AN ANALYSIS OF PROBLEM-SOLVING SKILLS IN CALCULUS APPLICATION TASKS AMONG SENIOR HIGH SCHOOL STUDENTS IN GHANA

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ASIA e UNIVERSITY

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ABSTRACT

This study investigated the difficulties that students in Senior High Schools in Ghana face when solving application problems in calculus. For over a decade, mathematics performance in Ghana has been persistently low, with national pass rates for Core Mathematics consistently below 50%. Results in Elective Mathematics are even more concerning, having fallen as low as 26% in 2006. A well-documented and significant part of this struggle involves application problems in calculus, where students are asked to use concepts in practical contexts like physics or economics. The Chief Examiner's reports consistently highlight this weakness. For example, the 2021 report noted that students could not apply integration to find velocity and distance from a given acceleration. This aligns with my own teaching experience, where I have observed that students often struggle to translate word problems to mathematical equations, requiring me to re-teach foundational concepts and straining the available class time. This study involved 960 Grade 11 students from twelve schools, selected from three of Ghana's six school categories in Greater Accra. A sequential explanatory mixed research design was employed, using Polya's problem-solving theory as a framework and the first three levels of Bloom's taxonomy to categorize cognitive skills. A researcher-developed cognitive test was used to assess student skills, and a questionnaire was used to solicit information on teachers' perceptions of problem-solving in calculus. All instruments were checked for reliability and validity. Quantitative data were analyzed using descriptive and inferential statistics. Content analysis of students' responses to the test items was conducted, and the cognitive test results were qualitatively analyzed to identify the errors made by students. Additionally, the responses of teachers to the questionnaire were examined. The results showed that students performed well on topics such as the trapezium rule and finding tangents and normals. However, they faced serious challenges with problems in rate of change, kinematics, optimization (maximization/minimization), and finding areas under a curve. The most common errors committed by students were conceptual, followed by procedural and technical mistakes. Students made more technical errors on questions requiring basic knowledge and comprehension, while conceptual errors dominated at the application level. The study also found a significant impact of school category on achievement, with Category A schools outperforming the other school categories. Teachers perceived rate of change as the most challenging topic to teach and the trapezium rule as the easiest. They reported using strategies like collaborative learning and small-group tutoring to help students. The study recommends increased professional development for teachers and that schools in lower categories be equipped with modern facilities to raise them to the standard of top-tier schools.

Keywords: Calculus, conceptual, application problems, Bloom’s taxonomy, word problems

APPROVAL

This is to certify that this thesis conforms to acceptable standards of scholarly presentation and is fully adequate, in quality and scope, for the fulfilment of the requirements for the degree of Doctor of Philosophy.

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Professor Dr Zulkarnain bin Kedah
Asia e University
Chairperson, Examination Committee
(25 August 2025)

DECLARATION

I hereby declare that the thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy is my own work and that all contributions from any other persons or sources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree at this or any other university. In making this declaration, I understand and acknowledge any breaches in this declaration constitute academic misconduct, which may result in my expulsion from the programme and/or exclusion from the award of the degree.

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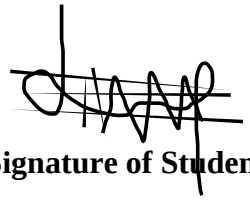

Signature of Student: **Date**: 25 August 2025

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LIST OF ABBREVIATIONS

A.U.C	Area Under Curves
AMP	African Mathematics program
ANOVA	Analysis of Variance
CRDD	Curriculum Research and Development Division (Ghana)
CVI	Content Validity Index
GES	Ghana Education Service
JSP	Joint School Project
M	Mean
MAG	Mathematics Association of Ghana
N	Total Number of participants
NEA	National Education Assessment
P.B.L	Project-Based Learning
S.D	Standard Deviation
SEIP	Secondary Education Improvement Project
SHS	Senior High School
TIMSS	Trends in International Mathematics and Science Study
WAEC	West Africa Examination Council
WASSCE	West Africa Senior Secondary Certificate Examination

CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter covers the Background of the study, Statement of the problem, Objective(s) of the study, Research questions, Research hypotheses, Justification and significance of the study, Theoretical framework, Conceptual framework. Theoretical contributions, Practical contribution, and Contribution to the methodology.

1.1 Background of the Study

Mathematics is an essential subject that empowers students with basic knowledge and profound proficiencies, playing a vital role in the 21st century (OECD, 2025). It is unique among all subjects due to its multifaceted and nuanced development, which encompasses numeracy, critical thinking, data literacy, and problem-solving (OECD, 2025). These skills are vital and necessary for technological advancements and for addressing complicated environmental and societal issues. Facilitating these abilities has the potential to enable students to conduct thorough analyses and approach problems with intuition. Mathematical skills underpin problem-solving in engineering and other related scientific courses (OECD, 2025).

One of the important areas in mathematics is calculus due to its broad applicability in real-life situations.

> *"Calculus originated from the studying of physical motion of the universe, such as the movement of the planets in the solar system and physical forces on Earth".* (Whitton, 2022).

Calculus is made up of both geometry and algebra in addition to infinity and limits. However, algebra and geometry aim at the characteristics of static and structures, and the focal point of calculus is about objects in motion (Whitton, 2022). Calculus is split into two sections, namely differential calculus and integral calculus which are inversely associated. Differential calculus is used to determine instantaneous rate of change whiles integral calculus is normally used to find the areas and volume of irregular geometric objects (Whitton, 2022).

Sir Isaac Newton and Gottfried Wilhelm Leibniz independently discovered calculus in the 17th Century in England and Germany respectively (Whitton, 2022). It is one of the most relevant subjects for science, engineering, business, industry, economics, and other fields (Zhang, 2003). Application problems in calculus cut across a lot of disciplines and are part of the Elective Mathematics syllabus required for the West Africa Secondary School Certificate Examination. Due to the relevance and numerous calculus applications in other studies, problem-solving in calculus has become very necessary. Solving problems is essential in the field of mathematics, which cannot be overlooked. The definition of problem-solving can be viewed from different angles, some of them include, Anderson (2009), problem-solving is an essential life skill that entails various processes, including analyzing, interpreting, projecting, evaluating, and thinking (Anderson, 2009, cited in Bal & Or, 2023). Problem-solving is a term used to describe a situation an individual confronts, which calls for a solution that is not readily available (Bal & Or, 2023).

Problem-solving is a higher mental activity that involves complicated activity (Simamora et al., 2018; Gursan & Yazgan, 2020). Problem could be grouped as a “routine” or