitude towards Mathematics	3 (12%)	6 (24%)	9 (36%)	7 (28%)	2.80	1.000	Moderate High

Note: N = 25, SD = Strongly Disagree, D = Disagree, A = Agree, SA = Strongly Agree

The data analysis in **Table 4.8** shows that majority of the respondents appeared to feel that mathematical modelling enhances problem solving skills as well as provision of enough preparation for industry. Also, they felt that mathematical modelling helps to aid some interdisciplinary connections between Mathematics and Engineering and helps in collaborative learning. Students also perceived that mathematical modelling increases real world application and understanding of Engineering, gives higher motivation and engagement as well as fostering positive attitude towards Mathematics. As a result, results in **Table 4.8** show that the majority of the students highly perceive that incorporating mathematical modelling in the teaching and learning on Engineering Mathematics at Mutare Technical College yields positive impacts.

4.6.1 Analysis of Table 4.8

1. ***Increases Real World Application and Understanding of Engineering Concepts:*** With a mean of 2.96 and a standard deviation of 0.889, students perceive that mathematical modelling enhances their understanding of real-world applications of engineering concepts. Lesh & Doerr, (2003); Hattie, (2009) asserts that mathematical modelling

provides students with the opportunity to apply mathematical concepts to real-world scenarios, reinforcing their understanding and relevance however, the moderate variability in responses reflects that while many students see the benefit, the extent of this impact may vary based on individual experiences.

2. ***Enhances Problem Solving Skills*****:** A mean of 3.16 and a standard deviation of 0.898 suggest that mathematical modelling is perceived as moderately high in enhancing problem-solving skills. This result supports the finding by Polya, (1957); Niss, (2003) which highlights mathematical modelling as a tool that develops critical problem-solving abilities by challenging students to formulate and solve complex problems. The moderate level of consensus among students indicates that while there is agreement on the benefits, the impact may not be uniformly experienced by all students.
3. ***Aids Some Interdisciplinary Connections Between Mathematics and Engineering:*** Students perceive mathematical modelling as positively aiding in interdisciplinary connections, with a mean of 3.04 and a standard deviation of 0.935. This aligns with Beane, (1997); Klein, (1996) on the value of interdisciplinary approaches in education, which emphasize how mathematical modelling bridges different fields, such as mathematics and engineering. The variability in responses suggests that the effectiveness of these interdisciplinary connections might differ based on the specific context and implementation of modelling activities.
4. ***Gives Higher Motivation and Engagement:*** A mean of 2.64 and a standard deviation of 1.036 indicate that while mathematical modelling is seen as contributing to motivation and engagement, this effect is perceived to be less pronounced. This finding contrasts with Schoenfeld, (1992) and Boaler, (2002) findings that suggests mathematical modelling can significantly enhance student engagement by making learning more relevant and interactive. The higher variability in responses may reflect

differing experiences with how modelling activities are integrated into the curriculum and their perceived effectiveness in boosting motivation.

5. ***Helps Collaborative Learning:*** With a mean of 2.92 and a standard deviation of 0.997, students view mathematical modelling as moderately high in assisting collaborative learning. This result supports Cohen, (1994); Johnson & Johnson, (1994) findings that highlights the role of collaborative problem-solving in modelling activities, which can foster teamwork and collective problem-solving skills. The variability in student responses indicates that while collaborative aspects are generally recognized, the extent of their impact can vary.

6. ***Provides Enough Preparation for Industry:*** A mean of 3.16 and a standard deviation of 0.800 suggest that mathematical modelling is perceived as providing moderate high preparation for industry. This finding is consistent with Borasi, (1994); Engle & Conant, (2002) emphasizing that mathematical modelling prepares students for real-world challenges by simulating industry-relevant problems and decision-making processes. The relatively high level of agreement reflects a strong belief in the practical benefits of modelling for career readiness.

7. ***Fosters Positive Attitude Towards Mathematics:*** A mean of 2.80 and a standard deviation of 1.000 indicate that mathematical modelling is perceived to moderately high foster a positive attitude towards mathematics. This result is in line with Schoenfeld, (1985); Boaler, (2002) suggesting that engaging in meaningful mathematical activities, such as modelling, can improve students' attitudes towards the subject. The higher variability in responses may point to differences in how students experience and perceive the impact of modelling on their attitudes towards mathematics.

4.7 Guidelines for effectively integrating mathematical modelling into college engineering mathematics courses.

This section presents the results found in relation to the Guidelines for effectively integrating mathematical modelling into college engineering mathematics courses. All the selected lecturers seem to show that they are aware of the guidelines that need to be observed when effectively integrating mathematical modelling into college engineering mathematics courses. This was supported by one of the respondents who articulated that:

I acknowledge that to effectively integrate mathematical modelling into college engineering mathematics courses, it is critical to address the issue of curriculum design and alignment of the program in the course. (Lecturer 01)

Lecturer 01 emphasizes the importance of curriculum design and alignment. Blum and Niss (1991), asserts that a well-structured curriculum that integrates mathematical modelling helps students see the relevance of mathematics in real-world applications and ensures that the subject matter is interconnected, rather than a series of disjointed topics. Furthermore, Howson, Keitel, and Kilpatrick (1981) argue that alignment with industry needs and academic standards is crucial. This ensures that the skills and knowledge students acquire are relevant and applicable in their future careers. The integration of mathematical modelling into the curriculum should also be aligned with the learning outcomes of the engineering programs, ensuring that it contributes to the overall educational goals.

Another respondent said that:

Effective integration of mathematical modelling into college engineering mathematics courses requires the need to address collaborative learning environment as well as making sure that as lecturers we give appropriate feedback to students. (Lecturer 02)

Lecturer 02 highlights the need for a collaborative learning environment and effective feedback, which are well-supported by educational theories. Vygotsky’s (1978) social constructivist theory emphasizes the importance of social interaction in learning. Collaborative learning environments allow students to work together, share ideas, and learn from each other, which is particularly beneficial in understanding complex mathematical models. Additionally, Hattie and Timperley (2007) stress the importance of feedback in the learning process. Feedback helps students understand their current level of performance, what they need to improve, and how to achieve their learning goals. In the context of mathematical modelling, timely and constructive feedback can help students refine their models and improve their problem-solving skills.

Regarding the issue of guidelines for integrating mathematical modelling into college engineering mathematics courses, the other lecturer mentioned that:

As lecturers we need to adopt appropriate pedagogical strategies when delivering our lectures to our esteemed students. (Lecturer 03)

Lecturer 03 focuses on adopting appropriate pedagogical strategies. According to Schoenfeld (1985), effective teaching strategies in mathematical modelling include the use of real-world problems, interdisciplinary approaches, and the integration of technology. These strategies make the learning experience more engaging and relevant for students. Furthermore, Blomhøj and Jensen (2003) argue that teachers should be facilitators of learning, guiding students through the modelling process rather than simply providing answers. This pedagogical approach encourages active learning and helps students develop critical thinking and problem-solving skills.

4.7.1 Curriculum Integration

In relation to the guidelines of effectively integrating mathematical modelling in the teaching and learning of Engineering mathematics courses, one of the lecturers echoed the following statement:

"*One of the key challenges I face is ensuring that the mathematical modelling components are aligned with the existing curriculum's learning objectives and outcomes. It can be difficult to integrate new material without disrupting the overall structure and flow of the course. Additionally, I need to consider the students' prior knowledge and skills, as well as the availability of resources and support, to ensure a smooth integration."* (Lecturer 01)

Lecturer 01's concern about aligning mathematical modelling components with existing curriculum learning objectives and outcomes is a significant challenge. According to Niss and Blum (1991), effective integration of mathematical modelling into the curriculum necessitates that it be seamlessly woven into the overall course structure without disrupting the flow. This integration requires careful planning to ensure that new content supports and enhances existing learning outcomes.

Another lecturer articulated that:

"*I find that a major challenge is balancing the level of mathematical complexity with the students' ability to understand and apply the concepts. Mathematical modelling requires a strong foundation in mathematical principles, but not all students may have the necessary background or skills. I need to find ways to scaffold the learning experience and provide additional support for students who may struggle with the mathematical aspects*."(Lecturer 02)

Lecturer 02 pointed about balancing the level of mathematical complexity with students' ability to understand and apply concepts, Schoenfeld (1985) emphasizes the importance of scaffolding to support students’ learning. This involves breaking down complex concepts into manageable parts and providing step-by-step guidance to help students build a strong foundation.

Additionally, differentiated instruction, as discussed by Tomlinson (2001), can be beneficial in addressing varied levels of student preparedness and ensuring that all students can engage with mathematical modelling.

The third lecturer said the following statements:

"*A significant challenge I face is convincing colleagues and administrators of the value and relevance of integrating mathematical modelling into the existing curriculum. There may be concerns about taking time away from other important topics or worries about students' ability to handle the additional complexity. I need to demonstrate the benefits of mathematical modelling, such as improved problem-solving skills and real-world applications, to gain buy-in and support for the changes."* (Lecturer 03)

Lecturer 03 highlights the challenge of convincing colleagues and administrators of the value of integrating mathematical modelling. Fullan (2001) notes that gaining buy-in from stakeholders is crucial for successful educational change. This often involves demonstrating the practical benefits of the new approach, such as enhanced problem-solving skills and the ability to apply mathematical concepts to real-world situations. Engaging stakeholders through presentations, workshops, and evidence of student success can help in overcoming resistance and securing support.

4.7.2 Pedagogical Approaches

In response to teaching strategies of effectively introducing mathematical modelling, one of the lecturers articulated the following statements:

"*I've found that using real-world examples and case studies is an effective way to introduce mathematical modelling concepts to students. By using scenarios that are relevant and relatable, students can see the practical applications of mathematical modelling and become more engaged in the learning process. I also use a combination of lectures, group work and* *hands-on activities to cater to different learning styles and promote active learning."* (Lecturer 01)

Lecturer 01 emphasizes the use of real-world examples and case studies, which is consistent with the literature on contextual learning. According to Lesh and Doerr (2003), using authentic scenarios helps students understand the relevance of mathematical concepts and enhances their engagement. Real-world problems make abstract mathematical ideas concrete, thereby increasing student motivation and participation. This approach aligns with experiential learning theories proposed by Kolb (1984), which stress the importance of concrete experiences in the learning process.

Further, to this a similar viewpoint was advanced by one of the lecturers:

"*I've had success with a 'problem-first' approach, where students are presented with a real-world problem or scenario and asked to develop a mathematical model to solve it. This approach encourages students to think critically and creatively, and to see mathematical modelling as a tool for problem-solving. I also provide scaffolding and support as needed and encourage students to reflect on their own learning and modelling processes*." (Lecturer 02)

Lecturer 02's 'problem-first' approach is supported by research on problem-based learning (PBL). Savery and Duffy (1995) advocate for PBL as it encourages critical thinking, creativity, and active problem-solving. By presenting students with a problem before introducing the mathematical concepts needed to solve it, students are motivated to learn and apply new knowledge. This method also aligns with constructivist theories, which suggest that learners construct knowledge through experiences and reflections (Vygotsky, 1978).

Similarly, another respondent highlighted that:

"*I've found that using visual aids, such as graphs, diagrams and simulations, is an effective way to introduce mathematical modelling concepts to students. Visualizations can help students understand complex systems and relationships and make the modelling process more tangible* *and accessible. I also use technology, such as modelling software and programming languages, to enable students to explore and experiment with different models and scenarios in a interactive and dynamic way*." (Lecturer 03)

Lecturer 03's use of visual aids and technology is corroborated by educational research emphasizing the importance of visualization in learning complex concepts. Mayer (2002) suggests that visual representations, such as graphs and diagrams, can significantly enhance understanding by making abstract concepts more tangible. Additionally, the use of technology and interactive tools aligns with findings by Kaput (1992), who argues that technology can provide dynamic and interactive ways to explore mathematical models, making learning more engaging and effective.

4.7.3 Student Engagement

With regards to student engagement as one of the key pillars of the guidelines of effectively introducing mathematical modelling in the teaching and learning of Engineering mathematics courses, one respondent said the following statements:

"*I use project-based learning to ensure students can apply mathematical modelling to real-world engineering problems. Students work on projects which provides them with real-world context and constraints. I also encourage students to validate their models with experimental data and iterate on their designs to ensure they are practical and effective."* (Lecturer 01)

Lecturer 01's use of project-based learning to apply mathematical modelling to real-world engineering problems aligns with research on experiential learning. According to Kolb (1984), experiential learning, including project-based learning, engages students by immersing them in practical problems and allowing them to apply theoretical knowledge in real-world contexts. This approach helps students see the relevance of their studies and enhances their problem-solving skills by providing a tangible context in which to apply their mathematical models. Validation of models with experimental data and iterative design processes are consistent with best practices in engineering education, which emphasize the importance of real-world testing and refinement (Dym et al., 2005).

Another respondent advanced the following sentiments:

"*I emphasize the importance of problem definition and formulation in mathematical modelling. Students learn to identify and articulate real-world engineering problems, and then develop models that address those specific problems. I also encourage students to consider multiple perspectives and constraints, such as economic, environmental, and social factors, when developing their models."* (Lecturer 02)

Lecturer 02's emphasis on problem definition and formulation highlights a crucial aspect of mathematical modelling that is supported by literature on effective problem-solving strategies. According to Polya (1957), clear problem definition and formulation are essential steps in solving complex problems. Encouraging students to identify and articulate real-world problems, while considering multiple perspectives and constraints, enhances their critical thinking and problem-solving abilities. This approach aligns with the constructivist view that students learn more effectively when they are actively involved in defining and addressing real-world challenges (Brusilovsky & Millán, 2007).

Responding to the issue of students' engagement, another respondent articulated the following statements:

"*I use a 'model-deploy-validate' approach to ensure students can apply mathematical modelling to real-world engineering problems. Students develop models, deploy them in a simulated or real-world environment, and then validate their performance using data and metrics. I also encourage students to reflect on their modelling process and identify areas for improvement, which helps them develop a more nuanced understanding of mathematical modelling in engineering contexts."* (Lecturer 03)

Lecturer 03’s 'model-deploy-validate' approach emphasizes an iterative process that is crucial for effective mathematical modelling. This approach reflects research on the iterative nature of engineering design, where models are continuously tested, validated, and refined based on feedback and data (Ulrich & Eppinger, 2015). Encouraging students to deploy models in simulated or real-world environments and reflect on their performance helps them develop a deeper understanding of the modelling process and its practical implications. Reflective practices, as suggested by Schön (1983), enable students to critically analyse their work and identify areas for improvement, fostering a more nuanced understanding of mathematical modelling.

4.7.4 Assessment and Evaluation

In significant to the issue of assessment and evaluation, one of the respondents echoed the following sentiments:

"*I've found that open-ended, scenario-based assignments are effective in evaluating students' modelling skills. Students are presented with a real-world scenario or case study and asked to develop a mathematical model to address a specific problem or question. This type of assignment allows students to demonstrate their ability to think critically, formulate problems, and develop creative solutions."* (Lecturer 01)

Lecturer 01's use of open-ended, scenario-based assignments aligns with the literature on authentic assessment. According to Wiggins (1990), authentic assessments require students to apply their knowledge to real-world scenarios, demonstrating their ability to think critically and solve complex problems. This type of assessment allows for a more comprehensive evaluation of students' modelling skills, including problem formulation, model development, and solution creativity.

Another respondent voiced the following statements:

"*I use a combination of individual and group projects, as well as presentations and written reports, to evaluate students' modelling skills. Students work on a semester-long project where they develop and refine a mathematical model, and then present their findings to the class. This allows me to assess their ability to communicate complex ideas, work collaboratively, and apply mathematical modelling to real-world problems."* (Lecturer 02)

Lecturer 02's approach of using a combination of individual and group projects, presentations, and written reports is supported by research on diverse assessment methods. Knight and Yorke (2003) argue that using multiple assessment forms provides a more holistic view of students' abilities, catering to different learning styles and skills. Group projects promote collaboration and communication, while individual projects assess personal understanding and application. Presentations and reports help evaluate students' ability to articulate and communicate complex ideas effectively, which is crucial in professional settings

Similarly, another respondent said the following sentiments:

"*I've had success with 'modelling cycles' assignments, where students are asked to develop, test and refine a mathematical model over several iterations. Each cycle includes a written reflection and self-assessment, which helps me evaluate their ability to think metacognitively about their modelling process. I also use peer review and feedback to encourage students to learn from one another and improve their modelling skills."* (Lecturer 03)

Lecturer 03's use of 'modelling cycles' assignments, including written reflections and self-assessment, is well-supported by the literature on iterative learning and metacognition. According to Schoenfeld (1985), iterative processes in learning allow students to refine their understanding and improve their skills through repeated practice. Reflective practices, as discussed by Schön (1983), encourage students to think about their thinking (metacognition), enhancing their problem-solving abilities and understanding of the modelling process. Peer review and feedback further reinforce this by providing diverse perspectives and promoting collaborative learning, as supported by Vygotsky’s (1978) social constructivist theory.

4.7.5 Resources and Support

In relation to the guidelines of effectively integrating mathematical modelling in the teaching and learning of Engineering mathematics courses, one of the respondents advanced the following statements:

"*Yes, I believe that having additional resources such as modelling software, computational tools, and data sets would enhance the integration of mathematical modelling in my courses. Additionally, having a dedicated tutor or teaching assistant who can provide one-on-one support to students would be beneficial, especially for students who struggle with the mathematical aspects of modelling."* (Lecturer 01)

Lecturer 01’s mention of the need for modelling software, computational tools, and data sets is supported by research on the integration of technology in education. According to Kaput (1992), technology enhances learning by providing dynamic, interactive tools that facilitate the exploration of mathematical models. Access to relevant software and tools allows students to engage more deeply with modelling processes, making abstract concepts more tangible. Furthermore, the presence of a dedicated tutor or teaching assistant is crucial for providing personalized support, particularly for students struggling with complex mathematical concepts (Bransford, Brown, & Cocking, 2000).

In response to the relevance of resources and support, another respondent articulated the following statements:

"*I think that collaborations with industry partners and real-world practitioners would be incredibly valuable. Having guest lectures, case studies and projects that are directly relevant* *to current industry challenges would help students see the practical applications of mathematical modelling. Additionally, having access to resources such as internships, job shadowing, and mentorship programs would provide students with hands-on experience and networking opportunities."* (Lecturer 02)

Lecturer 02's focus on industry collaboration aligns with experiential learning theories and the importance of real-world applications in education. Kolb (1984) emphasizes that learning is most effective when students can relate theoretical knowledge to practical experiences. Collaborations with industry partners, guest lectures, case studies, and relevant projects help bridge the gap between academia and industry, providing students with valuable insights into the practical applications of mathematical modelling. Additionally, opportunities such as internships and mentorship programs offer hands-on experience and professional networking, which are critical for students' career readiness (Lesh & Doerr, 2003).

The other respondent said the following statements:

"*I believe that professional development opportunities for instructors, such as workshops, conferences, and training programs, would be essential in enhancing the integration of mathematical modelling in our courses. Staying current with new technologies, methods, and pedagogies is crucial in effectively teaching mathematical modelling. Additionally, having a community of practice or peer network where instructors can share resources, ideas and best practices would be incredibly supportive and help to foster a culture of innovation and excellence in teaching mathematical modelling."* (Lecturer 03)

Lecturer 03's point about professional development for instructors highlights the need for continuous learning and adaptation in teaching practices. The literature underscores the importance of professional development in keeping educators current with new technologies, methodologies, and pedagogical strategies (Guskey, 2002). Workshops, conferences, and training programs enable instructors to enhance their skills and knowledge, ensuring that they can effectively teach complex subjects like mathematical modelling. Furthermore, creating a community of practice or peer network facilitates the sharing of resources, ideas, and best practices, fostering a collaborative environment that promotes innovation and excellence in teaching (Wenger, 1998).

4.7.6 Interdisciplinary Connections

The researcher managed to gather data in relation to interdisciplinary connections. As a result, one of the respondents highlighted that:

"*I connect mathematical modelling with other engineering subjects by using interdisciplinary case studies and projects that require students to apply concepts from multiple disciplines. This helps students see the connections between different subjects and how they can be used together to solve real-world problems."* (Lecturer 01)

Lecturer 01's use of interdisciplinary case studies and projects to connect mathematical modelling with other engineering subjects aligns with the literature on integrated curriculum design. According to Jacobs (1989), interdisciplinary teaching helps students make connections between different subject areas, leading to a deeper understanding of the material. By engaging in projects that require the application of concepts from multiple disciplines, students can see the practical relevance and interconnectedness of their knowledge, which enhances their problem-solving skills and prepares them for real-world challenges.

Further to this, a similar viewpoint was advanced by one of the respondents:

"*I use a systems-thinking approach to connect mathematical modelling with other engineering subjects. Students learn to model complex systems and analyse the interactions between different components, which requires them to draw on knowledge from multiple disciplines such* *as electrical engineering, computer science and physics. This helps students understand how mathematical modelling can be used to analyse and design complex systems*." (Lecturer 02)

Lecturer 02's systems-thinking approach, which involves modelling complex systems and analysing interactions between different components, is supported by research on systems thinking in education. Richmond (1993) argues that systems thinking helps students understand the complexity and interdependence of systems, fostering holistic thinking and analysis. This approach requires students to draw on knowledge from various disciplines, such as electrical engineering, computer science, and physics, demonstrating how mathematical modelling can be used to design and analyse complex systems. Such interdisciplinary learning promotes critical thinking and the ability to synthesize information from diverse fields.

Another respondent echoed the following statements:

"*I connect mathematical modelling with other engineering subjects by using a problem-based learning approach. Students are presented with real-world problems that require them to apply mathematical modelling, as well as concepts from other disciplines such as materials science, thermodynamics, and structural analysis. This approach helps students see the relevance of mathematical modelling to other subjects and how they can be used together to solve practical problems."* (Lecturer 03)

Lecturer 03's use of a problem-based learning (PBL) approach to connect mathematical modelling with other engineering subjects is well-supported by the literature on PBL. Savery and Duffy (1995) highlight that PBL presents students with real-world problems that require the integration of knowledge from multiple disciplines to develop solutions. This method helps students understand the relevance of mathematical modelling to other subjects and see how different concepts can be combined to address practical issues. PBL fosters active learning, critical thinking, and the application of theoretical knowledge to real-world scenarios, making learning more engaging and meaningful.

4.7.7 Student Feedback

In response to the relevance of student feedback, as one of the guidelines of integrating mathematical modelling, one of the respondents mentioned the following statements:

"*Students have told me that the mathematical modelling components of my courses have helped them develop a deeper understanding of the underlying principles of engineering and have made the material more engaging and relevant. Some students have also commented that the modelling activities have helped them develop problem-solving skills and think more critically about complex systems. However, some students have also mentioned that the modelling components can be challenging and require a significant amount of time and effort."* (Lecturer 01)

Lecturer 01's comments about students developing a deeper understanding of engineering principles and finding the material more engaging align with the literature on active learning and student engagement. Prince (2004) emphasizes that active learning strategies, such as mathematical modelling, increase student engagement and deepen understanding by involving students in the learning process. The hands-on nature of modelling helps students connect theoretical concepts to real-world applications, enhancing their comprehension and interest

Another respondent highlighted that:

"*I've received feedback from students that the mathematical modelling components of my courses have helped them see the practical applications of mathematical concepts and have made the math more meaningful and interesting. Students have also appreciated the opportunity to work on real-world problems and case studies, which has helped them develop a sense of purpose and motivation. However, some students have also suggested that more* *guidance and support would be helpful, especially for those who struggle with mathematical modelling*." (Lecturer 02)

Lecturer 02’s feedback that students appreciate seeing the practical applications of mathematical concepts aligns with the literature on relevance in education. According to Newmann et al. (1992), when students see the practical applications of what they are learning, their motivation and engagement increase. Working on real-world problems and case studies helps students understand the relevance of mathematical modelling, providing a sense of purpose and motivation to learn. This practical approach to learning is supported by constructivist theories, which advocate for learning experiences that reflect real-life contexts (Dewey, 1938).

Further, another respondent advanced the following statements:

"*Students have told me that the mathematical modelling components of my courses have been eye-opening and have helped them understand how mathematical modelling is used in industry and research. Some students have also commented that the modelling activities have helped them develop collaboration and communication skills, as they work in teams to develop and present their models. However, some students have also mentioned that the modelling components can be frustrating at times, especially when the models don't work as expected, and have suggested more opportunities for feedback and iteration."* (Lecturer 03)

Lecturer 03’s feedback that modelling activities help students develop collaboration and communication skills is supported by research on teamwork and communication in education. Johnson et al. (1998) highlights the benefits of cooperative learning, where students work together to solve problems and develop models, enhancing their interpersonal skills and ability to communicate complex ideas. These skills are crucial for professional success and are effectively developed through collaborative modelling activities.

4.7.8 Professional Development

In relation to the relevance of professional development, one of the respondents advanced the following statements:

"*No, I have not participated in any professional development workshops or conferences focusing on teaching mathematical modelling. I am really eager to attend one."* (Lecturer 01)

Lecturer 01's eagerness to attend professional development workshops but lack of participation underscores a common issue in education: the gap between the need for professional development and access to it. According to Guskey (2002), effective professional development is essential for teachers to stay updated with new teaching strategies and subject knowledge. The absence of such opportunities can limit an instructor's ability to implement innovative teaching practices effectively. Providing more accessible professional development opportunities is crucial for supporting educators in their professional growth.

Another respondent mentioned that:

"*I have participated in online courses and webinars related to teaching mathematical modelling, such as the 'Mathematical Modelling in Engineering' course. These professional development opportunities have helped me stay current with industry trends and best practices in mathematical modelling. They have also given me new ideas for projects and activities that I can use in my classroom, which has helped me create a more engaging and relevant learning environment for my students."* (Lecturer 02)

Lecturer 02's participation in online courses and webinars, such as the 'Mathematical Modelling in Engineering' course, aligns with the literature on the benefits of flexible and accessible professional development formats. Garet et al. (2001) found that high-quality professional development, including online courses, can significantly impact teaching practices by introducing new ideas and best practices. These formats allow educators to stay current with industry trends and apply new knowledge directly to their classrooms, enhancing the learning experience for students.

In a similar vein, another respondent suggested that:

"*I have been part of a faculty learning community focused on teaching mathematical modelling, which has been incredibly impactful on my approach. The community has provided a supportive environment where I can share my experiences, receive feedback, and learn from others. We have also collaborated on developing new curriculum materials and assessments, which has helped me refine my teaching practices. Through this community, I have shifted my focus from solely teaching mathematical techniques to also emphasizing the modelling process and applications*." (Lecturer 03)

Lecturer 03's involvement in a faculty learning community reflects the positive impact of collaborative professional development. According to Vescio, Ross, and Adams (2008), professional learning communities (PLCs) provide a supportive environment for educators to share experiences, receive feedback, and collaboratively develop new teaching materials and assessments. This collaborative approach fosters a culture of continuous improvement and innovation in teaching practices. The shift from focusing solely on mathematical techniques to emphasizing the modelling process and applications illustrates how PLCs can broaden educators' perspectives and enhance their instructional strategies.

4.7.9 Future Directions

In relation to the guidelines of effectively integrating mathematical modelling in teaching and learning of Engineering mathematics courses, the researcher gathered lecturers' views and one of the respondents mentioned the following statements:

"*I would like to see more emphasis on real-world applications and case studies in mathematical modelling courses. This could involve collaborations with industry partners or the use of real-world data sets. I would also like to see more focus on the modelling process itself, including the formulation of problems, the selection of appropriate models, and the interpretation of results. This would help students develop a more nuanced understanding of mathematical modelling and its limitations*." (Lecturer 01)

Lecturer 01's desire for more real-world applications and case studies in mathematical modelling courses is well-supported by educational research. According to Jonassen et al. (2006), using real-world problems and data sets in teaching can significantly enhance students' understanding and engagement by showing the practical relevance of their studies. Collaborations with industry partners and the use of real-world data help bridge the gap between academic knowledge and industry practices, preparing students for professional challenges they will face after graduation.

In addition, another respondent mentioned that:

"*I would like to see more innovative uses of technology in mathematical modelling courses, such as the use of simulation software, programming languages like Python or MATLAB, and online platforms for collaboration and sharing of models. I would also like to see more emphasis on interdisciplinary approaches to mathematical modelling, incorporating insights and methods from fields like computer science, physics, and biology."* (Lecturer 02)

Lecturer 02's interest in incorporating more advanced technology, such as simulation software, programming languages (e.g., Python, MATLAB), and online collaboration platforms, aligns with the literature on technology-enhanced learning. The integration of such technologies can facilitate more interactive and dynamic learning experiences, making complex mathematical modelling concepts more accessible and engaging (Mishra & Koehler, 2006). Additionally, interdisciplinary approaches are crucial as they help students see the interconnectedness of different fields and understand how mathematical modelling can be applied across various domains (Klein, 1990).

Similarly, another respondent highlighted that:

"*I would like to see more focus on the development of soft skills in mathematical modelling courses, such as communication, teamwork, and problem-solving. This could involve more group projects, presentations, and writing assignments. I would also like to see more emphasis on the ethical and societal implications of mathematical modelling, including issues like data privacy, bias, and the potential impacts of models on different stakeholders."* (Lecturer 03)

Lecturer 03's emphasis on developing soft skills such as communication, teamwork, and problem-solving is supported by research on essential skills for engineers. Shuman et al. (2005) highlight that modern engineering education must go beyond technical skills to include the development of these crucial soft skills, which are vital for effective teamwork and professional success. Incorporating group projects, presentations, and writing assignments helps students build these competencies. Additionally, focusing on the ethical and societal implications of mathematical modelling aligns with the growing emphasis on responsible engineering practices (Herkert, 2001). This includes understanding issues like data privacy, bias, and the broader impacts of models on society.

4.8 Chapter summary

The chapter analysed and interpreted the qualitative and quantitative results with the view to provide answers to the research objectives in chapter 1. Thus, chapter 4 was grounded in quantitative and qualitative analysis in interrogating issues around the following: guidelines for effectively integrating mathematical modelling into college engineering mathematics courses, current methods used in the teaching and learning of engineering mathematics at

Mutare Polytechnic College, challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College and impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College. In the analysis and interpretation of the results, the researcher managed to use tables as well as understandable comments. The next chapter will discuss the results/findings, draws conclusion and advances recommendations.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the study on Application of mathematical modelling in the teaching and learning of college engineering mathematics. The chapter concludes the research by making recommendations and suggestions on problems faced by students, lecturers and institutions in teaching and learning engineering mathematics.

5.2 Objectives

The main aim of the study was to develop guidelines for effectively integrating mathematical modelling into college engineering mathematics courses. A thorough investigation of current practices, challenges, benefits, and impacts of mathematical modelling in teaching and learning of college engineering mathematics has been carried out, all of which are essential for developing effective guidelines. The objectives of the study were as follows:

1. To develop guidelines for effectively integrating mathematical modelling into college engineering mathematics courses
2. To identify the current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College
3. To determine the challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College
4. To assess the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College

5.2.1 To develop guidelines for effectively integrating mathematical modelling into college engineering mathematics courses

The study highlighted the awareness and understanding among lecturers regarding the guidelines for effectively integrating mathematical modelling into college engineering mathematics courses. The findings suggest that lecturers are cognizant of the essential guidelines for integrating mathematical modelling into college engineering mathematics courses. A well-designed curriculum that seamlessly incorporates mathematical modelling is vital. This ensures that modelling is not treated as an isolated topic but is interwoven throughout the course, making it relevant and comprehensive. Creating a collaborative learning environment and providing regular, constructive feedback are critical components. These practices support student engagement and continuous improvement, which are necessary for mastering mathematical modelling concepts. The adoption of appropriate teaching methods significantly impacts the effectiveness of mathematical modelling integration. Strategies that promote active participation and problem-solving can greatly enhance students' learning experiences and outcomes.

5.2.2 To identify the current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College

The findings indicated that while traditional lecture methods remain predominant in engineering mathematics courses at Mutare Polytechnic College, there is a moderate adoption of other teaching methods such as demonstrations, discussions, and discovery learning. These methods can significantly enhance student engagement and understanding when effectively integrated. However, some methods, like field trips and inductive teaching, are underutilized, suggesting opportunities for a more diverse and engaging teaching approach.

5.2.3 To determine the challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College

The study showed that while there are significant challenges to incorporating mathematical modelling in engineering mathematics courses, there are also recognized benefits. Key challenges include negative attitudes, complexity of concepts, financial constraints, and hardware/software requirements. However, the benefits of enhanced conceptual understanding, critical thinking, integration of theory and practice, and interdisciplinary learning are also acknowledged by students.

5.2.4 To assess the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College

The study showed that incorporating mathematical modelling in Civil Engineering Mathematics courses at Mutare Polytechnic College has a moderately high positive impact on student learning and engagement. Students recognize several benefits, including enhanced problem-solving skills, better preparation for industry, and improved interdisciplinary connections. However, there is some variability in student experiences, particularly regarding motivation and engagement, and fostering a positive attitude towards mathematics.

5.3 Conclusion

The study concludes that while Mutare Polytechnic College employs a range of teaching methods in engineering mathematics, there is room for improvement to better address the challenges faced by students. Enhancing the use of interactive and student-centred teaching approaches, such as demonstrations, discussions, and field trips, can significantly improve student engagement, understanding, and practical application of engineering concepts. Additionally, addressing environmental and personal factors that hinder learning can create a more supportive and effective educational environment. By diversifying teaching methods and providing more comprehensive support, Mutare Polytechnic College can better equip its students with the skills and knowledge necessary for success in engineering mathematics and their future careers in engineering.

5.4 Recommendations

The researcher identified some possible solutions on the problems encountered in the application of mathematical modelling in teaching and learning college engineering mathematics. Based on the findings, the following recommendations are proposed.

5.2.1 To enhance the learning experience in engineering mathematics, institutions should design curricula that integrate mathematical modelling with input from industry professionals, ensuring alignment with current and future industry needs. Lecturers should cultivate a collaborative learning environment through group assignments, peer reviews, and interactive activities, while providing regular, constructive feedback via timely assessments and consultations. Teaching methods should actively engage students through techniques like active learning, problem-based learning, and real-world applications. Additionally, lecturers should pursue continuous professional development by participating in workshops, conferences, and training programs to stay abreast of the latest teaching strategies and advancements in mathematical modelling.

5.2.2 To enhance the educational experience, it is recommended to diversify teaching methods by incorporating interactive and student-centred approaches such as group discussions, problem-solving sessions, and hands-on activities, while ensuring demonstrations are well-planned and integrated into the curriculum. Increasing the frequency of field trips can link theoretical knowledge to real-world applications, enriching learning. Additionally, promoting discussion-based methods and adopting inductive teaching approaches will foster active learning, critical thinking, and problem-solving skills. A balanced use of deductive and inductive methods will cater to diverse learning styles, and supporting discovery learning with appropriate guidance will help students achieve their learning goals. Finally, providing professional development opportunities for lecturers will equip them with diverse teaching strategies to enhance student engagement and learning outcomes.

5.2.3 To address challenges in mathematical modelling education, institutions should implement workshops and seminars to highlight its importance and real-world applications, while promoting positive experiences through success stories. Complex concepts can be simplified using visual aids, practical examples, and step-by-step instructions, with additional support from tutoring and mentoring programs. Enhancing access to necessary software and tools, including exploring open-source options, is crucial, as well as seeking financial support from government and industry partners to provide resources and scholarships for disadvantaged students. Developing and distributing comprehensive instructional materials, upgrading hardware and internet facilities, and adapting curricula to better incorporate mathematical modelling are essential steps. Additionally, improving assessment and evaluation methods through continuous and project-based assessments will ensure a thorough understanding and effective application of mathematical modelling concepts.

5.2.4 To enhance mathematical modelling education, institutions should integrate real-world examples and case studies into the curriculum to highlight its relevance in engineering contexts. Emphasizing problem-solving exercises and projects will help develop students' skills, while promoting interdisciplinary learning through projects and collaborations will demonstrate the connections between mathematics and other engineering disciplines. Increasing student motivation and engagement through interactive methods like gamification and project-based learning is essential. Facilitating collaborative learning through group work will better prepare students for teamwork in professional environments. Strengthening industry partnerships will provide practical insights and application opportunities, and fostering a positive attitude towards mathematics through motivational strategies and supportive learning environments will further encourage student enthusiasm and achievement in the subject.

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Appendix I

5.5 Semi-structured questionnaire for the selected respondents

I am a final year Master of Science Education degree in Mathematics Education student with the Bindura University of Science Education carrying out a study on **Application of Mathematical modelling to teaching and learning of college engineering Mathematics at Mutare Polytechnic.**

Instructions
Kindly answer all questions.
Do not write your name on the questionnaire for anonymity and confidentiality reason, do not share neither discuss your responses with anyone. For a selected answer, use a tick. You may ask for assistance if you do not understand something or are not sure how to respond.

Section A: Personal profile

1. Sex [ ] Female [ ] Male
2. What is your age range (years)? 18 - 20 [ ] 21 - 22 [ ] 23 - 24 [ ] Above [ ]
3. Academic level Ordinary Level [ ] Advanced Level [ ] HND [ ]
   Bachelor's degree [ ]

Section B

RQ1: What are the current methods used in the teaching and learning of engineering mathematics at Mutare Polytechnic College?

1. What are the most popular teaching method(s) in Engineering Mathematics at Mutare Polytechnic College?

Teaching Methods	**Tick all which apply**
Lecture	
Demonstration	
Field trips	
Discussion	
Inductive	
Deductive	
Discovery	
Discovery	

b) How much do you agree with these statements about Engineering Mathematics: (Tick one box)

In Engineering Mathematics, A**: Lecture Method**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
B: Demonstration				
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
C: Field trips				
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
D: Discussion				
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
E: Inductive Teaching Method				
Promotes students' critical thinking and innovativeness in the Engineering programs				

Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
F: Deductive Teaching Method				
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				
G: Discovery Teaching Method				
Promotes students' critical thinking and innovativeness in the Engineering programs				
Helps in fostering students' conceptual understanding in Engineering programs				
Encourages creativity in Engineering programs				
Does not promote rote learning in Engineering students.				
Support hands -on experiences in Engineering practical				

Any other comments (if necessary)……………………………………………………………

RQ2: What are the challenges and benefits of incorporating mathematical modelling in the teaching and learning of Engineering mathematics at Mutare Polytechnic College?

Please indicate your opinion on these statements about Engineering Mathematics: (tick one box)

Statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
Negative attitude towards mathematical modelling				
Complexity of concepts				
Interdisciplinary nature				
Software and tools				
Limited financial support from parents/guardians/school authorities				
Shortage of instructional material				
Hardware requirements				
Limited access to internet facilities				
Curricula constraints				
Assessment and evaluation				

Any other comments (if necessary) …………………………………………………………

Please indicate your opinion on these statements about Engineering Mathematics: (tick one box)

Statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
Enhanced conceptual understanding				
Promotion of critical thinking and problem- solving skills				
Integration of theory and practice				
Preparation for professional practice				
Inter-disciplinary learning opportunities				

Any other comments (if necessary) …………………………………………………………

RQ3: What is the impact of mathematical modelling on student learning and engagement with selected aspects of the Engineering Mathematics Course at Mutare Polytechnic College?

Please indicate your opinion on these statements about Engineering Mathematics Course: (tick one box)

Statement	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
It increases real world application and understanding of Engineering concepts				
It enhances problem solving skills				
It aids some interdisciplinary connections between Mathematics and Engineering				
Gives higher motivation and engagement				
It helps collaborative learning				
Provides enough preparation for industry				
Fosters positive attitude towards Mathematics				

Any other comments (if necessary) …………………………………………………………

RQ4: What are the guidelines for effectively integrating mathematical modelling into college engineering mathematics courses?

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……… **Thank you for your cooperation**

Appendix II

5.6 Interview Questions

1. **Curriculum Integration:** What are the key challenges you face when integrating mathematical modeling into the existing curriculum?

2. **Pedagogical Approaches:** What teaching strategies have you found most effective for introducing mathematical modeling concepts to students?

3. **Student Engagement:** What methods do you use to ensure that students can apply mathematical modeling to real-world engineering problems?

4. **Assessment and Evaluation:** What types of assignments or exams have proven effective in evaluating students' modeling skills?

5. **Resources and Support:** Are there any additional resources or support systems you believe would enhance the integration of mathematical modeling in your courses?

6. **Interdisciplinary Connections:** How do you connect mathematical modeling with other engineering subjects or disciplines?

7. **Student Feedback:** What feedback have you received from students regarding the mathematical modeling components of your courses?

8. **Professional Development**: Have you participated in any professional development related to teaching mathematical modeling? If so, how has it impacted your approach?

9. **Future Directions**: What changes or innovations would you like to see in the integration of mathematical modeling into engineering mathematics courses?