CHAPTER I
INTRODUCTION

1.1 Background to the Study

Mathematics can be considered the language of science, technology, and engineering, and it is frequently stated that these fields cannot exist without mathematics (Develaki, 2020; Pepin et al., 2021). Mathematics contributes to the core of science and engineering and serves as a source of knowledge from which engineering students can draw from. This is a reason why in most of the science and engineering institutions, strong attachment to admission requirements is made with mathematics, and thus for a candidate to qualify for any of the science and engineering programs, he or she has to be reasonably strong in mathematics. Students who wish to pursue engineering degree courses and technical courses leading to engineering programs in the tertiary institutions are therefore expected to be at least above average in mathematics and mathematics related courses in many cases.

In tertiary institutions, across the globe, the numbers of students offering science and engineering courses are relatively smaller than the numbers in the non-science and engineering (Kibirige, 2017). Nevertheless, it is obvious that some students might have put in extra efforts to become scientists and engineers if they had known the role that mathematics could play in their lives. Many students have "no idea" what role mathematics will play in their future careers (Boaler, 2022). Some students might know the role mathematics can play in their future lives, however, poor starts and other factors prevents them from meeting the entry requirements for science, technology, engineering and mathematics (STEM) in tertiary institutions. In view of this, it is agreed that some students consider mathematics as a gateway to engineering, through which they develop their skills for sound design, whereas others regard mathematics as a gatekeeper, denying them entry into their talents as engineers (Ramniceanu et al., 2022; Torres, 2023).

In addition, various other factors also contribute to students' low performances in the aspects of mathematics that are designed as part of the engineering curricula in universities. There is a great suspicion that the average young person's orientation of mathematics towards the learning of engineering subjects and also engineering practices have changed, and this may be due to the following investigations: In this modern period, the use of technology and its practices in the broader society have changed significantly and people's interests, skills and activities have changed drastically (Brint, 2020). We live in the modern world where technological means of communications, information and entertainment are available anytime, anywhere and at low costs (Graham & Dutton, 2019). Therefore, the period of brainstorming is past and gone, and replaced by electronic brainstorming (Maaravi et al., 2021). In addition, there is a belief among some practicing engineers that the mathematics they learned is not or less applicable to their work (Kelley & Knowles, 2016). Nonetheless, mathematics remains the sole tool for solving engineering problems, making it essential to thoroughly learn its concepts across various applications.

According to research by Dash et al. (2018), electrical and electronic engineering (EEE) is the branch of engineering that develops the usage of electricity. It focuses on systems that produce, transfer, and transform high electrical currents into different kinds of energy, such as mechanical energy. Electrical engineers design, develop, test, and supervise the manufacturing of a wide range of electrical equipment, including electric motors, communications systems, radar and navigation systems, and equipment used in power generation. The electrical systems of cars and airplanes are also created by electrical engineers. Global Positioning System (GPS) devices, portable music players, and other electronic equipment are all designed and developed by electronic engineers. Many individuals also work in fields directly related to computer hardware.

EEE is inseparable from mathematics, with knowledge of algebra, calculus and others being crucial in this field. To mention a few, from circuit theory to control systems, thermodynamics to microprocessors, digital signal processing, linear control systems, high voltage engineering, microcontrollers with programming, robotics, solar energy systems, illumination, and communication, all these fields are fundamentally based on mathematics concepts. For example, knowledge of trigonometric identity is essential for the field of voltage generators, as well as for the computation of current, power, efficiency, RLC circuits, and other relevant parameters. Linear algebra is extensively used in digital signal processing, communication systems, circuit analysis, error control coding, power systems, and robotic circuits. Ordinary, linear, nonlinear, and partial differential equations all play crucial roles in EEE. They are essential in areas such as basic electric machines, antennas, power systems, optics, and even image processing. Fourier Transforms are also used in power systems, control systems, heat transfer, and signal processing. Knowledge of Vector algebraic is important in electromagnetism. We must have studied probability and statistics if we wish to determine the likelihood of signals and events in telecommunication networks and random processes. Therefore, as noted by Dash et al. (2018) and others, some of the mathematical tools employed in EEE are *Co-ordinate Geometry*, *Probability and Statistics, Complex Numbers, Linear algebra, Functions, Trigonometry, Vector analysis, Calculus, Differential Equation, Fourier and Laplace transform*.

With this background information, it is obvious that the level of mathematics of an EEE student has a great influence on the learning of electrical and electronic courses in the university. Mathematics is a fundamental component of EEE education, and students' math proficiency significantly impacts their performance in electrical engineering courses (Maher et al., 2022; Smith, 2022). However, research has shown that math misconceptions and weaknesses often emerge during high school, where students struggle with key concepts such as algebra and geometry (Fujii, 2020). These struggles perpetuate into technical schools, where students receive technical and vocational training in EEE, and ultimately affect their ability to excel in EEE programs at the university level (Drew, 2015). Furthermore, gender disparities in mathematics education persist globally, with females often underrepresented in STEM fields and experiencing lower confidence and proficiency in mathematics (Hammond et al., 2020; Reilly et al., 2019; Zhou et al., 2017). This trend is equally prevalent in Ghana, where there are cultural and societal factors may exacerbate gender disparities in math education (Yarkwah, 2020). Additionally, students with varying abilities, such as those with learning disabilities or English language learners, may face unique challenges in mathematics education (Stones & Glazzard, 2020). In Ghanaian high schools and technical schools, students often face challenges in mastering mathematics concepts crucial for electrical engineering, such as calculus and differential equations (Aboagye, 2015; Owusu, 2020).

Ghana, a country located in sub-Saharan Africa, has a population of 32.83 million, according to the 2021 population and housing census (Service, 2021). In order to keep up with the fast-paced global economy, Ghana's educational system needs to adjust and ensure that students obtain the necessary skills. It is crucial for the education of the younger generation to give priority to developing problem-solving, critical thinking, and higher-order thinking skills in order to adequately prepare them for the innovative challenges of the 21st century. A number of studies, such as those conducted by Turiman et al., (2012), D arling-Hammond et al., (2020), Erdoğan, (2019), Afandi et al., (2018) and Ball & Garton, (2005) emphasize the importance of school goals that prioritize these skills. This strategy will empower the young population of Ghana to make valuable contributions towards the future prosperity of the nation. Based on the data from the 2011 Trends in International Mathematics and Science Study (TIMSS) research, Ghanaian pupils are considered to have below-average thinking abilities. Ghanaian students are limited to practicing problems that primarily use basic cognitive abilities, such as knowledge or recollection, and do not need advanced critical thinking skills (Bonyah & Clark, 2022). Despite the commendable performance of Ghanaian teachers in most of the teacher preparation categories analyzed in the TIMSS study, there was no corresponding improvement in student success. Researchers are recommended to focus on researching the high-order thinking levels of their pupils, as suggested by Wardat et al., 2022.

The TIMSS study has been available for over ten years, however it seems that the issue still exists among EEE students in Ghanaian Technical Universities (TUs). A careful observation is that students with weaker Senior High School (SHS) mathematics background do not generally perform well in the EEE courses. Over one and a half-decade experience gained by the researcher, as an engineering mathematics lecturer in the department of electrical and electronic engineering in Cape Coast Technical University (CCTU) in Ghana, is that students who did not perform well in SHS mathematics mostly do not perform well in the engineering mathematics and also in the electrical and electronic engineering courses. This is obviously the reason for the grade 6 as the cut-off point for admitting students into the HND and undergraduate programs. Another careful observation by the researcher is that prerequisites that have been set in the HND EEE curriculum seem to be illogical. In fact, some students rather tend to perform better in some courses than their prerequires.

For its importance that cannot be compromised in the EEE curricula in the universities, students are taught mathematics courses that usually include the above-mentioned areas (Dash et al., 2018; Marg & Kunj, 2017; Tech, 2016). Students are therefore taught the techniques or strategies for solving various mathematics problems such as expansion in algebra, multiplying the exponent of a variable by a monomial and reducing it by one in the case of Differentiation and so on, but these strategies, depending on the skill or competence level acquired, may fail during the period of assessment (Arboledas et al., 2020; Minarni, 2019). The research will focus on the 'mathematics failure' that goes on to affects the understanding and its applications in the electrical and electronic engineering courses taken during the period of the program of study. In our attempt to capture the true meaning of the phenomenon without any hidden, we will call this 'failure effects' of mathematics. To give more insight into 'failure effects', we present two examples on the use of mathematics tools in EEE in which 'failure effects' of mathematics may easily be realized:

Linear algebra is a required course in majority of EEE programs. The study of equation systems, determinants, vector spaces, including function spaces, linear transformations, eigenvalues, eigenvectors, and quadratic forms are all included in linear algebra or matrix algebra. One of the most important uses of linear algebra in the world of electronics is the analysis of electrical circuits. Finding the current flowing through each component of a circuit is the goal of loop current analysis in electric circuits (Dash et al., 2018). For example, we can calculate the current that flows in each of the branches of an electrical circuit. N loop currents, which are the net currents, are required. The Kirchhoff's Voltage Law, applied to every loop, generates linear equations involving the currents $i_1, i_2, \dots\ i_N$ in the loops. This system of equations can be simplified and solved.

It should be realized that in solving this problem, the students need to be competent in (i) expansion, and (2) solving simultaneous linear equations in N variables (eliminations and substitution or by Gaussian elimination or any of the application of matrix to the solution to systems of linear equations). Lack of competence in this sense may lead to a wrong answer to the system of linear equations. Thus, the ‘failure effect’ of expansion (applying the distributive property of multiplication over addition) in this case would lead to wrong values for the currents i_1, i_2, . ., and/or i_N.

Complex analysis, which involves trigonometry, is used in EEE in two major areas. One area is signal processing and the other is control theory (Zhang, 2022). Other area is in communication systems such as broadband, Wi-Fi, picture-video-audio compression, and satellite communication. Also Signal filtering and reconstruction which describe RCL practices with the point of phasors, and other complex logical capacity techniques. Complex analysis is also used as a part of the examination of signals in signal processing (Van Drongelen, 2018). To illustrate its use, consider a coil having a resistance of 20Ω and in series with an inductance of 0.4H. If a current of 4 amps flows through the coil, then we can calculate the value of the supply voltage for a given frequency of 60Hz. In this case, the inductive reactance (X_L) is 151Ω, and the total impedance (Z) is 152.32Ω. The supply voltage (V_S) required is 610V, the voltage drop across the resistor (V_R) is 80V, and across the inductor (V_L) is 604V. The phase angle (ϕ) between the supply voltage and the current is 82.5^0.

Now, the calculations leading to the values above involves students’ competence in the use of Pythagoras Theorem, and basic trigonometric ratios. When working with signal Fourier Transform, which involves utilizing students’ competence in applications of complex numbers, converting time-based signals to their frequency-based equivalents is highly helpful. To improve the efficiency of correspondence channels, characterizing a signal on the basis of its frequency behavior, range, and configuration channels or transmission media. At this point, Fourier Transforms support flag examination and may even become the most significant element. Control theory is the second area of application, particularly in the analysis of the strength of system and controller design. It is therefore obvious that the ‘failure effect’ of the Pythagoras theorem, trigonometric ratios and complex numbers is the result of wrong impedance, voltage drops across each part, and the stage point between the supply voltage and the current.

By the context of this study, we therefore define *ripple effect of mathematics* as the influence that mathematics has on the EEE courses in a successive manner, particularly, from one semester EEE course to an EEE course in the following semester during a study program. It must be noted that proficiency in mathematics cultivates critical thinking, problem-solving, and analytical skills, which are essential for successive courses taken by students for overall success in engineering disciplines (Jahan, 2021). Hence, an EEE student’s failure to grasp the concepts of mathematics or any aspect of mathematics is expected to result in *ripple failure effect(s)* on the EEE courses. This underscores the responsibility of those developing and delivering mathematical education to these engineering students to ensure that programs are inclusive and cater to each student's unique needs (Kocdar et al., 2021). By addressing these specific needs, educational programs can better support students in overcoming the challenges associated with learning mathematics in engineering contexts.

The research therefore aims to investigate the ripple failure effects of mathematics on EEE courses, or how students’ levels of thinking in mathematics affect their achievements in EEE education. The study will go on to develop a model to classify these engineering courses according to how they are affected by mathematics (no, low, average or high effects), as this will help the institutions involved to plan how to run those courses in relation to students’ abilities in engineering mathematics. The formulation of the research problem is thus in Section 1.2.

1.2 Research Problem

Based on the background of the problems that have been explained, the study discusses the following problems:

1. Is there a collective failure effects of mathematics on the EEE courses?
2. Does a student’s cognitive level have a mediating role in the failure effects of mathematics on achievements in EEE education?

3. Do students' foundations in mathematics moderate their mathematics failure effects on their achievements in EEE education?
4. What are the failure effects of each domain of mathematics on individual EEE courses?
5. What are the classifications of the EEE courses on the basis of the levels of their failure effects of mathematics?
6. Is there any ripple effect of mathematics on the EEE courses in the phases of the HND program?

1.3 Research Objectives

In general, the study aims to determine the nature and levels of EEE students' failure effects of mathematics on the engineering courses they offer in Ghanian TUs, and therefore, how best their curriculum mathematics supports the engineering courses they study. The specific objectives in this study are:

1. To determine the collective failure effects of mathematics on the EEE courses.
2. To determine whether a student's cognitive level have a mediating role in the failure effects of mathematics on achievements in EEE education.
3. To determine whether students' foundations in mathematics moderate their mathematics failure effects on their achievements in EEE education.
4. To determine the failure effects of each domain of mathematics on individual EEE course.
5. To develop classification model for the EEE courses on the basis of the levels of failure effects of mathematics.
6. To determine any ripple effect of mathematics on the EEE courses in the phases of the HND program.

1.4 Research Benefits

The facts gathered by the study would help determine the state of affairs with respect to how a student's strength in a particular domain of mathematics, as well as his or her cognitive level affects his or her learning of the EEE courses. This, it is believed, would help both lecturers and students to be up and doing and pay attention to the negatively affected areas. Where there are failure effects, this study would help in stake holders' discussion in connection with review of the curriculum to give adequate grounds for the EEE students of the Ghanaian TUs to be able to study the courses in their chosen field without difficulty.

The classification analysis employed in the study is hoped to reveal the EEE courses which are not or slightly influenced by mathematics. Relevant refresher training programs involving such EEE courses can be organized by the universities in collaboration with the industries, to help review some fundamentals they might have forgotten or upskill on new information since we are in a technologically changing world. Relevant courses that do not involve strong mathematics will be better in this case, since the prospective participants would be out of the mathematics classroom.

The research is expected to reveal areas with cognitive issues in the MAT. If students exhibit any weaknesses in HOT ability, the necessary future action may be taken to sharpen students practical thinking skill during their training in the universities. This is what the industries are demanding from the tertiary institutions. Mathematics teaching and learning should equip students with the ability to think critically and creatively and problem-solving skill to enable them to compete in the industrial revolution 4.0 (Kusaeri et al., 2019; Lase, 2019). Finally, this study is expected to be a valuable resource for students and teachers in the field of EEE, and to complement existing research on the effects of mathematics on EEE courses.

1.4.1 Benefits of Theoretical Aspects

In the perspective of theory, the researcher hopes that this research can contribute to the dynamics of theory, regarding the concept of problem-solving theory and attribution theory. Furthermore, the researcher hopes that there will be a contribution to the development of theoretical studies on failure effects of mathematics on related academic achievement.

1.4.2 Policy Benefits

In terms of policy benefits, the researcher hopes that this research can make a positive contribution as a consideration in studies, especially in policy making related to review of curricula with respect to influential mathematics topics. This research is also expected to be an indication of policy-making with respect to the level of students' foundation in mathematics and cognitive development in the learning process. Relevant refresher training programs involving EEE courses that less rely on mathematics can be organized by the universities in collaboration with the industries, to help review some fundamentals they might have forgotten, or upskill on new information since we are in a technologically changing world. Relevant courses that do not involve strong mathematics will be better in this case, since the prospective participants will be out of the mathematics classroom.

1.4.3 Benefits of Practice

In terms of practice, it is believed, that both lecturers and students will be up and doing and pay attention to the mathematics-sensitive areas of the curriculum. Again, where there are cognitive problems such as low HOTS, the researchers hope that the problem would be improved by developing and training students with HOT problems.

1.4.4 Benefits in terms of Issues and Social Action

In terms of issues and social actions, it is anticipated that this research will be applied in real-world situations to carry out a variety of social actions and to develop issues pertaining to improving EEE education through modifications of teaching-learning process and review of mathematics contents of the HND EEE curriculum. It is also hoped that the study would serve as an important reference source for students and lecturers in the field of EEE, and also be supplementary to studies already undertaken in the area of influence of mathematics on EEE courses.

1.5 Dissertation Organizational Structure

The whole findings of the investigation and testing of the data gathered are contained in this dissertation, which is presented as a scientific manuscript. The organizational structure of the dissertation is as follows: CHAPTER I: INTRODUCTION, discusses the background of the research, formulation of the problem, objectives of the research, research benefits, and lastly about dissertation structure organization. In CHAPTER II: LITERATURE REVIEW, the researchers portray the theories relevant to this research and brief overview of the findings of various prior studies that will be found relevant to the study. CHAPTER III: RESEARCH METHODS contains methods used in completing the research, both in data collection and in analyzing the data for the research This section ends with ethical issues that shows that researchers conduct research based on applicable procedures. Chapter IV: Findings And Discussion presents report on a deep analysis of the data and discussion of results that contains the validity of data with the theory used in the research. Finally, Chapter V: Conclusion, contains the final results of the study, conclusions from the entire research as well as the implications and recommendations from in the research.