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Research Paper

The Efficacy of Model-Based Instructions in Teaching Algebra

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Abstract

Classroom learning relies on engaging teaching approaches. This study focuses on the efficacy of model-based instruction in teaching algebra to 8th-grade students at a public state college located in Tangub City, Misamis Occidental, Philippines, during the school year 2019-2020. Using purposive sampling, 40 students were divided into two groups of 20, each exposed to different teaching approaches. Pre- and post-tests were administered to both groups to assess performance before and after the treatment. To determine the students' level of performance, the researchers used the Performance Level Assessment Tool, where students' scores are categorized into five different levels: The Beginning Proficiency Level, the Developing Proficiency Level, the Approaching Proficiency Level, the Proficient Level, and the Advanced Proficiency Level. Mean was also used to determine the performance level of the groups before and after the experiment is conducted. Analysis of Covariance (ANCOVA) was used in determining the impact of teaching with algebraic modelling on students' performance in Mathematics. The collected data were statistically analyzed using Statistical Package for the Social Sciences (SPSS). The results revealed a significant improvement in the experimental group, with 80% achieving the Advanced Proficiency Level on the post-test, compared to 0% in the control group. The control group showed minimal improvement, with the majority remaining at the Beginning Proficiency Level (75%). ANCOVA confirmed a statistically significant difference ($p < .001$) in post-test scores between the two groups, favoring the algebraic modelling approach. These findings suggest that model-based instruction, specifically algebraic modelling, significantly enhances student performance in algebra.

Keywords: *Efficacy, Algebraic Modelling, Teaching Algebra, Pedagogy*

INTRODUCTION

Mathematics teaching must be aligned with current trends and orientations for each level, including kindergarten, primary school, secondary school, and high school, and must be updated accordingly. Efforts are being made to develop effective and efficient methods of teaching mathematics. One of the solutions to this may lie in trying new approaches in learning environments to encourage meaningful and permanent mathematical learning, especially by attempting to apply what is learned to real-world situations (Özer-Demir & Bukova-Güzel, 2024). Mathematics plays a crucial role in our lives. The application of mathematics is marked not only in the field of education, but in almost every aspect that we could think of: when we budget our monthly income, manage our time, and even in the infrastructure we see outside. Mathematical skills are an important goal of curricula at all levels of education (Ministry of National Education [MoNE], 2013, 2018; National Council of Teachers of Mathematics [NCTM], 2000). The traditional methods of teaching mathematics do not provide students with the opportunity to directly apply the mathematical concepts and processes they have learned to the real-world problems they encounter or to reflect on their life experiences and knowledge in the classroom. It is therefore essential that mathematics courses include practices that facilitate the use of mathematics in real life, or, in other words, support the use of mathematical concepts and processes to solve real-world

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problems (Erbaş et al., 2016; Özaltun et al., 2013; Özaltun Çelik & Bukova Güzel, 2019; Özer & Bukova Güzel, 2022). Modeling in mathematics is defined as the representation of real-life problems mathematically through continuous transitions between the mathematical and physical worlds (Bukova Güzel et al., 2016). Canbazoğlu and Tarım (2023) point out that mathematical modelling is prominent in applications such as TIMSS and PISA. According to PISA 2018, the proportion of students with the fifth and sixth proficiency levels, which determine a student's mathematical modelling skills, is 3.9% and 0.9%, respectively, based on the results. Turkey's mathematical literacy performance is below that of the majority of participating countries, and students are at the basic level in terms of mathematical skills (Canbazoğlu & Tarım, 2021b).

Mathematical modelling activities are essential in today's classroom since they provide students with various skills and enhance their learning development in mathematics. In the last few decades, many countries have started incorporating mathematical modelling into their educational curricula. The beneficial implementation of mathematical modelling in school contexts promotes positive impacts on the students' learning development, which is significant in learning mathematics. The incorporation of mathematical modelling into educational curricula allows students to gain experience in the application of mathematics and promotes a deeper understanding of mathematical concepts (Tasarib, Rosli, & Rambely, 2025). These practices are not just about solving equations but involve a comprehensive process where students engage in formulating, analyzing, interpreting, and validating mathematical models (Borromeo-Ferri & Blum, 2019). The educational value of mathematical modelling is widely acknowledged, particularly in developing students' abilities to apply mathematical knowledge in real-world situations (Kaiser & Brand, 2015). This integration also encourages the development of higher-order thinking skills, which are essential for students to explore solutions to learning challenges (Stillman et al., 2017).

In the Philippine education system, Mathematics is one of the top priorities in terms of the number of hours allocated per class in all levels. The Department of Education (DepEd) mandated a 50-minute time allocation every day in the old curriculum (Revised Basic Education Curriculum) and 1 hour for 4 days for the new curriculum (K to 12 Curriculum). Mathematics is also one of the subjects used to assess one's achievement at the national level, such as the National Career Assessment Examination and the National Achievement Test. In wanting to develop mathematical competency in the subject, to promote good camaraderie skills between students, and to establish rapport between teachers and students, various mathematics trainings for students and teachers are held in the country such as the Mathematics Teachers Association of the Philippines (MTAP) trainings and the Mathematics Trainers' Guild apart from the different mathematics enrichment and remedial programs advocated by various schools both in the private and public sectors.

Given the attention that the Philippine education system is devoting to Mathematics, various issues and difficulties still arise in teaching and learning the subject. This agrees with the statement made by Alkan (2013), who said that ever since the introduction of mathematics in the curriculum, mathematics has always been viewed as a problem area for pupils. In relation to that, it has been reported that during the 2003 Trends in International Mathematics and Science Study, the Philippines ranked near the bottom: third from the bottom in the fourth grade and fifth from the bottom in the eighth grade (Culaste, 2011).

In the Philippines, the attitude towards mathematics has always been a great concern, and according to Lee – Chua (2012), mathematics is feared due to the following reasons: terror teachers, learned helplessness, neglectful or pressure-inducing parents, society's denigration of deep thought, instant gratification, lack of motivation, and failure in examinations. According to Rysdon (2010), the primary reason why students are performing poorly in mathematics is that they still struggle to find the relevance of mathematics in their lives. Students are aware of how they can apply basic mathematical concepts in their daily lives, but when it comes to more complicated mathematical topics, and when students experience difficulties, they begin to question their essence.

Teachers, on their part, are finding ways to make their classes more engaging with mathematics by trying out new techniques and teaching methods that will interest and engage students. About that, there are plenty of teaching methods and strategies that the teachers could use. Still, this study utilized the integration of algebraic modelling because, according to Blomhøj (2009), the introduction of mathematical modelling and applications is probably, together with the introduction of information technology, the most prominent standard features in mathematics curricula reforms around the world.

Despite the recognized benefits of mathematical modeling in improving the understanding of students and problem-solving skills internationally, there is limited research that has been published on the application of model-based instruction in teaching algebra, specifically on algebraic modeling in the Philippines context. The connection between algebra and mathematical modeling, and how they can be used effectively in teaching algebraic concepts, is very difficult for most students. Many students have a hard time in solving algebraic problems, resulting in poor performance and negative attitudes toward the subject. Although previous studies have shown that mathematical modeling promotes a more profound understanding, critical thinking, and the applications of mathematics to real-life problems, evidence on its effectiveness in the Philippine classrooms remains hard to find. Thus, this study focuses on the efficacy of model-based instructions in teaching algebra to address the existing research gap.

The findings of this study contribute to the body of knowledge by providing evidence that model-based instructions, particularly algebraic modeling, are effective in improving students' understanding and performance in algebra. It will benefit the students at the said school as it could help to improve the mathematical competence of the students. For mathematics teachers, they could use algebraic modelling as a manipulative representation. Instead of having difficulty in teaching mathematics, the teacher could use algebraic modelling as a manipulative representation.

This study aimed to evaluate the impact of mathematics teaching pedagogy through algebraic modeling on Grade 8 students' performance in Mathematics. Specifically, the study sought to:

1. Describe the performance level of the students in the control and experimental group before and after the experiment; and
2. Analyze the impacts of teaching with algebraic modelling on students' performance in Mathematics.

LITERATURE REVIEW

This section shows a retrospective presentation of previously written material: research literature and concepts that have relevance and significance to the research under consideration.

Model-Based Instructions

Algebraic modelling is defined as the transformation of any problem situation into a mathematical model. However, this concept began to be used commonly to define the process, including all the steps of structuring, mathematizing, mathematical working, and interpretation/verification. Sometimes, the problem situation given is nothing more than a pre-structured mathematical problem or a mathematical problem that incorporates real-life elements. This is the classic "word problem" situation that generally occurs in schools. Using mathematics to solve problems encountered in real life is called the application of mathematics. Sometimes the application concept is used for a relation that binds real life to mathematics. In the last ten years, "application and modelling" concepts were used to explain any relations between real life and mathematics (Blum, 2002).

This systematic literature review provides a comprehensive overview of the current state of research on this topic, highlighting significant trends, consensus, and disagreements among scholars. By examining recent empirical studies, the review offers insight into the most effective practices and the obstacles that need to be overcome to maximize the benefits of mathematical modelling in education (Tasarib, Rosli, & Rambely, 2025, p. 2). The findings of this review contribute to the ongoing discussion on integrating mathematical modelling into curricula and provide valuable recommendations for future research and practice (Cevikbas et al., 2023).

According to Olkun et al. (2009), the modelling approach aims to develop methods that can discover patterns and relations, and apply these patterns and relations to solve other problems. Thus, through modelling, the aim is to enable the students to develop the skill to generalize, which is one of the basic skills in mathematical teaching. Mathematical modelling (a bi-directional process between daily life and mathematics) has become one of the most discussed and widely known topics in mathematics teaching in recent years. However, a less-than-desired level of interest is shown in the modelling topic throughout the world. The primary reason for this is that it is challenging for students and teachers due to the gap between educational objectives and school practices (Lesh & Doerr, 2003a). In fact, mathematics is a discipline whose teaching and learning is considered to be difficult. This difficulty results from the complex nature of mathematics.

Blum and Ferri outlined the cycle of the modelling process in 7 steps, as shown below, to facilitate cognitive analysis of modelling situations, which they also employed in their projects. Mathematical expression of a problem and the process of solving this problem by putting real life aside are shown cyclically in these steps. 1. Understanding the situation (problem) 2. Simplifying/structuring 3. Mathematizing 4. Mathematical working 5. Interpretation 6. Verification 7. Presentation

Firstly, the problem situation should be understood by the student, that is to say, "the situation model" is formed. After that, the situation is structured and turned into "a real model". The student should decide, especially on what is worth doing at this point. During the mathematizing process, which corresponds to the third step, the student turns "the real model" into a "mathematical model". The student conducts "a mathematical work (calculation, solving inequalities, etc.)" and reaches "the mathematical results" at the fourth step. Real results in daily life are interpreted and verified during the fifth step. Finally, the possible solutions to the problem are presented, and suggestions are made regarding the situation.

According to Arseven (2015), there are 3 different teaching approaches in modelling. These are as follows:

1) "General application approach" focuses on a specific application. Generally, the teacher introduces the model, and students use it in a controlled manner. This approach is mostly used in secondary schools, and it includes 4th (calculation, solving inequalities, etc.) and 5th steps (real results in the daily life are interpreted and verified) of the modelling process.
2) "Structure modelling approach" uses the real-life situations and covers all the stages of the modelling process from the 1st stage (the student should understand the problem situation) to the 7th stage (the possible solutions of the problem are presented). The teacher makes a critical effort to make a mathematical model used in the 3rd stage (mathematizing process).
3) "Open modelling approach". In this approach, students work with limited help from the teacher on the given problem, as the teacher does not have to control the students. This

approach is not used widely (White, 2001).

Algebraic Modelling Activity and Activity Samples. Mathematical modelling activities are mathematical modelling conducted by students in the classroom environment. The students, who work in small groups during these activities, develop their own mathematical interpretations of the problem situations and mathematize them. These activities are developed within the framework of the themes that interest the children, and they are organized in a way that encourages children to study and clarify the problem situation. At the end of modelling activities, the students present the models they developed to their friends using various illustration systems such as written symbols, verbal reports, diagrams on paper, or pictures (Doruk, 2012).

The implementation of modelling activities has a positive impact on mathematical representation skills because it bridges abstract concepts in mathematics with practical applications. According to Siller et al. (2023), the inclusion of fundamental models in mathematics education is essential for helping students comprehend difficult concepts like exponential growth by providing them with a structured representation. Tezer and Cumhur (2017) emphasize that students who are exposed to modelling demonstrate significant improvements in spatial reasoning and problem solving, highlighting the importance of representation in connecting abstract mathematics with real-world contexts. Albarracín and Gorgorió (2020) highlight the integration of mathematical concepts in project-based learning, where students leverage these concepts to address real-world issues effectively. This approach not only fosters the application of mathematical knowledge but also encourages students to develop a deeper conceptual understanding as they validate and defend their models within their communities. Furthermore, Xu et al. (2022) discuss the different perspectives held by mathematicians, mathematics educators, and teachers regarding the conceptual emphasis in modelling. While mathematicians and educators focus on the epistemological and pedagogical aspects, promoting a deep understanding of mathematical concepts during modelling, teachers often adopt a more applied perspective, emphasizing the practical application of these concepts in real-world scenarios. This divergence highlights the varying degrees of importance placed on conceptual understanding across different educational contexts.

According to Fletcher (2009), various teaching methods are used in teaching mathematical concepts to varying degrees of success. These methods are 'transmission' and 'interactive' approaches, and research has shown 'interactive' to be more effective than the 'transmission' approach.

In the transmission approach, also known as the traditional teaching method or teacher-centered instruction, the teacher acts as a reservoir of knowledge. The teacher who views himself as the sole supplier of knowledge takes control over almost every aspect of the teaching and learning process. His or her duty is to transmit or explain facts and procedures to learners. Learners are only asked to check if they are following the taught procedures. Such an approach creates boredom in class, encourages a passive attitude among learners, and makes them feel they have nothing to contribute (Fletcher, 2009). This method of teaching is also called a non-participatory teaching method because students do not participate in the lesson. The lesson, however, is conducted through explicit teacher explanations, including lectures and teacher-led demonstrations.

Carreira et al. (2020) emphasize the role of mathematical concepts in the development of biometric systems, where both school and university students engage in modelling tasks that require the application of complex mathematical tools. The study illustrates how different levels of mathematical knowledge influence the modelling process and the conceptual depth achieved by students.

Additionally, Lu and Huang (2021) underscore the challenge of integrating mathematical concepts into modelling within China's educational framework, where the curriculum traditionally emphasizes mathematical foundations over broader competencies.

On the other hand, the interactive approach is the situation where the learner is placed at the center of the learning process and seeks knowledge or information to solve a problem. A teacher using this approach believes that learners construct knowledge. The teacher's duty, therefore, is to choose appropriate learning tasks for learners, make the purpose of activities clear, and encourage them to explore and verbalize their mathematical thinking. This approach helps learners to gather, discover, or create knowledge in the course of an activity having a purpose. This active process is different from simply mastering facts and procedures.

Brown and Stillman (2017) observed that modelling tasks facilitate engagement by allowing students to relate mathematics to real-world contexts. This connection often shifts students' perceptions of mathematics from abstract concepts to practical tools, thereby increasing their motivation to learn. Xu et al. (2022) observed that teacher-centered instructional approaches typically result in limited student participation. However, the inclusion of modelling techniques promotes group work and independence, resulting in a more active and enjoyable learning environment. According to Greefrath (2020), the use of technology in modelling tasks has the potential to promote student engagement by making complex mathematical concepts more accessible and relevant. Consequently, this may lead to an increase in students' fundamental intention to investigate and comprehend the challenges.

Students' performance in mathematics, as indicated by the grades they achieved, is affected by various factors. Among the various aspects, this study will primarily focus on students' affective characteristics, which encompass study habits and study attitudes, referred to as study orientations, as reiterated by Biswas (2015). Two of the significant concerns of college students are getting control of time management and study habits. Kaushar (2013) notes that most students nowadays spend less time studying, a large portion of whom do not follow any calendar, and they are unfamiliar with the executives' ideas. Then again, propensities appear to be a vital determinant of academic performance (Cerna & Pavliushchenko, 2015).

Study attitude, on the other hand, can determine the extent to which learning occurs and how it occurs, as this influences the effort students put into understanding and practicing mathematical concepts and skills. If poor study orientations exist among the students, these could lead to low performance in mathematics. The orientation level of the students has a significant relationship with their academic performance (Bong, 2004; Horstmanshof & Zimitat, 2007).

Teaching Algebra

Teachers' knowledge and practices, as well as their development, in the teaching of algebra have been largely unexamined in the research literature. In the early 1990s, Kieran's review of the literature on the learning and teaching of school algebra pointed to the grave scarcity of the literature on teaching algebra and posed the need to describe "how the teaching of algebra ought to be considered in a different light from, say, the teaching of geometry or arithmetic" (Kieran, 1992, p. 394). Algebra teaching knowledge (ATK) refers to the pedagogical knowledge specific to the teaching of algebra that may not be projected in advanced mathematics courses (McCrory et al., 2012; Reckase et al., 2015). This knowledge type examines what makes a particular algebra concept challenging to learn, the misconceptions that result in precise mathematical inaccuracies, and how to address these situations (Donkor, 2021; Osei & Kubi, 2022; Yarkwah, 2017; Reckase et al., 2015). According to Reckase et al. (2015), Entsie (2021), and Donkor (2021), the algebra teaching knowledge falls within the pedagogical knowledge of teaching algebra and contains the mathematical knowledge needed to choose among algebraic tasks, emphasize particular concepts with curricular pathways in mind, designate mathematical goals within and across lessons, and to ratify other functions of teaching. Specifically, the algebra teaching knowledge examines how algebraic content is conveyed to learners for deeper understanding and appropriate applications, as well as how mathematics teachers impart mathematical knowledge utilizing their algebraic expertise. More importantly, mathematics teachers must first be knowledgeable in the subject matter to interact effectively with learners and effectively project their algebra teaching knowledge. Moreover, the pedagogical feature of algebra teaching knowledge distinguishes the algebra teacher from mathematicians and professionals outside mathematics education (Wilmot, 2016).

PCKA is the only triad algebra knowledge within the Expanded KAT framework (Donkor, 2021; Osei, 2020; Wilmot et al., 2018). This algebra knowledge domain arises from the intricate interconnections among the foundational algebra knowledge types (SAK, AAK, and ATK). PCKA is similar to Pedagogical Content Knowledge (PCK), which involves a complex combination of content and pedagogical knowledge, as conceptualized by Shulman (1986). However, whereas Shulman's conceptualization is generic, the Pedagogical Content Knowledge in Algebra (PCKA) is specific to algebra (Wilmot, 2016).

Researchers have argued that mathematics teachers need to integrate the three foundational algebra knowledge types to enable them to operate at PCKA, which is the ultimate algebra knowledge for effective teaching of algebra (Wilmot, 2016; Donkor, 2021; Entsie, 2021; Osei, 2020; Yarkwah, 2017; Osei & Agyei, 2023). In the mathematics classroom, PCKA guarantees the effective communication of algebra content and also contributes meaningfully to learners' understanding of algebra concepts based on its domain-specific nature. Additionally, mathematics teachers who possess and utilise the expertise of PCKA can teach algebra flexibly, remove likely challenges, and engage learners in deep cognitive reflections regarding algebra concepts, fostering a deeper and relational understanding for application and problem-solving. On this premise, PCKA is a non-negotiable advanced algebra knowledge that mathematics teachers should strive to achieve and utilize for the effective transmission of algebra to learners.

Conceptual Framework

This study is grounded in mathematical modelling rooted in Lesh et al. 's translation model (as cited in Suh, 2007), which posits that students form more significant relationships when mathematical ideas are represented in multiple modes, such as manipulatives, pictures, real-life contexts, verbal symbols, and written symbols. This model emphasizes that translation within and among various modes of representation makes concepts meaningful for students.

Aside from the model mentioned above, algebraic modelling stems from two learning theories: Social Constructivism and Metacognition (Wethall, 2011; Oswalt, 2012). In a Vygotskian perspective, it is asserted that an individual's learning is influenced by the interaction between the classroom and the outside world, combined with the learner's prior knowledge (Cobb, as cited in Wethall, 2011). Another important learning theory that algebraic modelling supports is the Theory of Metacognition, proposed by John Flavell, which pertains to an individual's ability to think about their own thinking. Temur (2012) emphasized that when students are aware of their own or their peers' thinking processes or strategies, it will be easier for them to perform analysis and model development while problem-solving. For this group activity to be successful, each group member should work together with one another, exhibit an open-minded nature, and develop a sense of ownership of the problem.

Algebraic modelling is the ability to apply concepts learned in class to real-world applications and to use the model to analyze a situation, draw conclusions, and make predictions. It is a mathematical process that involves observing a situation, conjecturing relationships, applying mathematical analyses, obtaining mathematical results, and reinterpreting the model (Lingefjärd, 2006). Figure 1 shows the simplified view of the algebraic modelling process.

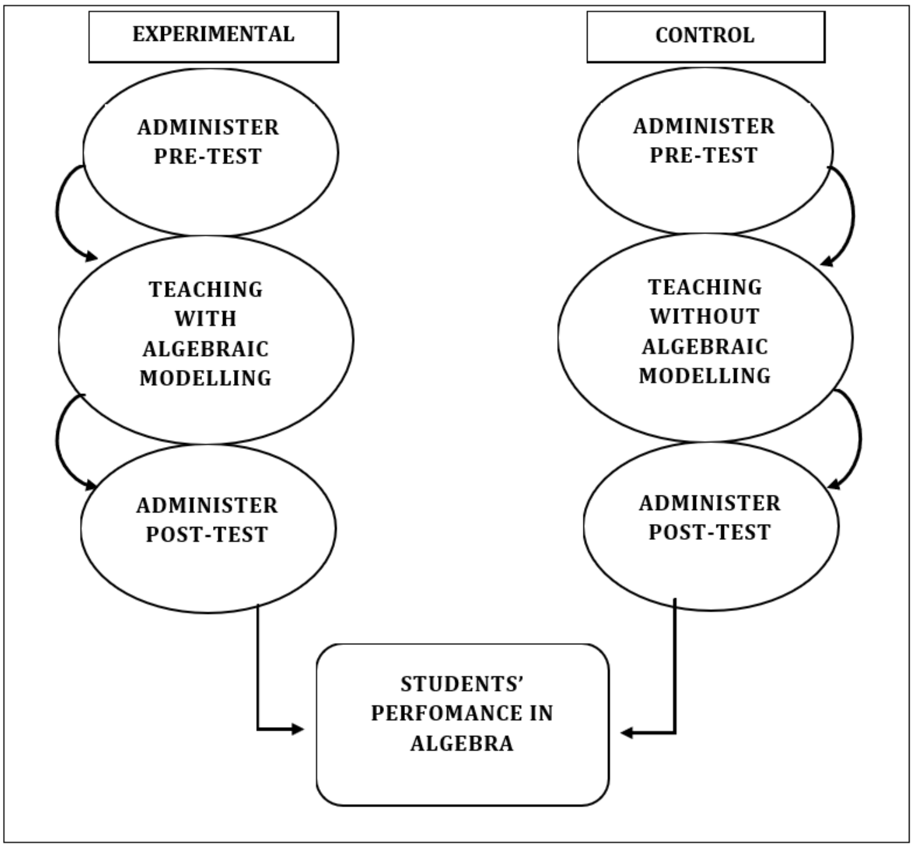

Figure 1. Simplified Mathematical Modelling Process (Cheng, 2001)

RESEARCH METHOD

This part presents the research design, research environment, research participants, research instruments, validation of test instruments, data gathering procedure, and statistical treatment.

Research Design

This study employed descriptive methods and quasi-experimental methods. The quasi-experimental design is a research methodology that lies between the rigor of a true experimental method (true experimental design includes random assignment to at least one control and one experimental/interventional group) (Hulley et al., 2013). The study employed descriptive methods to determine the level of performance in each participant before and after the experiment. Moreover, it is also used as a quasi-experimental method where two groups of participants – the experimental group and the control group are compared based on their level of performance during the pre-test and post-test examination. Its primary focus is to collect data quantitatively and to measure the effectiveness of the treatment applied (teaching with algebraic modelling) to the experimental group. This method also determines the impact of the independent variables (teaching with an algebraic modelling approach and teaching without an algebraic modelling approach) on the dependent variable (students' performance).

Research Environment

This study was conducted in a public state college located in Labuyo, Tangub City, Misamis Occidental, in the Philippines during the school year 2019-2020. Founded in 1971 as a vocational/agricultural school and later converted to a state college, the institution occupies an approximately 29-hectare campus situated near coastal resources and agricultural areas, which informs some of its extension priorities. The college offers a range of undergraduate programs organized into multiple colleges: Agriculture and Environmental Science; Arts, Humanities, and Social Sciences; Business and Management; Education (including majors in Mathematics and Biology); Engineering and Technology; Information and Communication Technology; and Mathematics and Natural Sciences. These academic units support both pre-service teacher education (including mathematics teacher training) and technology/ICT education relevant to this study.

During the period relevant to this research, the institution reported around 7,000 students, with an academic staff complement and administrative support that enable classroom instruction, laboratory work, and community extension activities. The college maintains an Office for Research, Innovation, Development, and Extension (RIDE), which organizes faculty write-shops, research capacity building, and community engagement programs across several barangays; it also adapted teaching modalities (online, modular, blended learning) in response to COVID-19 disruptions. Facilities supporting teaching and research include science and technology laboratories, laboratory buildings for hospitality and technical programs, and recently upgraded science laboratories funded through government assistance. These organizational and physical characteristics provided the instructional context, teacher cohorts, and learning environments sampled for this study.

Research Participants

The research participants in this study are from two sections of grade 8 students at the said public state college. The study employed purposive sampling using intact groups, followed by a matched-pairs technique to ensure comparability between the control and experimental groups. First, the Maxwell section with a total of 42 students is the control group; second, the Leeuwenhoek section with a total of 44 students is the experimental group. To make the two groups comparable, the researchers employed a pairing method where the first grades of the students in the Leeuwenhoek section are paired with the first grades of the Mathematics subject of the students in the Maxwell section. Only those who have the same grades or have a gap of one or two points were considered as paired respondents. After pairing, 20 pairs of students were selected in both sections.

To ensure that no other fundamental factors would get in the way of the results of the study, aside from the variables presented in the conceptual framework, both groups were handled by the same teacher, their classroom location is within the same area, and their class schedule interval is comparable.

This study focused on measuring the learning outcomes of the students in Mathematics through algebraic modelling. The topics used in teaching to measure the aimed result are: Addition of Integers, Subtraction of Integers, and Solving One-Step Equations. The experiment is conducted after the first grading period until the required topic is done, which consists of three meetings.

Research Instrument

This study used a researcher-made questionnaire with 30 questions, where all items are multiple-choice with four options each. The topics included in making this 30-item test questionnaire are: Addition of Integers, Subtraction of Integers, and Solving One-Step Equations.

The questionnaire was carefully designed based on the Most Essential Learning Competencies (MELCs) of the Grade 8 Mathematics curriculum prescribed by the Department of Education (DepEd). Each test item aligns with the learning competencies to make sure that students are assessed on content they have been formally taught. Before the test questionnaire was administered, it underwent checking from the thesis adviser and other Mathematics teachers in the Teacher Education Department. Pilot testing of the non-respondents for validation purposes was also conducted. This also used a researcher-made algebraic modelling as an instructional aid or a manipulative representation. To validate the research instrument, an item analysis of the questionnaire was conducted. It yielded a difficulty index of 0.63, indicating that the items are relevant for determining whether students have learned the concept being tested. The discrimination index was 0.62, indicating that it provides a more accurate assessment of students based on their knowledge of the topics being tested.

Data Gathering Procedure

This study involved two phases in gathering the data: The Pre-Assessment Phase and the Post-Assessment Phase.

The Pre-Assessment Phase involved the pre-test exam administered to the two groups of respondents to determine their Mathematics performance level before the experiment was conducted. The topics included in measuring the performance level of the respondents are: Addition of Integers, Subtraction of Integers, and Solving One-Step Equations.

The Post-Assessment Phase is characterized by the researchers using a post-test exam administered to the two groups of respondents to determine their Mathematics performance level after the experiment is conducted.

Statistical Treatment

This study used the following statistical tools in analyzing the results of the experiment.

1. Mean. This measure of central tendency was used to describe the level of performance of the two groups before and after the experiment.
2. ANCOVA (Analysis of Covariance). Used to evaluate the impacts of mathematics teaching pedagogy through algebraic modelling.

Data processing was conducted using Statistical Package for the Social Sciences (SPSS) software to ensure accuracy and proper analysis of the collected data.

Table 1. Performance Level Assessment Tool

Level of Proficiency	Equivalent Numerical Value
Advanced (A)	90% above
Proficient (P)	85% - 89%
Approaching Proficiency (AP)	80% - 84%
Developing (D)	75%-79%
Beginning (B)	74% below

This tool is anchored on the research study of Gamit, Antolin, and Gabriel (2017). The researchers categorized the equivalent numerical value of the scores of the students into five different levels of proficiency. Out of 30 items in a test: student's score of 14 and below or 74% below belongs to the Beginning Proficiency Level; student's score of 15 to 17 or 75% to 79% belongs to the Developing Proficiency Level; student's score of 18 to 20 or 80% to 84% belongs to

Approaching Proficiency Level; student's score of 21 to 23 or 85% to 89% belongs to Proficient Level; and student's score of 24 to 30 or 90% above belongs to the Advanced Proficiency Level.

FINDINGS AND DISCUSSION

This section presents the findings, analysis, and interpretation of data gathered, whose main objective is to know the impacts of teaching with algebraic modelling on students' performance of Grade 8 students in Mathematics in the said public state college.

Students' Performance Level

The tables below show the results of the students' performance level in Mathematics before and after the experiment was conducted.

Pre-test and Post-test of Control Group

Below is the analysis result of the scores of each participant in the Control group before and after the experiment was conducted.

Table 2. Pre-test and Post-test Table of the Control Group

Level of Proficiency	Number of Students	Percentage
Pre-Test		
Advanced (A)	0	0
Proficient (P)	0	0
Approaching Proficiency (AP)	0	0
Developing (D)	0	0
Beginning (B)	20	100.00
Post-Test		
Advanced (A)	0	0
Proficient (P)	0	0
Approaching Proficiency (AP)	0	0
Developing (D)	5	25.00
Beginning (B)	15	75.00

As shown in Table 2, the performance levels of the participants in the control group during the pre-test exam are as follows: there are 20 out of 20 participants, or 100% had a beginning. It shows that all the participants in the control group have low levels of performance in Mathematics during the pre-test exam, specifically in the topics: Addition of Integers, Subtraction of Integers, and Solving one-step equations.

On the other hand, the performance level of the control group during the post-test exam is as follows: there are 15 out of 20 participants, or 75% had a beginning, and 5 out of 20 participants, or 25% had developing. This result shows that almost half of the participants have low performance in Mathematics during the post-test exam. It emphasizes that teaching Mathematics without applying any innovative strategy in the classroom can lead to a low level of performance of the students. This is one of the reasons why Mathematics is considered by many students to be a difficult academic subject. This finding is consistent with Agoestanto et al. (2019), who stated that one of the causes of students' errors in algebraic thinking is students' lack of understanding of modeling algebraic forms.

This also implies that, although the teaching and learning process occurred, most reached only the developing proficiency stage, indicating a lack of skills. It is also revealed that none of them attained the proficient and advanced level in the Gamit et al. (2017).

Pre-test and Post-test of the Experimental Group

Below is the analysis result of the scores of each participant in the Experimental group before and after the experiment.

Table 3. Pre-test and Post-test Table of the Experimental Group

Level of Proficiency	Number of Students	Percentage
Pre-Test		
Advanced (A)	0	0
Proficient (P)	5	25.00
Approaching Proficiency (AP)	7	35.00
Developing (D)	8	40.00
Beginning (B)	0	0
Post-Test		
Advanced (A)	16	80.00
Proficient (P)	4	20.00
Approaching Proficiency (AP)	0	0
Developing (D)	0	0
Beginning (B)	0	0

As shown in Table 3, the performance levels of the participants in the experimental group during the pre-test exam are as follows: there are 8 out of 20 participants, or 40% had a developing proficiency, 7 out of 20 participants, or 35% had an approaching proficiency, and 5 out of 20 participants, or 25% belong to the proficient. These results show that most of the participants in the experimental group have low levels of performance in Mathematics during the pre-test exam.

On the other hand, the performance level of the experimental group during the post-test exam is as follows: there are 4 out of 20 participants, or 20% had a proficient level, and 16 out of 20 participants, or 80% had an advanced level. These results show that most of the participants in the experimental group during the post-test exam have levelled up their performance in Mathematics, specifically in the topics: Addition of Integers, Subtraction of Integers, and Solving One-Step Equations.

The results support the assumption of Wang et al. (2023), who stated that by practicing the modelling tasks, students gained the encouragement to analyze the real-world problem, thereby fostering students' skills to solve each matter by transforming it into a mathematical representation. This problem-solving skill allows students to develop the necessary skills for engaging with various real-world situations, which could drive them to navigate complex problems effectively. Chen (2022) similarly stated that facing real-world problems and solving the situation has the potential to enhance students' achievement in learning mathematics, whether routine or non-routine. Furthermore, Holenstein et al. (2022) agree that problem-solving skills used in mathematical modelling activities could bridge the gap between abstract concepts and practical mathematics. This connection cultivates their ability to apply their understanding effectively and reinforces the improvement of mathematical knowledge. Regular engagement in mathematical modelling activities and problem-solving exposes students to group discussions, potentially enhancing their skills and achievements. Additionally, it also emphasizes that modelling tasks encourage students to have a range of experiences, which may help them develop resilience in tackling irregular obstacles in mathematics and life (Lu & Huang, 2021).

Table 4. Means and Standard Deviation of pre-test and post-test results of the Control Group and the Experimental Group

Group	N	Minimum	Maximum	Mean	Std. Deviation
Control					
Pretest	20	5	11	8.35	1.496
Posttest	20	10	20	12.9	2.024
Experimental					
Pretest	20	15	23	18.2	2.567
Posttest	20	21	29	25.3	2.361

As shown in Table 4, the performance level of the control group during the pre-test exam is 8.35 with a standard deviation of 1.496. Based on the Performance Level Assessment Tools, 8.35 of 30 or 63.92% belong to Beginning. Meanwhile, their performance level during the post-test exam is 12.9 with a standard deviation of 2.024. Based on the Performance Level Assessment Tool, 12.9 of 30 or 71.5% belong to Beginning. This means that there is a level-up performance of the students in the control group after the demonstration approach (traditional) is applied, but only a little bit.

The table also shows the performance level of the experimental group during the pre-test and post-test exams. In the pre-test exam, the mean score is 18.2 with a standard deviation of 2.567. Based on the Performance Level Assessment Tools, 18.2 of 30 or 80.33% belong to the Approaching Proficiency (AP) Level. While in the post-test exam, the mean score is 25.3with a standard deviation of 2.361. Based on the Performance Level Assessment Tools, 25.3 of 30 or 92.17% belong to the Advanced Proficiency Level. This result signifies that the performance of the group after the experiment was levelled up to the Advanced Proficiency Level.

This can be attributed to the fact that most students could learn better if the teacher makes use of a mathematical model as a strategy in teaching. This further supports the study conducted by Chen (2022), which emphasizes the importance of modelling activities in fostering students' ability to apply mathematical concepts to practical contexts, thereby fostering critical thinking as they attempt to solve problems in various ways. This approach has the potential to improve problem-solving skills and encourage students' creativity (Wang et al., 2023; Xu et al., 2022). Besides, it could expand knowledge of mathematics and increase self-efficacy, which is essential for students who lack confidence in mathematics (Geiger et al., 2018; Haara, 2022).

Analysis of the Impacts of Teaching with Algebraic Modelling on Students' Performance in Mathematics

Table 5. Analysis of Covariance for pre-test and post-test results

Source	Type III Sum of Squares	df	Mean Squares	F	Sig.	Partial Eta Squared
Corrected Model	1430.007[a]	2	715.003	126.041	.000	.872
Intercept	215.601	1	215.601	38.006	.000	.509
PRETEST	13.907	1	13.907	2.452	.126	.062
GROUP	121.105	1	121.105	21.348	.000	.366
Error	209.893	37	5.673			
Total	16156.000	40				
Corrected Total	1639.900	39				

Table 5 shows a highly significant difference between the academic performances of the students exposed to two different approaches. In running the ANCOVA test, the selected dependent variable is the post-test, the covariate is the pre-test, and GROUP is determined as the treatment applied in two different classroom approaches. Based on the test, the resulting P value, 0.000, is much less than the set α, 0.05. This result tells that there is a highly significant difference between the academic performances of the students exposed to two different approaches. Even though we pair the top 20 in every section, the experimental group in the Leeuwenhoek section performs better than the control group or the Maxwell section. In contrast, the Algebraic Modelling Approach is more effective in teaching mathematics in the classroom, as shown in Table 3, as evidenced by the means of pre-test and post-test of the experimental group being higher than those of the control group. According to Xu et al. (2022), by fostering the ability to deal with modelling problems, students have the potential to deepen their involvement in learning, which leads to the development of their critical thinking abilities. It also emphasized that modelling activities cultivate critical thinking skills, enabling students to engage with STEM fields that enhance their mathematical comprehension (Geiger et al., 2018).

Implication

An excellent result of the previous discussions on teaching with algebraic modelling to students helps to make learning concepts clearer. It is qualified to the main goal of teaching using models to students, which enables the students to engage in cognitive and social tasks and teaches the students how to use them productively and to become powerful learners.

The study shows the importance of teaching with algebraic models and its impact on the students' performance. Using models in teaching algebra is a great way to make sure that teaching has the right levels of success and challenges. In the simplest form, modelling is about seeing before doing and therefore minimizing the ambiguity around an outcome.

The students who were exposed to the concept of teaching with algebraic models found its importance and can effectively model their own practice around the teacher's example. As a result, the students were able to analyze and use this approach in solving algebraic problems.

However, it is difficult to represent real-world systems in terms of mathematical relationships. Data are often unavailable or inaccurate. But models are enablers; they are there to help students see what outcomes could/should look like. It allows students to engage and succeed.

Thus, teachers are highly encouraged, especially algebra teachers, to use models in teaching in order to engage the students and keep them motivated. Further, in the future, no students will be left behind, saying “I hate mathematics at all”.

CONCLUSIONS

Based on the findings of the study, it was revealed that the experimental groups had increased their level of performance, as shown in Table 3, after the experiment was conducted. These findings directly address the research question in terms of the level of the students in the control and experimental groups before and after the experiment. With that, we can say mathematical modelling is the key to innovations. Using models in mathematics teaching is necessary to motivate the students, eliminate their fear and anxiety, and allow them to develop a positive approach towards mathematics, in addition to its many cognitive benefits, such as realizing meaningful learning, establishing a relation between mathematics and daily life, and developing problem-solving skills. The modelling approach is more effective than the traditional approach in teaching algebra in the classroom, in the sense that it was also determined that the students in the experimental group outperformed the students in the control group, in which the traditional method was used. These findings also address the research question in terms of the impacts of teaching with algebraic modelling on students' performance in Mathematics. Besides, it was also determined that the students showed positive attitudes towards mathematics when using the modelling approach. Therefore, that’s the reason why Mathematics in its purest form has incredible power and beauty.

LIMITATION & FURTHER RESEARCH

This study was limited to two intact Grade 8 classes in a public state college located in Labuyo, Tangub City, Misamis Occidental, Philippines, which affects the generalization of results. There is also a possibility that the short duration of the intervention and the small sample size may have influenced the results. Furthermore, although the researcher-made test was validated, it may not capture students' higher-order thinking and longer-term learning outcomes effectively.

Further research attempts should be made with larger and more diverse sample sizes, longer periods of intervention, and utilizing mixed methods for improved understanding of students’ engagement and conceptual understanding. Studies that incorporate technology-based or digital modelling tools are also a suggested aspect of studies to develop and continue improving teaching and learning in mathematics.

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