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PREDICTION MODEL FOR ENGINEERING STUDENTS' PERFORMANCE IN DIFFERENTIAL EQUATIONS

MODELO DE PREVISÃO DO DESEMPENHO DE ESTUDANTES DE ENGENHARIA EM EQUAÇÕES DIFERENCIAIS

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Abstract
This study developed a Mathematical Prediction Model that determines which among the prerequisite Mathematics courses best predict success performance in the Differential Equations. The study used 646 students enrolled in different engineering programs of the Technological University of the Philippines Manila Campus during the 2nd Semester of School Year 2018-2019. This study utilized document content analysis as a data gathering technique. Findings revealed that in all of the Mathematics courses considered in this study: MMW, Calculus I, Calculus II and Differential Equations, most of the students clustered on grades 82-84 and 85-87. The model showed that the grades of students in MMW and Calculus II are not significantly related to their performance in Differential Equations. However, only grades in Calculus I are measured significantly related to Differential Equations.

Keywords: Mathematical Prediction Model. Differential Equation. Calculus. Mathematics in the Modern World. Engineering Mathematics Performance.

Resumo
Este estudo desenvolveu um Modelo de Previsão Matemática que determina quais. dentre as disciplinas de matemática pré-requisitos. melhor predizem o desempenho bem-sucedido na disciplina de Equações Diferenciais. O estudo contou com 646 alunos matriculados em diferentes cursos de engenharia do Campus de Manila da Universidade Tecnológica das Filipinas durante o 2º semestre do ano letivo de 2018-2019. Este estudo utilizou a análise de conteúdo de documentos como técnica de coleta de dados. Os resultados revelaram que. em todas as disciplinas de matemática consideradas neste estudo: MMW. Cálculo I. Cálculo II e Equações Diferenciais. a maioria dos alunos se concentrou nas notas 82-84 e 85-87. O modelo mostrou que as notas dos alunos em MMW e Cálculo II não estão significativamente relacionadas ao seu desempenho em Equações Diferenciais. No entanto. apenas as notas em Cálculo I foram consideradas significativamente relacionadas às Equações Diferenciais.

Palavras-chave: *Modelo de Previsão Matemática. Equação Diferencial. Cálculo. Matemática no Mundo Moderno. Desempenho em Matemática de Engenharia.*

1 INTRODUCTION

It is all known that obtaining an engineering degree is an inherently challenging endeavor. Commencing with the foundational principles of engineering in the initial year, the curriculum progressively delves into more specialized areas, concentrating sharply on the chosen major discipline. Mathematics, widely acknowledged as a cornerstone of engineering, constitutes a significant portion of the academic landscape. Consequently, students possessing a robust mathematical groundwork discover the study requirements to be less strenuous, facilitating a more intuitive comprehension of intricate concepts.

Before 2013, the general education (GE) mathematics courses in the curricula of colleges and universities in the Philippines within engineering programs encompassed Algebra, Trigonometry, and Geometry, however, the enactment of Republic Act No. 10533, also recognized as the "Enhanced Basic Education Act of 2013," has brought about a transformative shift in the landscape of engineering degree programs. The previously mentioned GE Mathematics courses now constitute integral components of the Senior High School curriculum, underscoring the evolving nature of academic prerequisites in the pursuit of an engineering education.The implementation of the K to 12 program in the Philippines led to significant adjustments in the higher education curriculum, particularly in the General Education (GE) subjects. The Commission on Higher Education (CHED) revised the GE curriculum to align with the outcomes-based education framework and to complement the new subjects introduced in Senior High School. This revision reduced the number of GE units from 64 to 36, introducing subjects such as Mathematics in the Modern World, and eliminating courses like the Philippine Constitution from the core curriculum.

The Technological University of the Philippines (TUP), College of Engineering offers the following engineering degree programs such as Bachelor of Science in Mechanical Engineering, (BSME), Electrical Engineering (BSEE), Civil Engineering (CE) and Electronics Engineering (ECE). Common to these programs are the mathematics courses such as Calculus I, Calculus II, and Differential Equations (DEs). The course Engineering Data Analysis is also common to all; however, this course is more on statistics related content and sometimes taken at the same time with DEs.

With the introduction of K to 12 Basic Education Program since 2016, Mathematics courses undergo a curriculum change where most of the General Education Mathematics courses like Algebra, Geometry, Trigonometry, etc. are being taught in the senior high school levels. This means that in the tertiary (college) level, only one (1) Mathematics course is common for all degree programs which is Mathematics in the Modern World (MMW). In the case of engineering programs, 2 more Mathematics courses (Calculus I and Calculus II) served as a pre-requisite before taking the course Differential Equations.

The objective of this study is to develop a mathematical prediction model to determine which among the prerequisite mathematics courses—Calculus I, Calculus II, and MMW served as the most reliable predictor of student success in the course *Differential Equations*. This course is designed to enable students apply integration techniques in evaluating areas, volumes of revolution, force, and work; to use integration methods on both single-variable and multivariable functions; and to explain the physical interpretation of double and triple integrals.

This study is motivated by institutional observations indicating that a considerable number of engineering students face significant challenges in *Differential Equations*, with many ultimately failing the course. Such academic difficulties can delay students' graduation, increase tuition and miscellaneous expenses, and postpone their entry into the engineering profession.

If at-risk students can be identified early through a predictive model based on their performance in the prerequisite mathematics courses, targeted academic support can be provided to improve their chances of success. By proactively addressing academic difficulties, this study aims to reduce failure rates and support engineering students in completing their degree programs on time. Thus, the development of a predictive mathematical model is not only timely but also essential in enhancing academic outcomes and student retention in engineering programs.

2 LITERATURE REVIEW

Mathematics is often described as the science of patterns. Mathematicians seek to discover, analyze and classify patterns in both abstract objects and natural phenomena. The traditional domains of study are quantity (arithmetic), structure (algebra), space (geometry) and change (analysis). Mathematics offers distinctive and powerful modes of thought such as abstraction, generalization, deduction, inference, use of symbols and the axiomatic method. Mathematical truth is established through logical analysis and proof. As a universal discipline it is rich in both theory and applications. Mathematics is used as an essential tool in many fields, including the natural sciences, engineering, medicine, finance and the social sciences.

Under CHED Memo Order (CMO) No. 97 (BSME), No. 88 (BSEE), No. 101 (BSECE), and No. 92 (BSCE), these, different engineering degree programs, have common mathematics technical courses. Below presents the said courses and its descriptions:

Mathematics in the Modern World aimed for students to be able to: (Knowledge) discuss and argue about the nature of mathematics, what is, how it is expressed, presented, and used; used different types of reasoning to justify statements and arguments made about mathematics and mathematical concepts; discuss the language and symbol of mathematics. (Skills) use a variety of statistical tools to process and manage numerical data; analyze codes and coding schemes used for identification, privacy, and security purposes; use mathematics in other areas such as finance, voting, health and medicine, business, environment, arts and design, and recreation. (Values) appreciate the nature and uses of mathematics in everyday life; affirm honesty and integrity in the application of mathematics to various human endeavors. Topics include linear and exponential growth; statistics; personal finance; and geometry, including scale and symmetry. Emphasizes techniques of problem-solving and application of modern mathematics to understanding quantitative information in the everyday world.

Calculus I targets that at the end of the course, the students must be able to: differentiate algebraic and transcendental functions; apply the concept of differentiation in solving word problems, analyze and trace transcendental curves. On the other hand, Calculus II makes sure that after completing this course, the student must be able to: apply integration to the evaluation of areas, volumes of revolution, force and work; use integration techniques on single and multi-variable functions; explain the physical interpretation of the double and triple integral. Finally, Differential Equations aimed for students to be able to: apply integration for the evaluation of areas, volumes of revolution, force and work; use integration techniques on single and multi-variable functions; explain the physical interpretation of the double and triple integral.

Student performance in mathematics and engineering courses has been a focal point of educational research, particularly in the context of the challenges posed by the COVID-19 pandemic and the subsequent shifts in teaching methodologies. Recent studies have highlighted the multifaceted factors influencing student outcomes in these disciplines.

A study by Marcos et al. (2020) examined the entry competencies and performance in mathematics of first-year engineering students in state universities in Region 3, Philippines. The findings revealed that students demonstrated average competencies in general mathematics, with below-average performance in subjects like probability and statistics, pre-calculus, and basic calculus. Despite these challenges, students with higher entry competencies in mathematics performed better in their engineering mathematics courses. The study emphasizes the importance of strengthening foundational mathematical skills to enhance performance in engineering disciplines. In a comparative assessment conducted by Abad (2020), the academic performance in mathematics of freshman civil engineering students was analyzed. The study found that students from public senior high schools under the STEM track performed better in mathematics enhancement and differential calculus compared to their peers from other tracks. This suggests that the quality of pre-university education plays a significant role in shaping students' mathematical abilities and, consequently, their performance in engineering courses.

In addition, a study by Bengmark et al. (2020) investigated the relationship between first-year engineering students' performance in mathematics and their motivational values and self-efficacy beliefs. The research indicated that students' task performance was influenced by their motivation and self-efficacy, with gender differences observed in these factors. These findings underscore the need for addressing psychological factors to improve student performance in mathematics and engineering courses. Furthermore, a study by Chen et al. (2022) explored the influence of mathematics on the academic performance of mechanical engineering students. The research highlighted that students' mathematical skills significantly impacted their performance in engineering courses, suggesting that a strong foundation in mathematics is crucial for success in engineering disciplines. Collectively, these studies illustrate that student performance in mathematics and engineering courses is influenced by a combination of foundational knowledge, educational background, psychological factors, and teaching methodologies. Addressing these aspects holistically is essential for enhancing student success in these critical areas.

The study of Differential Equations is pivotal in engineering and applied sciences, serving as a bridge between theoretical mathematics and practical problem-solving. However, students often encounter challenges in mastering this subject due to various interrelated factors. Psychological elements such as self-efficacy, motivation, and attitudes toward mathematics significantly impact students' performance in Differential Equations. A study by López-Reyes et al. (2022) found that students' motivation and engagement in learning activities positively influenced their understanding and application of mathematical concepts, including differential equations. This aligns with findings from a study by Aisha et al. (2017), which identified self-regulated learning strategies and goal orientations as crucial for enhancing problem-solving abilities in differential equations. Additionally, mathematical anxiety has been shown to negatively affect performance, as it can impair working memory and problem-solving capabilities. The effectiveness of teaching methodologies plays a critical role in students' success in Differential Equations. López-Reyes et al. (2022) implemented blended learning strategies, combining synchronous and asynchronous activities, which led to improved student performance in mathematical modeling and differential equations. Similarly, a comprehensive literature review by Lozada et al. (2021) highlighted that active learning, problem-based learning, and the use of technological tools enhance students' conceptual understanding and application of differential equations. Prior knowledge and cognitive abilities are fundamental determinants of success in Differential Equations. A study by López-Reyes et al. (2022) emphasized the importance of foundational mathematical skills, such as calculus, in understanding and solving differential equations. Furthermore, consistent practice and the development of effective study habits are essential for mastering the complex concepts presented in Differential Equations. **Hence,** student performance in Differential Equations is influenced by a combination of psychological, instructional, and cognitive factors. Addressing these factors through targeted interventions and supportive teaching strategies can enhance student success in this critical area of study.

2.1 Predictors of differential equations

Calculus I is widely recognized as a foundational "gateway course" in many STEM degree programs. Success or failure in this course often influences students' decisions to continue in their chosen majors, making it a critical area of academic research. Due to high attrition rates in STEM fields, identifying the factors that contribute to student success in Calculus I has become a priority for many universities.

George (2019) examined the relationship between student and class-level characteristics and performance in Calculus I using Hierarchical Linear Modeling (HLM). This method was appropriate due to the nested structure of students within class sections. The study explored multiple models, including one that incorporated anxiety as a mediating variable. Factors such as students' academic level, gender, participation in on-campus tutoring, and enrollment in STEM or engineering programs were considered at the individual level. At the class level, variables included mode of instruction (online vs. face-to-face), semester (Fall vs. Spring), class size, and instructor gender. The dependent variable across all models was students' final grade in Calculus I. In another study, Yushau and Omar (2019) focused on the influence of preparatory courses on performance in Calculus I at King Fahd University of Petroleum and Minerals (KFUPM). Analyzing data from over 2,000 bilingual Arab students, they found that performance in two preparatory-year mathematics courses and English proficiency significantly predicted success in Calculus I. Furthermore, the old placement test was more predictive of student success than the newly implemented one.

Agatep (2018) explored how performance in foundational math subjects could predict success in Differential Calculus at ACLC Macau. Results showed that final grades in College Algebra were the strongest predictor, emphasizing the importance of pre-calculus coursework in laying the foundation for calculus success. Islam and Al-Ghassani (2015) analyzed performance data from 615 students at Sultan Qaboos University to evaluate whether high school achievements and gender could predict success in Calculus I. Their regression analysis found that high school math and overall GPA were significant predictors. Interestingly, while female students entered the university with higher high school grades, male students had a higher failure rate (28% compared to 7%), suggesting that additional factors such as gender-based educational experiences may influence college performance.

Sule and Saporu (2015) applied logistic regression to examine the performance of upper-level students in a foundational calculus course. They identified GPA, students' perception of course difficulty, and the perceived real-world relevance of course concepts as significant predictors of academic success. These findings suggest the need for interventions targeting both cognitive and affective factors.

Lastly, Post et al. (2019) explored whether high school mathematics curricula affected students' subsequent performance in college-level math. Analyzing data from over 4,000 students, they found no strong relationship between the type of high school math curriculum and college calculus performance. Prior math achievement, as measured by ACT scores, was a more consistent predictor of success.

Together, these studies point to a complex web of factors influencing Calculus I success, including academic preparedness, instructional quality, study habits, self-efficacy, and contextual classroom variables. These findings underscore the need for a multi-pronged approach to student support, including curriculum alignment, academic advising, tutoring programs, and pedagogical innovations that address both cognitive and non-cognitive dimensions of learning.

3 METHODS

3.1 Research design

This study utilized a descriptive research design, which is focused on systematically describing the current status or characteristics of a phenomenon without manipulating any variables. Descriptive research aims to provide an accurate portrayal of existing conditions through methods such as surveys, observations, and fact-finding inquiries. Unlike experimental research, descriptive research does not attempt to establish cause-and-effect relationships but rather seeks to answer fundamental questions about who, what, when, where, and how regarding the subject under investigation. It is especially useful in situations where the researcher has little or no control over the variables involved and is primarily interested in capturing the present state of affairs.

In the context of this study, the descriptive approach was essential for gathering comprehensive data on students' academic performances in prerequisite mathematics courses and their subsequent success in Differential Equations. By employing this method, the study aimed to identify patterns and relationships among existing academic records without introducing experimental manipulation. This approach allows for the collection of empirical evidence necessary to develop a predictive model that can forecast student success based on prior academic achievements.

The primary objective of this research was to create a Mathematics prediction model that determines which prerequisite Mathematics courses—such as Calculus I, Calculus II, and Mathematics in the Modern World—best predict students' performance in the Differential Equations course. This model is intended to assist educators and academic advisors in identifying students who may require additional support, thereby improving retention and success rates within engineering and related STEM programs.

3.2 Sample

The study was conducted in the Technological University of the Philippines (TUP) Manila, a coeducational state university known for its strong focus on engineering and technological education. This study utilized data from 646 students enrolled across various engineering programs in TUP Manila during the second semester of the 2018-2019.

3.3 Data

The researcher requested from the Dean of College of Engineering the grades of engineering students enrolled in the four mathematics courses, namely: Mathematics in the Modern World (MMW), Calculus I, and Calculus II and Differential Equations. The grades were evaluated using Table 4, the grading system of TUP.

Table 1

Technological University of the Philippines (TUP) Grading System

Performance	Descriptive Rating	Action Taken
97 - 100	Excellent	
94 - 96	Superior	
91 - 93	High Average	
88 - 90	Average	
85 - 87	Low Average	Passed
82 - 84	Satisfactory	
79 - 81	Fair	
76 - 78	Poor	
75	Passed	
74 and Below	Failed	Failed

It can be seen from Table 1 that grades from 100 down to 75 are all passing grades, while from 74 and below are failing grades. TUP utilized "passed" or "failed" descriptive ratings. Grades for 94-100 are such high grades with a descriptive rating of "superior to excellent". "Average to high average" performance ranges from 88 to 93. The lowest performance is clustered at 76-78 described as 'poor".

3.4 Data gathering procedures and analysis

The researcher requested permission to the Dean of College of Engineering to conduct the study. Upon approval, another request was submitted to the Office of the Registrar for the release of the grades of engineering students in Differential Equations (DEs) and its prerequisite courses namely: Calculus I, Calculus II, and Mathematics in the Modern World. The gathered data were used to determine the predictors of performance in the course Differential Equations.

In this study, statistical treatments were employed to analyze the academic performance of engineering students in key mathematics courses and to develop a predictive model for success in Differential Equations. To assess students' academic performance in the three prerequisite mathematics courses both percentage scores and arithmetic means were calculated. Similarly, the students' performance in the Differential Equations course was evaluated using percentage and arithmetic mean to provide a clear overview of their overall achievement in each subject. To examine the relationship between students' performance in Differential Equations and their scores in the three prerequisite courses, mean values were used to compute and analyze potential significant correlations.

Furthermore, to determine which among the three mathematics courses best predicts student success in Differential Equations, regression analysis was applied. Specifically, linear regression was utilized to construct a predictive model, which mathematically expresses the relationship between the independent variable (students' performances in prerequisite courses of DEs) and the dependent variable, which is their performance in Differential Equations. Linear regression develops an equation based on existing data that allows prediction of the dependent variable (also called the response or criterion variable, often denoted as y) from known values of the independent variables (also referred to as explanatory or predictor variables, typically denoted as x). This model provides valuable insights into which prerequisite course most strongly influences success in Differential Equations, enabling targeted academic interventions.

4 RESULTS AND DISCUSSION

4.1 Academic performance of the engineering students

Academic performance, often termed academic achievement, reflects the degree to which students, educators, or institutions meet their educational goals, whether short-term milestones or long-term accomplishments. These achievements are commonly marked by the successful completion of key benchmarks such as secondary school diplomas or bachelor's degrees. Within engineering education, academic performance is especially critical due to the discipline's heavy reliance on mathematics to tackle complex analytical and problem-solving challenges.

Engineering students require a strong foundation in mathematics because it supports numerous engineering courses and skills essential for their field. A solid grasp of mathematical concepts not only facilitates academic success but also sustains motivation and progress throughout their engineering curriculum (Sagdullaeva & Atabekovich, 2023). Given the fundamental role of mathematics, regularly monitoring and assessing students' performance in core math courses is essential.

Tables 2 through 5 summarized the academic performance of engineering students at the Technological University of the Philippines in four crucial mathematics subjects: Calculus I, Calculus II, Mathematics in the Modern World, and Differential Equations.

Illustrated in Table 2 (Calculus I), of the 646 students, the majority scored between 82 and 87, with 44.4% scoring 82–84 and 37.0% scoring 85–87. A smaller portion, 11.3%, earned scores between 79 and 81. No students scored above 93 or below 74, and the overall mean score was 84.04, reflecting a generally satisfactory performance among the cohort. The mean performance of 84.04 classified the students to satisfactory level of performance. These results align with prior research emphasizing the critical influence of foundational math courses like Calculus I on engineering students' academic progression. This is significant as Yushau and Omar (2019) found that strong performance in preparatory mathematics significantly predicts success in advanced math courses, highlighting the importance of early competence. Also noted that factors such as students' academic readiness and engagement affect outcomes in gateway STEM courses like Calculus I, which is often regarded as a pivotal challenge in engineering education (George, 2019). The relatively high mean score in this study suggests many students at TUP possess the necessary mathematical skills; however, continued support remains important for those performing below average.

Calculus I itself deals primarily with the study of rates of change, involving concepts such as limits, derivatives, and the application of differentiation techniques. Building on knowledge of various functions—exponential, quadratic, trigonometric—students learn to find derivatives and apply differentiation to solve real-world problems, forming a foundation for further study in physics, engineering, and other scientific fields. The importance of Calculus I is underscored by historical applications such as Isaac Newton's development of the laws of motion and gravity through calculus. George (2019) used Hierarchical Linear Modeling to analyze factors influencing student success in Calculus I, considering both individual and class-level variables. Yushau and Omar (2019) similarly conducted multiple regression analyses with over 2,000 bilingual students at King Fahd University, finding that success in Calculus I strongly depended on preparatory math courses and their interaction. Despite its importance, calculus remains challenging for many students due to its conceptual complexity and the level of practice required. Students must commit significant effort to mastering problem-solving techniques to succeed in this foundational course.

Table 2

Frequency and Percentage Distribution of the Mathematics Performances of Engineering Students in Calculus I

Mathematics Performance	Frequency	Percentage (%)
97 - 100	0	0
94 - 96	0	0
91 - 93	1	0.20
88 - 90	38	5.90
85 - 87	239	37.0
82 - 84	287	44.4
79 - 81	73	11.3
76 - 78	8	1.2
75	0	0
74 and Below	0	0
Total	**646**	**100.00**
Mean = 84.04 (Satisfactory)		

Consistent with the data presented in Table 2, Table 3 indicates that the majority of students scored between 82–84 (n=306) and 85–87 (n=219) in Calculus II. The mean performance of 84.17 classifies the students' performance at a satisfactory level.

Calculus II introduces the concept of integration and its application to various physical problems, such as evaluating areas, volumes of revolution, force, and work. The course covers fundamental formulas and various techniques of integration, applied to both single-variable and multivariable functions. Additionally, it includes tracing functions of two variables to better appreciate the interpretation of double and triple integrals as volumes of three-dimensional regions bounded by two or more surfaces.

Research by Van de Sande and Reiser (2018) examined the impact of summer breaks on engineering students' performance in Calculus II. Their study found that students who took a summer break between the first two courses in the introductory calculus sequence lost the equivalent of about half a course grade more than those who took both courses in the same academic year. This "summer gap effect" was most pronounced among the strongest students, suggesting that extended breaks may contribute to the loss of talented engineering majors.

In terms of teaching approach, Mohammad et al. (2023) compared achievement and engagement of students in calculus using flipped and traditional learning. Results revealed that students from flipped classroom enjoyed the intervention, however, traditional classroom reported higher levels of satisfaction, interest and retention. Furthermore, Gerstle (2019) stated the challenges of engaging students outside the classroom through effective homework assignments. While creating assignments that test computational abilities is straightforward, designing tasks that encourage creative and deep thinking about course concepts is more challenging.

At the Technological University of the Philippines (TUP), the two Calculus courses are taught in consecutive semesters. These courses are handled by faculty members from the College of Science, specifically within the Mathematics Department. Many of these instructors possess educational backgrounds, making them well-versed in various pedagogical approaches. Traditionally, engineering students at TUP enhance their understanding of Calculus through self-directed learning or by participating in group study sessions. They tend to be less dependent on direct instruction or the learning resources provided by their teachers.

Table 3

Frequency and Percentage Distribution of the Mathematics Performances of Engineering Students in Calculus II

Mathematics Performance	Frequency	Percentage (%)
97 - 100	1	0.2
94 - 96	0	0
91 - 93	0	0
88 - 90	52	8.0
85 - 87	219	33.9
82 - 84	306	47.4
79 - 81	60	9.3
76 - 78	8	1.2
75	0	0
74 and Below	0	0
Total	**646**	**100.00**
Mean = 84.17 (Satisfactory)		

Table 4 demonstrated that the majority of students scored within the 82–84 (n=323) and 85–87 (n=223) grade ranges in *Mathematics in the Modern World* (MMW). This clustering around the mid-to-high performance range corresponds to a mean score of 84.07, which classifies the students' academic performance at a satisfactory level. *MMW* is a core general education course introduced in the revised Philippine college curriculum as part of the K to 12 educational reform. The course emphasizes the nature of mathematics and its relevance in daily life, aiming to enhance students' appreciation of the discipline's practical, intellectual, and aesthetic dimensions.

Roman and Villanueva (2019) conducted a study that examined the relationship between students' perceived acquisition of MMW competencies and their academic performance. Involving 271 first-year college students, their findings revealed that students demonstrated a high level of acquisition in the key competencies of the course—specifically in knowledge, values, and skills. Although students reported experiencing slight difficulties with certain topics, their overall performance in the subject remained satisfactory. Importantly, the study concluded that both the extent of competency acquisition and the level of difficulty experienced were significantly correlated with students' academic performance in MMW.

This aligns with the notion that mathematical performance is not merely a function of cognitive skills, but is also influenced by students' perceived challenges and their engagement with the subject matter. Supporting this perspective, Buddo et al. (2019) explored the Realistic Mathematics Education (RME) approach, which seeks to enhance students' ability to apply mathematical concepts to real-world contexts. Their design–action research involving in-service student-teachers indicated that learners often struggle with transferring mathematical knowledge to practical applications. Although there was no statistically significant improvement in performance, participants reported positive experiences using the RME framework. The study underscores the importance of fostering contextualized and interactive learning environments to deepen students' understanding and engagement in mathematics.

Together, these findings suggest that while students at the Technological University of the Philippines generally perform satisfactorily in MMW, their success is closely linked to how well they internalize the subject's competencies and how effectively they are supported in applying mathematics beyond the classroom. Efforts to reinforce real-world applications and address perceived learning difficulties could further enhance performance in this foundational course.

Table 4

Frequency and Percentage Distribution of the Mathematics Performances of Engineering Students in Mathematics in the Modern World

Mathematics Performance	Frequency	Percentage (%)
97 - 100	1	0.20
94 - 96	0	0
91 - 93	0	0
88 - 90	37	5.70
85 - 87	223	34.50
82 - 84	323	50.0
79 - 81	52	8.0
76 - 78	10	1.50
75	0	0
74 and Below	0	0
Total	**646**	**100.00**
Mean = 84.07 (Satisfactory)		

4.2 Academic performance in differential equation

Table 5 revealed that the majority of engineering students scored within the 82–84 (n=194) and 85–87 (n=337) grade ranges in *Differential Equations*. The computed mean score of 85.22 places the overall student performance at a **low-average** level. Although this suggests that most students are coping adequately with the course content, it also indicates room for improvement, particularly in mastering higher-order problem-solving skills essential for engineering applications.

Differential Equations is a critical subject in the engineering curriculum, as it equips students with the tools to model and solve problems involving rates of change in fields such as physics, electronics, and mechanical systems. The ability to interpret and solve differential equations meaningfully is strongly linked to a student's mathematical maturity and their ability to apply concepts in real-world contexts. In a study by Bibi et al. (2018), the role of **context familiarity** was explored in relation to students' performance in solving differential equations. Conducted at the pre-university level, the study administered three context-based DE tasks to 430 students, evaluating their responses across three main stages: understanding, planning, and execution. The results revealed that students performed better when the problem context was familiar—particularly with tasks related to physics and compound interest—compared to biological contexts. However, students still struggled significantly in the final stage of arriving at correct answers, with logical reasoning errors notably increasing. This suggests that while contextual familiarity enhances comprehension and planning, there is still a critical need to strengthen procedural and analytical skills.

These findings are highly relevant to the performance of students at the Technological University of the Philippines. Despite their relatively acceptable average score, consistent performance at higher levels of abstraction and application may still be a challenge. This underscores the importance of aligning instruction with real-life applications and familiar contexts to enhance motivation and comprehension. A context-based teaching strategies can significantly improve problem-solving in Differential Equations, a principle that could be effectively applied to improve outcomes in engineering education.

Mathematics, when taught in a way that highlights its relevance to real-world technologies and modern applications, can greatly enhance student engagement. In engineering, where mathematical modeling is integral to innovation and design, it is vital that instructors go beyond abstract theories. They must demonstrate how Differential Equations operate within practical, relatable contexts—be it through physics simulations, engineering case studies, or financial models. This approach not only improves academic performance but also fosters a deeper appreciation of the subject as a living, dynamic tool in solving real-world problems.

Table 5

Frequency and Percentage Distribution of the Mathematics Performances of Engineering Students in Differential Equation

Mathematics Performance	Frequency	Percentage (%)
97 - 100	0	0
94 - 96	0	0
91 - 93	1	0.2
88 - 90	86	13.3
85 - 87	337	52.2
82 - 84	194	30.0
79 - 81	23	3.6
76 - 78	3	0.5
75	0	0
74 and Below	2	0.3
Total	**646**	**100.00**
Mean = 85.22 (Low Average)		

It is evident that the engineering students' academic performance in pre-requisite courses, and Differential Equations consistently falls within from satisfactory to low-average range. This pattern may be attributed to the inherent difficulty of engineering mathematics subjects, which demand not only procedural competence but also a high level of conceptual understanding and analytical reasoning. Achieving higher grades in these courses proves to be a challenge for many students, particularly when transitioning from general to specialized mathematical applications.

Engineering is widely recognized as one of the most demanding academic programs in higher education. Its extended duration—often spanning five years compared to the typical four-year undergraduate degree—reflects the rigor and depth of training required. Unlike programs in the arts or business, which often emphasize subjective reasoning, creativity, or interpretive skills, engineering education is heavily grounded in objective, quantitative disciplines. Courses in engineering mathematics and applied sciences require mastery of complex problem-solving methods, abstract thinking, and technical precision. These demands contribute to the overall difficulty of achieving top-level academic performance in core mathematics subjects and underscore the need for enhanced instructional support and learning strategies tailored to the engineering context.

4.3 Significant relationship between the academic performance in differential equations

Table 6 illustrated the computed relationship between the characteristics of the three Mathematical courses with Differential Equations using correlation coefficient. The results indicate that **Mathematics in the Modern World** ($p = 0.1390$) and **Calculus 2** ($p = 0.123$) are **not significantly related** to students' performance in **Differential Equations,** given that their p-values are greater than the significance level of 0.05. This finding is understandable, particularly in the case of Mathematics in the Modern World (MMW), which is a **general education course mandated for all college students** under the Commission on Higher Education (CHED) Memorandum Order (CMO) No. 20, series of 2013. As a core subject, MMW aims to provide a broad appreciation of mathematical thinking and its application in daily life, rather than focus on the technical depth required in advanced mathematics for engineering students.

In contrast, **Calculus I** (p = 0.042) shows a **significant relationship** with performance in Differential Equations, as its p-value falls below the 0.05 threshold. This is expected, considering that Calculus I serves as a **fundamental prerequisite** for higher-level mathematics courses in engineering, including Differential Equations. The foundational concepts in Calculus I—such as limits, derivatives, and introductory integrals—are essential tools used extensively in solving differential equations. In most engineering curricula, both Calculus I and Calculus II are **required prerequisite courses** before enrolling in Differential Equations, thereby reinforcing their critical role in preparing students for success in this advanced subject.

Table 6

Significant Relationship between the Mathematics Performance of the Engineering Students in Differential Equation and the Mathematics Performance of the Pre-requisite Subjects.

Mathematics Performance – Differential Equation					
Mathematics Performance of the Pre-requisite Subjects	**Pearson Coefficient**	**Interpretation**	**p-value**	**Decision**	**Remarks**
Mathematics in the Modern Word	-0.058	Weak Negative Correlation	0.139	Failed to Reject Ho	Not Significant
Calculus I	.0800	Weak Positive Correlation	0.042	Reject Ho	**Significant**
Calculus II	0.061	Weak Positive Correlation	0.123	Failed to Reject Ho	Not Significant

Note: "If p value is less than or equal to the level of significance (0.05) reject Ho, otherwise failed to reject Ho."

4.4 Predictor and mathematical model for differential equations

Linear regression is a basic statistical method used to understand the relationship between a dependent variable (y) and one or more independent variables (x) (Moore et al., 2016). When there is only one independent variable, it is called simple linear regression; with two or more, it is called multiple linear regression. The method uses a straight-line equation to predict the value of y based on x. The model's coefficients are calculated from the data. A key assumption is that the average value of y changes linearly with x. While some variations estimate other values like the median, linear regression mainly looks at average trends. Unlike multivariate analysis, which looks at joint outcomes, linear regression focuses on predictions based on known values of x. It is widely used because it is straightforward to apply and the results are easy to interpret.

In the context of **engineering education,** particularly in **engineering mathematics**, linear regression plays a critical role in modeling and predicting student performance. Engineering mathematics involves the application of mathematical theories, scientific computing, and practical problem-solving to tackle complex real-world challenges. A core skill in this field is **mathematical modelling**—the process of creating abstract representations of systems using mathematical language. These models are central not only in engineering disciplines such as electrical or mechanical engineering but also across fields like biology, climate science, data science, and economics. As defined by Eykhoff (1974), a mathematical model is "a representation of the essential aspects of an existing system (or a system to be constructed) that presents knowledge of that system in usable form."

This study utilized **predictive modeling** to identify which among the pre-requisite mathematics courses best predicts student success in **Differential Equations**, a key subject in the engineering curriculum. Predictive modeling involves the use of mathematical and computational techniques to forecast future outcomes based on input data. In particular, this study applied **linear regression analysis** to construct a model that predicts performance in Differential Equations based on students' grades in prior mathematics courses. The advantage of such models lies in their ability to quantify relationships between academic performance in earlier courses and expected outcomes in more advanced subjects.

Table 7 shown significant factors in Predicting the Mathematics Performance of the Engineering Students in Differential Equation. For foregoing discussion of the regression equation, the following symbols are used: x_1 (Mathematics in the Modern World), x_2 (Calculus 1), and x_3 (Calculus II).

Table 7

Multiple Linear Regression: Significant Factors that Predict the Mathematics Performance of the Engineering Students in Differential Equation

Independent Variables	Regression Coefficient	p-value	Decision	Remarks
Constant	79.003	0.000	Reject Ho	**Significant**
Mathematics in the Modern Word (x_1)	-0.070	0.068	Failed to Reject Ho	Not Significant
Calculus I (x_2)	0.0830	0.029	Reject Ho	**Significant**
Calculus II (x_3)	0.0610	0.091	Failed to Reject Ho	Not Significant

Note: "If p value is less than or equal to the level of significance (0.05) reject Ho, otherwise failed to reject Ho."

Strickland (2015) discusses the **Generalized Linear Model (GLM)**, a more flexible extension of linear regression that accommodates a variety of response variable distributions. GLMs allow for the use of *link functions* to relate predictors to the response variable and adjust for non-constant variance in predictions. This flexibility enhances the robustness of predictive models in educational research, where data may not always follow a normal distribution.

In sum, the application of linear regression in this study aligns with best practices in predictive modeling within the field of educational analytics. It offers valuable insights into how foundational courses such as Calculus I, Calculus II, and Mathematics in the Modern World contribute—individually and collectively—to student success in Differential Equations. These findings can inform curriculum planning, targeted academic support, and strategic interventions aimed at improving learning outcomes in engineering programs.

The result of the data processing of students' performance in the 4 Mathematics courses as predictors of performance in Differential Equation resulted to the regression model below:

4.5 Regression model

$$\hat{y}_{Differential\ Equation} = 79.003 - 0.070\ x_{1_{MMW}} + 0.0830 x_{2_{Calculus\ I}} + 0.0610 x_{3_{Calculus\ II}} \quad (1)$$

example: (Student A)

Math Courses	Grades
X_1 (Math in Modern World)	80
X_2 (Calculus 1)	85
X_3 (Calculus II	90

4.6 Sample computation

$$\hat{y}_{Differential\ Equation} = 79.003 - 0.070\ x_{1_{MMW}} + 0.0830x_{2_{Calculus\ I}} + 0.0610x_{3_{Calculus\ II}} \quad (2)$$

= 79.003 – 0.070 (80) + 0.0830 (85) + 0.0610 (90)

= 79.003 – 5.6 + 7.055 + 5.49

= 73.403 + 7.055 + 5.49

= 85.948 predicted performance of Student A in Differential Equation

A regression model can be used to predict students' future performance in Differential Equations based on their academic results in prerequisite subjects such as Mathematics in the Modern World, Calculus I, and Calculus II. Mathematical models like this help describe, explain, and predict complex systems using quantitative data. According to Lowe, Carter, and Coper (2018), mathematical modelling involves a step-by-step process distinct from traditional problem-solving, and can be an effective teaching tool, especially when supported by technology and practical activities. Similarly, Remo (2019) explored how college students' pre-enrolment factors—such as high school GPA and entrance exam scores—relate to their performance in Mathematics in the Modern World (MMW). The study found only a weak positive correlation, with these factors accounting for just 3% of the variance in student performance, indicating limited predictive power. Nonetheless, difficulties in MMW were linked to students' academic preparedness. Meanwhile, Kula et al. (2018) examined how mathematics student teachers create modelling problems, revealing that effective models are those that are realistic, engaging, and mathematically sound. Their study emphasized the importance of modelling training for educators to ensure meaningful application of mathematical concepts. Together, these studies highlight the value of regression and modelling in both predicting student performance and enhancing mathematics education.

5 CONCLUSIONS

The study found that in all the mathematics courses considered—Mathematics in the Modern World, Calculus I, Calculus II, and Differential Equations—most students' grades were clustered within the 82–84 and 85–87 ranges. Among these subjects, Mathematics in the Modern World did not show a significant relationship with performance in Differential Equations or Calculus II. However, Calculus I was found to have a statistically significant relationship with Differential Equations, suggesting that foundational skills acquired in Calculus I are critical for success in more advanced topics. The study also developed a regression model to predict students' performance in Differential Equations based on their grades in previous mathematics subjects:

$$\hat{y}_{Differential\ Equation} = 79.003 - 0.070\ x_{1_{MMW}} + 0.0830x_{2_{Calculus\ I}} + 0.0610x_{2_{Calculus\ II}} \quad (3)$$

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DATA SHARING STATEMENT

Data supporting the findings and conclusions are available upon request from the author.

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Authors' Contribution

The author solely investigate, collect data, analyze and write the article.

Data availability

All datasets relevant to this study’s findings are fully available within the article.

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