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CORRELATING PERFORMANCE IN DEMONSTRABLE COURSES AND MATHEMATICS ACHIEVEMENT AMONG BS MECHANICAL ENGINEERING STUDENTS AT TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES

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ABSTRACT

This study investigates the correlation between the academic performance of BS Mechanical Engineering students in demonstrable courses and their achievement in specific mathematics subjects, including Calculus 1, Calculus 2, Differential Equations, Engineering Data Analysis, and Advanced Mathematics. The demonstrable courses under scrutiny encompass Machine Design 1 and 2, Mechanical Engineering Project Study 2, Industrial Plant Engineering, Power Plant Design with Renewable Energy, and Mechanical Engineering Laboratory 3. Additionally, it seeks to identify which aspects of mathematics achievement most significantly impact students' performance in engineering demonstrative courses. Employing a descriptive-correlational approach, the research utilizes multiple linear regression analysis. The sample comprises 184 out of 225 mechanical engineering graduates from the Technological University of the Philippines across various campuses during the 2021-2022 academic year. Data collection involved document analysis to procure students' final grades from the respective university registrar offices. Both quantitative and qualitative analyses were conducted, with qualitative insights derived from interviews with ten faculty members from the Mechanical Engineering Department regarding perceived student challenges in demonstrable courses.

Keywords: mathematics courses, mathematics achievement, engineering demonstrable courses, performance in engineering demonstrable courses, difficulties in mathematics, mathematics framework.

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1. INTRODUCTION

In this century, mathematics has become the backbone of prosperity in every field of life. It has been recognized as a major factor in development. It has helped the field of engineering develop. In all fields of engineering, knowledge of mathematics is vital as it provides the platform for numerically describing, modelling, and solving complex engineering problems. According to Mohamed *et al*. (2020), mathematics is an essential tool that is required as knowledge utilized in all engineering fields of study.

Mathematics is well known as the father of all sciences. Without mathematics, it is impossible to think about any scientific study (Pandey, 2017). In addition, Mathematics is the language used in the understanding and deliverance of scientific notions describing the problem at hand. Mathematics courses are recognized as a critical foundation for the study of engineering and often are pre-requisite courses for the engineering curriculum. Lohgheswary, Preethy, and Gobithaasanc (2019) stressed that Mathematics and Engineering are the key elements in STEM (Science, Technology, Engineering, Mathematics) education. Thus, a strong foundation in Engineering Mathematics will ensure a good understanding of engineering concepts.

There is no doubt about the importance of mathematics in engineering education. Mathematics courses serve as the foundation of every engineering program. This is because engineering theories and principles were mainly based and formulated through mathematical concepts (Santos & Vicencio, 2022). Additionally, to carry out any engineering calculation, one must have an excellent mathematical background of the underlying engineering principles in any given topic (Mohamed *et al*., 2020).

Mathematics therefore, contributes to the core of engineering. Mathematics helps engineers achieve pure precision when building or adjusting something. Engineers use aspects of mathematical skills such as analytical skills to develop and assess solution for formulating efficiency and correctness (Tolbert & Cardella, 2017). It is the key academic hurdle in producing a supply of engineering graduates (Goold & Devitt, 2021). It also serves as a source of knowledge from which engineering students can draw from.

“Mathematics in Engineering”, refers to mathematics as a service subject for engineering programs, usually taught by mathematicians, as well as mathematics as an integrated part of engineering sciences, where it constitutes specific practices with mathematics being more than just a language for engineers (Pepin, Biehler, & Gueudet, 2021).

In today's world, engineering is regarded as one of the most significant academic fields. Engineering is one of the most in demand and attractive degree programs in college as it is considered both rewarding and challenging

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(Boles & Whelan, 2017). And almost everyone on the planet is aware of its significance. No nation will evolve or be able to grow its economy unless engineering practices are adopted. Engineering degree programs are designed to equip students with cognitive learning or technical knowledge related to mathematics, technology and allied sciences to better understand how society can be developed and improved from breakthrough innovations (Dotong & Laguador, 2020).

Mechanical engineering in particular is a driving force of the economy toward industrialization. It is one of the oldest and broadest engineering fields (Ali, 2023). It is concerned with mechanical design, energy conversion, solar energy, manufacturing processes, and many more. It focuses on the application of physics and mathematics to the design and manufacturing of mechanical systems and products. Additionally, it is highly focused on the design and production of tools and machinery which are used in the wide field of engineering.

The need for the growth of domestic mechanical engineering, which provides the country's economy with means of production, promotes the development of all manufacturing industries, fuel and energy, transport and logistics, extractive sectors of the economy and agriculture is revealed and substantiated (Kurmanov *et al*., 2021). In a message delivered by Paradela (2023) during the 7th International Mechanical Engineering Research Conference (IMERC) held in Cebu City, he stressed that "Mechanical engineers like all of you here, therefore, assume not only the vital role of pursuing sustainable growth. You have a serious role as well to use mechanical engineering, being the converging point of all other engineering fields, to make sustainable growth an essential part of those other disciplines," (https://region7.dost.gov.ph).

The State "recognizes the importance of mechanical engineers in nation building and development. Their talents, through sustainable human development, shall be promoted…[and] the State shall develop and nurture competent, virtuous, productive and well-rounded mechanical engineers whose standard of professional practice and service shall be excellent, qualitative, world-class and globally competitive through regulatory measures, programs, and activities. This is laid out in R.A. 8495 (Philippine Mechanical Engineering Act).

The educational training that a mechanical engineer receives equips him or her with an exhaustive comprehension of the mathematical and scientific theories as well as the guiding principles that underpin the fundamental components of machinery and mechanical systems, which are the foundation of most, if not all, industrial processes (http://mekaniko-sl3.blogspot.com/2011/01/me-law-mechanical-engineering-and.html). Mechanical engineers often use formulas in mathematics to determine the amount of energy and force exerted by a machine.

Mathematics holds a relevant and unique place in the curriculum, most especially in the engineering curriculum. It is an essential tool in a mechanical engineering program, since it is required to solve problems, to analyze mathematical relations, and to use the laws of nature, which are mathematical expressions (htpps://work.chron.com). Calculus, differential equations, engineering data analysis, and advanced mathematics are taught because they are important to many engineering subjects, such as fluid mechanics, heat transfer, mechanics of materials, and many more. Calculus, for instance, is used to compute complex objects, and surface area to determine forces that will cause friction. Differential equations are used to predict the dynamic response of a mechanical system, while engineering data analysis is a crucial skill for making informed decisions and optimizing processes. Engineering students must be able to apply mathematical knowledge and skills in the various engineering problem-solving tasks and design.

The Commission on Higher Education (CHED) issued Memorandum Order No. 97, series of 2017, entitled "Policies, Standards and Guidelines for the Bachelor of Science in Mechanical Engineering (BSME) Program Effective Academic Year 2018-2019". It specified the core competencies expected of BSME graduates regardless of the type of higher education Institutions (HEIs) they graduate from. It also specified the mathematics courses included in the curriculum. In mechanical engineering, for instance, calculus is applied in the minimization of fan energy consumption in ventilation and air-conditioning systems (Karpuk, 2019). Calculus is also applied to figure out the velocity and acceleration of a vibrating object. In addition, Engineering Data Analysis (EDA) is an analysis tool of industries to analyze processes in order to enhance the competitiveness of a company. Data analysis theories and principles are used in testing or quality control in the manufacturing industry (https//www.fs-technology.com). Furthermore, differential equations (DE) are used to explain concepts of thermodynamics, which are considered in designing or implementing a system. DE is also used to find out the exact equation for the displacement of nodes in vibration (jbitdoon.com). Moreover, Advanced Mathematics is used to apply advanced mathematical tools to solve mechanical engineering problems. Matrices, for example, play an important role in the strength of materials.

To evaluate these foundations equipped by the mechanical engineers, the Philippine Regulation Commission (PRC) uses the Mechanical Licensure Examination to assess and guarantee the quality of mechanical engineers who will work in various manufacturing industries here and abroad. Records show that in the August 2021 ME board exam, the passing rate was 39.77 percent, and in the February 2022 ME board exam, the passing rate was 56 percent. In the August 2022 ME board exam, the passing rate was 54.15 percent (mb.com.ph). In the February 2023 ME board exam, 62.17 percent of the examinees passed, while 50.34 percent of the examinees passed the August 2023 ME board exam.

The Technological University of the Philippines-Manila, though, obtained a 71.68 percent passing rate in the February 2023 ME Licensure Examination, while it obtained 89 percent in the February 2022 Licensure Examination, way above the national passing rate. The ME licensure exam covers the topics of Power Plant Design with Renewable Energy, Industrial Plant Engineering, and Machine Design. These are the demonstrable courses included in the study.

To sustain the passing rate in the licensure examination for mechanical engineering in TUP, there is a need to conduct a study on the link between the mathematics achievement of the ME students and their performance in demonstrable courses in the mechanical engineering curriculum. It is along this premise that this study was conducted. It endeavored to investigate which among the mathematics subjects taken and passed by the BS mechanical engineering students of the Technological University of the Philippines (TUP) correlate with their performance in the 3rd and 4th year demonstrable courses. It also attempted to determine the mathematics courses affecting the performance of the BSME students in the engineering demonstration courses. These courses are termed demonstrable, as reflected in the curriculum map of the BSME curriculum.

In mechanical engineering, the PEO'S are as follows: within 3-5 years after obtaining a BSME degree, a graduate is expected to demonstrate the following: established in ME and allied fields in the area of research and development which enable him/her to hold a position beyond his/her entry level in an organization, sustained development through graduate studies and/or professional training, and a sense of responsibility, good ethical behavior, and professional commitment through involvement in community engagement activities and active field of mechanical engineering which promote social awareness and equity (https://www.msuiit.ed).

This study hopes to contribute to the growing body of literature on student achievement and performance. The result of this investigation will provide valuable input to curriculum planners in their plans to improve the mechanical engineering program curriculum. It will also provide meaningful data to mathematics educators in their efforts to improve the delivery of mathematics instruction. Furthermore, the outcome of the study will serve as a springboard for the TUP administration to craft policies and guidelines on how to improve the engineering program. Lastly, the study, it attempted to develop a mathematics framework that will help improve mechanical engineering students' achievement in their math courses and their performance in the engineering demonstration courses.

2. OBJECTIVES

The main concern of this study is to investigate the relationship between the performance in engineering demonstrative courses and the mathematics achievement of the mechanical engineering students of the Technological University of the Philippines Manila campus, Visayas campus, and Taguig campus.

Specifically, the study aimed to fulfill the following objectives:

2.1 Determine students' performance in the following engineering demonstrative courses:
2.1.1 Machine Design 1
2.1.2 Machine Design 2
2.1.3 Mechanical Engineering Project Study 2
2.1.4 Industrial Plant Engineering
2.1.5 Power Plant Design with Renewable Energy
2.1.6 Mechanical Engineering Laboratory 3
2.2 Assess the level of students' mathematics achievement in the following courses:
2.2.1 Calculus 1
2.2.2 Calculus 2
2.2.3. Differential Equations
2.2.4 Engineering Data Analysis
2.2.5 Advanced Mathematics
2.3. Find out a significant relationship between the students' performance in their engineering demonstrative courses and mathematics achievement.
2.4 Determine the difficulties related to mathematics encountered by the students in the engineering demonstrative courses related to mathematics.

3. METHODOLOGY

The descriptive-correlational research method was used in this study, together with a quantitative and qualitative approach. The study under this design was concerned with acquiring facts or information relevant to the specified condition or scenario for the goal of description and the inclusion of adequate analysis and interpretation. This form of research is appropriate when the individuals differ, and it is desired to determine the extent to which different conditions and scenarios are obtained among these subjects (Calmorin, 2007). Furthermore, this study design was used to collect the necessary data and techniques to allow for the seamless scaling of the numerous research activities, providing the most information. Furthermore, it offers the researcher a backbone structure for planning the answer to the study question or testing the hypothesis (Pawar, 2020).

A descriptive study, which is commonly employed in educational research, tries to collect measurable data for statistical analysis through the use of target respondents. It is based on the nature of the current situation. It also describes the study's subjects without interfering with or modifying the variables. According to Pawar (2020), the quantitative strategy tries to measure numeric figures, quantity, and amounts, but the qualitative technique allows a researcher to employ texts for discoveries, topic quality, and the type of picture from the researcher's point of view.

The Mechanical Engineering faculty who were interviewed were chosen by the ME Department Head.

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The faculty members chosen were all licensed engineers with permanent posts at the University at varying levels. They are all master's degree holders with a major in engineering, which is vertically aligned with their Bachelor's degree as a condition for tenure and promotion in teaching. Furthermore, some of them have doctorates, and others have doctoral units. The faculty members who were chosen have been teaching the demonstrable courses for some years and are considered experts in their domains.

Documentary analysis was used to collect the quantitative data, final grades in Mathematics and Demonstrable courses required for the project. The information was gleaned from the files of TUP's Office of the University Registrar (OUR), which keeps student records.

Document analysis is a methodical approach to studying or evaluating materials. According to Bowen (2009), the researcher must assess the document's original intent. The process entails analyzing THE SCHEME (Technology, Health, Environment, Sciences, Community, Habitat, Ethics, Mathematics, and Ecology), The Official International Journal of IBMORAS, electronic and physical documents in order to analyze them, comprehend their significance, and develop the information they contain (https://www.indeed.com).

Bowen defines document analysis as a process of "evaluating documents in such a way that empirical knowledge and understanding are produced and understanding is developed."

An open-ended interview guide was utilized to collect qualitative data from Mechanical Engineering (ME) professors on their thoughts or opinions about the issues faced by 4th-year ME students.

The number of variables in a specific period or in a group that constitutes part of the whole is represented by frequency and percentage.

The mean and standard deviation of the data determine its central tendency and the distribution of scores around its respective mean.

Pearson product-moment coefficient of correlation (r) determines the association between Mechanical Engineering students' mathematics achievement and performance in demonstrable courses.

Multiple Linear Regression employs a straight line to assess the connection between the quantitative dependent variable and two or more independent variables. This statistical tool calculates the model's variation and the relative contribution of each independent variable to the total variance. It was used in this study to see which of the five (5) mathematical courses had an effect on each of the six (6) demonstrated courses. All significance tests were performed at the.05 level.

4. RESULTS AND DISCUSSIONS

2.1 Students' Performance in Machine Design 1.

Table 1
Distribution of Students' Performance in Machine Design 1

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	4	2.174
Good	2.00-2.50	143	77.717
Satisfactory/Pass	2.75-3.00	37	20.109
Total		184	100

Mean=2.37/(Good Performance), SD=0.257

Based on Table-1, there are 4 or 2.174 percent of students who got grades described as very good performance, 143 or 77.717 percent of the students got grades in good, and 37 or 20.109 percent of the students who got grades described as satisfactory performance. The mean grade is 2.37 with a standard deviation of 0.257 that falls in the range of good performance. Result suggests that a vast majority of the ME students were able to apply the principles of machine elements and materials engineering in the design of machine elements, determine the design factor and design stresses, and were able to apply these in the design of machine elements. In addition, they were able to solve problems involving different types of stresses and applied the various codes in the design of machine elements.

2.2 Students' Performance in Machine Design 2.

Table 2
Distribution of students' Performance in Machine Design 2

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.57	15	8.152
Good	2.00-2.50	122	67.304
Satisfactory/Pass	2.75-3.00	47	25.543
Total		184	100

Mean=2.43/(Good Performance), SD= 0.19

As presented in Table-2, there are 15 or 8.152 percent of the students who got grades described as very good performance, 122 or 67.304 percent of the students who got grades described as good performance, and 47 or 25.543 percent of the students who got grades described as satisfactory performance. The mean grade is 2.43 with a standard deviation of 19.292, which falls in the level of good performance. It can be said that ME students were able to understand the concepts in Machine Design 2. The large value of the standard deviation suggests that the grades of the students are dispersed from the mean. This result indicates that students were able to understand the fundamental knowledge, concepts and skills in the analysis of components that are integrated into a complete machine or a mechanical system; specify suitable types and sizes of flexible power transmitting elements to transmit a given amount of power at specific speeds, for a certain mechanical application; perform the evaluation, analysis and design of different types of brakes and clutches, fly wheels, and riveted and welded joints for safety; determine the types of gears needed for a certain application, and to design the gear specifications to their safe operation; and select a suitable bearing, from existing catalogs or standards, in reporting a shaft for a certain application.

2.3 Students' Performance in ME Project Study 2.

Table 3
Distribution of Students' Performance in ME Project Study 2

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	46	25.000
Good	2.00-2.50	117	63.587
Satisfactory/Pass	2.75-3.00	21	11.413
Total		184	100

Mean=2.09/(Good Performance), SD= .355

From Table-3, there are 46 or 25 percent of students who got grades described as very good performance, 117 or 63.587 percent of students who got grades described as good performance, and 21 or 11.413 percent of students who got grades described as satisfactory performance. The mean grade is 2.09 with a standard deviation of 0.355, which falls in the level of good performance. It is worthy to note that the majority of the ME students had good project development. The small value of SD indicates homogeneity of the grades around its mean. This result means that the students were able to use the techniques, skills, and modern tools in producing the thesis project, prepare a written project study paper in a prescribed format, present orally the project to the panel, and produce actual mechanical systems as a solution to an identified and formulated mechanical engineering problem.

2.4 Students' Performance in Industrial Plant Engineering

Table 4
Distribution of Students' Performance in Industrial Plant Engineering

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	30	16.304
Good	2.00-2.50	137	74.456
Satisfactory/Pass	2.75-3.00	17	9.239
Total		184	100

Mean=2.10/Good Performance, SD= 0.290

Based on Table-4, there are 30 or 16.304 percent of students who got grades described as very good performance, 137 or 74.456 percent of students who got grades described as good performance, and 17 or 9.239 percent of students who got grades described as satisfactory performance. The mean grade is 2.10 with a standard deviation of 0.290, which falls in the category of good performance. Result indicates that most of the students were able to perform computation and analysis leading to the design of industrial plant facilities, evaluate the performance of the different plant facilities considering some realistic constraints such as economic, environmental, health and safety, social, and ethical; select system components and equipment, and design a simple industrial system within the environment of other engineering disciplines.

2.5 Students' performance in Power Plant Design with Renewable Energy.

Table 5
Distribution of Students' Performance in Power Plant Design with Renewable Energy

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	45	24.457
Good	2.00-2.50	100	54.348
Satisfactory/Pass	2.75-3.00	39	21.195
Total		184	100

Mean=2.22/(Good Performance), SD= 0.381

As displayed in Table-5, there are 45 or 24.457 percent of students who got grades described as very good performance, 100 or 54.348 percent of students who got grades described as good performance, and 39 or 21.195 percent of students who got grades of satisfactory performance. The mean is 2.22 with a standard deviation of 0.381, which falls in the level of good performance. Result suggests that the students were able to identify the components of the different power plants, explain the different types of renewable energies, evaluate the performance of the different power plants, and design a simple power plant considering some realistic constraints such as economic, environmental, health and safety, social, and ethical.

2.6 Students' performance in ME Laboratory

Table 6
Distribution of Students' Performance in ME Laboratory 3.

Performance Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	14	7.609
Good	2.00-2.50	162	88.043
Satisfactory/Pass	2.75-3.00	6	3.261
Failure	3.25-5.00	2	1.087
Total		184	100

Mean=2.31/(Good Performance, SD= 0.451

From Table-6, there are 14 or 7.609 percent of students who got grades described as very good performance, 162 or 88.043 percent of students who got grades described as good performance, 6 or 3.261 percent of students who got grades described as satisfactory performance, and 2 or 1.087 percent of students who got grades described as failure. The mean final grade is 2.31 with a standard deviation of 0.451, which falls in the level of good performance. Result indicates that most of the students were able to design and conduct experiments involving performance tests, heat balance, and efficiency of internal combustion engine (ICE) and power plants, design and conduct experiments involving performance tests and heat balance of refrigeration and air-conditioning systems, perform experiments independently, and present and prepare technical reports on laboratory experiments designed and conducted.

Overall, the performance of ME students in all the engineering demonstrative courses is described as good. This result implies that the students have a good grasp of the theories, principles, and concepts of these courses.

3. STUDENTS' MATHEMATICS ACHIEVEMENT

3.1 Calculus 1 Achievement

Table 7
Distribution of Students' Achievement in Calculus 1

Achievement Descriptions	Grade	Frequency	Percentage
Superior	1.25	2	1.087
Very Good	1.50-1.75	13	7.065
Good	2.00-2.50	91	49.457
Satisfactory/Pass	2.75-3.00	78	42.391
Total		184	100

Mean=2.50/(Good Achievement), SD= 0.429

As presented in Table-7, there are 2 or 1.09 percent of students who got grades described as superior achievement, 13 or 7.07 percent of students who got grades described as very good achievement, 91 or 49.46 percent of students who got grades of good, and 78 students or 42.39 % got grades described as satisfactory achievement. The mean grade is 2.50 with a standard deviation of 0.43, described as good achievement in Calculus 1. Result suggests that the majority of the students were able to differentiate algebraic and transcendental functions, apply the concepts of differentiation in solving word problems, and analyze and trace transcendental curves.

Table 8
Distribution of Students' Achievement in Calculus 2

Achievement Descriptions	Grade	Frequency	Percentage
Superior	1.25	17	9.24
Very Good	1.50-1.75	75	40.761
Good	2.00-2.50	32	17.39
Satisfactory	2.75-3.00	48	26.09
Failure	5.00	12	6.52
Total		184	100

Mean=2.36 (Good Performance), SD= 0.92

As can be gleaned from Table-8, there are 17 students, or 9.24 % got grades described as superior achievement, 75 students, or 40.76 % got grades described as very good achievement, 32 students, or 17.39 % got grades described as good achievement, 48 students, or 26.09 % got grades described as satisfactory achievement, and 12 students, or 6.52 % got grades described as failure. The mean grade is 2.36 with a standard deviation of 0.92, which falls in the level of good achievement in Calculus 2. The result indicates that less than half of the students were able to apply integration to the evaluation of areas, volumes of revolution, force, and work; use integration techniques on single and multi-variable functions; and explain the physical interpretation of the double and triple integrals.

Table 9
Distribution of Students' Achievement in Differential Equations

Achievement Descriptions	Grade	Frequency	Percentage
Very Good	1.50-1.75	15	8.15
Good	2.00-2.50	107	58.15
Satisfactory	2.75-3.00	62	33.70
Total		184	100

Mean=2.40 (Good Achievement), SD= 0.37

As displayed in Table-9, 15 students or 8.15 % got grades described as very good achievement, 107 students or 58.15 % got grades described as good achievement, and 62 students or 33.70 % got grades described as satisfactory achievement. The mean grade is 2.40 with a standard deviation of .37 which is in the category of good achievement in Differential Equations. Result indicates that the majority of the students were able to apply the concept of Laplace Transforms in solving differential equations, recognize different kinds of differential equations, determine the existence and uniqueness of the solution, select appropriate methods of solution, interpret the obtained solution relate differential equations to various practical engineering and scientific problems.

Table 10
Distribution of Students' Achievement in Engineering Data Analysis

Achievement Descriptions	Grade	Frequency	Percentage
Superior	1.25	6	3.26
Very Good	1.50-1.75	40	21.74
Good	2.00-2.50	99	53.80
Satisfactory	2.75-3.00	39	21.21
Total		184	100

Mean=3.15, (Satisfactory Achievement) SD= 12.75

From the table, it can be seen that there are 6 students, or 3.26 % got grades described as superior achievement, 40 students, or 21.74 % got grades described as very good achievement, 99 students, or 53.80 % got grades described as good achievement, and 39 students, or 21.21 % got grades described as satisfactory achievement. The mean is 3.15 with a standard deviation of 12.75, which falls in the description of satisfactory achievement in Engineering Data Analysis. The large value of *SD* suggests that the grades of the students are scattered about the mean. Result indicates that the majority of the students were able to apply statistical methods in the analysis of data and design experiments involving several factors.

Table 11
Distribution of Students' Achievement in Advanced Mathematics

Achievement Descriptions	Grade	Frequency	Percentage
Superior	1.25	1	0.54
Very Good	1.50-1.75	26	14.13
Good	2.00-2.50	66	35.87
Satisfactory	2.75-3.00	91	49.46
Total		184	100

Mean=2.49, (Good Achievement) SD= 0.47

As can be seen in Table-11, 1 student or 0.54 % got a grade described as superior achievement, 26 students or 14.13 % obtained grades described as very good achievement, 66 students or 35.87 % got grades described as good achievement, and 91 students or 49.46 % got grades described as satisfactory. The mean grade is 2.49 with a standard deviation of 0.469, which is described as good achievement in Advanced Mathematics. The results indicate that the majority of the students were able to satisfactorily solve problems in mathematics utilizing the different parameters, laws, theorems, and methods of solution in advanced mathematics; use numerical methods to solve engineering problems; and select or design the most efficient numerical solution to a problem.

In the five mathematics courses, four manifested good achievement by the mechanical engineering students, and one (1) course, which is Engineering Data Analysis, is at the satisfactory level of achievement. Also, it was only in the course Calculus 2 that students failed, though only a very small percentage (6.52 %).

The overall mean grade of 2.58 falls in the category of good achievement in the mathematics courses. The result suggests that the students are equipped with the necessary knowledge and skills in mathematics needed in their higher engineering courses, especially the demonstrable courses. This finding agrees with the research finding of Mohamed *et al*. (2020) that to carry out any engineering calculation, a student must have a good mathematical background in the underlying engineering principles.

Table 12
Relationship between Students' Achievement in Mathematics Courses and Performance in Machine Design 1

Mathematics Courses	Machine Design 1 *r*-value	Interpretation	*p*-value	Decision on Ho	Interpretation
Calculus 1	.135	Very weak	.037	Reject	Significant
Calculus 2	.401	Moderate	.000	Reject	Highly Significant
Differential Equations	.342	Weak	.000	Reject	Highly Significant
Engineering Data Analysis	.283	Weak	.042	Reject	Significant
Advanced Math	.184	Very weak	.007	Reject	Significant

$p<.05$, Significant

This implies that one can expect their performance in Machine Design 1 to improve if their achievements in mathematics courses are enhanced. The findings of the present study support that a significant correlation exists between students' math proficiency and their performance in applied engineering subjects, as revealed in the study of Bischof, Swolfer, and Rubesa (2015).

Table13
Relationship between Students' Achievement in Mathematics Courses and Performance in Machine Design 2

Independent Variables	Machine Design 2 Performance r-value	Interpretation	p-value	Decision on Ho	Interpretation
Calculus 1	.120	Very weak	.001	Reject	Significant
Calculus 2	.233	Weak	.010	Reject	Significant
Differential Equation	.432	Moderate	.000	Reject	Significant
Engineering Data Analysis	.041	Very weak	.075	Fail to Reject	Not Significant
Advanced Math	.156	Very weak	.007	Reject	Significant

P<.05, Significant (2-tailed)

This implies that one can expect their performance in Machine Design 2 to improve if their achievements in mathematics courses are enhanced. The findings of the present study support that a significant correlation exists between students' math proficiency and their performance in applied engineering subjects, as revealed in the study of Bischof, Swolfer, and Rubesa (2015).

Table 14
Relationship between Students' Achievement in Mathematics Courses and Performance in ME Project Study 2

Independent Variables	ME Project Study 2 Performance r-value	Interpretation	p-value	Decision on Ho	Interpretation
Calculus 1	.194	Very weak	.004	Reject	Significant
Calculus 2	.253	Weak	.000	Reject	Highly Significant
Differential Equation	.331	Weak	.000	Reject	Highly Significant
Engineering Data Analysis	.196	Weak	.106	Fai to Reject	Not Significant
Advanced Math	.528	Moderate	.001	Reject	Significant

p<.05, Significant (2-tailed)

Calculus 1 achievement has a positive, significant, very weak correlation with ME Project Study 2 performance since the r-value is 0.194 (p=.004). This positive value suggests that, if the students perform well in Calculus 1, they will be more likely to perform well in ME Project Study 2. The students can solve problems on optimization, rates of change, related rates, tangents and normals, and approximations; partial differentiation and transcendental curve tracing. Calculus helps students to produce actual mechanical systems as a solution to an identified and formulated mechanical engineering problem, find critical points, and solve optimization problems that are valuable in designing mechanical systems for maximum efficiency or minimum cost in ME Project Study 2. These procedures are useful to produce a well-developed project and a good written report.

Calculus 2 achievement has a significant positive weak correlation with ME Project Study 2 since the r-value is .253 (p<.001). The positive value suggests that if the students perform well in Calculus 2, they are more likely to perform well in ME Project Study 2. The students can apply integration in the evaluation of areas, volumes of revolution, force, and work; use integration techniques on single and multi-variable functions; and explain the physical interpretation of the double and triple integrals. Calculus 2 helps improve the ability of the students to find optimal solutions, such as minimizing material usage while maximizing structural strength. If students could apply the various integration techniques, then they could be successful in the conceptualization of their project design and fabrication towards the finalization of their project.

Differential Equations achievement has a significant positive weak correlation with ME Project Study 2 performance since the r-value is .331 (p<.001). The positive value suggests that if the students perform well in Differential Equations, they will be more likely to perform well in ME Project Study 2. The students have the ability to apply the concept of Laplace Transforms in solving differential equations, recognize different kinds of differential equations, determine the existence and uniqueness of the solution, select appropriate methods of solution, interpret the obtained solution, and relate differential equations to various practical engineering and scientific problems. Differential Equations helps the students to make specifications of their project, describe the motion of mechanical components and systems, and predict the dynamic response of a mechanical system in ME Project Study 2.

Engineering Data Analysis achievement has no significant relationship with ME Project Study 2 performance since the r-value is .196 and the p-value is .106, which is greater than alpha. The students' ability to apply statistical methods in data analysis and design experiments is not strong enough to be related to the improvement of their performance in ME Project Study 2, given the sample size. Engineering Data Analysis more likely helps the students understand, optimize, and enhance the performance and reliability of mechanical systems and components and systems in ME Project Study 2 using various statistical tools.

Advanced Mathematics achievement has a significant positive moderate correlation with ME Project Study 2 performance since the r-value is 0.526 (p.001). The positive value suggests that if the students perform well in Advanced Math, they will be more likely to perform well in ME Project Study 2. The students have ability to solve problems in mathematics utilizing the different parameters, laws, theorems, and methods of solutions in advanced mathematics, use numerical methods to solve engineering problems and select or design the most efficient numerical solution to a problem, Advanced Math helps the students in their projects, providing the tools and techniques necessary for modeling complex systems, analyzing data, and solving intricate engineering problems in ME Project Study 2.

The results of the correlation analysis between students' achievement in Math courses and Industrial Plant Engineering are presented in Table-15 below.

Table 15
Relationship between Students' Achievement in Mathematics Courses and Performance in Industrial Plant Engineering

Independent Variables	Industrial Plant Engineering Performance r-value	Interpretation	p-value	Decision on Ho	Interpretation
Calculus 1	.243	Weak	.001	Reject	Significant
Calculus 2	.411	Moderate	.000	Reject	Significant
Differential Equation	.372	Weak	.001	Reject	Significant
Engineering Data Analysis	.042	Very weak	.093	Fail to Reject	Not Significant
Advanced Math	.234	Weak	.001	Reject	Significant

p<.05, Significant (2-tailed)

Calculus 1 achievement has a significant positive weak correlation with Industrial Plant Engineering performance, the *r*-value is 0.243 (p=.001). The positive value suggests that, if the students perform well in Calculus 1, they will be more likely to perform well in Industrial Plant Engineering. The students can solve problems on optimization, rates of change, related rates, tangents and normals, and approximations; partial differentiation and transcendental curve tracing. Calculus 1 helps students to analyze the rate of deterioration of equipment, to schedule maintenance activities to prevent unexpected failures, and to optimize processes to improve efficiency and reliability in Industrial Plant Engineering. If the students could apply optimization rates of change and related rates, then they could design industrial systems and evaluate the performance of different plant facilities.

Calculus 2 achievement has a significant positive moderate correlation with Industrial Plant Engineering performance since the *r*-value is 0.411 (p<.001). The positive value suggests that if the students perform well in Calculus 2, they will be more likely to perform well in Industrial Plant Engineering. The students can apply integration in the evaluation of areas, volumes of revolution, force, and work; use integration techniques on single and multi-variable functions; and explain the physical interpretation of the double and triple integrals. Calculus 2 helps the students to calculate volumes of irregular shapes, which is important in determining the volume of containers. Thanks, and other storage vessels; apply environmental engineering in calculating the total impact of pollutants; and assess and mitigate environmental effects of industrial processes in Industrial Plant Engineering. If students could apply the various integration techniques, then they could perform computations and analyses leading to the design and evaluation of industrial plant facilities.

Differential Equations achievement has a significant positive weak correlation with Industrial Plant Engineering performance since the *r*-value is 0.372 (p=.001). The positive value suggests that, if the students perform well in Differential Equations, they will be more likely to perform well in Industrial Plant Engineering. The students can apply the concept of Laplace Transforms in solving differential equations, recognize different kinds of differential equations, determine the existence and uniqueness of the solution, select appropriate methods of solution, interpret the obtained solution, and relate differential equations to various practical engineering and scientific problems. Differential Equations helps the students to model dynamic behavior of processes, design controllers that regulate and stabilize industrial systems, and set up material balance equations in chemical and manufacturing processes in Industrial Plant Engineering. Application of theories and principles in DE by the students could enable them to design a plant in a cost-effective manner that will separate in a safe and reliable manner.

Engineering Data Analysis achievement has no significant correlation with Industrial Plant Engineering performance since the *r*-value is 0.042 and the *p*-value is greater than 0.05 (p>.05).

The students can apply statistical methods in the analysis of data and design experiments involving several factors; however, these abilities are not strong enough to be related to the enhancement of their performance in Industrial Plant Engineering, given the sample size.

Engineering Data Analysis is more likely to help students to monitor the performance of industrial equipment and to identify variations, deviations, and potential issues that may impact performance in Industrial Plant Engineering.

Advanced Mathematics achievement has a significant positive slight correlation with Industrial Plant Engineering performance since the *r*-value is 0.234 (p=.001).

The positive value suggests that if the students perform well in Advanced Mathematics, they will be more likely to perform well in Industrial Plant Engineering. The students can solve problems in mathematics utilizing the different parameters, laws, theorems, and methods of solutions in advanced mathematics; use numerical methods to solve engineering problems; and select or design the most efficient numerical solution to a problem. Advanced Math helps the students to provide a theoretical foundation and analytical tools necessary for addressing complex challenges in Industrial Plant Engineering. Understanding numerical techniques, numerical differentiation and integration, and the ability to find solutions to linear and non-linear equations could enhance students' performance in Industrial Plant Engineering,

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particularly in the design, installation, and evaluation of industrial plants.

Table-16 presents the relationship between students' achievement in mathematics courses and their performance in Power Plant Design with Renewable Energy.

Table 16
Relationship between Students' Achievement in Math Courses and their Performance in Power Plant Design with Renewable Energy

Independent Variables	Power Plant Design with Renewable Energy Performance				
	r-value	Interpretation	*p*-value	Decision on Ho	Interpretation
Calculus 1	.141	Very weak	.002	Reject	Significant
Calculus 2	.475	Moderate	.000	Reject	Significant
Differential Equation	.472	Moderate	.000	Reject	Significant
Engineering Data Analysis	.059	Very weak	.212	Fail to Reject	Not Significant
Advanced Math	.353	Weak	.000	Reject	Significant

P<.05, Significant (2-tailed)

Calculus 1 achievement has a significant positive very weak correlation with Power Plant Design with Renewable Energy performance since the *r*-value is 0.141 (p=.002). The positive value suggests that if the students perform well in Calculus 1, they will be more likely to perform well in Power Plant Design with Renewable Energy. The students can solve problems on optimization, rates of change, related rates, tangents and normals, and approximations; partial differentiation and transcendental curve tracing. Calculus 1 helps students to design and analyze the performance of turbines in hydroelectric, wind, or tidal power plants. This involves optimizing blade profiles, analyzing fluid dynamics, and maximizing energy extraction from the flowing resource. It helps them to analyze the rate of energy production, study the instantaneous power output, and assess how changes in environmental conditions or system parameters impact the rate of energy generation in Power Plant Design with Renewable Energy. Students' understanding of principles of optimization, rates of change and related rates could enhance their performance in Power Plant with Renewable Energy, in particular, the design of a renewable energy power operating system and the economic analysis of various power plants.

Calculus 2 achievement has a significant positive moderate correlation with Power Plant Design with Renewable Energy performance since the *r*-value is 0.475 (p<.001). The positive value suggests that if the students perform well in Calculus 2, they will be more likely to perform well in Power Plant Design with Renewable Energy. The students can apply integration in the evaluation of areas, volumes of revolution, force, and work; use integration techniques on single and multi-variable functions; and explain the physical interpretation of the double and triple integral, Calculus 2 helps the students to find the peak power output of renewable energy sources by determining the maximum value of the power function over a given time interval, engineers can design systems that can handle peak demands. Applying the various integrations in the selection and design of power plants could enhance students' performance in the course Power Plant Engineering with Renewable Energy.

Differential Equations achievement has a significant positive moderate correlation with Power Plant Design with Renewable Energy performance since the *r*-value is 0.472 (p<.001). The positive value suggests that if the students perform well in Differential Equations, they will be more likely to perform well in Power Plant Design with Renewable Energy. The students can apply the concept of Laplace Transforms in solving differential equations, recognize different kinds of differential equations, determine the existence and uniqueness of the solution, select appropriate methods of solution, interpret the obtained solution, and relate differential equations to various practical engineering and scientific problems. Differential Equations helps the students to model the motion of wind turbine components and the conversion of kinetic energy from the wind into electrical energy, and to describe the dynamics of the wind turbine rotor, generator, and control systems in Power Plant Design with Renewable Energy. Understanding the processes involved in integrating single- and multi-valued functions and applying them in the design, installation, and evaluation of power plants, considering some constraints, could enhance the performance of the students in Power Plant Design with Renewable Energy.

Engineering Data Analysis achievement has no significant correlation with Power Plant Design with Renewable Energy performance since the *r*-value is 0.059 and the *p*-value is greater than 0.05 (p>.05). The students can apply statistical methods in the analysis of data and design experiments involving several factors however, these abilities are not strong enough to be related to the enhancement of their performance in Power Plant Design with Renewable Energy given the sample size. Engineering Data Analysis is more likely to provide the students with valuable insights for resource assessment, system modeling, economic analysis, reliability optimization, and overall performance enhancement.

Advanced Mathematics achievement has a significant positive weak correlation with Power Plant Design with Renewable Energy performance since the *r*-value is 0.353 (p<.001), and the *p*-value is less than alpha. The positive value suggests that, if the students perform well in Advanced Mathematics, they will be more likely to perform well in Power Plant Design with Renewable Energy. The students can solve problems in mathematics utilizing the different parameters, laws, theorems, and methods of solutions in Advanced Mathematics; use numerical methods to solve engineering problems; and select or design the most efficient numerical solution to a problem. Advanced Mathematics provides the students with the mathematical tools necessary for modelling, optimizing, and understanding the complex interactions within these systems. Engineers use advanced mathematical techniques to ensure efficient, reliable, and sustainable energy generation from renewable sources. Applying numerical techniques, finding roots of equations, curve tilting, interpolation, numerical differentiation and integration, and finding solutions to non-linear, linear, and ordinary differential equations could enhance students' performance in the selection, design, and evaluation of power plants with renewable energy.

Table 17
Relationship between Students' Achievement in Math Courses and Performance in ME Lab 3

Independent Variables	ME Lab 3 Performance				
	r-value	Interpretation	*p*-value	Decision on Ho	Interpretation
Calculus 1	.296	Weak	.023	Reject	Significant
Calculus 2	.260	Weak	.010	Reject	Significant
Differential Equations	.369	Weak	.000	Reject	Highly Significant
Engineering Data Analysis	.053	Very weak	.075	Fail to Reject	Not Significant
Advanced Math	.253	Weal	.001	Reject	Significant

P<.05, Significant (2-tailed)

Calculus 1 achievement has a significant positive weak correlation with ME Lab 3 performance since the *r*-value is .260 (p=.023). The positive value suggests that, if the students perform well in Calculus 1, they will be more likely to perform well in ME Lab 3. The students can solve problems on optimization, rates of change, related rates, tangents and normals, and approximations; partial differentiation and transcendental curve tracing. Calculus 1 helps the students to understand the principles involved in heat transfer, fluid flow, and mechanical behavior. It is a fundamental tool for interpreting experimental data and gaining insights into the dynamic and thermodynamic aspects of various mechanical systems in ME Lab 3.

Calculus 2 achievement has a significant positive weak correlation with ME Lab 3 performance since the *r*-value is 0.059 (p=.010). The positive value suggests that if the students perform well in Calculus 2, they will be more likely to perform well in ME Lab 3. The students can apply integration in the evaluation of areas, volumes of revolution, force, and work; use integration techniques on single and multi-variable functions; and explain the physical interpretation of the double and triple integrals. Calculus 2 helps the students to analyze and interpret experimental data, providing a deeper understanding of the physical principles governing various mechanical systems and processes.

Differential Equations achievement has a significant positive slight correlation with ME Lab 3 performance since the *r*-value is .369 (p<.001). The positive value suggests that if the students perform well in Differential Equations, they will be more likely to perform well in ME Lab 3. The students can apply the concept of Laplace Transforms in solving differential equations, recognize different kinds of differential equations, determine the existence and uniqueness of the solution, select appropriate methods of solution, interpret the obtained solution, and relate differential equations to various practical engineering and scientific problems. Differential Equations helps the students to model the dynamic behavior of mechanical systems, predict transient responses, and analyze various physical phenomena encountered in experimental setups in ME Lab 3.

Engineering Data Analysis achievement has no significant correlation with Power Plant Design with Renewable Energy performance since the *r*-value is .053 and the *p*-value is greater than 0.05 (p>.05). The students can apply statistical methods in the analysis of data and design experiments involving several factors, Engineering Data Analysis did not more likely aids the students to understand complex phenomena, validating theoretical models, and optimizing mechanical systems for improved performance and reliability in ME Lab 3. The students' ability to analyze experimental data could not more likely facilitate the preparation and presentation of technical reports on experiments designed and conducted in ME Lab 3.

Advanced Mathematics achievement has a significant positive slight correlation with ME Lab 3 performance since the *r*-value is .253 (p=.001). The positive value suggests that if the students perform well in Advanced Math, they will be more likely to perform well in ME Lab 3. The students can solve problems in mathematics utilizing the different parameters, laws, theorems, and methods of solutions in advanced mathematics; use numerical methods to solve engineering problems; and select or design the most efficient numerical solution to a problem. Advanced Mathematics provides students with the theoretical foundation and analytical tools necessary for accurate modeling, optimization, and analysis of experimental data in ME Lab 3. Increased understanding of numerical techniques, numerical differentiation and integration could help improve students' performance in the design and conduct of experiments in ME Lab 3.

Table 18
VIF Values for the Math Courses (Calculus 2 and DE) with Industrial Plant Engineering

Model	Dimension	VIF (Calculus 2)	VIF (DE)
1	1	.04	
2	2	.96	
2	1	.01	.00
	2	.87	.02
	3	.12	.98

As seen in the table, VIF values are less than 5, indicating a low correlation between Calculus 2 and DE. That is, there is no multicollinearity between Calculus 2 and DE.

This statistical tool was used to estimate the relationship between two or more independent variables and one dependent variable. It may lead to a more accurate understanding of the relationship of each factor with the outcome.

Table 19
Regression Analysis for the Relationship Between Students' Achievement in Mathematics Courses and Performance in Machine Design 1

Model	Unstandardized Beta Coefficient	Standard Error	t-value	*p*-value	Interpretation	R^2
1 (Constant)	2.11	.235	45.91	.000		
Calculus 2	.11	.019	6.01	.000	Significant	.106
2 (Constant)	1.83	.236	16.00	.000		
Calculus 2/	.12	.019	6.37	.000	Significant	
Calculus 1	.11	.040	2.67	.008	Significant	.148
3 (Constant)	1.66	.230	11.93	.033		
Calculus 2/	.20	.021	4.55	.000	Significant	
Calculus 1	.09	.041	2.15	.008	Significant	
Differential Equation	.11	.053	2.11	.036	Significant	.217

Note: ANOVA for Regression Model 1; F(1.182)=8.944, p=.000; Model 2: F(2,181)=6.820, p=.033; Model 3: F(3,180)=6.545, p=.036, Significant at .001 level (p<.001).

In Table-19, the results of the regression analysis are displayed. Three models were generally based on stepwise regression analysis. In the table, the unstandardized beta coefficients, standard errors, *t*-values, and *p*-values for all the predictors are shown. Five variables were entered into the regression equations: the students' final grades in Calculus1, Calculus 2, Differential Equations, Engineering Data Analysis, and Advanced Mathematics. In model 1, the first variable (Calculus 2) was introduced into the regression equation, obtaining an unstandardized beta coefficient of .11, which is significant at p=.000 level. This result indicates that for every unit increase in Calculus 2 achievement, Machine Design 2 performance increases by .11 unit. In Model 2, after Calculus 2, Calculus 1 achievement was entered into the regression model, with unstandardized coefficients of .119 and .107, respectively, which are significant at t, p=.000 and .008 levels, respectively. These results suggest that in Model 2, for every unit increase in Calculus 2 achievement, Machine Design 1 performance increases by .119 unit, while for every unit increase in Calculus 1 achievement, Machine Design 1 performance increases by .107 unit.

In the full Model 3, the achievement in Differential Equation was introduced into the multivariate regression equation, which is significant at p=.036 level. The unstandardized coefficients are .20, .09, and .11, respectively. These values indicate that for the combined contribution of Calculus 2, Calculus 1, and Differential Equations achievements, for every unit increase in Calculus 2 achievement, Machine Design 1 performance increases by .20 unit; for every unit increase in Calculus 1 achievement, Machine Design 1 performance increases by .09 unit; and for every unit increase in Differential Equations achievement, Machine Design 1 performance increases by .11 unit.

Model 1 reflects that Calculus 2 achievement first entered into the regression model as a factor that influences Machine Design 1 performance. The adjusted R^2 of .106 indicates that Calculus 2 achievement caused a 10.6 percent variance in Machine Design 1 performance. The estimated regression on Model 1 is given below:

$$Y_1 = .11X_2 + 2.11$$

For Model 2, the adjusted R^2 is .148. This value suggests that the combination of Calculus 2 and Calculus 1 caused a 14.8 percent variance in Machine Design 1 performance. The estimated regression on Model 2 is given below:

$$Y_1 = .12X^2 + .11X_1 + 183$$

For the full Model 3, the adjusted R^2 is .217. This value indicates that Calculus 2, Calculus 1, and Differential Equations achievement taken together accounted for 21.7 percent of the variation in Machine Design 1 performance. The estimated regression for the full Model 3 is given by the equation,

$$Y_1 = .20X_2 + .09X_1 + .11X_3 + 1.66$$

Calculus is used in Machine Design 1 to model and analyze dynamic systems and to calculate the rate of change of variables such as acceleration and force. Meanwhile, DE is used to model the behavior of complex dynamic systems such as the flow of fluids (guava.com)

Table 20
Regression Analysis for the Relationship Between Students' Achievement in Mathematics Courses and Performance in Machine Design 2

Model	Unstandardized Beta Coefficient	Standard Error	*t*-value	*p*-value	Interpretation	R^2
1 (Constant)	2.04	7.613	2.68	.008		
Advanced Mathematics	6.42	3.009	-2.13	.034	Significant	.024

Note: ANOVA for Regression Model 1; F(1.182)=13.963 p=.034; Significant at .001 level (p<.001)

Presented in Tabl- 20 is the result of the regression analysis between ME students' achievement in the five mathematics courses and their performance in Machine Design 2. As can be seen in the table, only Advanced Mathematics achievement was entered into the regression model. The unstandardized beta coefficient value is 6.42. The adjusted R^2 for the full Model 1 is .024. This result suggests that 2.4 percent of the variance in Machine Design 2 performance is accounted for by students' achievement in Advanced Mathematics. The estimated regression on Model 1 is given below;

$$Y_2 = 6.42X_5 + 2.04$$

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Table 21
Regression Analysis for the Relationship Between Students' Achievement in Mathematics Courses and Performance in ME Project Study 2

Model	Unstandardized Beta Coefficient	Standard Error	*t*-value	*p*-value	Interpretation	R^2
1 (Constant)	1.10	.120	9.12	.000		
Advanced Math	.40	.048	8.39	.000	Significant	.275
2 (Constant)	1.50	.173	8.67	.000		
Advanced Math	.40	.046	8.60	.000	Significant	110
Calculus 1	.16	.051	- 3.17	.002	Significant	.326
3 (Constant)	1.39	.177	7.81	.000		
Advanced Math	.38	.047	8.17	.000	Significant	
Calculus 1	.15	.050	-2.92	.004	Significant	
Calculus 2	.06	.024	2.38	.018	Significant	.338

Note: ANOVA for Regression Model 1; F(1,182)=26.425, p=.000; Model 2: F(2,181)=22.946, p=.002; Model 3: F(3,150)=15.133), p=.000

As seen in the table, three models were generated. For Model 1, the first variable that entered the regression equation was Advanced Mathematics achievement. The value of the unstandardized beta coefficient (.40) indicates that for every unit increase in achievement in Advanced Mathematics, ME Project Study 2 performance increases by .40 units. For Model 2, after Advanced Math, the second variable that was entered into the regression model is Calculus 1. The unstandardized beta coefficient (.16) indicates that for every unit increase in Advanced Math achievement, performance in ME Project Study 2 increases by .16 unit. The three mathematics courses' achievement taken together in Model 3 show the unstandardized beta coefficients of .38, .15, and .06 for achievement in Advanced Math, Calculus 1, and Calculus 2, respectively. This result indicates that for every unit increase in Advanced Mathematics achievement, ME Project Study 2 increases by .38 unit, for every unit increase in Calculus 1 achievement, ME Project Study 2 increases by .15 units, and for every unit increase in Calculus 2 achievement, ME Project Study 2 performance increases by .06 unit. The adjusted R^2 (.275) for Model 1 indicates that 27.5 percent of the variance in ME Project Study 2 performance is explained by the students' achievement in Advanced Mathematics. The estimated regression for model 1 is given below:

$Y_3 = .40X_5 + 1.10$

For Model 2, the Adjusted R^2 is .326 which suggests that the combination of Advanced Mathematics and Calculus 1 achievement caused a 32.6 percent variance in ME Project Study 2 performance. The estimated regression is given below:

$Y_3 = .40X_5 +.16X_1 +1.50$

For the full Model 3, the Adjusted R^2 (.338) indicates that the achievements in Advanced Mathematics, Calculus 1, and Calculus 2 taken together caused a 33.8 percent variance in ME Project Study 2 performance. The estimated regression is given below:

$Y_3 = .38X_5 + .15X_1 + .06X_2 + 1.39$

Table 22
Regression Analysis for the Relationship Between Students' Achievement in Mathematics Courses and Performance in Power Plant Design with Renewable Energy

Model	Unstandardized Beta Coefficient	Standard Error	*t*-value	*p*-value	Interpretation	Adjusted R^2
1 (Constant)	1.78	.066	27.06	.000		
Calculus 2	.19	.027	7.21	.000	Significant	.22
2 (Constant)	1.14	.156	7.33	.000		
Calculus 2	.13	.029	4.60	.000	Significant	
Differential Equations	.32	.072	4.45	.000	Significant	.29
3 (Constant)	1.01	.163	6.21	.000		
Calculus 2	.14	.029	4.87	.000	Significant	
Differential Equations	.22	.082	2.68	.008	Significant	
Advanced Math	.15	.058	2.53	.012	Significant	.31
4 (Constant)	.71	.200	3.56			
Calculus 2	.16	.029	5.37		Significant	
Differential Equations	.17	.083	2.01	.046	Significant	
Advanced Math	.16	.058	2.82	.005	Significant	
Calculus 1	.14	.056	2.51	.013	Significant	.33

Note: ANOVA for Regression Model 1: F(1,182)=52.01, p=.000; Model 2: F(2,181)=38.62, p=.000; Model 3: F(3,180)=28.62, p=.000: Model 4: F(4,179)=22.83, p=.000, Significant at .001 level ($p \leq .001$)

As can be seen in Table-22, four models were generated. The ANOVA result for the regression showed a significant linear association between the variables. Model 1 reflects that Calculus 2 was an influential factor in Power Plant Design, with the Renewable Energy performance of the students. The Adjusted R^2 of .22 indicates that Calculus 2 achievement caused a 22 percent variance in Power Plant Design with Renewable Energy performance. Model 1 reveals that achievement in Calculus 2 influences student performance in Power Plant Design with Renewable. Presented below are the estimated regression on Model 1.

$Y_4 = .19X_2 + 1.78$

The value of the unstandardized (.19) indicates that for every unit increase in Calculus 2 achievement, Power Plant Design with Renewable Energy increases by .19 unit. For Model 2, achievement in Differential Equations was entered into the regression model. The adjusted R^2 of .29 indicates that the combination of Calculus 2 and Differential Equations achievement explains a 29 percent variance in Power Plant Design with Renewable Energy performance of the students.

The estimated regression on Model 2 is given below:

$Y_4 = .13X_2 + .32X_3 + 1.14$

The unstandardized coefficients (.13 and .32) indicate that for every unit increase in Calculus 2 achievement, Power Plant Design with Renewable Energy performance increases by .13 units, while for every unit increase in Differential Equations achievement, the said demonstrable cause by .32 units.

Advanced Mathematics was the next mathematics course to enter the regression model. For Model 3, the Adjusted R^2 of .31 indicates that Calculus 2, Differential Equations, and Advanced Mathematics achievement in combination earned a 31 percent variance in Power Plant

Design with Renewable Energy performance of the students. Model 3 reveals that achievements in the abovementioned mathematics course influence students' performance in Power Plant Design with Renewable Energy. Below is the estimated regression for Model 3.

Y_4=.14X_2 + .22X_3 +.15X_5 + 1.01

The values of the unstandardized coefficients (.14, .22, .15) indicate that for every unit increase in Calculus 2 achievement, Power Plant Design with Renewable Energy performance increases by .14 unit; for every unit increase in Differential Equations achievement, the said demonstrable course increases by .22 unit; and for every unit increase in Advanced Mathematics achievement, Power Plant Design with Renewable Energy increases by .15 unit.

For the full Model 4, Calculus 1 achievement was entered into the regression model. The adjusted R^2 of .33 indicates that the combined achievement in the four mathematics courses (Calculus 2, Differential Equations, Advanced Mathematics and Calculus 1) caused a 33 percent variance in students' performance in Power Plant Design with Renewable Energy. It was revealed in Table-23 that, taken together, Calculus 2, Differential Equations, Advanced Mathematics and Calculus 1 influence students' performance in Power Plant Design with Renewable Energy. Given below is the estimated regression for Model 4.

Y_4=.16X_2 + .17X_3 +.16X_5 + .14X_1 + .71

The unstandardized coefficients (.16, .17, .16, and .14) reveal that in the final Model, for every unit increase in Calculus 2 achievement, performance in Power Plant Design with Renewable Energy meaning demonstrable course increase by .16 unit; for every unit increase in Differential Equations achievement there is an increase of .17 unit in the said demonstrable course performance; for every unit increase in Advanced Mathematics achievement, an increase in .16 unit and for every unit increase in Calculus 1 achievement, an increase of .14 unit in Power Plant Design with Renewable Energy performance.

Model 4 manifests that the four mathematics courses influence the students' performance in the said demonstrable course.

This result is aligned with the study of Athvale *et al*. (2021) that the performance of students in prerequisites is a strong predictor of their performance in the current courses.

The unstandardized beta coefficient is .156 for Calculus 2, .168 for Differential Equation, .162 for Advanced Math, and 140 for Calculus 1, for full model 4. This result indicates that taken together, for every unit increase in Calculus 2 achievement, performance in Power Plant Engineering with Renewable Energy increases by .156 unit; for every unit increase in Differential Equation achievement, performance in Power Plant Engineering with Renewable Energy increases by .168 unit; for every unit increase in achievement in Advanced Math, performance in the said demonstrable course increases by .162 unit; and for every unit increase in Calculus 1 achievement, performance in the demonstrable course increases by .140 unit.

Table 23
Regression Analysis for the Relationship Between MATH Achievement in Mathematics Courses and Performance in ME Laboratory 3

Model	Unstandardized Beta Coefficient	Standard Error	*t*-value	*p*-value	Interpretationn	R^2
1 (Constant)	1.71	.174	9.80	.000		
Advanced Math	.24	.069	3.54	.001	Significant	.151
2 (Constant)	2.06	.221	9.32	.000		
Advanced Math	.35	.079	4.38	.000	Significant	
Differential Equations	.25	.100	- 2.53	.012	Significant	.096

Note: ANOVA for Regression Model 1; F(1,182)=12.890, p=.001; Model 2: F(2,181)=9,600, p=.012;: Significant at .001 level (p<.001)

Model 1, as presented in Tabl- 23, reveals that Advanced Mathematics first entered into the regression model; then, in the full Model 2, the significant predictors of performance in ME Lab 3 are students' achievement in Advanced Mathematics and Differential Equations. The values of the unstandardized beta coefficients are .35 and .25, respectively. This result indicates that for every unit increase in Advanced Mathematics achievement, ME Lab 3 performance increases by .35 unit; while for every unit increase in Differential Equation achievement, ME Lab 3 performance decreases by .25 unit. The estimated regression on Model 1 is given below:

Y_6 = .24X_5 + 1.71

The Adjusted R^2 (.096) indicates that 9.6 percent of the variance in ME Lab 3 performance is explained by Advanced Mathematics and Differential Equation achievement taken together. The regression on Model 2 is given below:

Y_6 = .35X_5 .25X_3 + 2.062

In the regression of Mathematics courses achievement and Industrial Plant Engineering (IPE) performance, no variables entered into the regression model; hence, it can be said that achievement in all five mathematics courses does not significantly influence IDE performance.

It is worthy to note that Engineering Data Analysis (EDA) has no significant predictor of demonstrable course performance in this study. This may be because a lot of statistical packages exist, and several online calculators can be accessed where results and interpretation are displayed such that without a full understanding of the concepts of EDA, students can have a

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successful performance in engineering demonstrative courses.

In addition, in ME Project Study 2 and ME Lab 3, the projects are more often prototype developments where only basic statistical computations are required.

The regression reveals that 4 out of 5 (80 percent) mathematics courses have an influence on performance in demonstrable courses. It is worthy to mention that the Engineering Data Analysis achievement was found not to be a significant factor of performance in engineering demonstrative courses. Differential Equations achievement needs thorough knowledge of both differentiation and integration to solve problems; hence, it is not surprising that the three courses positively influence performance in engineering demonstrative courses. In the case of Advanced Mathematics which has a significant influence on 4 out of 6 (67 percent) demonstrable courses performance, the topics under it such as first order linear differential equations, finding roots of equations, systems of linear algebraic expressions, and solutions to ordinary differentials are prerequisite knowledge in the understanding of the four courses: namely Machine Design 2, ME Project Study 2, Power Plant Design with Renewable Energy, and ME Lab 3.

Advanced Mathematics covers topics on complex analytic functions, matrices, and determinants, Laplace transforms, finding roots of algebraic and transcendental equations, finding solutions of linear algebraic and non-linear equations, and ordinary differential equations. Two-thirds (67 percent) of the demonstrable course performances have an effect on students' knowledge and understanding of these topics. Machine Design, in particular, applies the concepts covered in Advanced Mathematics to design machine elements or the whole machine, such as motors, gears, pulleys, and so on.

The same concepts are needed in Power Plant Design and Renewable Energy since creating a design needs machinery and apparatus such as turbines and generators.

These findings confirm the study of Athavale *et al*. (2021) that the performance of the students in prerequisites is a strong predictor of their performance in the current courses. Likewise, the criteria published by the Accreditation Board of Engineering and Technology, Inc. (ABET) for accrediting Mechanical Engineering Programs stressed that the program curriculum must require students to apply mathematics (including multivariable calculus and differential equations) to model, analyze, design, and realize physical systems, components, or processes. Regression analysis results revealed that, overall, the principles and concepts of Advanced Mathematics were the most useful in most students' knowledge and understanding of the engineering demonstrative courses. This finding implies that Advanced Mathematics must be given more emphasis by the teachers handling the course.

Develop a Mathematics Framework to Enhance the Performance in Demonstrable Courses

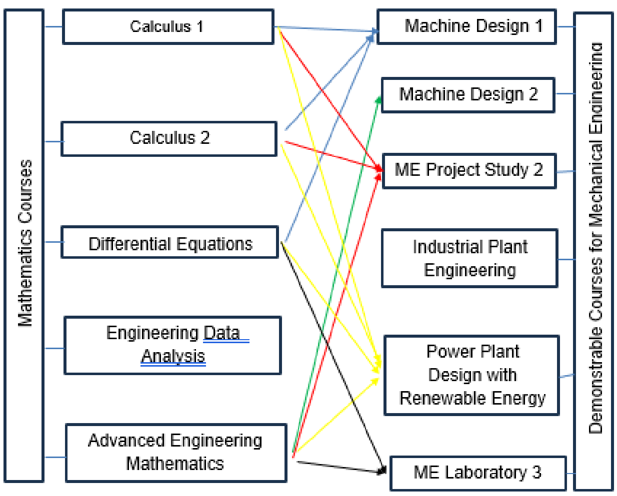

Figure 3. Mathematics Framework for Enhancement of Demonstrable Courses of Mechanical Engineering Student

The regression analysis suggests that Calculus 2, Calculus 1, and Differential Equations are significant predictors of students' achievement in Machine Design 1. The overall models are statistically significant, and the predictors collectively account for a moderate portion of the variance in the achievement.

Likewise, the regression analysis for Machine Design 2 suggests a weak relationship between the predictors and the achievement in the course. Specifically, the variable "Advanced Mathematics" has a significant negative effect on performance in Machine Design 2. The overall model has a low explanatory power, with only 2.4% of the variance in achievement explained by the predictors. It's important to note that the relationship is very weak, and caution should be exercised in drawing strong conclusions based on these findings.

Moreover, the regression analysis for ME Project Study 2 indicates that Advanced Math, Calculus 1, and Calculus 2 are significant predictors of students' achievement. The overall model has a moderate relationship with the response variable, explaining a substantial portion (33.8%) of the variance in achievement in ME Project Study 2.

Subsequently, Power Plant Engineering with Renewable Energy suggests that Calculus 2, Differential Equations, Advanced Math, and Calculus 1 are all significant predictors of students' achievement. The overall model has a moderate correlation with the response variable, explaining a substantial portion (34.6%) of the variance in achievement in Power Plant Engineering with Renewable Energy.

Finally, the regression analysis for ME Laboratory 3 suggests that Advanced Math and Differential Equations are significant predictors of students' achievement. The overall model has weak correlations with the response variable, explaining only 9.6% of the variance in achievement in ME Laboratory 3. While the predictors are statistically significant, caution should be exercised in drawing strong conclusions due to the weak overall model performance.

4. SUMMARY OF FINDINGS

The findings of the study are as follows:

5.1 Seventy-eight percent of the students had final grades in Machine Design 1 categorized as good, and the mean grade, 2.37 (SD=.26), is also categorized as good. In Machine Design 2, 66.34 percent got grades in the level of good, and the mean grade of 3.43 (SD=.19) is also described as good. For the demonstrable course ME Project Study 2, 63.60 percent obtained grades in the level of good, the same category as the mean grade 2.09, SD=.35. About three-quarters or 74.5 percent of the students got grades of good, the same category on the mean grade of 2.10, (SD=.23) for the course Industrial Plant Engineering. In addition, majority or 54.34 percent of the students performed at the level good in Power Plant Engineering with Renewable Energy, same description in terms of the mean grade of 2.22, (SD=.38). Further, a vast majority or 88 percent of the students got final grades described as good with a mean grade equal to 2.31, (SD=.45) which falls in the level of good in the demonstrable course ME Lab 3.

In summary, the students performed at the level of good in all six demonstrable courses.

5.2 Close to half, or 49.40 percent, of the students had achievement described as good in Calculus 1. The mean grade of 2.50 (SD=.43) is also described as good. In Calculus 2, 40.80 percent of the students achieved at a very good level, with a mean grade of 2.26, which falls in the category of good achievement. Meanwhile, the majority, or 53.80 percent, obtained a grade of good in Engineering Data Analysis. However, the mean grade of 3.15 is described as Satisfactory, and the standard deviation is large, SD=12.75, indicating heterogeneity of scores around its mean.

5.3 In Differential Equations, 60.00 percent of the students got grades described as good. The mean grade of 2.40 (SD .37) is also described as good. In addition, 35.80 percent had grades described as good in Advanced Mathematics, and the mean grade is 2.49 (SD=.47), which falls in the range of good achievement.

Results of correlation analyses revealed that all the mathematics courses' achievements have a significant positive relationship with Machine Design 1 performance. In Machine Design 2, only Engineering Data Analysis had no significant relationship with the demonstrable course (r=.04, p=.075). The same result was obtained with ME Project Study 2, where Engineering Data Analysis had no significant relationship with the demonstrable course (r=.20, p=.106). Engineering Data Analysis and Industrial Plant Engineering also did not have a significant relationship (r=.04, p=.093); the same is true with Engineering Data Analysis and Power Plant Engineering with Renewable Energy (r=.06, p=.212), and Engineering Data Analysis with ME Lab 3 (r=.05, p=.075.

In sum, 4 of the 5, or 80.00 percent, of the mathematics courses' achievement had a significant positive relationship with performance in each of the six (6) engineering demonstrable courses.

5.4 Difficulties encountered by the students in the engineering demonstrative courses related to mathematics are mastery of basic skills, appreciation of the mathematics course, and appreciation of the engineering program.

5. CONCLUSIONS

From the findings of the study, the following conclusions were derived:

a) The performances of mechanical engineering students in the engineering demonstration courses, namely Machine Design 1, Machine Design 2, ME Project Study 2, Industrial Plant Engineering, Power Plant Design with Renewable Energy, and ME Laboratory 3, are described as Good.

b) The achievements of the students in the mathematics courses, namely Calculus 1 and 2, Differential Equations, Engineering Data Analysis, and Advanced Mathematics, are described as Good.

c) There is a significant positive relationship in the following:

a. Machine Design 1 has significant positive relationships with Calculus 1, Calculus 2, and Differential Equations.
b. Machine Design 2 has a significant positive relationship with Advanced Mathematics.
d. ME Project Study 2 has significant positive relationships with Calculus 1, Calculus 2, and Advanced Mathematics.
e. Industrial Plant Engineering has no significant positive relationships with mathematics courses.
f. Power Plant Design with Renewable Energy has significant positive relationships with Calculus 1, Calculus 2, Differential Equations, and Advanced Math.
g. ME Laboratory 3 has significant positive relationships with Differential Equations and Advanced Mathematics.
f. Significant positive relationships exist between achievement in Calculus 1, Calculus 2, Differential Equations, and Advanced Mathematics and engineering demonstrative courses

d) The achievement in mathematics courses, Calculus 1 and 2, Differential Equations, and Advanced Mathematics affects the performance of the mechanical engineering students in the engineering demonstrative courses.

e) ME students encounter difficulties related to their courses (see Table-24, page 129)

f) A mathematical framework can be developed that can be used as a guide in planning programs to improve ME students' performance in engineering demonstrative courses.

RECOMMENDATIONS

In light of the findings of the study and the conclusions derived, the following recommendations are hereby advanced:

a) Teaching approach and assessment tools should be examined to improve students' achievement in mathematics and their performance in engineering demonstrative courses.

b) Other courses such as Physics and Chemistry are considered contributory to students' performance in demonstrable courses.

c) This study should be replicated at other higher education institutions to increase its generalizability.

d) Further studies should be conducted to include other higher engineering courses as the outcome variables.

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