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Effect of flipped instruction on pre-service teachers' performance, and challenges in learning differential calculus

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EFFECT OF FLIPPED INSTRUCTION ON PRE-SERVICE TEACHERS' PERFORMANCE, AND CHALLENGES IN LEARNNG DIFFERENTIAL CALCULUS

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DECLARATION

STUDENT'S DECLARATION

I, STEPHEN GNINTAN LAKAPI, declare that this thesis, with the exception to quotations and references contained in already published works which have all been identified and acknowledged appropriately, is entirely my own original work, and it has not been submitted, either in apart or whole, for another degree elsewhere.

SIGNATURE: …………………………….…………….

DATE: ………………………………….………………

SUPERVISOR'S DECLARATION

I, hereby declare that, the preparation and presentation of this research work was duly supervised by me and that the work was supervised in accordance with the guidelines on the supervision of research work by Faculty of Mathematics Education, Department of Mathematics Education of the University for Education, Winneba.

SUPERVISOR'S NAME: PROF. PETER AKAYUURE

SIGNATURE: …………………………….…………

DATE: …………………………………..…………

DEDICATION

To my two elder brothers, Charles and John.

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ABSTRACT

The study investigated effect of flipped instruction on pre-service teachers' performance in differential Calculus. It further investigated the challenges pre-service teachers face in their quest to learn differential calculus. The theoretical frame work adopted in the study was the Bloom's Taxonomy. Bloom's taxonomy guided the researcher in preparing and administering the test items. The study utilized mixed method approach involving quasi-experimental design in which two colleges of education were randomly selected from Eastern and Greater Accra regions and assigned as college A and college B respectively. A sample of 120 pre-service teachers from the two colleges of education were randomly selected for the study. A calculus achievement test and an interview guide were used to collect data, the instruments were subjected to validity and reliability tests. Both quantitative and qualitative data were collected and analyzed using descriptive and inferential statistics, as well as content analysis. The study found that flipped instruction aids pre-service teachers perform better in differential calculus as compared to the lecture method of teaching. The study further revealed that flipped instruction helps pre-service teachers perform better in all the aspects of the Bloom Taxonomy. The challenges faced by pre-service teachers in learning differential calculus, as identified by the study, included ineffective teaching approaches adopted by college tutors, inadequate exercises to consolidate learning, and ineffective use of teaching and learning materials.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This opening chapter one sets the study in context. It presents the background of the study; statement of the problem, purpose of the study, objectives of the study as well as the educational significance and sets out the research questions guiding the study. The chapter further highlights the delimitation and limitations and concludes by outlining the organization of the dissertation.

1.1 Background of the study

Mathematics education is regarded as a critical foundation in the progress of Economics, Science and Engineering and Computing which are essential for any nation striving for advancement. Consequently, educational frameworks in nations that prioritise developmental outcomes place significant role on Mathematics instruction (Obolo, 2004; Carpenter, Franke, & Levi, 2003). In Ghana, Mathematics is treated as a core subject and elective subject which is one of the criteria for determining student eligibility for admission into higher education and for pursuing various professional paths (Fletcher, 2005).

Furthermore, Mathematics may be perceived through its application in daily life and activities, demonstrating its unifying role across diverse scientific disciplines and their respective fields (Gyasi-Agyei & Obeng-Denteh, 2014; Fletcher, 2005). In this context, it is essential that mathematics and its fundamental concepts are effectively taught at both pre-tertiary and tertiary education levels through an engaging teaching and learning framework, in order to address the evolving demands of students (Adu-Agyem & Osei-Poku, 2012; Gyasi-Agyei & Obeng-Denteh, 2014).

The term Calculus originates from Latin, which means ‘stone,’ a reference to the stones historically utilised by Romans for counting purposes. As Mathematicians sought to quantify infinitesimally small values, they appropriated this same term (Rahul, 2016). While it has been established that some fundamental concepts of Calculus were recognised in Indian Mathematics, it was the contributions of Newton and Leibniz that heralded a transformative period in the field (Rahul, 2016). The significance of Calculus lies in its vast array of applications in daily life. For example, architects and engineers apply integration techniques to calculate the materials required for the construction of complex, curved structures, like the domes of sports arenas. In Electrical engineering, Calculus is employed to ascertain the precise length of power cables needed to connect substations that may be located miles apart. Additionally, space flight engineers routinely utilise Calculus when orchestrating long-duration missions. Biologists apply differential calculus to assess the growth rate of bacterial cultures in response to varying variables such as temperature and nutrient availability. Statisticians use Calculus to interpret survey data, thereby assisting in the formulation of strategic business plans for various companies (Rahul, 2016). Graphic artists incorporate Calculus when evaluating the behavior of three-dimensional models under rapidly changing conditions, ultimately contributing to the creation of realistic environments in films and video games. In the realm of Chemistry, Calculus aids in calculating reaction rates and serves to gather essential insights regarding radioactive decay processes (Rahul, 2016). The field of calculus cultivates foundational proficiencies, enhancing logical thinking, deductive reasoning, analytical reasoning, and problem-solving abilities (Russell, 2014).

Because of the numerous applications of Calculus in real-life, it is one of the courses studied at the colleges of education in Ghana. College of education calculus content consist of three main aspects; limits, differentiation and integration which is studied in first semester of third year of the colleges of education academic calendar. Calculus constitutes a significant part of the mathematics curricula at both the senior high school level and colleges of education, holding distinct status as a separate subject in the curriculum of educational institutions in Ghana.

However, the approach to teaching and learning Mathematics especially calculus in schools has not met the rationale of the current education document on how it should be taught. In order to ensure high-quality Mathematics education, it is important for educators to promote an engaging learning environment within the mathematics classroom. This approach will cultivate a basis for exploring and comprehending the surrounding world, and will also establish a basis for advanced studies in Mathematics and related disciplines in higher education (MOE, 2019).

The instruction and acquisition of calculus present significant challenges. This difficulty arises from the fact that, it has broader divisions such as differential calculus, Limits and Integral calculus. Differential calculus, which bases on derivatives, is instrumental in assessing the steepness of functions, determining the slope of tangent lines to curves at specified points, analyzing the rate of a function's output in relation to its input, and identifying critical points on graphs. While some students may successfully solve problems involving differentiation, they often struggle to articulate the concept of derivatives in terms of rate of change, tangent slopes, and limits (Bingölbali, 2008). Research indicates that students frequently encounter challenges in grasping interrelated calculus topics such as functions, limits, tangents, and derivatives (Mahir, 2009). The field of calculus is commonly seen as challenging to master, primarily due to the inadequate presentation methods employed in teaching these concepts (Park, 2012).

However, the case was not different in this study area, as the many student teachers still continue to suffer in understanding the concepts of calculus. For instance, some of the student teachers had this to say about their misconception on calculus "Calculus problem s are really difficult; That's why we commit many errors; Why are we even learning this difficult thing called calculus?; Where are we going to apply this thing called Calculus in our daily lives?; Who even brought this thing called Calculus for us to learn?; It that what actually we are going to teach when we get to the classroom?; We do not see the essence of it and that's why we also just learn it anyhow to pass our exams and go". The aforementioned remarks reflect the negative sentiments expressed by third-year pre-service teachers at Presbyterian College of Education, Akropong-Akuapem, who faced challenges within their calculus course. The feedback provided by these pre-service teachers can be attributed to the Mathematics instructors' failure to effectively communicate the importance of calculus, which is essential for understanding subjects such as Differential Equations, Vector Analysis, Complex Analysis, and advanced mathematical concepts.

Also, the mathematics tutors were not left out as they also had this to say about the pre-service teachers' unwillingness to learn the concepts in Calculus. "We do not have good pre-service teachers enough ready to learn the concepts in Calculus, pre-service teachers are mostly unprepared when it is time for teaching them mathematics courses, pre-service teachers are mostly conscious about their studies when it's time for their end of semester exams; the only time you see them being serious because they want to pass their exams''. These were some of the concerns raised by some mathematics tutors concerning the bad performance of the pre-service teachers in mathematics learning especially Calculus. Whilst some of these comments may seem to be the truth to a large extent, the full conclusion cannot be peddled around the pre-service teachers alone and their bad performances. It is often said that the beginning of students' errors is a function of many-to-many variables such as the students themselves, methods used in teaching the students by the teachers, what is stipulated in the curriculum to be taught and then the environment in which the students find themselves. So, it is difficult to say that students as the only variable is responsible for the cause of an error (Brodie, 2014; Shalem, Sapire & Sorto, 2014; Makonye, 2012).

In recent years, it has been noted that there is no content error analysis on the pre-service teachers' end-of-semester examination scripts during a conference marking. The attention is been laid more on the correctness or incorrectness of the solutions, that is, where the student commits an error at that stage it is marked with a cross and where the correct answer is given a tick. Tutors seem less concerned about knowing the origin of pre-service teachers' errors, as they are unable to identify, interpret, evaluate and remediate. Khazanov (2008) reported that, when mathematics tutors are already thinking of the possible mistakes that are likely to be committed from a specific mathematics topic, their lesson preparations, as well as their lesson evaluation methods, will be sharper in addressing the students' likely mistakes more effectively. By doing so, the students acquire the needed and intended knowledge and skills efficiently. The issue of conceptual difficulties Ghanaian students face in achieving their goals in education needs to be addressed with importance.

Research studies have attributed some learners' inability to solve problems with calculus and its related concepts to the weak understanding of functions and other related graphs (DBE, 2014; DBE, 2015). Some learners' weaknesses are attributed simply to the procedures used when practicing the routine steps followed in solving calculus problems. Zachiarides et al. (2007) argues that procedural understanding should be focused more rather than conceptual understanding when teaching calculus which will contribute towards learners' difficulties in dealing with calculus problems. The main objective of teaching is learning. This is why teachers are continually trying out effective approaches that will work for particular subjects. A typical classroom allocates time in a way familiar to anyone: students gather during class sessions to hear lectures from a teacher and take down notes, and then students work on homework and projects outside of class. This traditional classroom setup is not best for learning calculus. Students are expected to be inside the classroom with maximum teacher's supervision when they need the least help and they are faced with easier cognitive activities. The more difficult tasks given to students are usually done outside the classroom on their own without the help of the teacher or their peers. Flipping the setup of the classroom seems to be an improvement: students acquire fundamental concepts and basic learning competencies through readings, video lectures and other sources outside the classroom, and then put them to work on high-level cognitive tasks inside the classroom (Talbert 2012). In this way, students do challenging tasks inside the classroom where teacher's help is much needed and easily be extended to them. The flipped classroom promises conforms to the way students learn today in this digital world. It promises a more engaging and effective instruction process. In fact, students became engaged in the material more regularly than before flipping the classroom setup and had shown enthusiasm in classroom discussion (Gaughan 2014). In a traditional classroom, instruction is primarily given inside the classroom in a 60-to-120-minute time allotment where students learn the basics of the lesson and are sent home with a great deal of similar tasks given inside the classroom but with increased level of difficulty.

Conversely, in a flipped classroom, the setup is exactly opposite. Flipped instruction is an approach applied in an inverted classroom. Flipped is a specialized term for the general term blended (Margulieux et al. 2014). Flipped instruction employs interactive learning tasks inside the classroom, and direct individual instruction outside the classroom. In this approach, the content is delivered as homework through video tutorials, online interactive activities or reading assignments. Prior instruction is given outside the classroom through varied sources meticulously prepared or collated by the teacher to the students for them to learn the basics on their own, in lieu of letting the teacher lecturing in class. The classroom then becomes the place to work through problems, advance concepts, and to engage in collaborative learning. The 60-to-120-minute class time is used to further students' learning. Flipped instruction makes students get actively involved and cognitively awakened. It makes teachers easily query individual students, check out for misconceptions on some concepts, and clarify incorrect notions. With this approach, there is an individualize learning for all students, which will certainly increase their achievement and interest level. Students are learning with control of time, place and pace. Students learn best when they are in an environment that gives them the opportunity to feel competence, relatedness, and autonomy (Deci & Ryan 2000).

Educators want to break the traditional lecture-oriented instructional model by focusing on student learning needs and capitalizing their potentials. Flipped instruction can enable teachers to shift from teacher driven to student-centered learning. This shift unveils one characteristic in an outcomes-based education where students are responsible for their own learning and the teacher acting as guide-on-the-side. Flipped instruction also addresses the development of media and technology skill, a 21st century skill the College of Education curriculum promises to cultivate among pre-service students.

Moreover, according to Peter Pappas, an international trainer on the improvement of the quality of teaching and learning, in a webinar he delivered in 2012 at his website peterpappas.com, there are two key factors driving the increased adoption of the flipped classroom model: poor learning outcomes and prevalence of online video. Based on his report, only 69% of students who start high school finish four years later, and an average of 7,200 students drop out of high school each day, totaling 1.3 million a year. One culprit to this alarming statistic is on the traditional model 'one-size-fits-all' of education teachers have been adopting. This model often results in limited concept engagement and severe consequences. Moreover, the availability of online video and increasing student access to technology has paved the way for flipped classroom models.

As an educator, the researcher never ceases to improve his teaching in order to ensure students' learning by trying out various ways that may seem to work for others and staying updated with current trends in education keeping in mind students' learning styles. It is with this reason that the researcher conceptualized this Flipped Instructional model which was proposed by Militsa Nechkina, a member of United Socialist Soviet Republic (USSR) Academy of pedagogical Science in 1984.

1.2 Statement of the Problem

Pre-service teachers have difficulties solving problems relating to concepts of Calculus. Current teaching and learning in the classroom do not reflect the importance of Calculus in the lives of students, and the emphasis that is placed on it in the mathematics curriculum. Colleges of Education are still bound to the traditional approach, which is teacher centered. The teacher centered traditional teaching method turns students into passive listeners, which makes students deficient in differential Calculus and its applications and reasoning. In this method of teaching, most students resort to memorization as they are not given chances of problem solving, using information, that is, reforming the knowledge and they are not provided with hands-on activities that will actively engage them and help them use their thinking skill effectively (Chong & Abdullah, 2013).

Although Pre-service teachers have not done enough Calculus at the Senior High School level, the Calculus topics being treated at Colleges of Education (Institute of Education, University of Cape Coast, 2005) are not so different from those at the Senior High School (Ministry of Education, 2010). Their abysmal performance in Calculus may be probably due to the ineffective teaching methods and inappropriate use of teaching resources in the traditional Ghanaian classrooms.

The Flipped Instructional model has been applied to many curricula to improve Calculus classroom instruction and performance of students in many developed nations but in Ghana, the literature appears to suggest that there has been little investigation involving the Flipped Instructional model. Thus, very little studies have applied the Flipped model to determine the level of performance in differential Calculus of pre-service teachers in the Ghanaian Colleges of Education and also to improve Calculus instruction. In an attempt to seek a teaching strategy that can improve Pre-service teachers' performance in differential Calculus, this study investigated the effect of the Flipped Instruction (FI) on pre-service teachers' performance and interest in learning differential Calculus which is taught in Ghanaian Colleges of Education.

1.3 Purpose of the study

The purpose of the study was to investigate the effect of Flipped Instruction on Pre-service teachers' academic achievement in differential Calculus and whether Flipped Instruction could aid them develop interest in learning differential Calculus. The study had also aimed at finding out the challenges students face in learning differential calculus as well as whether there was significant difference in performance in differential calculus between College A and B of the study.

1.4 Objectives of the Study

The study was guided by the following objectives:

- To explore the effect of the Flipped Instruction on performance of pre-service teachers in differential calculus.
- To find out the challenges pre-service teachers face in learning differential calculus.

1.5 Research Questions

In pursuance of the objectives stated above, the study sought answers to and was structured around three main research questions. These were as follows:

- Does the use of Flipped Instruction have effect on pre-service teachers' performance in differential calculus?
- What are some of the challenges college of education students face in learning differential calculus?

In answering the first questions, the hypothesis below was formulated for the study.

H_0: There is no significant difference in performance between the pre-service teachers who were taught using flipped instruction in College A and pre-service teachers who were taught without the use of the flipped instruction in college B in the post-test.

1.6 Significance of the Study

This study is unique and significant as it represents, as far as the researcher has been to ascertain, an attempt to investigate the effectiveness of the Flipped Instruction in improving performance of students in Ghanaian Colleges of Education. The measure and the description of Ghanaian per-service teachers understanding of Calculus shall be of great interest to the mathematics teacher educators, assessment developers and Pre-service teachers' curriculum developers.

As the school curriculum is a major factor in shaping the quality of education (CRDD, 2007), the findings that will come out of this study can be used to help curriculum developers and College of Education tutors on how to use the Flipped Instruction model in order to improve the academic achievement of students in Calculus.

In this research, it is expected that pre-service teachers will be engage in mathematical communications where they explain their ideas clearly and also follow each other's reasoning rather than just the tutor's instruction. As a result, the researcher is optimistic that the use of the Flipped Instruction will not only improve pre-service teachers' academic achievement in Calculus but would also offer Pre-service teachers enhanced opportunities of varied forms of mathematical communications which are absent in other forms of teaching approaches such as the tutor-centered approach.

Moreover, the research would help dispel pre-service teachers' general negative perception about the Mathematics and Calculus in particular which would influence their teaching of Mathematics positively at the basic level after completing their programme. Also, the study would add new knowledge to mathematics education as well as serve as a reference material at the library for Mathematics educators and the general public.

In summary, the Flipped model can provide a framework on which Calculus instructions can be structured and taught in schools; teachers could, for example, attempt first to raise their learners' interest in Calculus through videos in order to improve the Calculus performance of their learners. Also, the study would aid Ghanaian pre-service teachers to overcome some barriers they encounter in using their informal strategies in the process of acquiring more sophisticated strategies. It is hoped that this will in turn sustain interest in Calculus as pre-service teachers progress to higher classes and make them derive the full benefit of having a good knowledge of Calculus.

1.7 Delimitations of the Study

The main delimitations of this study were as follows:

1) The study focused only on pre-service teachers enrolled particularly in two Colleges of education.
2) The study focused on third year pre-service teachers in two Colleges of Education studying Mathematics in the Easter and Greater Accra region of Ghana.
3) The study analyzed only the pre-service teachers' performance and interest in differential calculus based on the scripts of pre-service teachers who wrote the test.
4) The study was both descriptive and inferential in nature so the findings of the study can be generalized.

1.8 Limitations of the Study

The limitations of a pre-service teacher's performance and interest in differential calculus can arise from various factors. Some of the limitations includes;

1. Insufficient mathematical background: Pre-service teachers may not have a strong foundation in calculus or may have gaps in their understanding of prerequisite mathematical concepts. This can hinder their grasp of the fundamental principles underlying derivatives.
2. Limited exposure to different representations. Pre-service teachers may have limited exposure to various representations of derivatives, such as graphs, equations, and real-life applications. Without experiencing diverse representations, their understanding of derivatives may be restricted to a narrow perspective.
3. Difficult in identifying and applying differentiation rules. Pre-service teachers may struggle with identifying and applying different differentiation rules accurately. They may have difficulty understanding the concept of the derivative as a limit and subsequently applying the quotient rule, chain rule and other rules correctly.
4. Difficult connecting concepts to real-life situations. Pre-service teachers may struggle to connect the abstract concept of derivatives to real-life situations, such as rates of change, optimization, and motion problems. This can hinder their ability to effectively teach the concept and provide meaningful examples to students.

1.9 Organization of the Study

The study would be organized systematically in five chapters. In chapter one, the background of study, statement of the problem, purpose of the study, objectives of the study, research questions, and significance of the study, delimitation, limitations of the study and the organizational plan would be presented. The theoretical framework and the relevant literature review would be presented in chapter two. The researcher would describe the research design and methodology in chapter three. Results and discussion would be done in chapter four. Chapter five would consist of summary of key findings, conclusion and implications for practice, recommendations, and areas for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter primarily focuses on varied views on what other authors have written concerning the topic under study. The literature review focused on the theoretical framework, conceptual framework, some issues concerning calculus in school mathematics curriculum, pre-service tutors Mathematics education, effects of the flipped Instruction on students' performance in Calculus, students' motivation to learning Calculus as well as constructivist approach to instruction.

2.1 Theoretical Framework: Bloom taxonomy

Problem-solving is a cognitive process (Klieme, 2004; Krulik & Rudnick, 1980; Mayer & Wittrock, 2006). As a result, the study determined that using Bloom's taxonomy to assess the students' problem-solving skills in differential calculus was the most efficient method. Bloom taxonomy is a classification system used to characterize and distinguish distinct levels of human cognition, such as thinking, learning, and understanding (Bloom, 1994). The cognitive domain, affective domain, and psychomotor domain are the three main domains of the taxonomy, which was first published in 1956 by a team of cognitive psychologists led by Benjamin Bloom. The taxonomy provides an indication of the type of cognitive activity necessary to correctly answer questions, not a measure of difficulty. This indicates that mastery of the previous level is required to advance to the next level of learning. The cognitive model has been used by teachers to guide development of assessment (testing and evaluating students' learning). According to Forehand (2012), it is critical for teachers to assess their students' abilities. This may be done accurately, according to the author, by using "a taxonomy of levels of intellectual behavior necessary in learning." Bloom's taxonomy, according to the author, gives a measurement instrument for thinking and so accurately meets this function. The taxonomy's main goal was to create a logical framework for teaching and learning objectives that would aid in the development of new knowledge, skills, and understanding. The cognitive skill levels are classified by Bloom as "knowledge, understanding, application, analysis, synthesis, and evaluation" (Bloom, 1956). The taxonomy has been described as hierarchical in nature (Forehand, 2012), with the first three levels of cognition (knowledge, understanding, and application) indicating lower levels of cognition and higher-order skills (analysis, synthesis, and evaluation) (Bloom, 1956)

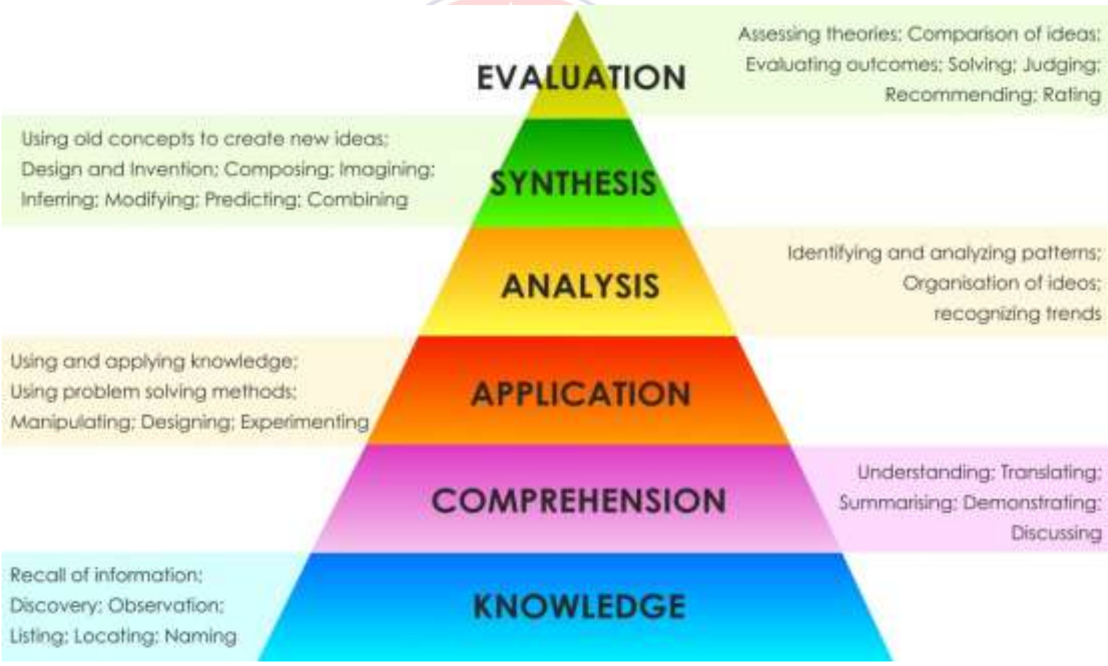


Figure 1: The Bloom taxonomy

Source: Bloom 1956

2.1.1 Knowledge

Knowledge cognitive demand deals with recall or recognition of terms, ideas, procedures, theories, formulas and so on. Some of the verbs use include List, define, describe, show, name, what, when, etc.

2.1.2 Comprehension

Comprehension cognitive demand examines learners on the ability to grasp the meaning of previously learned material. This may be shown by translating material from one form to another, interpreting material (explaining or summarizing) or predicting consequences or effects. Verbs use include Summarize, compare and contrast, estimate, discuss, etc.

2.1.3 Application

Application cognitive demand requires the ability to apply the material studied in new and real-life situations. It may include how to use rules, methods, concepts, principles, laws, theories, and equations. Verbs normally use include, Apply, calculate, complete, show, solve, modify, etc.

2.1.4 Analysis

Analysis cognitive demand requires the ability to disassemble material into its constituent parts so that its organizational structure may be understood. This exercise may include the identification of the different constituent parts, the examination of the relationships between the various parts and the understanding of the organizational principles involved. Separate, arrange, classify, explain, etc are some of the verbs considered under analysis.

2.1.5 Synthesis

Synthesis cognitive demand requires the ability to integrate parts to form a new whole. Some of the verbs use include; Integrate, modify, substitute, design, create, what if..., formulate, generalize, prepare, etc.

2.1.6 Evaluation

Evaluating cognitive demand necessitates learners making decisions about ideas. Compare, conclude, defend, explain, and support are some of the keywords used in framing questions.

Since it has been used by educational role-players for many years, Bloom's taxonomy has stood the test of time and has become the standard for developing frameworks for learning, teaching, and evaluation goals in the process. Due of its long history and broad use, it has been shortened, enlarged, and reinterpreted in a variety of ways (Forehand, 2012). Bloom's taxonomy was modified in 2001 by Lorin Anderson, a former student of Bloom, with the assistance of a team of cognitive psychologists, curriculum theorists, instructional researchers, and testing and assessment specialists. They felt that learning was a continuous process, hence they preferred to use verbs (action words) rather than nouns to describe cognitive levels. As a result, three cognitive levels have been renamed, and the top two cognitive levels have been swapped.

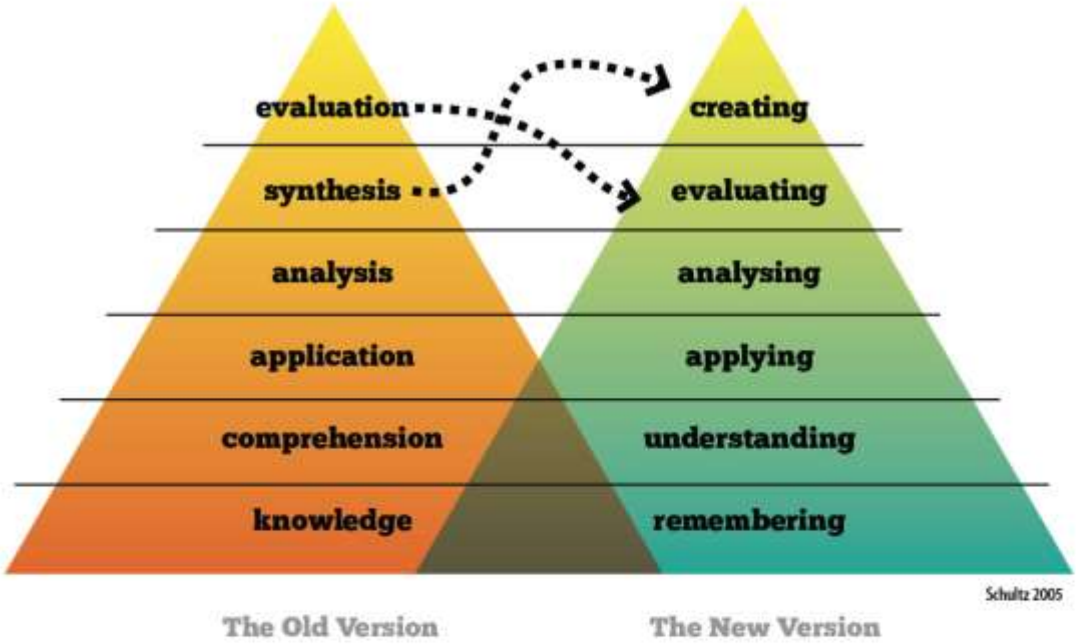


Figure 2: Comparing bloom's taxonomy to the revised bloom taxonomy

The researcher recognizes the revised Bloom's taxonomy with revisions to the original names; nonetheless, the researcher adopted the old taxonomy's language because of its universal acceptability across fields and national borders (Karaali, 2011). The taxonomy is useful in the educational community for a variety of reasons, one of which is to track the progress of teaching and learning. Because it provides a grasp of the multiple levels of cognition that are important for learning, the taxonomy provides an accurate measure of learners' capacities. As a result, Bloom's taxonomy is used in this study to assess learners' performance in differential calculus.

2.2 Conceptual Framework

The figure 3 shows the conceptual framework of flipped instruction. Bennet et al. (2012) stated that although two flipped classrooms do not look similar, they have shared features which is active delivery of information before the class so the students will have extra time to do activities in class. Next, the teacher will become the facilitator to guide the students rather than dispensers of facts and students will become active learners rather than passive learners who listen to the information given. With the usage of online sharing platform such as Google Classroom, this will create a permanent archived tutorial of the class content. Students will have the opportunity to learn independently. Thus, the students would have extra time to complete the task and activity during class time. The conceptual framework of flipped classroom is based on the elements of Internet of Things (IoT), which are things, people, process and data. There are two parts in a flipped classroom setting, which are before class and while class.

2.2.1 Before Class

In before class setting, the things involved are devices that the students can use at home such as laptop, computer, smartphone and tablet. Next, the people refer to the teacher and students. The teacher will provide the students with instructions for the task before the lesson that they need to do. The students' act as an independent learner as they only need to watch the video and follow the teacher's instruction. They are responsible for their own learning, thus making them as an independent learner. This activity describes the teacher's role as an instructor.

All activities out of the class is flexible, regardless of place and time, depending on the students' academic levels and individual needs (Moffett, 2015). For this research, as the participants are pre-service teachers, cooperation among themselves is needed to ensure a successful flipped classroom setting as it will aid them supervise themselves to do some discussions before meeting the teacher. However, colleagues are only needed to supervise their peers as it is also part of self-regulated learning. Self-regulated learning is the process element of Internet of Things (IoT) that happens in flipped classroom.

The data of flipped classroom refers to the knowledge acquisition on how the students get the input for problem-solving skills in calculus. This corresponds with Bloom's Revised Taxonomy, which involved remembering and understanding skills. The teacher needs to provide authentic materials before the class, such as lecture video or virtual reality activity about the topic that they are going to learn. Supplementary video link from www.youtube.com can be provided for the students to watch as additional materials. The materials would be available in educational platform such as Google Classroom and Microsoft Teams.

2.2.2 While in Class

After the pre-class task was done, the students will proceed with in-class activities. The example of things element in while class activity is teaching aids such as writing books and calculators. In this stage, the teacher will act as the facilitator while students will become active learners which represent the people. The students will receive guidance from the teacher during class interaction and activities. Teachers can improve interaction with students, monitor and scaffold individual development, and give direct feedback (Moffett, 2015). Scaffolding is known to align with constructivism. Once students can do the tasks on their own, the teacher need only supervise them. This is a part of knowledge construction which is the data. The students move from the lower part to the higher part of Bloom's Revised Taxonomy which are applying, analyzing, evaluating and creating.

The process of flipped classroom involves active learning and collaboration. Winne & Hadwin, (2013) suggested three types of collaboration regulations. Firstly, every group member must take responsibility for his or her learning. Secondly, every group member must support other group members in regulating their learning (co-regulated learning), and the group must collectively regulate their learning processes (shared regulation of learning). When the students are collaborating during the planning phase, task performance and reflection, it is known as shared regulation (Järvelä et al, 2016). According to Andrews, Leonard, Colgrove, & Kalinowski (2011), active learning may occur when an instructor avoids lecturing and students ask a question or focus on an assignment designed to help their comprehension, such as think–pair–share conversation or pair plays and exchange their responses with the entire class. Such approach puts learning within the construction of knowledge presented through peer-interaction and direct feedback. Construction of knowledge happens when students use the input of writing they have before class and use it in the activity of writing that happens in class.

According to Sams & Bergmann (2012), flipped classroom is a student-centred approach to learning where the role of the students is as active learners. The instructor or the teacher will act as the facilitator to guide, motivate and give appropriate feedback to the students' performance. By implementing flipped classroom approach, the teacher can flip the classroom by moving the traditional lecture lesson to video and the students can watch and listen to the video before they enter the class. This will provide the students freedom to watch the video according to them and encourage them to learn independently. This will also enhance students' collaborative learning. By flipping the class, the teacher would not spend so much time in class explaining the topic and the students would get ample of time by executing the projects collaboratively and individually, depending on the activities. In addition, by applying flipped classroom approach, the students will have the opportunity to use various type of technology media in learning activity independently. The instructors will also utilize various technology media in their lesson (Zainuddi & Attaran, 2016)

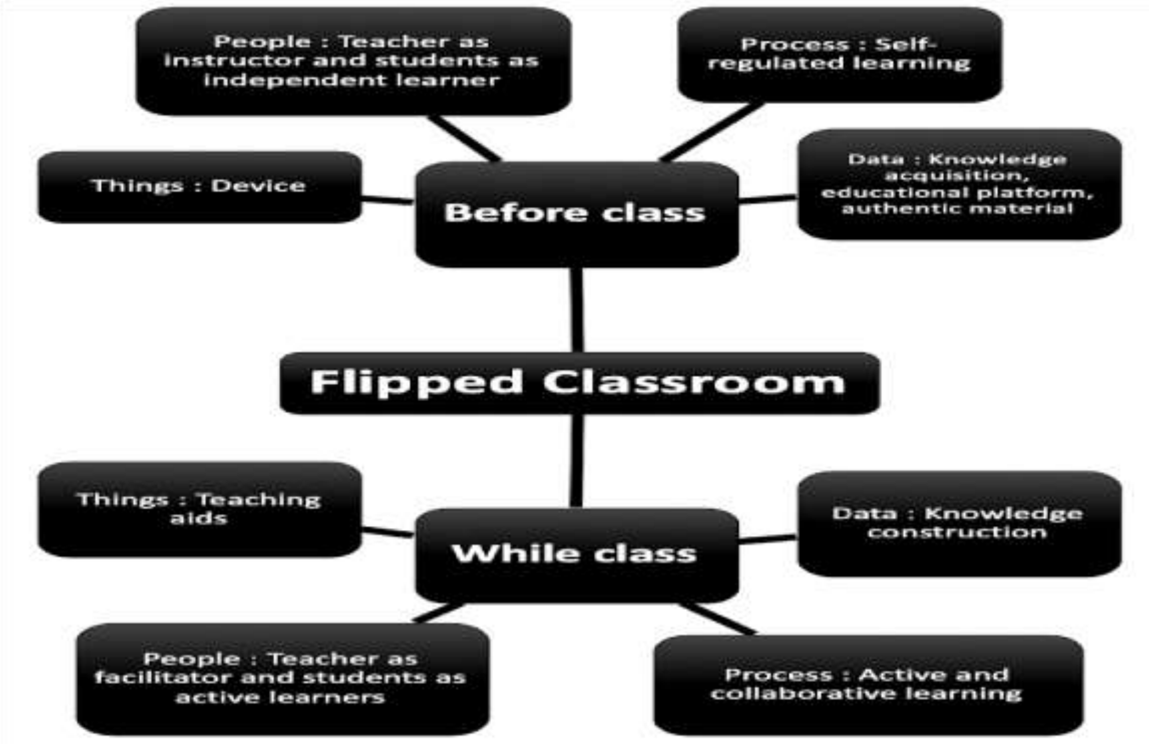


Figure 3: Conceptual framework of flipped instruction

2.3 Importance of Calculus in the School Mathematics Curriculum in Ghana

The incorporation of Calculus into the school mathematics curriculum has been a topic of debate among educators and policy makers. This literature review aims to provide evidence-based support for the inclusion of Calculus in the school mathematics curriculum, highlighting its importance and benefits for students' academic and intellectual development.

First of all, calculus enhance critical thinking skills. Ferrini-Mundy, Graham & Buffington (2019) emphasized that Calculus fosters critical thinking skills, including problem-solving and analytical reasoning. Students engaged in calculus learn to approach complex problems, break them down into manageable steps, and apply Mathematical concepts to arrive at solutions. This ability to think critically and analytically not only benefits students but also extends to other disciplines and real-world challenges.

Secondly, calculus prepares students for higher education in Ghana. Gosman & Dore (2018) argued that Calculus is a fundamental prerequisite for various fields in higher education such as engineering, Physics, Economics and Computer Science. A strong foundation in Calculus enables students to tackle advanced topics and research in these fields, preparing them for successful careers and higher education pursuits, Supporting STEM Education and Careers.

According to the National Research Council (2012), Calculus plays a vital role in promoting Science, Technology, Engineering and Mathematics education. STEM oriented careers increasingly demand a strong mathematical background and Calculus is an integral part of developing that foundation. Students exposed to calculus are more likely to pursue STEM-

- related studies and careers, helping to address the shortage of professionals in these fields.

Moreover, calculus helps in cultivating mathematical maturity of students. In their study, Jones & Smith (2020) highlighted that calculus is an essential component in developing students' mathematical maturity. The abstract and theoretical nature of calculus challenges students to think conceptually, expanding beyond basic procedures and algorithms. This deeper comprehension of mathematical principles contributes to a more holistic understanding of the subject.

Furthermore, it helps in enhancing problem-solving abilities of students. According to Smith & Lee (2019), the study of calculus enhances students' problem-solving abilities. Calculus problems often require the integration of various mathematical concepts and techniques, encouraging students to apply learned knowledge in novel situations. The continuous exposure to such problem-solving scenarios hones students' abilities to think critically and approach challenges with creativity.

2.4 Teaching of Calculus in Schools

The teaching of Calculus is a crucial component of the mathematics curriculum in Colleges of Education. It provides pre-service teachers with the fundamental tools to analyze and model various real-world phenomena, making it an essential subject for future studies in science, engineering, economics and other quantitative fields. Calculus teaching has been revolutionized for the last three decades due to the contributions of a number of mathematics educators. The technology-driven changes inspired a major university-centered "Calculus Reform Movement" in the late 1980s and early 1990s (Kinley, 2017). The three events, "Towards a Lean and Lively Calculus" conference in 1986, "Calculus for a New Century" symposium in 1987, and "Priming the Calculus Pump" in 1990, signaled the beginning of calculus reform to make calculus lean and lively, relevant to applications by including contemporary mathematics that reflected new technology. The themes of calculus reform movement include: involving students in doing mathematics instead of lecturing at them; stressing conceptual understanding rather than only computation; developing meaningful problem-solving abilities; exploring patterns and relationships instead of just memorizing formulas; becoming engaged in open-ended, discovery-type problems rather than doing routine (Kinley, 2017).

In the first place, curriculum Integration and Placement**.** Calculus is typically taught as part of the college of education mathematics curriculum, usually in the first semester of level three hundred. Its integration into the curriculum depends on the educational standards and guidelines set by each state or country. The placement of Calculus in the latter years allows students to build a solid foundation in algebra and trigonometry before delving into the more advanced concepts of calculus (Cohen, 2018).

Again, to ensure effective teaching and learning of calculus, educators often adopt various pedagogical approaches. Some commonly used methods include:
algebraic approach: An algebraic approach is most closely related to the traditional approach of teaching calculus. Elk [3] utilized a lecture-based format representing a logical extension of algebra to transition into calculus courses. He proposed the basic algebraic ideas imbedded in the concepts of derivative and integral. He presented an illustration that comprises three scenarios related to division by zero: 0/a, a/0, and 0/0, where 'a' signifies any non-zero number. He underscored that differentiation is required to assign meaning to the third scenario (0/0) under suitable conditions. Furthermore, he introduced the concept of both the y-coordinate and the x-coordinate converging to zero. As the distance between the points diminishes, the individual components of this distance also reduce to very small values. Consequently, the ratio of the change in the y-coordinate to the change in the x-coordinate leads both the numerator and the denominator to approach zero, thus resulting in the 0/0 situation (Kinley, 2017).

- Active learning: Encouraging students to actively participate in their learning process through discussion, problem-solving activities and hands-on exercises enhance their understanding of calculus concepts (Freeman et al, 2014).
- Technology Integration: Leveraging technology such as graphing calculators and computer software can aid visualization and analysis of complex functions, making abstract concepts more accessible (Honewarter & Preiner, 2019).

- Real-world Applications: Integration real-world applications of calculus in lessons help students appreciate the relevance and practicality of the course, promoting engagement and motivation (Pierce & Stacey, 2017).

Moreover, ensuring conceptual understanding when teaching calculus by educators enhances its better grasp by students. Teaching Calculus involves fostering a deep conceptual understanding rather than relying solely on procedural knowledge. Emphasizing the meaning behind concepts like limits, derivatives and integrals allows students build a solid foundation for more advanced topics (Calson et al, 2019). Encouraging students to articulate their understanding in their own words and through visual representations enhances their comprehension (Bressoud, 2017).

Furthermore, being aware of difficulties and misconceptions students hold about calculus improves its delivery by educators. Educators should be aware of common student difficulties and misconceptions related to calculus. Some challenges include:

a. Misunderstanding the concept of limit and its application to derivatives and integrals.
b. Confusion between notations and properties of differentiation and integration.
c. Difficulty grasping the graphical interpretation of calculus concepts.

Addressing these challenges require targeted instructional strategies and ongoing formative assessment to identify and correct misconceptions (Lawson, 2019).

Also, the use of appropriate assessment and evaluation tools by educators can also improve its delivery in Ghana. Effective assessment of calculus learning involves a balanced approach, combining formative and summative methods. Formative assessment such as quizzes and group discussions, provide feedback to both student teachers, identifying areas for improvement. Summative assessment, including examinations and projects, evaluate overall mastery of calculus concepts (Black & William, 2018).

In conclusion, the instructional methodologies discussed serve to help learners in cultivating a conceptual grasp of the principles underlying differentiation and integration. While each methodology offered distinct strategies for presenting these concepts to students, they all aimed to transcend mere procedural competence. The varied approaches utilised students' existing knowledge, historical perspectives, real-life applications, visual representations, and technology-assisted calculations (Kinley, 2017).

2.5 Students' Performance of Mathematics in National and International Assessment in Ghana

Assessment is required to determine students' performance. Apart from classroom assessment, also known as School Based Assessment (SBA), different grade levels in Ghana do not require an external assessment scheme that evaluates students' performance and success on a termly or yearly basis (Mills & Mereku, 2016). However, national terminal assessments are available for select grades, such as BECE for grade 9 (JHS 3) and WASSCE for grade 12 (SHS 3). However, national terminal assessments are available for select grades, such as BECE for grade 9 (JHS 3) and WASSCE for grade 12. (SHS 3). Other form of national assessment includes National Educational Assessment (NEA).

Since 1995, UNICEF has conducted the National Educational Assessment (NEA) in Ghana in conjunction with the Ministry of Education. The previous two editions were held in 2013 and 2016. The goal was to assess students' proficiency in mathematics and

English in primary 3 (P3) and primary 6 (P6). The test results will provide the Ghana Education Service (GES) with an indicator of the effectiveness of the primary education system (Ministry of Education, 2013). The test included all ten regions of Ghana at the time, with a sample of 550 public and private schools and 36,905 students participating. The domain covered by the test included numbers and numerals, basic operations, measurement, shape and space, and data collection and handling. Cognitive abilities covered by the test were distributed among four level

- Knowledge
- Understanding
- Application and,
- Reasoning/ critical thinking

A score of 35% was regarded minimal proficiency, while a score of 55% or higher was considered proficient. The test results showed that just about 11 percent of P6 students achieved competence, compared to 22 percent of P3 students. Furthermore, roughly 40% of students failed to obtain even the bare minimum of mathematical competence (Ministry of Education, 2013). A similar outcome was recorded in the assessment's 2016 edition. In 2016, the test was given to students in primary 4 (P4) and primary 6 (P6). To better accord with Ghana's language of instruction policy, the test was updated to assess P4 students rather than P3 students (Ministry of Education, 2016). The examination, like in 2013, covered ten regions and 550 public and private schools, with a total of 35,996 students. 22 percent of P4 students achieve proficiency, but 45.2 percent fail to attain even the bare minimum (Ministry of Education, 2013). For P6 children, 37.9 attained proficiency, while 28.4 did not meet the minimum standard.

Students' low achievement in mathematics is not limited to the primary school level. According to the Educational Sector Performance Report (2015), students in the country obtain much lower pass rates in mathematics when compared to essential disciplines such as social studies, English language, and integrated science. In addition, when comparing the pass rate of mathematics to the pass rate of other key subjects such as Social Studies, Integrated Science, and English Language in the 2012 and 2016 editions of the report, students' academic performance in mathematics has been quite poor for years. Specifically, the reports have revealed an unfavorable and low level of students' academic achievement in mathematics in Senior High Schools, and if there is progress, it is not significant in comparison to the other core disciplines (EMIS, 2016). The chief examiners' report, in particular, revealed that students' performance in core mathematics have been poor in the national assessment (WASSCE). It was clear that students' performance in core mathematics was not encouraging.

According to statistics, it will not be until 2020 that more than 65 percent (65.71 percent) of candidates earn a grade of A1 to C6 (the qualifying grade for university admission) in core mathematics. In 2020, candidate performance decreased in percentage terms (54.11 percent). Following these years, student performance in WASSCE has been below average, with pass rates of 32.4 percent in 2015, 33.12 percent in 2016, 41.66 percent in 2017, and 38.15 percent in 2018. Students' performance in international assessments (TIMSS) has likewise fallen short of expectations. The Trend in Mathematics and Science Study (TIMSS) is an international large-scale assessment in mathematics and science for grade 8 (JHS 2) students in a few select countries throughout the world. The objective of the assessment is to provide policymakers with insights regarding student achievement and the efficacy of the educational system (MOE, 2014a, 2014b). Anamuah-Mensah et al. (2004) reported, as referenced in Mills & Mereku (2016), that Ghanaian students exhibited notably poor performance in the TIMSS 2003 mathematics assessments. The country's mean scale score in Mathematics was a low 276, positioning Ghana second to last in the overall rankings, specifically 45th out of 46 nations that participated. The TIMSS 2003 report, also cited by Anamuah-Mensah et al. (2004), indicated that Ghana's results were among the weakest among African nations involved in the examination. They emphasized that the inability of Ghanaian students to achieve higher academic standards highlights the need for targeted interventions to help learners build a robust foundation in essential knowledge and skills necessary for tackling more challenging cognitive tasks.

The 2007 Trends in International Mathematics and Science Study (TIMSS) showed that, although there was a slight improvement in mathematical performance, Ghana's results were still significantly low when compared to the mathematics education standards of other assessed countries. Anamuah-Mensah et al (2008) noted that there was a substantial discrepancy in the mathematical competencies of Ghanaian students, with the lowest achievers scoring as little as 130 and the highest scoring up to 430. Notably, all these scores fell short of the average scale score of 500 and the maximum possible score of 800 in the assessment.

According to the above reports, it is clear that students have performed poorly in both national and international examinations. Students' bad performance must be addressed.

2.6 Problems of Teaching and Learning Calculus in Ghana

Calculus is a fundamental branch of mathematics that plays a vital role in various scientific, engineering and technological fields. However, its successful teaching and learning present challenges in different educational settings, including Ghana. This piece seeks to explore the various evidence-based research on the specific difficulties and factors affecting the teaching and learning of calculus in Ghana.

In the first place, limited Access to educational resources and infrastructure in Ghana is a major challenge affecting the teaching and learning of calculus. In Ghana, access to quality educational resources and infrastructure have been a significant concern (Asare, 2018). A study by Kumi-Asante and Ofori-Adjei (2017) revealed that a lack textbooks, digital resources and internet connectivity in many schools hindered students' access to supplementary materials required for a comprehensive understanding of Calculus concepts.

Again, effective teaching of Calculus relies on educators who possess both strong content knowledge and pedagogical skills. However, a study by Ampadu, Adu-Gyamfi and Boadi (2019) highlighted that many mathematics educators in Ghana lack adequate training in Calculus, leading to challenges in delivering the subject effectively.

Moreover, the medium of instruction in most schools in Ghana is English. However, many students come from diverse linguistic backgrounds where English may not be their first language. This language barriers can impede students' comprehension of complex calculus terminologies and concepts (Boateng, 2016).

Another difficulty students face in the learning of calculus is their preconceptions and Attitudes. Research by Adjei and Kumi (2018) demonstrated that students often bring preconceived notions about mathematics including Calculus from their previous educational experiences. These preconceptions may result in negative attitudes towards the subject, affecting their motivation and performance.

Furthermore, lack of practical application and contextualization of calculus also pose a challenge to students in their quest to learn it. The relevance of Calculus in real-life applications is often not emphasized in the Ghanaian educational system. Studies by Asamoah-Hassan and Yidana (2019) indicated that students struggled to see the practical applications of Calculus in solving real-world problems leading to disinterest and disengagement.

Abstract and complex nature of calculus is also another problem students' face in their attempt to learn it. Parrot & Kwan (2017) indicated that the teaching and learning of calculus can be challenging as it involves abstract and complex ideas hence can make difficult for students to learn and apply the concepts.

Mensah (2017) also added that poor students' performance in trigonometry also affect their performance in calculus. He said students registered for calculus in their first year at the university perform badly in the operation of trigonometric. This indicates that learners might lack a solid grounding in trigonometry, a necessary basis for mastering calculus. Furthermore, insufficient training opportunities impede the successful teaching of calculus. Significant perceived obstacles to the implementation of Information and Communication Technology (ICT) in Mathematics instruction in Ghana include a lack of knowledge regarding the integration of ICT into educational lessons and a scarcity of training opportunities.This suggest that teachers may not have adequate training and resource to effectively teach calculus (Douglas & Joke, 2010).

Finally, Assessment Methods used in measuring students' performance in calculus tend to pose a challenge to them. Traditional assessment methods in Ghanaian classrooms often focus rote memorization and regurgitation of fact rather than evaluating student' problem-solving abilities and critical thinking skills. A study by Adjei, Tawiah and

Ntiamoah (2020) suggested that such assessment practices may not accurately measure students' understanding of Calculus concepts.

2.7 Pre-Service Teachers' Mathematics Education

Education is essential for both personal growth and the enhancement of human capital, which contributes significantly to the socio-economic advancement of a nation. Moreover, teacher education is pivotal in equipping individuals to effectively manage the educational process in schools. The European Union (2012) has asserted that "within educational institutions, teaching professionals are the most important determinants of how learners will perform; and it is what teachers know, do, and care about that matter" (Newman, 2013).

Asante and Mereku (2012) have indicated that "the low standard of Mathematics proficiency among pupils and students alike has persisted for decades and test information has consistently indicated problems in the way students learn" (p.23). In 2003 and 2007 Ghanaian JHS2 students participated in the Trends in international Mathematics and Science Study (TIMSS) assessment. The abysmal performance of the students in TIMSS in 2003 placed Ghana at the $45th$ position on the overall Mathematics achievement results table (Anamuah-Mensah, Mereku & ASabere-Ameyaw, 2004).

Despite an enhancement in performance in TIMSS 2007 compared to 2003, the scores achieved by students remained below those of all participating African countries (Anamuah-Mensah, Mereku & Asabere-Ameyaw, 2008). Consequently, it is critical to examine the training and preparation provided to pre-service Mathematics teachers. This attention is warranted because the quality of education delivered to students is closely linked to the caliber of teachers within the educational framework (Ampiah, 2010, p.3).

A similar trend is observed among Senior High School (SHS) students in Ghana, as their performance levels have been disappointing. Consequently, a significant proportion of students entering colleges of education possess low grades in Mathematics (Adu-Yeboah, 2011). Such deficiencies may adversely influence the quality of teachers produced by these institutions, given that many incoming students lack a solid basis in Mathematics. Asante and Mereku (2012) contend that it is important for teachers to possess a comprehensive understanding of the topics and methodologies they instruct, which is why the design of the bachelor's degree program in Mathematics education emphasizes Content Knowledge.

Consequently, given the limited mathematical basis of the majority of pre-service teachers, significant role lies with the educators in colleges of education to cultivate their development into proficient mathematics instructors for future responsibilities.

The primary institutions responsible for the training of teachers in basic education are the colleges of education. Over the last four decades, teacher education in Ghana has witnessed several shifts, largely driven by policy revisions aimed at equipping teachers to satisfy the evolving educational requirements of the nation. These revisions have led to the emergence of diverse groups of educators, each possessing various certificatons (Anamuah-Mensah, 2006). Initially, Colleges of Education, previously referred to as Teacher Training Institutes, provided a 2-year Post-Middle Certificate "B" program, followed by a 4-year Post-Middle Certificate "A" program, and a 2-year Post-Secondary Certificate "A" program. The duration of the 2-year program was eventually extended to 3 years, operating in conjunction with the 4-year certificate "A" programs until its discontinuation during the 1980s (Addo-Obeng, 2008).

In the early 2000s, after conducting an extensive evaluation of Ghana's educational framework, the government released a White Paper asserting that every Teacher Training College will transition to diploma-granting institutions and will be affiliated with universities focused on education (Government of Ghana, 2004). As a results, in 2008, 38 Teacher Training Colleges, previously recognised as equivalent to level 4 in the International Standard Classification of Education (ISCED 4), were reclassified as Colleges of Education (COE) to provide higher education.

Before their transition and reclassification as higher education institutions, the former Teacher Training Institutions (TTIs) operated under the jurisdiction of the Ghana Education Service (GES), which is the regulatory body for primary and secondary education in the country. The oversight of TTIs was managed by the Teacher Education Division, a subdivision of GES. Consequently, GES was accountable for the funding, personnel appointments, and the establishment of admission criteria for these institutions. In contrast, the Institute of Education at the University of Cape Coast has been tasked with the evaluation and certification of graduates from the TTIs. Over the years, the Institute of Education has worked in conjunction with the Teacher Education Division to formulate and continuously assess the curriculum for teacher education prior to university entry in Ghana (Opare, 2008).

The Colleges of Education Act, Act 847, was enacted in 2012 to officially recognise the new status of educational institutions. Consequently, these institutions have been integrated under the National Council for Tertiary Education (NCTE), the governmental body accountable for overseeing tertiary education institutions in Ghana.

Following the reclassification of Teacher Training Institutions (TTIs) to Colleges of Education (COEs) in 2008, these colleges have encountered various challenges concerning oversight, infrastructure, governance, and independence.

These colleges implement a semester-based system, wherein pre-service educators are guided through a carefully structured curriculum designed to prepare them for teaching all subjects within the basic school framework. The mathematics curriculum, along with the overall curricular design of the colleges, integrates both content and pedagogical methodologies. Methodology courses are introduced in the third year of the program, after trainees have completed foundational mathematics content courses. This approach is intended to enhance students' mastery of content knowledge prior to their introduction to pedagogical strategies in the subsequent year. The evolution of colleges of education has been responsive to national educational demands and specific changes at the primary education level.

According to the Colleges of Education Act, Act 847 of 2012, the objectives for a College of Education include:

- Training students to develop essential professional and academic competencies for teaching in both pre-tertiary and non-formal educational settings.
- Enhancing the professional and academic abilities of in-service teachers through ongoing education.
- Offering programs aimed at fostering effective teaching in disciplines such as science, mathematics, and information and communication technology, to meet contemporary societal needs.
- Establishing connections with pertinent institutions and the broader community to ensure comprehensive teacher training.

In 2018, the Colleges of Education in Ghana underwent a transition from three-year Diploma in Basic Education awarding institutions to four-year degree -awarding institutions. The colleges were further affiliated with the Education oriented Universities. At present, pre-service educators engage in six semesters of coursework at the college level, followed by a year-long internship in basic educational settings. The initial three years are dedicated to the acquisition of subject knowledge and pedagogical methods, while the fourth year is focused on practical teaching experience in schools, a structure commonly referred to as the "IN-IN-IN-OUT" framework (Asante & Mereku, 2012).

In the curriculum for pre-service teachers enrolled in the Science program, the content of Calculus is delivered during the first semester of their third year through a course designated as "Learning, Teaching and Applying Calculus".

The topics treated include; Limits and Continuity, Derivatives 1, Derivatives 2, Application of derivatives, Linear kinematics, Integration, Numerical integration, and Application of integration.

The undergraduate curriculum in colleges of education significantly prioritizes both content knowledge and pedagogical practices to provide a robust foundation in mathematics and pedagogical content knowledge. However, the time devoted to various subjects appears insufficient, particularly considering the generally weak mathematical and calculus foundations among pre-service teachers. This lack of adequate time forces many college instructors to expedite the coverage of topics in a mechanical fashion to meet the timeline for the end-of-semester assessments, rather than fostering a deep understanding among students. Such a method of instruction promotes rote learning rather than meaningful engagement with the material. As observed by Sakyi (2014), there is an urgent need to transition away from rote learning and the exam-focused educational framework prevalent in Ghana, which produces persons who struggle with problem-solving and applying their knowledge creatively (p. 4).

In addition to insufficient time allocation for various mathematical subjects, it appears that colleges of education lack appropriate instructional and learning resources. Observations by the researcher in several colleges of education reveal a lack of mathematics textbooks specifically designed for pre-service teachers. Both college lecturers and students primarily rely on materials intended for Senior High School (SHS) students, alongside a few pamphlets authored by college Mathematics instructors in addition to the content presented on whiteboards during instruction.

Moreover, the colleges of education lack Teaching and Learning materials (TLMs) especially for teaching Calculus. In the view of Adu-Yeboah (2011) the few materials that are available are used in a way that fails to engage with why and how they work to produce understanding. What may be needed are new TLMs and resources which call for more critical engagement with teaching and learning resources for learning Mathematics especially Calculus. It must be noted that “the extent of trainees’ exposure to and understanding of curricular materials, including textbooks shapes their level of effectiveness in teaching school Mathematics” (Adu-Yeboah, 2011, p.2)

In conclusion, the curriculum in the College of Education places significant emphasis on Mathematics content knowledge, which occupies a substantial portion of the program. But the circumstances present in colleges of education, as outlined in this section, hinder the complete fulfillment of the overarching goals of teacher education. Educational reformers should re-evaluate the methods in which certain content areas are developed and taught, specifically aiming to facilitate a deeper understanding among pre-service teachers regarding how these concepts can be imparted through strategies and resources that promote substantial comprehension. Implementing mathematical investigations may serve as a potential approach to redirecting this focus (Adu-Yeboah, 2011).

2.8 Effects of Flipped Instruction on students Calculus achievement

Active participation of students through discussions, problem-solving, and various tasks has increasingly become prevalent in educational practices in recent years. The flipped classroom model represents a successful interactive teaching approach, particularly in university-level Mathematics courses (Jungic et al., 2015; Maciejewski, 2015; Murphy et al., 2015; Petrillo, 2015). This model emphasises that content delivery occurs outside of class, enabling the in-class time to be devoted to collaborative learning and conceptual understanding through peer discussions and problem-solving activities (DeLozier & Rhodes, 2016). Although the implementation of the flipped classroom can vary, many educators adopt this approach with the aim of enhancing the time students spend on solving problems (Naccarato & Karakok, 2015). The social interaction fostered by teamwork and discussions is seen as a critical element of interactive classrooms (Naccarato & Karakok, 2015; Weurlander et al., 2016). Research supports the effectiveness of active learning environments over traditional lecture formats, particularly in STEM disciplines (Freeman et al., 2014, Deslauriers et al., 2011; Mazur, 1997; Hake, 1998). Furthermore, video presentations appear to match the efficacy of traditional lectures in delivering course material (DeLozier & Rhodes, 2016).

The existing literature on student learning emphasises that engagement in meaningful activities significantly enhances the learning process (Entwistle, 2009; Wimpenny & Savin-Baden, 2013). These activities encompass cognitive, emotional, and behavioral dimensions (Trowler, 2010), and the complexity of active engagement involves individual and social factors, as well as the broader learning context (Kahu, 2013). However, students occasionally encounter challenges in their learning journeys, experiencing difficulties in understanding (Weurlander et al., 2016; Wimpenny & Savin-Baden, 2013). Nonetheless, interactive teaching methods hold potential for bolstering student engagement (Weurlander et al., 2016), which has been shown to correlate positively with academic performance, especially among lower-performing students (Carini et al., 2006).

Many studies documenting positive outcomes of the flipped classroom in calculus have been reported. For instance, Jungic et al. (2015) found that students regarded the video lectures as beneficial for class preparation and appreciated the ability to learn at their preferred pace. Other studies corroborate these findings (Cronhjort & Weurlander, 2016; Love et al., 2014). One student expressed the advantage of being able to pause or rewind video lectures, stating that this capability enhanced their understanding of the material (Love et al., 2014, p. 323). In-class activities, such as responding to clicker questions related to mathematical problems, were also well-received and allowed students to think independently before collaborating with peers, which facilitated learning (Weurlander et al., 2016a; Jungic et al., 2015).

The question of whether students achieve better outcomes in flipped mathematics classrooms has been addressed in various studies. Murphy et al. (2015) reported that students in a flipped linear algebra course performed significantly better on final exams compared to their peers in traditional lecture settings. Analysis of specific exam questions revealed that students in the flipped class offered more comprehensive explanations in their solutions, indicating a deeper understanding of the underlying concepts. Likewise, Petrillo (2015) noted an improvement in student performance in the flipped classroom, alongside a reduction in failure rates. Supporting this trend, Love et al. (2014) found that students in flipped classes exhibited a notably greater average increase in exam scores than those in traditional lecture environments. A larger-scale study involving 690 first-year calculus students confirmed that the flipped classroom students outperformed their peers from traditional lecture classes (Maciejewski, 2015). Conversely, a recent study pointed to only marginally better performance in the flipped classroom, noting the difference was more pronounced in conceptual than procedural questions (Wasserman et al., 2015). Additionally, it was discovered that students proficient in foundational mathematics but lacking calculus knowledge tended to gain the most from the flipped classroom approach (Maciejewski, 2015).

At the KTH Royal Institute of Technology, most engineering students enroll in the SF1625 Calculus I course, which comprises a total of 42 hours of lectures, 26 hours of tutorials, and 12 hours of seminars. Students are organized into different lecture groups, and study programs undertake the course concurrently with a shared examination. Historically, the failure rate for the written exam has ranged between 15-50%, influenced by the particular study program. In the traditional teaching framework, calculus instructors typically focused on presenting key theorems, proofs, and exemplary applications. There were noticeable variations in teaching styles among lecturers, particularly concerning student engagement and use of examples, though generally, limited time was allocated for peer discussions and hands-on problem-solving.

Since 2012, instructors experimented with interactive teaching methods in calculus. One lecture group utilised a peer instruction model (Mazur, 1997), which was tailored to mathematics by incorporating a greater variety of clicker questions targeting conceptual understanding as well as limited calculations and proof comprehension. Initial results were promising, suggesting enhanced student learning (Cronhjort et al., 2013). A survey revealed that engagement and alienation aptly described students' experiences with the interactive model (Weurlander et al., 2016). While many students expressed enthusiasm for learning calculus through peer instruction, others preferred a combination of traditional lectures and interactive segments. However, some students found the peer instruction model challenging and expressed frustration, as it demanded more from them and conflicted with their preferred learning styles (Weurlander et al., 2016).

The subsequent year introduced preparatory videos to assist students in preparing for in-class interactive activities. These videos included integrated online quizzes on the Scalable Learning platform (www.scalable-learning.com). An investigation based on focus-group interviews with students from various implementations of the flipped classroom highlighted five essential components valued by students: introductory films focusing on fundamental concepts, associated quizzes to stimulate critical thinking, individualized quiz feedback that prompted preparation, in-class interactive challenges, and appropriate difficulty levels that fostered both confidence and academic rigor (Cronhjort & Weurlander, 2016).

The aforementioned research consistently demonstrates that flipped classroom methodologies positively influence student learning outcomes in calculus. Additionally, Mikaelcronhjort et al. (2017) conducted comparative research on student learning outcomes between flipped classrooms and traditional pedagogical approaches.

Their study focused on quantitative data from a Calculus Baseline Test administered pre- and post-instruction, survey results that specifically assessed student engagement related to improved learning in flipped settings, and course final exam outcomes.

During the fall semester of 2015, eight study programs simultaneously undertook the calculus course. Educators were assigned to study programs based on preferences, with four programs utilizing interactive teaching methods and four adhering to conventional lectures. As a result, 226 students from four programs engaged in the flipped-classroom model, while 413 students participated in traditional lecture settings. All aspects of the course, including textbooks, tutorials, seminars, and final exams, remained consistent across both formats. The final examination comprised nine open-ended problems requiring complete solutions. Ultimately, it was reported that students in the flipped classroom exhibited a 13% higher normalized gain on the Calculus Baseline Test compared to the control group.

2.9 Difficulties in Learning differential Calculus (Derivatives)

The concept of Derivatives marks the initial encounter for students with the notion of limits, which necessitates calculations that extend beyond fundamental arithmetic and algebra, especially involving processes that require indirect reasoning. According to Tall (1992), educators often adopt an" informal" methodology, deliberately engaging with the technical concepts to facilitate understanding. Nevertheless, despite various instructional approaches, a pervasive discontent and lack of comprehension regarding calculus courses have been reported globally over the past decade. For example, in France, the homeland of Bourbaki's logical frameworks, mathematics educators identified fundamental flaws in formal learning methods. The Institute de Recherche sur l'Enseignement des Mathématiques (IREMs) continually advocates for ensuring the subject matter resonates more meaningfully with students (Artigue, 2020). In the United Kingdom, a recent report from the London Mathematical Society has acknowledged the challenges associated with university-level mathematics and has called for a reduction in course content, along with a complete restructuring of the curriculum (London Mathematical Society, 1992).

A case study by Sello Makgakga (2012) indicated that students performed more effectively in calculating derivatives through differentiation rules rather than applying first principles. Students demonstrated insufficient proficiency in finding derivatives from first principles, while their performance improved with established differentiation rules. Orhun's (2012) research indicated that learners struggled significantly in analyzing and interpreting derivative functions.

In the United States, statistics revealed that of the 600,000 students enrolled in college calculus in 1987, only 46% achieved a passing grade of D or higher (Anderson & Loftsgaarden, 1987). This general atmosphere of dissatisfaction has catalyzed the Calculus Reform Movement, which involves considerable investment in pedagogical innovations and technological tools, albeit with limited initial focus on cognitive research. The difficulties associated with learning derivatives have prompted several researchers to investigate the challenges faced by students, aiming to enhance their learning experiences. The present research intends to examine the key challenges encountered by pre-service teachers in learning derivatives, which contribute to their inadequate performance in differential calculus. Previous research by Tall (1992) highlighted various obstacles students face regarding limits, infinite processes, and terminology such as limit, tends to, approaches, and as small as you please, along with issues related to quantifiers and symbolic numeric representations. The preference for procedural methods over conceptual understanding was also noted. To address these challenges, effective instructional strategies, foundational skills, and computer programming tools like Maple and GeoGebra can significantly aid in overcoming the difficulties associated with understanding derivatives. Moreover, this paper elucidates specific challenges that students encounter in their study of derivatives, which often result in subpar performance. Araaya and Sideli (2012) emphasized that mathematics educators teaching introductory calculus concepts at the secondary level must exercise significant pedagogical content knowledge due to the widespread difficulties students face in learning calculus.

2.10 Reflection on the Various Literatures

The reviewed literature primarily addresses the performance of students in differential Calculus, the challenges they encounter while learning about derivatives, and various instructional strategies aimed at fostering student engagement with calculus in order to alleviate these difficulties. Numerous studies concentrate on enhancing conceptual understanding and addressing prevalent misconceptions. However, specific factors contributing to students' difficulties and their unsatisfactory performance in differential calculus have not been explored in the aforementioned studies. Moreover, the unique obstacles encountered by learners in the context of differential calculus have not been adequately documented in the existing literature. Therefore, my research aims to identify the specific challenges that pre-service teachers experience and to investigate the diverse teaching methods employed by college instructors in conveying the principles of differential calculus.

CHAPTER THREE

METHODOLOGY

3.0 Overview

The research aimed to examine the effect of Flipped Instruction on the performance of pre-service teachers in differential calculus, as well as the challenges pre-service teachers encounter while learning differential calculus. To achieve these objectives, specific research questions were developed to direct the investigation.

- Does the use of Flipped Instruction have effect on pre-service teachers' performance in differential calculus?
- What are some of the difficulties college students face in learning differential calculus?
- To address the initial research inquiry, the following hypothesis was proposed:
- H_0: There is no statistically significant difference in performance on the post-test between pre-service teachers instructed through flipped learning at college A and those taught through traditional methods at college B. This chapter outlines the research methodology employed in the investigation, detailing aspects such as research design, target population, sample selection and sampling methods, as well as the research instruments and processes for data collection. Additionally, the chapter elaborates on the considerations regarding the research instruments, emphasising the importance of establishing their validity and reliability, alongside the procedures for experimentation and data analysis techniques.

3.1 Research Design

In alignment with the objectives of the study, the researcher implemented a mixed-methods approach, specifically using a quasi-experimental design as the methodological framework for inquiry. The mixed-methods methodology is characterized by the simultaneous collection, analysis, and integration of both quantitative and qualitative data within a single research initiative or across multiple studies (Creswell, 2003; Creswell, 2006). The qualitative methods applied in this investigation facilitated a deeper comprehension of the effects of Flipped Instruction on the variables being studied.

The fundamental assertion underlying mixed-methods research is that the integration of both quantitative and qualitative strategies yields a more comprehensive understanding of research issues than the use of either method in isolation (Creswell, 2006, p. 5). Furthermore, the aim of this approach is to leverage qualitative findings to provide explanations and justifications for the quantitative outcomes observed (Fife-Schaw, 2012).

A quasi-experimental study serves as an empirical investigation designed to evaluate the causal effects of an intervention on a designated demographic. This type of study is conducted in real-world contexts as opposed to purely controlled laboratory settings (Vanderstoep & Johnson, 2009; Hashemi, 2014).

Shadish, Cook, and Campbell (2002) noted that quasi-experimental designs remain prevalent among researchers today for three key reasons:

- to satisfy practical considerations related to funding, administrative policies in educational institutions, and ethical standards.

- to assess the efficacy of an intervention that has already been implemented by educators before the evaluation process was initiated.
- when researchers seek to allocate more resources toward enhancing external and construct validity.

In this study, a pre-test/post-test two-group design was utilized under the quasi-experimental framework. Within this design, the researcher compared pre-service teachers instructed through traditional methods with those taught using the Flipped Instruction approach. Both groups participated in pre-tests and post-tests; however, only those pre-service teachers instructed with the Flipped Instruction method received the specified treatment. The pre-test data provided insight into the comparability of the pre-service teachers who were taught via traditional methods and those who experienced the Flipped Instruction prior to the treatment.

3.2 Population

McMillan and Schumacher (2006) characterize a target population as a collection of elements, which may consist of individuals or objects, fulfilling specific criteria to which a researcher intends to generalize the outcomes of the study. The research was carried out across two colleges of education, designated as A and B (pseudonyms for confidentiality), located in the Eastern and Greater-Accra Regions of Ghana, respectively. The researcher strategically selected these two institutions due to their accessibility and convenience, a method acknowledged by McMillan and Schumacher (2006) as both valid and practical. Consequently, the target population encompassed all third-year pre-service teachers from various colleges of education throughout Ghana. Pre-service teachers are individuals undergoing training to qualify as novice professional educators. In Ghana, these students typically range in age from 18 to 30 years and represent a diverse array of ethnicities within each college. The curriculum for pre-service teacher education is standardized across the nation, and all institutions adhere to the same academic calendar. The pre-service teachers have completed their senior high school education in Mathematics, achieving success on the West African Senior School Certificate Examination (WASSCE), which evaluates their skills, including in Calculus. Nonetheless, a significant proportion of these students enroll in teacher training with relatively low Mathematics grades.

As a matter of fact, pre-service teachers have similar characteristics in terms of multiple ethnicities, age difference, entry WASSCE qualification in Mathematics and the institutions that oversee their certification. Third year students were considered because they were offering the Calculus course as at the time of the study.

3.3 Sample and Sampling technique

The present study utilised a non-probability sampling technique, specifically convenience sampling, to select two colleges of education, identified as College A and College B, located in the Eastern and Greater Accra Regions of Ghana, respectively. College A refers to the 'Presbyterian College of Education, Akropong-Akuapem' in the Eastern Region, while College B designates the 'Accra College of Education'in the Greater Accra Region.

Students in these colleges are recruited from across all 16 regions of Ghana. The researcher deemed these two institutions suitable for the study because it allowed for close monitoring of the pre-service teachers' progress throughout the intervention phase.

Moreover, simple random sampling was employed as a secondary sampling method to select participants for this research. This choice aimed to mitigate bias and provide each selected sample unit with an equal opportunity for inclusion. The selection of sample units from the population was executed through a random process utilising a random number generator, ensuring that every participant had an equal probability of being chosen for the study.

The sample consisted of 120 third-year pre-service teachers, 60 pre-service teachers taught with flipped instruction (in college A) and the other 60 pre-service teachers taught using the traditional method (college B).

Table 1: Distribution of Sample Size from each College

	College A	College B
Males	40	40
Females	20	20
Total	60	60

3.4 Research instruments

In light of the nature of the research questions addressed, the instruments employed for data collection comprised a test (including both a pre-test and a post-test) as well as an interview.

3.4.1 Test

The test instrument was a pen-and-paper Calculus achievement test (refer to Appendix A). The test consisted of 10 subjective "questions" that assessed students' ability to procedurally solve, apply, and analyze, concepts in differential calculus as well as demonstrate problem-solving skills in a variety of ways. There were 10 test items: item 1 and 8 were on finding first derivative of some given functions from first principles, item 2 was on limits while item 3 was on implicit differentiation. Items 4,5,9 and 10 were on application of differentiation to solve problems involving volume of a sphere, equation of tangent and normal to curves, turning points, and linear kinematics respectively. Whereas item 6 was on finding first derivative of a function using rules of differentiation. Item 7 was on a proof involving the second derivative of functions.

Sixty pre-service teachers each from college A and B wrote the test.

There were no multiple-choice questions. This was done in order to lessen, if not completely eliminate, guessing. Using a cognitive test, according to Nesher (1987), allows pupils to freely express themselves without fear of being judged. This method of data collection was judged to be the most appropriate because standard classroom observations may not be complete because some students may choose not to speak out of fear or shyness. Cognitive tests highlighted students' strengths and limits, according to Flanagan, et al., (2009). While employing a task to find students' strengths and weaknesses in a topic may induce fatigue and exhaustion, these authors feel that it also has desirable side effects, such as adequate documenting of students' outcomes for empirical verification. By comparing their findings to those of their peers, they can be generalized.

3.4.2 Development of the Test

The researcher prepared the test. Bloom's taxonomy, Colleges of Education Calculus course manual and the SHS mathematics curriculum assessment criteria was used to help develop the test. The questions were written in accordance with the curriculum, ensuring that the test accurately reflected the substance of the curriculum. The test was timed but the time was enough to avoid putting undue pressure on learners and the risk of making mistakes due to time constraints; this method ensured that learners may perform to their full potential. According to Ogbonnaya (2006), in order to derive a valid and accurate conclusion from a study based on student achievement, the study must use assessments that is connected with the curricular requirements expected to be learned. This means that the achievement test was consistent with the curriculum's examination guidelines or assessment guidelines. This served as the foundation for developing the test instrument. To guarantee that the test instruments were properly aligned with the framework and data, the following steps were taken:

Step 1

The numerous contents to be learned in in differential calculus from the colleges of education, as specified in the curriculum, were written down, as well as the curriculum assessment guidelines. To aid in the collection of questions, a variety of textbooks and past examination questions were gathered. The Colleges of education Calculus course manual and Bloom's taxonomy guided the development of the test. This taxonomy divided questions into categories based on their cognitive demands. Cognitive demands: knowledge, comprehension, application and analysis, were all tested in the questions.

Table 2: Indicators Determining the Cognitive Domain of Questions

Aspects of Cognitive Domain	Indicators
Knowledge Aspect	Competence tested include things learned by student, recalled, mentioning the facts, concepts, definitions, proposition and such.
Comprehension Aspect	Competence tested include understanding the meaning of a material but in a low level, for example, interpret or construct an information into something more meaningful information.

Application Aspect	Competence tested is using the knowledge they have gained, to apply the concept, using a mathematical procedure to a problem that is familiar to the students.
Analysis Aspect	Competence tested in the form of the ability of learners to think critically to identify the problem to interpret part of the question into one new system
Synthesis Aspect	Competencies tested is the ability of students to construct something new from a variety of elements, concepts, design rules and so on.
Evaluation Aspect	Competence tested is student's ability to make the criteria, review and consider the (error, accuracy, statutes) and are able to assess

Table 3: Sample Test items by cognitive category

Cognitive Category	Sample item
Knowledge	Obtain from the first principle the derivative of $3x^2 + 2x - 4$ Find $\frac{dy}{dx}$ $at\ (1,6)\ of\ 2x^2 + xy - 3y^2 = 9.$
Comprehension	Find $\frac{dy}{dx}$ $at\ (1,6)\ of\ 2x^2 + xy - 3y^2 = 9.$ Differentiate the following with respect to x. (a) $\sqrt{(2x-1)^3}$ (b) $sin^3 x$
Application	Differentiate from the first principle with respect to $x, the\ function\ \ y = \sqrt{x}.$ If the volume of a sphere is growing at the rate of $24cm^3/s$ when the radius is $6cm$. Find the rate of increase of the radius at that time.

	A particle moves in a straight line in such a way that its distance $s\,metres$, from a fixed point 0 after time $t\,seconds$ is given by $s = 2t^3 - 9t^2 + 12t + 3$. Find (a) Its velocity after 3 seconds (b) When and where the particle is momentarily at rest. (c) Its acceleration after 2 seconds.
Analysis	Find the equation of the tangent and that of the normalto the curve $y = x^3 - 2x^2 + 3x - 3$ at the point (2,3).
Synthesis	If $y = \frac{ax+b}{x^2}$, where a and b are constants, show that $x^2\frac{d^2y}{dx^2} + 4x\frac{dy}{dx} + 2y = 0$.
Evaluation	Determine the nature of the of the turning points of the following functions: $(i)\ y = 2x^2 - 8x + 10$ $(ii) = x^3 - 6x^2 + 12 - 5$

Table 4: Distribution of questions based on Bloom's taxonomy

Question Number	Blooms' Cognitive level
1	Knowledge
2	Comprehension
3	Knowledge
4	Application
5	Application
6	Comprehension
7	Synthesis
8	Comprehension
9	Evaluation
10	Application

Step 2

Two college mathematics tutors were given the questions to moderate. All of the moderators had at least eight years of experience teaching mathematics; therefore, they were deemed qualified to do so. They reviewed the mark distribution and alignment of questions with the mathematics curriculum statement to regulate the diction. The questions were adjusted in accordance with their feedback.

Step 3

The test was pilot-tested in a college that did not participate in the study after the questions were modified. This was done prior to the start of the studies. A pilot study is referred to as preparation studies (Moore et al, 2011). These studies are conducted before the main study to demonstrate the effectiveness of the research methodologies or data gathering. To avoid contamination, this pilot study used 30 students, all females because the college is an all-female college. Contamination occurs when data is obtained from the same subject multiple times in the pilot study (Makonye, 2011).

The students were required to write the study's proposed test. The scripts of the students were marked and analyzed. The learners expressed issues regarding the clarity of some of the language used in the test after completing it. The problems that arose as a result of the question formulation were addressed. My supervisor and two other specialists in the field of mathematics were given the final instrument to assess the mark distribution, language, and content covered.

3.4.3 Administration and grading of the Test

The test used comprised both pre-test and post-test for the study. The test was written by all third-year pre-service teachers who participated in the study. All the participants answer sheets from the test were marked and scored (see appendix A) by the researcher. The test consisted of 10 written questions.

The grading method attracted a maximum of 14 points for question ten, 6 points for question two and 10 points for each of the remaining questions. This means that students procedures as well as their final answers attracted marks. A student's total score from the test ranged between $0 \text{ } and \text{ } 100$. The test as well as the marking scheme is at appendix A and B respectively.

3.4.4 Interview Guide

Interview was conducted using the interview guide to ascertain pre-service teachers' challenges in learning differential calculus in order to answer research question 2 (see Appendix B). The interview consisted of 5 items. The interview was structured and conducted with all the pre-service teachers having their turn to respond to the questions. To conduct it with ease, all the pre-service teachers were assembled by the researcher in a classroom after school hours and questions on the challenges of student teachers in their quest to learn differential calculus concepts were presented by the researcher to them. In all, a total of twenty-five (25) students took part of the interview and lasted for about 30 minutes.

3.4.5 Validity and reliability of instruments

Validity refers the degree to which research instruments are genuinely authentic and accurate, serving as evidence that a particular instrument measures what it is intended to measure (Mushquah & Bova, 2007; William, 2011). The approaches to assessing validity in this study were grounded in these established conceptions of validity.

To ensure the validity of the research instruments (test items), the researcher reviewed the Calculus curriculum, consulted with their supervisor, and examined pertinent Mathematics literature aimed at pre-service teachers. This thorough examination provided clarity on the learning expectations for pre-service teachers, thereby enabling the researcher to design the instruments accordingly. The primary objective of the test items was to evaluate the pre-service teachers' conceptual understanding of various facets of differential calculus. Consequently, the questions were solely focused on their comprehension of differential calculus concepts. Following the development of the test items, the researcher sought feedback from his supervisor to verify their quality. Additionally, several experience tutors from colleges of education were engaged to review the test items, contributing insights to ensure that the content areas addressed in this study aligned with the established domain relevant to the pre-service teachers' training.

Furthermore, a random selection of 40 pre-service teachers from the Presbyterian Women College of Education, Aburi, was conducted, with the participants tasked with responding to the test items. This exercise aimed to identify any ambiguities in the questions and to gauge the estimated time required for completing the test. The responses to the test items were evaluated using a scoring rubric, which assisted in refining the instruments.

3.4.6 Reliability

Conversely, reliability denotes the consistency of a measuring instrument or tool, such as a test or questionnaire, and pertains to the degree to which it produces consistent results across repeated measures (William, 2014). It reflects the dependability of the measuring instrument. In the present research, the split-half method was employed to assess the reliability of the instruments utilised. This technique involves creating a singular test comprising multiple items, which are subsequently divided into two equivalent sections based on the even-odd item criterion. The scores of pre-service teachers from these two halves were then correlated employing the Spearman-Brown formula, which is commonly used in reliability assessments. The computed reliability coefficient was found to be 0.75, indicating a substantial level of reliability for the instrument.

3.5 The use of flipped instruction

The flipped instruction was applied to the pre-service teachers in College A whereas the lecture method of instruction was applied to the pre-service teachers in College B throughout the study. According to Talbert (2012), the flipped classroom model entails that student first engage with essential concepts and foundational skills via readings, video lectures, and other resources outside of class. Subsequently, they apply this acquired knowledge to complex cognitive tasks during in-class sessions. This approach enables students to tackle challenging activities, such as curve sketching, which benefits significantly from direct teacher assistance. Ultimately, it offers a more interactive and efficient instructional experience.

The intervention process took a maximum of four weeks in both College A and B after which a post-test was administered to the pre-service teachers and their sheets marked and scores recorded.

3.5.1 The video Lessons

In order to apply the flipped instruction effectively, the researcher recorded self-tutorial videos on concepts of differential calculus. The videos were not borrowed from the internet but designed by the researcher because he wanted to ensure clarity of the language for better understanding of the concepts. The video had tutorial sessions where pre-service teachers watched and followed the lessons. At the end of each lesson, assignments were uploaded for students' practice. The videos were designed in four lessons and given to pre-service teachers in college A accordingly for a period of four weeks. The content of the first video covered limits of functions. The second video covered differentiation by the first principles whereas the third video covered application of the rules of differentiation to find derivatives of functions. The fourth video covered application of differentiation to solve some real-world problems.

3.5.2 Time schedule by the researcher to enable him commune between the two college of education

As the time the researcher was implementing the intervention process in these colleges of education, he was on vacation because he teaches in a double track school. The researcher first went to college A and gave them a video lesson for them to watch for one week. As at the time pre-service teachers in college A was watching a video lesson in week one, then the researcher went to college B to teach them the same content of the video given to pre-service teachers in college A. The difference here is that the pre-service teachers in college B were taught the same concepts by the traditional lecture method without them pre-watching a video on it. This process was repeated throughout the intervention period of the research. That was how the researcher designed the time that enabled him communed between the two colleges of education. The weeks and the activities that were undertaken in each week by the researcher are described below:

Week 1: Pre-service teachers in College A were given the self-made video tutorial on differentiation by the first principles developed by the researcher and reading assignment in advance to go through at home for a week to enable them grasp the basic concepts before the researcher met them in class to work through their problems in the first week. In that process, the researcher guided the pre-service teachers to solve problems they deem challenging either in the video, the assignment or on the concept under study**.** That took a maximum of 2 hours. The assignment items in the video for week 1 included:

Find from the first principles the derivative of:

$(a)\frac{1}{x}$ (b) x^3 $(c)\ (x+3)^2$ (d) $2x^2+\frac{3}{x}$ (e) $(3x^4+x^3)$

Week 2: Another video tutorial recorded by the researcher himself and assignments were given to pre-service teachers in College A on the rules of differentiation to again go through at home for a week. Then the researcher met them in class for two hours to work through their problems. Here, the researcher asked students to come out with their difficulties so that he could guide them solve them. Flipped instruction also allows students to do collaborative learning hence, students were encouraged to work in groups. That was done in the second week of the experimentation period. The assignment content in the video included:

Find with respect to x the derivative of the following functions:

1. $y = (3x^4 + 4x^2)(x^2 - 1)$ 2. $y = (x^4 + 3)^7$ 3. $y = \left(\sqrt{2x^3 - 5}\right)^3$

4. $\frac{x-1}{x+1}$ 5. $\frac{1-x^2}{1+x^2}$ 6. $\frac{2x+3}{(x+3)^2}$

Week 3: Again, a video lesson recorded by the researcher and assignment on differentiation of implicit functions were given to pre-service teachers in College A go through for another week to enable them learn before meeting the researcher for 2 hours in the classroom for face-to-face discussions where the researcher guided them through

what they did not understand in the video or assignment and also helped solve challenging tasks on the topic. The assignment content was as follows:

1. If $y^2 + x^2 = 2pxy$, where p is a constant, find $\frac{dy}{dx}$
2. $(1 + x^2)(1 + y^2) - px^2$, where p is a constant, show that $xy(1 + x^2)\frac{dy}{dx} = (1 + y^2)$
3. $x^2 + y^2 = ay(1 + x^2)$, where a is a constant, find $\frac{dy}{dx}$
4. Find the derivative of $x^3 + 4xy^2 - 7 = y^3$
5. Find the slope of the tangent to the circle $x^2 + y^2 = 4$

Week 4: In the fourth week, a recorded video lesson by the researcher and assignment was given to pre-service teachers in the College A on application of differentiation. That was given to pre-service teachers to learn for a week before meeting the researcher for 2 hours for classroom discussions where he again worked through their problems. During the class discussions, students were encouraged to also assist their colleagues in the areas that they could. The assignment was also as follows:

1. A particle moves in a straight line in such a way that its distance $s\ cm$ from a fixed point 0 after time t seconds is given by $s = t^3 - 15t^2 + 63t - 40$. Calculate

   (a) the distance from 0 when the particle is momentarily at rest.

   (b) Its velocity when acceleration is zero.

2. A particle moves in a straight line such that its distance $s\ metres$ from a fixed point 0 after time t seconds is given by $s = \frac{2}{3}t^3 - 4t^2 + 6t + \frac{1}{3}$. Calculate

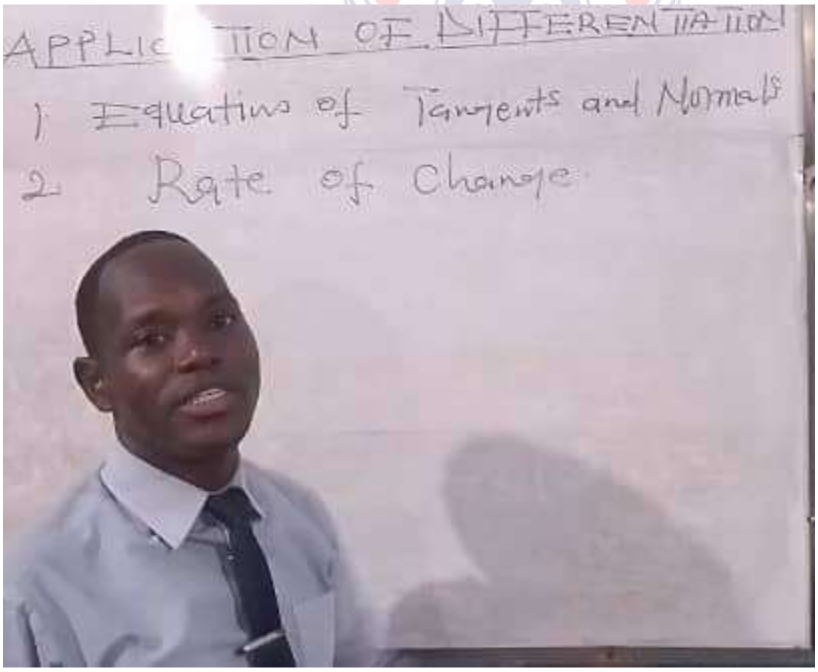
   (a) Its velocity after 4 seconds

   (b) The time when the particle is momentarily at rest.

   (c) The distance travelled by the particle at that time.

3. The tangent to the curve $y = x^3 - x^2 + 1$ at p passes through the points $(1, -3)\ and\ (3, 13)$. Find the possible coordinates of p.

4. Determine the nature of the turning point of $y = (x-1)(x+2)^2$



3.6 The non-flipped instruction (The traditional method)

The following were the steps followed in the non-flipped instruction.

Week 1: Pre-service teachers in College B met the researcher for 2 hours classroom teaching on differentiation by the first principles. They were taught using the lecture method without any prior video or assignment given to them on the topic to learn the basics. The assignment items were as follows:

Find from the first principles the derivative of:

(a) $\frac{1}{x}$ (b) x^3 (c) $(x+3)^2$ (d) $2x^2 + \frac{3}{x}$ (e) $(3x^4 + x^3)$

Week 2: The researcher again met the pre-service teachers in College B in the second week and taught them the rules of differentiation using the lecture method. Their difficulties were addressed through questions and answers. The content of their assignment included:

Find with respect to x the derivative of the following functions:

1. $y = (3x^4 + 4x^2)(x^2 - 1)$ 2. $y = (x^4 + 3)^7$ 3. $y = \left(\sqrt{2x^3 - 5}\right)^3$

4. $\frac{x-1}{x+1}$ 5. $\frac{1-x^2}{1+x^2}$ 6. $\frac{2x+3}{(x+3)^2}$

Week 3: Pre-service teachers in College B were taught differentiation of implicit functions in the third week of the experimentation period using the traditional lecture method where their concerns were addressed through questions and answers. The assignment items were as follows:

1. If $y^2 + x^2 = 2pxy$, where p is a constant, find $\frac{dy}{dx}$
2. $(1 + x^2)(1 + y^2) - px^2$, where p is a constant, show that $xy(1 + x^2)\frac{dy}{dx} = (1 + y^2)$
3. $x^2 + y^2 = ay(1 + x^2)$, where a is a constant, find $\frac{dy}{dx}$
4. Find the derivative of $x^3 + 4xy^2 - 7 = y^3$
5. Find the slope of the tangent to the circle $x^2 + y^2 = 4$

Week 4: The researcher taught the pre-service teachers in College B application of differentiation in the fourth week of the experimentation period still using the traditional lecture method.

After the use of the flipped instruction on the pre-service teachers in College A and the traditional method on the pre-service teachers in College B, the researcher administered the same test items used during the pre-test to students in both College A and B. That enabled him ascertained whether there was significant difference in the scores of the students in the pre-test and the post-test. The items below constituted assignment items for lesson four:

A particle moves in a straight line in such a way that its distance $s\ cm$ from a fixed point 0 after time t seconds is given by $s = t^3 - 15t^2 + 63t - 40$. Calculate

(c) the distance from 0 when the particle is momentarily at rest.

(d) Its velocity when acceleration is zero.

A particle moves in a straight line such that its distance $s\ metres$ from a fixed point 0 after time t seconds is given by $s = \frac{2}{3}t^3 - 4t^2 + 6t + \frac{1}{3}$. Calculate

(d) Its velocity after 4 seconds

(e) The time when the particle is momentarily at rest.

(f) The distance travelled by the particle at that time.

The tangent to the curve $y = x^3 - x^2 + 1$ at p passes through the points $(1, -3)$ *and* $(3, 13)$. Find the possible coordinates of p.

Determine the nature of the turning point of $y = (x - 1)(x + 2)^2$

3.7 Data collection procedure

In the initial phase of the first semester, the researcher engaged with two Colleges of Education. Introduction letters were secured from the Head of the Mathematics Department at the University of Education, Winneba, which facilitated the research process in these institutions. Upon meeting with the administrative leaders of the colleges, the researcher articulated the study's objectives and sought their collaboration for the fieldwork. Subsequently, the researcher conducted instructional sessions for pre-service teachers at College A utilising a flipped classroom approach, while at College B, the traditional lecture method was employed. Additionally, the researcher administered both pre-tests and post-tests, along with conducting interviews. The evaluation of the tests was performed in accordance with a designated marking scheme.

The variables were then coded and the data keyed in. The file was saved for future analysis.

3.8 Data analysis procedure

Kothari (2004) describes data analysis as a systematic procedure encompassing the editing, coding, classification, and tabulation of the gathered data. This process entails various operations aimed at effectively summarizing and structuring the data obtained from the field.

3.8.1 Research Question One

This study primarily generated quantitative data derived from assessments of pre-service teachers. Consequently, the researcher utilized both descriptive and inferential statistical analysis. Descriptive analysis was employed to elucidate the experiences of pre-service teachers regarding their comprehension of differential calculus concepts. This approach facilitated the organization and interpretation of data by examining the distribution of scores across different constructs and assessing the interrelationships among these scores. Specifically, various descriptive statistics, including minimum and maximum values as well as measures of central tendency, were implemented to analyze, characterize, and compare the quantitative data collected in this research. The Statistical Package for the Social Sciences (SPSS) version 26 was utilized for the statistical analysis pertaining to the first research question. In particular, an independent samples t-test was conducted at a 95% confidence level to compare pre-service teachers' conceptual understanding of differential calculus based on pre-test results. Additionally, paired samples t-tests (dependent t-tests) at the 95% confidence level were employed to evaluate the mean score differences between pre-service teachers from College A and College B in both the pre-test and post-test scenarios. The null hypothesis postulated that there would be no significant difference in the performance of pre-service teachers instructed via flipped instruction in College A compared to those receiving traditional instruction in College B during the post-test, and this hypothesis was tested at a significance level of 0.05.

3.8.2 Research Question Two

The second research question yielded qualitative data through interviews with pre-service teachers, which were recorded for analysis. In qualitative research, data analysis involves contextualization, wherein the findings are interpreted in light of the interview data (Mertler & Charles, 2005). The analysis employed a thick description approach, following the transcription of interviews and the identification of response categories that addressed the research questions. The researcher conveyed all significant outcomes from the study through comprehensive description and interpretation of the results.

3.9 Ethical Considerations

Regarding the issue of consent, the researcher initially articulated the primary and specific objectives of the study to the academic authorities within the colleges before initiating the research. Permission was secured to conduct the study on their premises. Informed consent was obtained from the school's leadership, the mathematics department head, teachers, and participating students prior to the commencement of data collection. Respondents were also informed of their right to withdraw from the study at any point. Prior to the interviews, the researcher assured participants that all data gathered would be securely stored and treated confidentially. To uphold confidentiality, all individuals and institutions involved were assigned pseudonyms in the data analysis and interpretation processes, thus safeguarding against the disclosure of any identifying information.

Upon administering assessments and recording scores, the researcher revisited the colleges to engage with pre-service teachers regarding their results, reinforcing the corroboration of the data. This interaction aimed to convince the pre-service teachers that the scores accurately reflected their competencies in the corresponding academic areas. This process of validation, as described, aligns with what Lincoln and Guba (1985) termed member checking, which serves to formally document participants' agreement on the accuracy of the researcher' s records regarding their contributions.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This research aims to employ a combination of quantitative and qualitative methodologies to examine the effect of flipped instruction on the performance of Ghanaian pre-service teachers in differential calculus. Additionally, it explores the challenges encountered by these pre-service teachers as they endeavor to master differential calculus.

The findings of the study and discussion of the findings are presented in two sections according to the research questions.

4.1 The Calculus Achievement Test Results

This section discusses the findings from the Calculus Achievement Test. The assessment was administered twice, once as a pre-test and again as a post-test throughout the research. Initially, prior to implementing the Calculus Achievement Test at College A and the instructional lectures at College B, all pre-service teachers within the sample undertook the Calculus Achievement Test as the study's pre-test. This assessment comprised 10 essay questions, requiring the pre-service teachers to articulate their answers in writing. Following the instructional treatment, a comparable test was given to the participating pre-service teachers as the post-test of the study.

4.1.2 Performance of pre-service teachers in college A and B in the Pre-Test

The assessment items were meticulously developed in alignment with Bloom's Taxonomy, taking into account the first research question. Pre-service teachers who displayed a solid understanding and provided accurate answers to the items were categorized as correct. Those who attempted the items but did not achieve the full score designated for each test item were classified as partially correct, whereas responses indicating a substantial lack of knowledge were deemed completely incorrect. Additionally, a small number of pre-service teachers did not engage with certain test items; these instances were labeled as "skipped."

Table 5: Calculus Achievement Pre-Test. Item analysis for Both Colleges

	College B				**College A**			
	Correct	Partially Correct	Completely Wrong	Skipped	Correct	Partially Correct	Completely Wrong	Skipped
Item	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
1	20(33)	27(45)	8(14)	5(8)	19 (32)	30(50)	8(13)	3 (5)
2	4(6)	11(18)	36(60)	9(16)	2 (3)	10(17)	40(67)	8(13)
3	21(35)	31(51)	8(14)	0(0)	**16** (26)	31(52)	10(17)	3(5)
4	3(5)	13(21)	33(55)	11(19)	**1** (2)	12(20)	40(67)	7(11)
5	18(30)	27(45)	13(22)	2(3)	**17** (28)	33(55)	9(15)	1(2)
6	0(0)	16(27)	37(62)	7(11)	**0** (0)	10(17)	35(58)	15(25)
7	0(0)	5(8)	39(65)	16(27)	**0** (0)	4(6)	40(67)	16(27)
8	2(3)	20(33)	32(54)	6(10)	**2** (3)	19(32)	33(55)	6(10)
9	1(2)	17(28)	38(63)	4(7)	**0**(0)	15(25)	42(70)	3(5)
10	0(0)	10(17)	40(66)	10(17)	**1**(2)	7(11)	42(70)	10(17)

The data presented in Table 5 indicates that pre-service teachers from both colleges exhibited comparable performance on the first, third, and fifth items. Specifically, for item one, a significant number of pre-service teachers (27), which constitutes 45%, had a partial understanding of the material in college B, while 20 pre-service teachers, representing 33%, answered it correctly. In college A, 30 pre-service teachers, or 50%, also had a partial understanding of item one, and 19 pre-service teachers, equating to 32%, answered it correctly. The similarity in the percentages of 33% and 32% of the correct responses in colleges B and A respectively indicates that both groups performed almost identically on this item during the pre-test, suggesting that pre-service teachers from both colleges did not experience significant difficulty in deriving functions from the first principles.

In contrast, Table 5 illustrates a notable decline in performance for item two across both colleges during the pre-test phase. Only 4 pre-service teachers, representing 6%, answered this item correctly in college B, and similarly, just 2 pre-service teachers, or 3%, answered correctly in college A. This underscores the challenges faced by pre-service teachers in expressing functions as partial fractions and subsequently computing limits.

As mentioned earlier, Table 5 reveals satisfactory performance in item three; out of 60 pre-service teachers, 21 of them, representing 35%, responded correctly in college B, while 31, corresponding to 51%, provided partial responses. In college A, 16 pre-service teachers (26%) answered item three correctly, with another 31 (51%) delivering partial answers. This reflects a strong similarity in pre-service teachers' performances across both colleges prior to the intervention.

Moreover, the results from Table 5 show that the performance of pre-service teachers in item four was considerably deficient during the pre-test. The majority of pre-service teachers (33), accounting for 55%, answered this item incorrectly in college B, and 40 pre-service teachers (67%) in college A also responded incorrectly. This indicates that pre-service teachers in both institutions struggled with applying differentiation concepts to address real-world problems.

The outcomes for items six, seven, eight, nine, and ten in the pre-test were also unsatisfactory due to their application-based nature. For instance, in college B, 40 pre-service teachers (66%) answered item ten incorrectly, while in college A, 42 pre-service teachers (70%) also achieved incorrect responses for the same item. This further corroborates that pre-service teachers from both colleges faced substantial challenges with practical applications prior to the treatment intervention.

4.1.3 General Comparison of Pre-test Scores of pre-service teachers in college A and B

Table 6: Mean, Standard Deviation, Minimum and Maximum Pre-test Scores for pre-service teachers in college A and B

Group	N	Mean	Stand Dev	Minimum	Maximum
College B	60	34.25	4.18	21	62
College A	60	33.31	3.74	20	60

Comparing the minimum and maximum scores pre-service teachers obtained in college B to the minimum and the maximum scores in college A from Table 6, it can be observed that college B had a minimum score of 21%, and maximum score of 62% as against the minimum score of 20%, and the maximum score of 60% in college A. This revealed no significant difference between pre-service teachers' performance in college A and B. Further comparing the mean score of 34.25 of pre-service teachers in the college B to a mean score of 33.31 of their counterparts in college A still point to the fact that there was no significant difference in their performance in the pre-test. It further indicated how similar their performances were before the treatment.

4.1.4 Independent Sample t-test Statistic

An independent samples t-test was performed to examine the scores of pre-service teachers from both College A and College B for a more in-depth evaluation of their performance. The outcomes of the independent samples t-test regarding the pre-test scores of the participants are displayed in Table 7.

Table 7: Independent Sample t-test of pre-test of pre-service teachers in college A and B

Groups	N	Mean	Std.Dev	t-value	df	p-value
College B	60	34.25	4.18	0.08	59	0.423
College A	60	33.31	3.74			

Table 7 illustrates the findings from the independent-samples t-test conducted on the pre-test scores. The data indicate that college B achieved a slightly higher mean score (Mean=34.25%) compared to college A (Mean=33.31%). To determine if the difference in mean scores between pre-service teachers from colleges A and B was statistically significant, an independent-samples t-test was utilised. The outcomes presented in Table 7 demonstrate that there was no statistically significant difference in the mean scores between the pre-service teachers of college B (M=34.25, SD=4.18) and those from college A (M=33.31, SD=3.74), with a p-value of 0.423, which exceeds the significance threshold of 0.05. These findings imply that pre-service teachers at both colleges A and B exhibited a comparable level of conceptual understanding of differential calculus prior to the initiation of the intervention.

4.1.5 Performance of pre-service teachers in college A and B in the Post-Test

Following the implementation of the flipped classroom model with pre-service educators at College A, as opposed to the conventional lecture method (tutor-centered approach) utilised with pre-service educators at College B, a calculus achievement examination was subsequently conducted for all pre-service teachers across both institutions. This assessment aimed to evaluate the impact of the flipped classroom method on the performance of pre-service teachers in the domain of differential calculus.

Table 8: Calculus Achievement Post-Test. Item analysis for Both Colleges

	College B				College A			
	Correct	Partially Correct	Completely Wrong	Skipped	Correct	Partially Correct	Completely Wrong	Skipped
Item	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
1	28(47)	21(35)	11(18)	0(0)	49(82)	8(13)	3(5)	0(0)
2	23(39)	20(33)	15(25)	2(3)	37(62)	18(30)	4(6)	1(2)
3	28(47)	28(47)	4(6)	0(0)	47(78)	10(17)	3(5)	0(0)
4	9(15)	25(42)	20(33)	6(10)	20 (33)	38(64)	2(3)	0(0)
5	30(50)	22(37)	8(13)	0(0)	50 (83)	10(17)	0(0)	0(0)
6	11(18)	28(47)	17(28)	4(7)	19(32)	38(63)	3(5)	0(0)
7	18(30)	32(53)	10(17)	0(0)	35 (59)	20(33)	5(8)	0(0)
8	29(48)	23(38)	7(12)	1(2)	42(70)	18(30)	0(0)	0(0)
9	23(38)	23(38)	11(19)	3(5)	46(77)	12(20)	3(3)	0(0)
10	36(60)	20(33)	4(7)	0(0)	51(85)	9(15)	0(0)	0(0)

The results in Table 8 indicates that pre-service teachers in college A performed better in all the items as compared to their counterparts in college B in the post-test. For instance, item 3 where pre-service teachers in college B had previously performed marginally better than their colleagues in college A in the pre-test, the post-test results in table 8 shows that 47 pre-service teachers representing 78% of the pre-service teachers in college A had it correct in the post-test as compared to 28 pre-service teachers representing 47% who had it correct in college B in the post-test. Another clear difference in performance between the pre-service teachers in the two colleges is seen in item ten. Whereas a majority (51) pre-service teachers representing 85% in college

A had item 10 correct in the post-test, only 36 pre-service teachers representing 60% of their counterparts in college B had item 10 correct in the post-test. This improved performance in all the items by pre-service teachers in college A could be attributed to the use of flipped instruction.

4.1.6 General Comparison of Post-test Scores of pre-service teachers in college A

Table 9: Mean, Standard Deviation, Minimum and Maximum Post-test Scores for pre-service teachers in college A and B

Group	N	Mean	Stand Dev	Minimum	Maximum
College B	60	36.28	4.3	26	67
College A	60	55.71	4.56	47	84

Table 9 compares the post-test results of the pre-service teachers within college A and B after the treatment. For instance, comparing a mean score of 55.71 in college A to that of 36.28 in college B show a mean difference of 19.43 between the colleges in the post-test. This huge difference in the means show how better the performance is in college A as compare to college B. The results further show a maximum score of 84% by pre-service teachers in college A as compared 67% in college B. The results showed an improvement in the pre-service teachers' understanding of differential Calculus in the post-test. However, the improvement is much better in college A as compared to college B. This improvement might be due to the use of flipped instruction in college A.

4.1.7 Research question 1: Does the use of Flipped Instruction have effect on pre-service teachers' performance in differential calculus?

The initial research inquiry concentrated on evaluating the effect of Flipped Instruction on enhancing students' performance in differential calculus. To address this inquiry, the following hypothesis was established for the investigation:

H_0: There exists no substantial difference in the performance outcomes of pre-service teachers from College A and College B in the post-test.

The independent sample t-test of Post-test was performed to ascertain whether the differences in the performance between the pre-service teachers in college A and B were enough to be significant. Table 10 reveals that the mean score of pre-service teachers in college B in the post-test was 36.28 while that of the mean score of college A in the post-test was 55.71 with the mean difference of 19.43. Table 10 presents the results of the independent sample t-test for pre-service teachers' post-test scores and as can be seen from this table the difference highlighted above was statistically significant as $p < 0.05$. Hence the null hypothesis that there is no significant difference in performance between pre-service teachers taught using flipped instruction and those taught using the lecture method in the post-test was rejected.

Table 10: Independent Sample t-test of Post-test of College A and B

	N	Mean	Std.Dev	Mean difference	t-value	df	p-value
Post-test (College B)	60	36.28	4.30	19.43	-30.77	59	0.00
Post-test (College A)	60	55.71	4.56				

4.1.8 Research Question 2: ***What are some of the challenges college of education students face in learning differential calculus****?*

In order to answer research question three, a structured interview which consisted of five items was conducted to seek pre-service teachers' views on the challenges they face in learning differential Calculus. Twenty-five pre-service teachers were interviewed.

On the first question which sought to find out how well the areas of their course manual concerning differential Calculus were covered by their tutors, all the participants responded that the teachers adequately covered all the calculus contents areas in the course manual. Student teacher 1 responded that "*We have been taught all the aspects except numerical methods (Trapezium and Simpson's rules) which we started but could not complete it*." Student teacher 7 also respondent that they were taught all the aspects including numerical methods. These statistics confirms that coverage of differential Calculus contents in the course manual was not a contributing factor to the challenges of pre-service teachers in learning differential calculus.

The second item was to find out how well teaching and learning materials were employed by their tutors. Responses from the participants revealed that, 92% (23) were of the view that, their tutors never used the teaching and learning materials in teaching differential calculus concepts. 8% (2) of them also responded that the teaching and learning materials were sometimes used by their tutors which included projectors. Student 4 respondent that "*the tutors always do all the illustrations on the marker board; we have never been shown any other teaching and learning material apart from the white board illustrations.*" According to student 9, *the tutors once showed them a video about the history of mathematics and pictures of the two seventeenth century's* *brightest minds, sir Isaac Newton of gravitational fame, and the philosopher and mathematician Gottfried Leibniz who are believed to have created calculus*. The large percentages in the 'never' and 'sometimes' categories imply that some challenges of the pre-service teachers in their learning of differential calculus concepts may be attributed to lack or inadequate use of teaching and learning materials.

The third item was to find out if the Calculus textbooks at the colleges of education contain enough activities to enhance understanding. Sixty percent (60%) that is (15) of the respondents were of the view that their textbooks (Hand-outs) contained enough activities to consolidate understanding of differential calculus concepts whilst 40% (10) of the respondents were also of the view that the textbooks (Hand-outs) do not contain enough activities. Student 11 responded that, "*we have a lot of textbooks (Hand-outs) and all of them contain hundreds of activities to be practiced.*" Furthermore, student 8 also responded that, "*we have textbooks and workbooks on Calculus and these textbooks and workbooks contain a lot of activities which we sometimes practice but the question we were given in the test, I have not seen some in our textbooks especially question number 7 and 8.*" Student teacher 12 and 21 agreed to student 8 response. These responses on the adequacy of activities in the textbooks revealed that, textbooks were not so much a problem contributing to the challenges faced by pre-service teachers in their learning of calculus concepts but their concern was with the types of activities contained in the textbooks.

The fourth item requested students to describe the teaching approach adopted by their teachers in teaching calculus. 92% (23) of pre-service teachers described their teachers approach of teaching calculus concepts as more of a lecture method as against 8% (2) for discovery and group activity-oriented approaches to teaching. Student 22 responded that, "*our teacher does all the talking, on few accusations he will ask us do we understand? There is little to no time to even ask questions."* Student 17 also responded that, *"our teachers sometimes start with questions and try for us to say a lot of the things he is supposed to teach us. Sometimes too he will give us examples and solve the example with us."* Analysis of responses on teachers' approaches of teaching differential calculus concepts suggested that teacher's approaches in delivering such topics was among some of the factors contributing to the challenges of pre-service teachers.

Finally, students were to ascertain if exercises or test given to them by their teachers were enough to consolidate the various concepts of differential calculus taught to them. This is because frequencies of assignments also help students to consolidate concepts learnt. The more assignments given to students meant more opportunity for practice and better consolidation of concepts learnt. All the respondents 100% (25) admitted that tutors gave them mathematics assignments on differential calculus concepts. However, they described frequency of such assignments as being on the average, indicated that there was a gap in assignments with regards to differential calculus concepts in mathematics.

Discussion of Major Findings

The findings of the analysis presented above were used to provide answers to the research questions of the study. In all there were three research questions that guided the study. This section addresses the research questions.

Research Question One

In this study, the primary aim of the first research question was to examine the effect of Flipped Instruction on the performance of pre-service teachers in differential

Calculus. The results revealed that Flipped Instruction, as an instructional method, afforded pre-service teachers novel learning experiences during their differential calculus lessons. These experiences encompassed collaborative group work and peer interactions. Consequently, this instructional approach provided pre-service teachers with enriched opportunities for diverse forms of mathematical communication that are typically lacking in traditional teaching methods, such as the tutor-centered approach.

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The results obtained from the independent samples t-test revealed no statistically significant difference in the performance of pre-service teachers from colleges A and B during the pre-test phase (prior to the implementation of flipped instruction), with p-values exceeding 0.05. This finding indicates that the pre-service teachers from both institutions exhibited equivalent levels of competency before the educational intervention. However, following the intervention, the post-test results highlighted a significant disparity in performance between the pre-service teachers at college A and those at college B, with a p-value of less than 0.05, which favored the experimental group in college A.

Moreover, the independent samples t-test analysis of pre-test scores confirmed that there was no notable difference in the conceptual understanding of differential calculus among pre-service teachers from colleges A and B. Conversely, the comparative analysis of pre-test and post-test scores revealed a significant enhancement in performance among college A's pre-service teachers, with statistical significance at $p<0.05$. Further examination showed a greater mean difference of 22.4 for college A relative to a mere 2.03 for college B in the post-test scores. This observed mean difference suggests that pre-service teachers in college A outperformed those in college B following the intervention, which may be attributed to the adoption of flipped instruction techniques in college A.

Lastly, analysis of the performance of pre-service teachers across various levels of Bloom's Taxonomy indicated that their scores in the pre-test were comparable between the two colleges. However, post-intervention assessments revealed that pre-service teachers in college A significantly outperformed their peers in college B across all facets of Bloom's Taxonomy. This improvement can also be linked to the implementation of flipped instruction in college A.

Research question 2

In addressing the second research question, it was determined that the students' performance in differential calculus was not adversely affected by the absence of calculus topics in the mathematics curriculum. However, an analysis of students' perceptions regarding the pedagogical strategies employed by their instructors revealed that 92% believed that a predominantly lecture-based approach was utilised in delivering calculus lessons. This observation aligns with the findings of Fletcher (2003) and Osafo-Affum (2001), who asserted that the role of mathematics teachers in Ghana has historically been that of a lecturer and disseminator, systematically conveying the structure of mathematical concepts. This situation echoes the insights of Anamuah-Mensah et al. (2008), who discussed the overall performance of Ghanaian students in Mathematics as highlighted in the Trends in International Mathematics and Science Studies (TIMSS) 2007 report, which also pointed to the instructional methods employed by teachers. Anamuah-Mensah et al. (2008) noted a concerning trend in Ghana, where there appears to be a rapid transition between topics, suggesting that the teaching level is often superficial. This situation frequently results in students failing to attain a profound understanding of specific topics, which consequently impacts their performance negatively.

Furthermore, in the realm of teaching and learning resources utilised for calculus instruction, it became apparent that educators must enhance their use of such materials if they acknowledge their significance. Interview data indicated that teachers hardly incorporate these teaching aids. This finding supports Akkoyunlu's (2002) perspective that instructional resources can motivate students and facilitate their engagement with lessons, thereby providing them access to information and opportunities for evaluation. The incorporation of teaching and learning materials is also critical for improving the overall quality of education, as affirmed by Akkoyunlu (2002).

Additionally, other factors identified as influencing students' understanding of calculus concepts included a lack of sufficient practice exercises to reinforce the material presented, as well as assessment methods that inadequately fostered students' problem-solving abilities across various cognitive domains.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter presents a concise summary of the research findings and their practical implications. Additionally, it suggests recommendations and potential directions for future research.

5.1 Summary of study

The research examined the effect of Flipped Instruction on the performance of pre-service teachers in differential calculus. Additionally, the study identified the difficulties encountered by pre-service teachers while learning differential calculus. The investigation was structured around specific research questions:

- Does the use of Flipped Instruction have effect on pre-service teachers' performance in differential calculus?
- What are some of the challenges pre-service teachers in the colleges of education face in learning differential calculus?
- The research methodology adopted in this study was a mixed methods approach that utilised a quasi-experimental design for data collection and analysis. Specifically, the quasi-experimental framework implemented was the pre-test/post-test design involving two distinct groups. Data were gathered through testing and a structured interview guide.
- The target population consisted of pre-service teachers from various Colleges of Education across Ghana. The sample included 120 third-year pre-service teachers, divided equally with 60 from College A and 60 from College B. Additionally, 25 pre-service teachers from College A were randomly selected

for interviews. The findings from the various data collection methods, including pre-test results, post-test outcomes, and interview responses, were integrated to address the research questions, with each question examined through the lens of the relevant data sources.

5.2 Major findings

The results of the research are compiled and organized according to three sub-sections that correspond with the research questions.

5.2.1 Research question one: Does the use of Flipped Instruction have any effect on pre-service teachers' performance in differential calculus?

The results of this study revealed a notable distinction between the pre-test and post-test performance of pre-service teachers from Colleges A and B, with the data favoring the pre-service teachers from College A. Consequently, the involvement of these pre-service teachers in the Calculus Achievement Test demonstrated a considerable improvement in their post-test scores. Additionally, the analysis indicated that pre-service teachers from College A outperformed their peers in College B across all dimensions of Bloom's Taxonomy in the post-test assessment.

5.2.2 Research question two: What are some of the challenges college of education students face in learning differential calculus

The research question three sought to find out some challenges pre-service teachers face in learning differential calculus concepts. A structured interview was conducted with 25 respondents. At the end of the interview which lasted for about 35 minutes, some challenges pre-service teachers face were identified. It was found out that approaches adopted by teachers in the teaching of calculus concepts were not effective to aid understanding of calculus concepts. Also, Exercises given pre-service teachers were not enough for students to practice on all aspects of the cognitive domains to consolidate concepts taught. Furthermore, Lack of effective use of teaching learning materials inhibit students' proper understanding of the calculus concepts.

5.3 Summary

This research investigates the effectiveness of Flipped Instruction for pre-service teachers at College A compared to traditional lecture-based instruction at College B. Following the intervention, both groups exhibited improvement in their post-test scores relative to their pre-test results. Notably, the cohort from College A demonstrated superior performance compared to their counterparts at College B. This suggests that Flipped Instruction positively influences the academic performance of pre-service teachers. The incorporation of hands-on activities utilizing concrete manipulative materials provided equitable assistance to all pre-service teachers, leading to a deeper conceptual understanding of calculus concepts addressed during the study. This aligns with previous investigations into the application of Flipped Instruction in teaching differential calculus in Ghanaian educational settings. The Flipped Instruction methodology holds promise for enhancing pre-service teachers' calculus reasoning and their comprehension of calculus concepts, equipping them to effectively teach mathematics at the basic level upon graduation from College of Education.

When evaluating the pre-test and post-test scores of calculus achievement for pre-service teachers in College B, it was evident that there was no significant improvement, indicating that lecture-based instruction may not facilitate better performance. Conversely, the integration of Flipped Instruction within calculus lessons notably enhances learner outcomes, fosters student motivation, and cultivates positive attitudes towards learning calculus. Furthermore, this instructional framework supports pre-service teachers' performance across various levels of Bloom's Taxonomy.

Mathematics instructors within Colleges of Education are encouraged to transition away from traditional lecture methods, particularly in the context of teaching calculus, and to emphasize hands-on activities with concrete manipulative materials as part of the Flipped Instruction approach to facilitate easier comprehension of calculus concepts. The results of this study indicate that implementing Flipped Instruction can significantly improve the performance of pre-service teachers in calculus in Ghana. For the government to enhance the mathematics performance of Ghanaian students in both international and national assessments, such as TIMSS, BECE, and WASSCE, the adoption of Flipped Instruction is crucial. Thus, the insights gained from this study are valuable for policymakers, educators, and other stakeholders aiming to elevate students' calculus performance in Ghana through the Flipped Instruction model.

5.4 Recommendations

Based on the results of this study, the following recommendations are proposed:

• Mathematics instructors at the Colleges of Education should consider revising their pedagogical approaches to incorporate Flipped Instruction in their lesson preparation and delivery. This recommendation aligns with findings indicating that pre-service teachers found calculus lessons utilising Flipped Instruction to be more engaging, as it alleviated monotony and enhanced the ease and enjoyment of learning differential calculus.

• Tutors in the College of Education should be motivated to integrate a greater variety of exercises and educational resources, such as projectors and television sets, to facilitate the demonstration or presentation of calculus concepts to pre-service teachers. This suggestion is supported by evidence showing a deficiency in the quantity of exercises provided to reinforce learning, as well as inadequate utilisation of instructional materials by tutors when teaching calculus.

• Curriculum designers, textbook authors, and policymakers are urged to examine the Flipped Instructional Model for insights into how to enhance student achievement in mathematics, particularly in Calculus. This recommendation is substantiated by findings that suggest the model could substantially improve learners' conceptual understanding of Calculus in Ghana.

5.5 Areas for further research

The educational implications derived from the results of this study indicate the necessity for additional research into the flipped instructional approach within Ghanaian educational contexts. The following recommendations for future research are proposed:

- This study focused exclusively on differential calculus through the flipped instructional model. Future studies could explore the application of this model in other aspects of calculus, such as limits and integral calculus.

- Furthermore, research could be expanded to incorporate a broader range of Colleges of Education, thereby providing a comprehensive understanding of how flipped instruction can enhance the performance of pre-service mathematics teachers in Ghana.

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APPENDICES

APPENDIX A: PRE-TEST AND POST-TEST ITEMS

Calculus Achievement Test

Dear student**,**

I am an MPhil Mathematics Education Student of the University of Education, Winneba. I am conducting a research study to enable me write my thesis. Kindly answer the questions as accurately as possible.

The answers are for educational purpose and are in no way meant for individual or personal assessment. Your answers will be treated as strictly confidential.

Thank you for your co-operation.

Name of College…………………………………………………………………..…

Student number……………………………………………………………………

Level…………………………………………………………..

Male [ ] Female [ ] Tick appropriately

<u>Directions</u>

Do **not** open this test booklet until you are told to do so.

This test is made up of **10** questions. **Attempt all the questions**.

The test will last for **two and half hours**, take your time and answer all the questions to the best of your ability. Good Luck.

1. Obtain from the first principle the derivative of $3x^2 + 2x - 4$

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2. Express $f(x) = \frac{5x^2+3}{x^2-2}$ $in\ the\ form\ A + \frac{B}{x^2-2}$ and hence find the limiting value of $f(x)$ as x approaches infinity.

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3. Find $\frac{dy}{dx}$ $at\ (1,6)\ of\ 2x^2 + xy - 3y^2 = 9$.

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4. If the volume of a sphere is growing at the rate of $24cm^3/s$ when the radius is $6cm$. Find the rate of increase of the radius at that time.

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5. Find the equation of the tangent and that of the normal to the curve $y = x^3 - 2x^2 + 3x - 3$ at the point (2,3).

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6. Differentiate the following with respect to x.

(a) $\sqrt{(2x-1)^3}$

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(b) sin^3x

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7. If $y = \frac{ax+b}{x^2}$, where a and b are constants, show that $x^2\frac{d^2y}{dx^2} + 4x\frac{dy}{dx} + 2y = 0$.

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8. Differentiate from the first principle with respect to x, $the\ function\ \ y = \sqrt{x}$.

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9. Determine the nature of the of the turning points of the following functions:

$(i)\ y = 2x^2 - 8x + 10$

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$(ii)\ y = x^3 - 6x^2 + 12 - 5$

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10. A particle moves in a straight line in such a way that its distance $s\ metres$, from a fixed point 0 after time $t\ seconds$ is given by $s = 2t^3 - 9t^2 + 12t + 3$. Find

(c) Its velocity after 3 seconds

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(d) When and where the particle is momentarily at rest.

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(e) Its acceleration after 2 seconds.

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APPENDIX B: MARKING SCHEME

Calculus Achievement Test

No	Details	Mark
Q1	Let $f(x) = 3x^2 + 2x - 4$	M1
	$f(x+h) = 3(x+h)^2 + 2(x+h) - 4$	M1
	$= 3(x^2 + 2xh + h^2) + 2x + 2h - 4$	M1
	$= 3x^2 + 6xh + 3h^2 + 2x + 2h - 4$	M1
	$f(x+h) - f(x) = 3x^2 + 6xh + 3h^2 + 2x + 2h - 4 - (3x^2 + 2x - 4)$	M1
	$= 3x^2 + 6xh + 3h^2 + 2x + 2h - 4 - 3x^2 - 2x + 4$	M1
	$= 6xh + 3h^2 + 2h$	M1
	$\frac{f(x+h) - f(x)}{h} = \frac{h(6x + 3h + 2)}{h}$	M1
	$= 6x + 3h + 2$	
	$\lim_{h\to 0} \frac{f(x+h) - f(x)}{h} = \lim_{h\to 0} 6x + 3h + 2$	
	$= 6x + 2$	
	$Thus\ f^1(x) = 6x + 2$	A2 [10 $\boldsymbol{Marks}$]
Q2	$\frac{5x^2 + 3}{x^2 - 2} = 5 + \frac{13}{x^2 - 2}$	M2 for $5 + \frac{13}{x^2-2}$

	$\lim_{x\to\infty} \frac{5x^2+3}{x^2-2} = \lim_{x\to\infty} 5 + \frac{13}{\infty^2-2}$	**M1 for** $\lim_{x\to\infty} 5 + \frac{13}{\infty^2-2}$
	$= 5 + \frac{13}{\infty}$	**M1 for** $5 + \frac{13}{\infty}$
	$= 5 + 0$	
	$= 5$	**A2 for limit = 5**
		[**6** ***Marks***]
Q3	$\frac{dy}{dx}\ at\ (1,6)\ of\ 2x^2 + xy - 3y^2 = 9.$	
	$4x + x\frac{dy}{dy} + y - 6y\frac{dy}{dx} = 0$	**M2 for differentiating**
	$4x + y + x\frac{dy}{dy} - 6y\frac{dy}{dx} = 0$	**M1 for grouping like terms**
	$x\frac{dy}{dy} - 6y\frac{dy}{dx} = -4x - y$	**M1 for simplifying**
	$\frac{dy}{dx}(x - 6y) = -4x - y$	**M1 factorizing**
	$\frac{dy}{dx} = \frac{-4x-y}{x-6y}$	**M1 for** $\frac{-4x-y}{x-6y}$

	$\frac{dy}{dx}$ $at\ (1,6) = \frac{-4(1)-6}{1-6(6)}$	**M1 for substituting**
	$= \frac{-10}{1-36}$	**M1 simplifying**
	$= \frac{-10}{-35}$	
	$= \frac{2}{7}$	**A2 for** $\frac{2}{7}$ [$\mathbf{10\ Marks}$]
Q4	Rate at which volume is increasing is given by $\frac{dv}{dt}$.	
	When the radius (r) is $6cm$, $\frac{dv}{dt} = 24cm^3/s$	
	We wish to find the rate of increase of radius, $\frac{dr}{dt}$.	**B2 for** $24cm^3/s$
	By the chain rule, $\frac{dr}{dt} = \frac{dr}{dv} \times \frac{dv}{dt}$	
	Volume(v) of a sphere $\frac{4}{3}\pi r^3 \Rightarrow \frac{dv}{dr} = 4r^2 \Rightarrow \frac{dr}{dv} = \frac{1}{4\pi r^2}$	**M1A1 for** $\frac{1}{4\pi r^2}$
	At the instant when $r = 6cm, \frac{dr}{dv} = \frac{1}{4\pi(6^2)} = \frac{1}{144\pi}$	**M1A1 for** $\frac{1}{144\pi}$
	Hence, when $r = 6cm$, $\frac{dr}{dt} = \frac{dr}{dv} \times \frac{dv}{dt}$	
	$= \frac{1}{144\pi} \times 24$	**M2 for** $\frac{1}{144\pi} \times 24$

	$= \frac{1}{6\pi} cm/s$	**A2 for $\frac{1}{6\pi} cm/s$** **[10 $Marks$]**
Q5	$y = x^3 - 2x^2 + 3x - 3$ $f'(x) = \frac{dy}{dx} = 3x^2 - 4x + 3$ The gradient of the tangent at the point (2,3) is $f'(2) = 3(2)^2 - 4(2) + 3 = 7$ The equation of the tangent at the point (2,3) is therefore given by $y - 3 = 7(x - 2)$ $y = 7x - 11$ The gradient of the normal at point (2,3) is $-\frac{1}{7}$ The equation of the normal at point (2,3) is given by $y - 3 = -\frac{1}{7}(x - 2)$ $\Rightarrow 7y - 21 = -x + 2$	**M2 for differentiating** **M1 A1 for** $f'(2) = 7$ **M1 for $y = 3 = 7(x - 2)$** **A1 for $y = 7x - 11$** **B1 for $-\frac{1}{7}$** **M1 for substitution**

	Hence, the equation of the normal is $7y + x - 23 = 0$	**M1 for multiplying through by 7** **A1 for $7y + x - 23 = 0$** **[10 *Marks*]**
Q6	$y = \sqrt{(2x-1)^3} \Rightarrow y = (2x-1)^{\frac{3}{2}}$ $Let\ u = 2x - 1 \Rightarrow y = u^{\frac{3}{2}}$ $\Rightarrow \frac{du}{dx} = 2$ $\frac{dy}{du} = \frac{3}{2}u^{\frac{1}{2}}$ $\frac{dy}{dx} = \frac{du}{dx} \times \frac{dy}{du} = 2 \times \frac{3}{2}u^{\frac{1}{2}}$ $= 3u^{\frac{1}{2}}$ But $u = 2x - 1$ $\therefore \frac{dy}{dx} = 3\sqrt{2x-1}$	M1A1 for $\frac{du}{dx} = 2$ M1A1 for $\frac{dy}{du} = \frac{3}{2}u^{\frac{1}{2}}$ M1 for $\frac{dy}{dx} = 2 \times \frac{3}{2}u^{\frac{1}{2}}$ A1 for $3\sqrt{2x-1}$
$(\boldsymbol{b})$	$y = sin^3x$ Let $u = sinx \Rightarrow y = u^3$	

	$\frac{du}{dx} = cosx$ $\frac{dy}{du} = 3u^2$ $\frac{dy}{dx} = \frac{du}{dx} \times \frac{dy}{du} = cosx.3sin^2x$ $\therefore \frac{dy}{dx} = 3sin^2xcosx$	M1 for $\frac{du}{dx} = cosx$ M1 for $\frac{dy}{du} = 3u^2$ M1 for $\frac{dy}{dx} =$ $cosx.3sin^2x$ A1 for $3sin^2xcosx$ [**10 *marks***]
7	$y = \frac{ax+b}{x^2} \Rightarrow yx^2 = ax + b$ Differentiating with respect to x, we have $y.2x + x^2\frac{dy}{dx} = a \Rightarrow 2xy + x^2\frac{dy}{dx} = a$ For the second derivative, we have $\left(2y + 2x\frac{dy}{dx}\right) + \left(x^2\frac{d^2y}{dx^2} + 2x\frac{dy}{dx}\right) = 0$ $x^2\frac{d^2y}{dx^2} + 2x\frac{dy}{dx} + 2x\frac{dy}{dx} + 2y = 0$ which gives	B1 for $yx^2 =$ $ax + b$ M3 for first derivative of all terms correct M3 for second derivative for all terms correct.

	$\therefore x^2\dfrac{d^2y}{dx^2} + 4x\dfrac{dy}{dx} + 2y = 0$	M1 for simplifying. A2 for the conclusion. [**10 *Marks***]
8	Given $f(x) = \sqrt{x}$ $f(x+h) = \sqrt{x+h}$ $f(x+h) - f(x) = \sqrt{x+h} - \sqrt{x}$ $\sqrt{x+h} - \sqrt{x} = \dfrac{(\sqrt{x+h} - \sqrt{x})(\sqrt{x+h} + \sqrt{x})}{\sqrt{x+h} + \sqrt{x}}$ $= \frac{x+h-x}{\sqrt{x+h}+\sqrt{x}}$ $= \frac{h}{\sqrt{x+h}+\sqrt{x}}$ $\dfrac{dy}{dx} = \dfrac{h}{\sqrt{x+h} + \sqrt{x}} \times \dfrac{1}{h}$ $= \frac{1}{\sqrt{x+h}+\sqrt{x}}$ $\dfrac{dy}{dx} = \lim_{h\to 0} \dfrac{1}{\sqrt{x+h} + \sqrt{x}} = \dfrac{1}{\sqrt{x+0} + \sqrt{x}}$ $= \dfrac{1}{\sqrt{x} + \sqrt{x}}$ $\therefore \dfrac{dy}{dx} = \dfrac{1}{2\sqrt{x}}$	M1 M1 M1 M1 M1 M1 M1 M1 M1 A1 for $\frac{1}{2\sqrt{x}}$ [**10 *Marks***]

	$(i)\ \ y = 2x^2 - 8x + 10$	
9	$\frac{dy}{dx} = 4x - 8$	M1 for differentiation
	At stationary point, $\frac{dy}{dx} = 0\ \Rightarrow 4x - 8 = 0$	
	$x = 2$	A1 for $x = 2$
	When $x = 2$, $\ y = 2(2)^2 - 8(2) + 10 = 2$	
	Meaning the stationary point is $(2,2)$	A1 for $y = 2$
	$\frac{d^2y}{dx^2} = 4$	
	Since $\frac{d^2y}{dx^2} > 0, it\ implies\ that\ (2,2)$ is minimum point.	M1 for second derivative = 4
	$(ii)\ y = x^3 - 6x^2 + 12x - 5$	
	$\frac{dy}{dx} = 3x^2 - 12 + 12$	A1 for concluding that point (2,2) is a minimum point.
	At stationary point, $\frac{dy}{dx} = 0$	
	$\Rightarrow 3x^2 - 12 + 12 = 0$	
	$\Rightarrow (x-2)(x-2) = 0, which\ gives\ x = 2$	
	When $x = 2$,	M1 for differentiating
	$y = 2^3 - 6(2)^2 + 12(2) - 5 = 3$	
	Thus, the stationary point is $(2,3)$	
	$\frac{d^2y}{dx^2} = 6x - 12$	A1 for $x = 2$
	When $x = 2$,	A1 for $y = 3$
	$\frac{d^2y}{dx^2} = 6(2) - 12 = 0$	

10	Since $\frac{d^2y}{dx^2} = 0$, it follows that the stationary point (2,3) is a point of inflexion. (a) given $s = 2t^3 - 9t^2 + 12t + 3$ The velocity $(v) = \frac{ds}{dt} = 6t^2 - 18t + 12$ When $t = 3\ sec$ $v = 6(3)^2 - 18(3) + 12$ $= 12m/s$ (b)The particle comes to rest momentarily when $v = 0$ Thus, $6t^2 - 18t + 12 = 0 \Rightarrow t^2 - 3t + 2 = 0$ $\Rightarrow (t-1)(t-2) = 0$ $t = 1\ or\ t = 2$ Hence, at $t = 1$ sec $and\ t = 2\ sec$ after the projection the particle came to rest momentarily. $s = 2t^3 - 9t^2 + 12t + 3$ When $t = 1\ sec.,\ s = 2(1)^3 - 9(1)^2 + 12(1) + 3 = 8m$ When $t = 2\ sec., s = 2(2)^3 - 9(2)^2 + 12(2) + 3 = 7m$	M1 for second derivative A1 for concluding that the stationary point (2,3) is a point of inflexion. $[\mathbf{10}\ \boldsymbol{Marks}]$ M1 for differentiating at least one term correct. A1 for $6t^2 - 18t + 12$ M1 for substituting 3 A1 for $v = 12m/s$ M1 for $(t-1)(t-2) = 0$

	Hence, the particle came to rest momentarily after travelling	
	$7m\ and\ 8m\ from\ the\ point\ O\ of\ projection.$	A2 for $t = 1, 2$
	(c) the acceleration $a = \frac{dv}{dt} = 12t - 18$	M1 for substituting 1
	When $t = 2$,	A1 for $s = 8m$
	$a = 12(2) - 18$	M1 for substituting 2
	$= 6m/s^2$	A1 for $s = 7m$
		M1 for differentiating
		M1 for substituting 2
		A1 for $a = 6m/s^2$
		[**14** ***Marks***]

APPENDIX C: LESSON PLANS

LESSON PLAN 1

SUBJECT: Calculus

Topic: Differentiation from first principles

Duration: 120 minutes

Target group: CE level 300

Researcher: Stephen Gnintan Lakapi

- **Teaching and Learning Materials:**

Graph board, mathematical sets, papers, laptop and projector (for tutor) for displaying diagrams

- **Relevant Previous Knowledge**

Pre-service teachers are familiar with the concept of gradient and can find gradient of straight lines.

- **Teaching and Learning Objectives**

By the end of the lesson, the pre-service teacher will be able to:

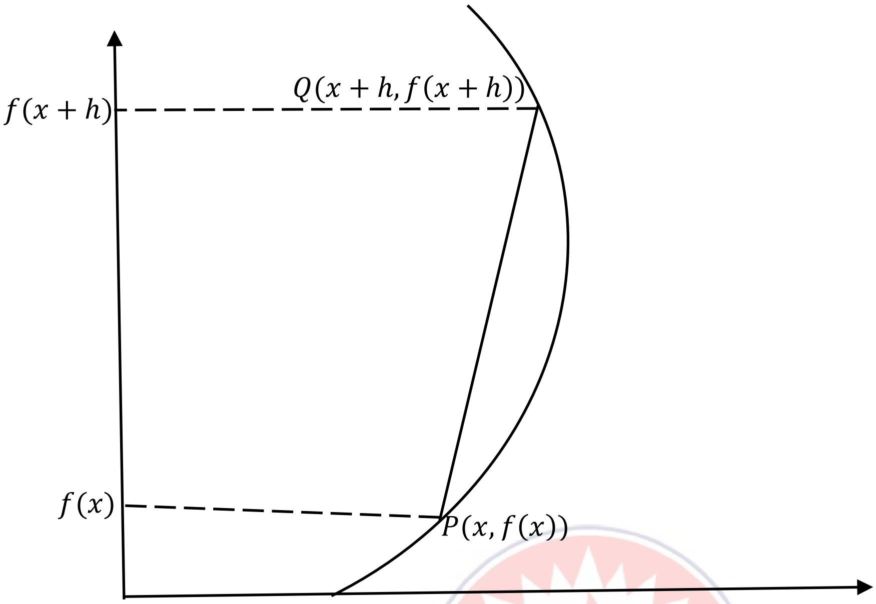
- Find from first principles the derivative of at least, three given curves (functions).

Introduction: Tutor begins the lesson by revising pre-service teachers RPK by asking them to find the gradient of a straight line that passes through points A(7,7) and B(9, 11). Ans: 2

- **Teaching and Learning Activities**

ACTIVITY 1

Tutor sketches a curve on the graph board and guides pre-service teachers to deduce the gradient function from it as shown below.



The gradient of line $PQ = \frac{f(x+h)-f(x)}{h}$, where h is the change in x.

The limiting value of $\frac{f(x+h)-f(x)}{h}$ as h approaches zero is denoted by $\frac{dy}{dx}$. Thus,

$$\frac{dy}{dx} = \lim_{h \to 0} \frac{\Delta y}{\Delta x} = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

$\frac{dy}{dx}$ is called the gradient function of the curve $y = f(x)$. The functional notation of $\frac{dy}{dx}$ is $f'(x)$. This means that $\frac{dy}{dx}$ is the same as $f'(x)$ and is also called the derivative or differential coefficient.

ACTIVITY 2

Tutor guides pre-service teachers through the steps in finding derivatives of functions from first principles.

There are four steps to follow when finding the derivative of functions from first principles. These are:

1. Form $f(x+h)$
2. Form $f(x+h)-f(x)$
3. Divide by h to obtain the gradient of the chord, that is $\frac{dy}{dx}=\frac{f(x+h)-f(x)}{h}$
4. Find the limit of this gradient as h tends to zero, that is $\lim_{h\to 0}\frac{\Delta y}{\Delta x}$

ACTIVITY 3

Tutor guides pre-service teachers in smaller groups to use the steps identified to solve some give examples.

Examples 1. Find from first principles the derivative of $f: x \to (x+2)^2$

SOLUTION

Given $f(\boldsymbol{x}) = (x+2)^2$

$f(x+h) = (x+h+2)^2$

$$f(x+h)-f(x) = \{(x+2)+h\}^2-(x+2)^2$$

$$= \{(x+2)^2+2(x+2)h+h^2\} - (x+2)^2$$

$$= 2(x+2)h+h^2$$

$$\frac{dy}{dx} = \frac{f(x+h)-f(x)}{h} = \frac{2(x+2)h+h^2}{h} = 2(x+2)+h$$

$$\frac{dy}{dx} = \lim_{h\to 0} 2(x+2)+h = 2(x+2)+0$$

$$\therefore \frac{dy}{dx} = 2(x+2)$$

Example 2: Find, from the first principles, the derivative of $f(x) = \sqrt{x}$

SOLUTION

Given $f(x) = \sqrt{x}$

$f(x+h) = \sqrt{x+h}$

$f(x+h) - f(x) = \sqrt{x+h} - \sqrt{x}$

$$\sqrt{x+h} - \sqrt{x} = \frac{(\sqrt{x+h} - \sqrt{x})(\sqrt{x+h} + \sqrt{x})}{\sqrt{x+h} + \sqrt{x}}$$

$$= \frac{x+h-x}{\sqrt{x+h}+\sqrt{x}}$$

$$= \frac{h}{\sqrt{x+h}+\sqrt{x}}$$

$$\frac{dy}{dx} = \frac{h}{\sqrt{x+h} + \sqrt{x}} \times \frac{1}{h}$$

$$= \frac{1}{\sqrt{x+h}+\sqrt{x}}$$

$$\frac{dy}{dx} = \lim_{h\to 0} \frac{1}{\sqrt{x+h} + \sqrt{x}} = \frac{1}{\sqrt{x+0} + \sqrt{x}}$$

$$= \frac{1}{\sqrt{x} + \sqrt{x}}$$

$$\therefore \frac{dy}{dx} = \frac{1}{2\sqrt{x}}$$

CONCLUSION

Tutor ends the lesson by inviting pre-service teachers to summarize the salient points learnt. Tutor gives students assignment and encourages them to do with it all urgency.

ASSIGNMENT

Find from the first principles the derivative of:

(b) $\frac{1}{x}$ (b) x^3 (c) $(x+3)^2$ (d) $2x^2 + \frac{3}{x}$ (e) $(3x^4 + x^3)$

Video for Lesson 1

LESSON PLAN 2

SUBJECT: Calculus

Topic: Rules of differentiation

Sub-Topic(s): Product, quotient and chain Rule

Duration: 120 minutes

Target group: CE level 300

Researcher: Stephen Gnintan Lakapi

- **Teaching and Learning Materials:**

Mathematical sets, papers.

- **Relevant Previous Knowledge**

Pre-service teachers can find derivative of functions from first principles.

- **Teaching and Learning Objectives**

By the end of the lesson, the pre-service teacher will be able to:

- Apply the various rules of differentiation to find derivatives of some given functions.

Introduction: Tutor begins the lesson by revising pre-service teachers RPK by asking them to find derivative of $y = x^2$ from the first principles.

- **Teaching and Learning Activities**

ACTIVITY 1

Tutor guides pre-service teachers to apply the product rule to obtain the first derivative of some functions.

Differentiation of a product: The product rule of differentiation states that the derivative of the product of two functions is equal to the second function multiplied by the derivative of the first, plus the first function multiplied by the derivative of the second. Thus:

If $y = uv$, where u and v are functions of $x, then$

$$\frac{dy}{dx} = v\frac{du}{dx} + u\frac{dv}{dx} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Example 1: Obtain the first derivative of $y = (2x + x^2)(3x + x^3)$

Solution

$y = (2x + x^2)(3x + x^3)$

Let $u = 2x + x^2 \Rightarrow \frac{du}{dx} = 2 + 2x$

$v = 3x + x^3 \Rightarrow \frac{dv}{dx} = 3 + 3x^2$

$\frac{dy}{dx} = (3x + x^3)(2 + 2x) + (2x + x^2)(3 + 3x^2)$

$= 6x + 6x^2 + 2x^3 + 2x^4 + 6x + 6x^3 + 3x^2 + 3x^4$

$= 5x^4 + 8x^3 + 9x^2 + 12x$

ACTIVITY 2

Tutor guides pre-service teachers to apply the quotient rule to obtain the first derivative of some functions.

Differentiation of a quotient: The product rule of differentiation states that the derivative of the quotient of two functions is equal to the denominator multiplied by the derivative of the numerator, minus the numerator multiplied by the derivative of the denominator, all divided by the square of the denominator. Thus:

Suppose $y = \frac{u}{v}$ where u and v are functions of x and $v \neq 0, then$
$\frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$.. (2)

Example 2: find $\frac{dy}{dx}$ if $y = \frac{3x^4}{x^2-1}$

Solution

Given $y = \frac{3x^4}{x^2-1}$

$u = 3x^4 \Rightarrow \frac{du}{dx} = 12x^3$ and $v = x^2 - 1 \Rightarrow \frac{dv}{dx} = 2x$

$$\frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2} = \frac{(x^2-1)(12x^3) - 3x^4(2x)}{(x^2-1)^2}$$

$$= \frac{12x^5 - 12x^3 - 6x^5}{(x^2-1)^2}$$

$$\therefore \frac{dy}{dx} = \frac{6x^5 - 12x^3}{(x^2-1)^2}$$

ACTIVITY 3

Tutor guides students to use the chain rule to differentiate functions with respect to x.

The **Chain rule** is for differentiation of a composite function, that is function of a function. According to the chain rule, $\frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx}$.

Example 3: differentiate $\sqrt{3x+2}$ with respect to x.

Solution

Let $y = \sqrt{3x+2} = (3x+2)^{\frac{1}{2}}$

If $u = 3x + 2$ then $y = u^{\frac{1}{2}}$. Thus, $\frac{du}{dx} = 3$ and $\frac{dy}{dx} = \frac{1}{2}u^{-\frac{1}{2}}$

$$\frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx} = \frac{1}{2}u^{-\frac{1}{2}} \times 3 = \frac{3}{2}u^{-\frac{1}{2}}$$

$$= \frac{3}{2}(3x+2)^{-\frac{1}{2}}$$

$$= \frac{3}{2(3x+2)^{\frac{1}{2}}}$$

$$\therefore \frac{dy}{dx} = \frac{3}{2\sqrt{3x+2}}$$

CONCLUSION

Tutor ends the lesson by inviting pre-service teachers to summarize the salient points learnt. Tutor gives students assignment and encourages them to do it with all urgency.

ASSIGNMENT

Find with respect to x the derivative of the following functions:

1. $y = (3x^4 + 4x^2)(x^2 - 1)$ 2. $y = (x^4 + 3)^7$ 3. $y = \left(\sqrt{2x^3 - 5}\right)^3$

4. $\frac{x-1}{x+1}$ 5. $\frac{1-x^2}{1+x^2}$ 6. $\frac{2x+3}{(x+3)^2}$

Video for Lesson 2

LESSON PLAN 3

SUBJECT: Calculus

Topic: Differentiation of implicit functions

Duration: 120 minutes

Target group: CE level 300

Researcher: Stephen Gnintan Lakapi

- **Teaching and Learning Materials:**

  Mathematical sets, papers

- **Relevant Previous Knowledge**

Pre-service teachers can apply the various rules of differentiation to find first derivative of functions

- **Teaching and Learning Objectives**

By the end of the lesson, the pre-service teacher will be able to:

- Find derivatives of implicit functions.

Introduction: Tutor begins the lesson by revising pre-service teachers RPK by asking them to find the first derivative of $y = \sqrt{4x^2 - 7}$

Teaching and Learning Activities

ACTIVITY 1

Tutor guides pre-service teachers to identify implicit functions.

Implicit functions are not given directly on explicitly. Examples are $x^2y - 3x = 2$ and $y = 5x^2y$.

ACTIVITY 2

Tutor guides pre-service teachers to differentiate some implicit functions.

Example: Given that $x^4 + y^4 = 2x$, find $\frac{dy}{dx}$

Solution

$$4x^3 + 4y^3\frac{dy}{dx} = 2$$

$$4y^3\frac{dy}{dx} = 2 - \ 4x^3$$

$$\frac{dy}{dx} = \frac{2 - \ 4x^3}{4y^3}$$

Example 2. If $x^2 + y^2 = 2pxy$, differentiate each term with respect to x.

Solution

$$2x + 2y\frac{dy}{dx} = 2p\left(y(1) + x\frac{dy}{dx}\right)$$

$$2x + 2y\frac{dy}{dx} = 2py + 2px\frac{dy}{dx}$$

Divide through by 2.

$$x + y\frac{dy}{dx} = py + px\frac{dy}{dx}$$

$$y\frac{dy}{dx} - px\frac{dy}{dx} = py - x$$

$$\frac{dy}{dx}(y - px) = py - x$$

$$\frac{dy}{dx} = \frac{py - x}{y - px}$$

CONCLUSION

Tutor ends the lesson by inviting pre-service teachers to summarize the salient points learnt. Tutor gives students assignment and encourages them to do it with all urgency.

ASSIGNMENT

6. If $y^2 + x^2 = 2pxy$, where p is a constant, find $\frac{dy}{dx}$
7. $(1 + x^2)(1 + y^2) - px^2$, where p is a constant, show that $xy(1 + x^2)\frac{dy}{dx} = (1 + y^2)$
8. $x^2 + y^2 = ay(1 + x^2)$, where a is a constant, find $\frac{dy}{dx}$
9. Find the derivative of $x^3 + 4xy^2 - 7 = y^3$
10. Find the slope of the tangent to the circle $x^2 + y^2 = 4$

Video for Lesson 3

LESSON PLAN 4

SUBJECT: Calculus

Topic: Application of differentiation

Sub-Topic: Linear Kinematics

Duration: 120 minutes

Target group: CE level 300

Researcher: Stephen Gnintan Lakapi

- **Teaching and Learning Materials:**

  Mathematical sets, papers

- **Relevant Previous Knowledge**

Pre-service teachers can differentiate functions appropriately.

- **Teaching and Learning Objectives**

By the end of the lesson, the pre-service teacher will be able to:

- Solve at least two problems involving linear kinematics.

Introduction: Tutor begins the lesson by revising pre-service teachers RPK by asking them to find the first derivative of $y = \sqrt{4x^2 - 7}$

Teaching and Learning Activities

ACTIVITY 1

Tutor guides pre-service teachers to explain the key concepts under linear kinematics, thus, displacement, velocity and acceleration.

Kinematics is the study of the position of a moving object, and how it changes.

Linear kinematics refers to the study of motions in a straight line without the consideration of the nature of the forces acting or the laws of motion.

Displacement: is distance covered by a moving object in a specific direction. The displacement (s) can be expressed as a function of time (t), that is $s = f(t)$.

Velocity (v) of a moving particle is the rate of change of displacement with respect to time. It is speed of a particle in a specific direction. It therefore follows that when you differentiate distance with respect to time, you obtain velocity. Thus, $v = \frac{ds}{dt}$

Acceleration (a) of a moving particle is the rate of change of velocity (v) with respect to time (t). It therefore follows that when you differentiate velocity with respect to time, you obtain acceleration. Thus, $a = \frac{dv}{dt}$ $or\ a = \frac{d^2s}{dt^2}$

ACTIVITY 2

Tutor guides pre-service teachers to solve problems on linear kinematics.

Example 1: An object is thrown into the air such that its height $h\ metres$, after time t seconds is given by $h = 36t - 4t^2$. Find:

(a) The velocity at time $t = 0$

(b) The time taken to reach the maximum height.

Solution

(*a*) Given $h = 36t - 4t^2$

The velocity $(v) = \frac{dh}{dt} = 36 - 8t$

When $t = 0,\ v = 36 - 8(0) = 36m/s$

(b) at maximum height, $v = 0$

Thus, $36 - 8t = 0$ which give $t = 4.5\ seconds$

The time taken to reach the maximum height is $4.5s$

The maximum height $36(4.5) - 8(4.5)^2 = 81m$

Example 2: A ball is thrown vertically upwards. Its height $(h\ m)$ above the ground at time t seconds is given by $h = 32t - 8t^2$. Find

(a) The velocity of the ball at $t = 1$

(b) The maximum height reached

Solution

(a) Given $h = 32t - 8t^2$

The velocity $(v) = \frac{dh}{dt} = 32 - 16t$

When $t = 1,\ v = 32 - 16(1) = 16m/s$

(b) at maximum height, $v = 0$

Thus, $32 - 16t = 0$ which give $t = 2\ seconds$

The time taken to reach the maximum height is $2s$

The maximum height $32(2) - 8(2)^2 = 32m$

CONCLUSION

Tutor ends the lesson by inviting pre-service teachers to summarize the salient points learnt. Tutor gives students assignment and encourages them to do it with all seriousness.

ASSIGNMENT

5. A particle moves in a straight line in such a way that its distance $s\ cm$ from a fixed point 0 after time t seconds is given by $s = t^3 - 15t^2 + 63t - 40$. Calculate

(f) the distance from 0 when the particle is momentarily at rest.

(g) Its velocity when acceleration is zero.

6. A particle moves in a straight line such that its distance $s\ metres$ from a fixed point 0 after time t seconds is given by $s = \frac{2}{3}t^3 - 4t^2 + 6t + \frac{1}{3}$. Calculate

(g) Its velocity after 4 seconds

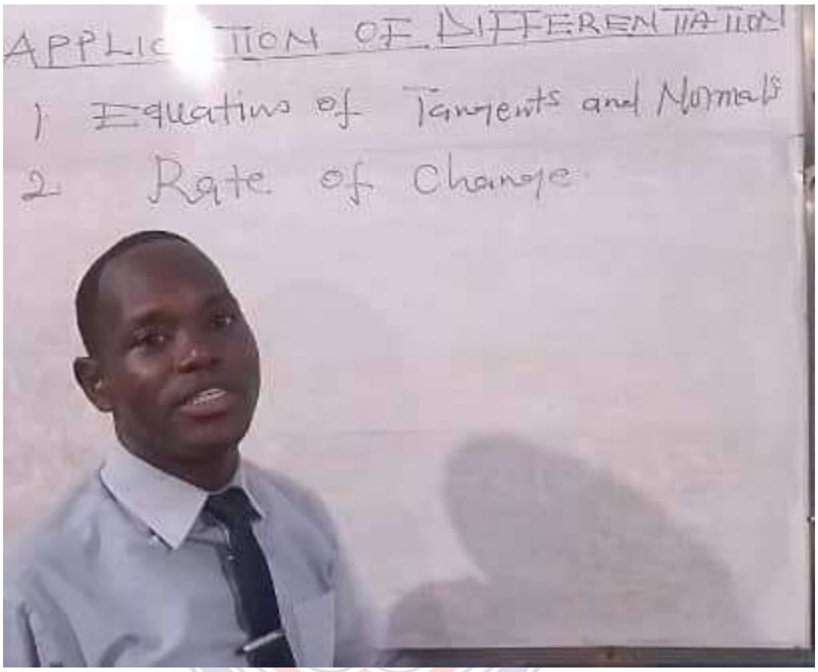
(h) The time when the particle is momentarily at rest.

(i) The distance travelled by the particle at that time.

7. The tangent to the curve $y = x^3 - x^2 + 1$ at p passes through the points $(1, -3)\ and\ (3, 13)$. Find the possible coordinates of p.

8. Determine the nature of the turning point of $y = (x - 1)(x + 2)^2$

Video for Lesson 4



APPENDIX D: INTERVIEW QUESTIONS

1. How well did your teachers teach areas of the syllabus concerning differential calculus?

    (a) Partially Taught [ ] (b) Adequately Taught [ ] (c) Never Taught [ ]

2. How often were teaching learning materials employed by your teachers in the course of teaching of calculus?

    (a) Always [ ]   (b) Sometimes [ ]   (c) Never [ ]

3. Did textbooks available to you contain enough activities that consolidated your understanding of calculus concepts?

    (a) Yes [ ]   No [ ]

4. In your view how would you describe the teaching approach adopted by your teachers mainly in the teaching of differential calculus?

    ....

5. Were assignments/quizzes given by your teachers enough to consolidate the various concepts on differential Calculus?

    (a) Average [ ]   (b) Adequate [ ]   (C) Not Adequate [ ]

APPENDIX E: INTRODUCTORY LETTER

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF MATHEMATICS EDUCATION
P. O. Box 25, Winneba, Ghana
math@uew.edu.gh
+233 (020) 2041076

5th June, 2023

Dear Sir/Madam,

LETTER OF INTRODUCTION: STEPHEN GNINTAN LAKAPI (220028278)

I write to introduce to you the bearer of this letter, Mr. Stephen Lakapi, a postgraduate student in the University of Education, Winneba. He is reading for a Master of Philosophy degree in Mathematics Education and as part of the requirements of the programme, he is undertaking a research titled – ***The Effect Of Flipped Instruction On Motivation And Academic Achievement of Pre-Service Teachers In Calculus.***

He needs to gather information to be analysed for the said research and he has chosen to do so in your institution. I would be grateful if he is given the needed assistance to carry out this exercise.

Thank you.

Yours faithfully,

DEPARTMENT OF MATHEMATICS EDUCATION
UNIVERSITY OF EDUCATION
WINNEBA

Dr. Sylvester Ali Frimpong
Graduate Coordinator

APPENDIX F: PERMISSION FOR DATA COLLECTION

PRESBYTERIAN COLLEGE OF EDUCATION
AKROPONG AKUAPEM
(FOUNDED 1848)

P. O Box 27,
Akropong-Akuapem
Ghana, West Africa.

Email: info@pceakropong.edu.gh
Website: www.pceakropong.edu.gh
Tel: +233 (0) 553970432
Bankers: GCB Bank Akropong-Akuapem

Our Ref: ……………………
Your Ref: …………………..

Date: 20th June, 2023

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF SCIENCE EDUCATION, DEPARTMENT OF MATHEMATICS
P.O.BOX 25
WINNEBA

Dear Sir,

COLLECTION OF DATA FOR RESEARCH

I write in response to your letter dated 5th June, 2023 on the above subject.

Having studied the content of the letter. We are pleased to inform you that your request has been upheld.

Kindly contact the head of Mathematics and Information Communication and Technology Development for any assistance that you may require.

Wishing you success in your endeavor.

Yours faithfully,

VICE PRINCIPAL
PRESBYTERIAN COLLEGE OF EDU
AKROPONG-AKUAPEM

VIVIENNE OCRAN

AG. VICE PRINCIPAL