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The Impact of Experiential Learning Methodology on Students' Conceptual Knowledge in Calculus

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ABSTRACT

This study aims to find out the impact of experiential learning on students' conceptual knowledge in Calculus of Senior High School (S.H.S) two students in Ghana. Conceptual understanding of calculus is crucial in the fields of applied sciences, business, and engineering and technology subjects. However, the current position of students understanding of limit of functions and derivatives indicates that students possess only procedural knowledge developed from rote learning of procedures in calculus without insight of core concepts. Hence, the researcher used quasi-experimental design involving two sample groups: experiment and control group to determine the effectiveness of experiential learning in promoting student's conceptual knowledge.

The sampling technique was purposive involving 67 students from SHS two students of Krobo Community Day SHS in Techiman North District of Ghana in the academic year of 2022/2023. The instrument used in this research was multiple choice test consisting of 25 questions.

The data analysis in this research used independent sample t-test to examine the research question. The results of the study show t(df) = -6.657, p= 0.000 which is less than $\alpha = 0.05$ which means that there is a significant difference between the experimental and control group, implies experiential learning methodology in Mathematics is effective to improve the students' conceptual knowledge in calculus in the experimental group. Recommendations include adoption of experiential learning method by mathematics teachers as an effective teaching pedagogy and Planners of mathematics curriculum and all other subjects' curriculum should include experiential learning techniques. This will make learners develop positive attitude towards the study of mathematics.

Keywords: Experiential learning, conceptual knowledge, calculus, procedural knowledge.

1. INTRODUCTION

Mathematics is the foundation of all scientific investigations and all human development activities (Kurumeh, 2006). Mathematics is critical to the growth of individuals and countries because it contributes meaningfully to the scientific and technological development of nations. Any country seeking to advance in science and technology must prioritize mathematics. Mathematics education research has been growing quickly over the past three decades (Kilpatrick, 1992).

Researchers have been focusing on understanding the nature of mathematical reasoning, teaching, and learning which will improve mathematics teaching. In the last two decades, there has been extensive research in the teaching and learning of undergraduate mathematics, topics such as functions (Stewart 2015), and topics from post-calculus (Zazkis, 1996).

Experiential learning theory defines learning as the process whereby knowledge is created through the transformation of experience (Kolb, 1984).

Experiential learning stimulates the students in their activities to think, explore, ask, make decision, and apply what they have learned. Experiential learning is designed to give a comprehensive learning experience (Llewellyn & frame, 2012).

Experiential learning theory defines learning as a process consisting of four steps. According to Kolb, students should experience four phases of learning when learning a topic. Experiential learning cycle should be structured from concrete experiencing to observation and then from abstract conceptualization to active experimentation (Kolb, 1984). Concrete experiences are turned into abstract concepts within this process and these concepts are used in attaining new experiences.

Calculus is a discipline of mathematics that arose from the necessity for continuous change in quantities. It is concerned with the infinitely small and indefinitely large quantities of a function (Muzangwa & Chifamba, 2012). Most undergraduate programs in science, technology, and engineering require calculus theory. Calculus conceptual understanding among students has an impact on their performance and engagement in other academic areas as well as in mathematics. Calculus was first taught in high schools thanks to the development of the calculus teaching advance program, which started in the United States and eventually spread to every country in the world.

Calculus is currently included in the high school curriculum in a number of nations. For instance, the studies conducted by Brijlall and Ndlovu (2013), Etin (2009), and Idris (2009), respectively, indicated South Africa, Turkey, and Malaysia. One of the goals of the reform was to give students the opportunity to comprehend basic supporting concepts and adequately prepare them for advanced levels (Engelbrecht et al 2005).

Contrary to the objective, theoretical and empirical analysis revealed that students' learning is procedural and devoid of conceptual knowledge (Bezuidenhout, 2001; Brijlall and Ndlovu, 2013; Ferrini-Mundy and Gaudard, 1992; Idris, 2009; Juter, 2006; Kinley, 2016; Muzangwa & Chifamba, 2012).

According to the constructivist theory of knowledge construction, students' capacity to conceptualize ideas and create mental pictures is a significant contributor to their conceptual knowledge (Aspinwell & Shaw, 2002). It is well documented that the traditional method of calculus is ineffective in dwindling the challenges and delusions. Many educational theorists and philosophers have recently produced a number of ideas and models centred on students' learning processes. This is done to provide an effective alternative to the traditional, theoretical, and didactic teaching approaches that were formerly the standard in educational institutions.

2. STATEMENT OF THE PROBLEM

Calculus conceptual understanding is essential in the disciplines of applied sciences, business, engineering, and technology. However, the current state of students understanding of limit of functions and derivatives demonstrates lack of conceptual understanding and merely have procedural knowledge from memorizing calculus operations. (Aspinwall & Miller, 2001). To increase the small number of aspiring scientists, technicians, mathematicians, and engineers, conceptual calculus proficiency is crucial. (Sadler & Sonnert, 2016). Furthermore, Herbert (2013), Idris (2009), and Naidoo and Naidoo (2007) have established a variety of teaching approaches, many of which are computer-integrated. Despite these attempts, the difficulties of teaching calculus remain, and student performance falls below expectations. Additionally, there hasn't been a lot of study done on using experiential learning to increase students' conceptual understanding in calculus. Therefore, the problem of this study is to find out the impact of experiential learning methods on the conceptual knowledge of students in calculus concepts.

3. LITERATURE REVIEW.

3.1 Historical Review of Experiential Learning

From a historical perspective, it is crucial to keep in mind that Socrates' instruction methods, which employed inquiry approaches, might be considered the first justifications of experiential education (Chesters, 2012). However, it is generally acknowledged that Hann's "Outward Bound" school during the Second World War and Dewey's "learning by doing" attitude might be called principles (Roberts, 2005). Education is a process of living, not a preparation for future life, according to Dewey (1897). But Hann felt that school should prepare pupils not just for higher education but also for life experiences. As a result, he used educational approaches to instil self-assurance, cooperation, and determination in his students (Stetson, 1941).

John Dewey was among the pioneer thinkers to accentuate realism in education in the 1930s. Dewey saw the official curriculum as domineering, with input from a small group of scholars. He thought that applied and diverse experiences better prepared learners for life by learning through various activities, which was more useful than traditional formal curriculum (Dewey, 1986, 1997). Maria Montessori believed that education is gained "not by listening to words but by experiencing the environment" (Saha&Adhikari, 2023).

Kurt Lewin's study of group dynamics, directed in the middle of the 1940s, was a further foreshadowing of conventional experiential learning since it involved more individuals and had a broader range of influence (Marrow, 1977). Lewin's work on organizational behaviour in group settings and action research, on the other hand, concentrated on a relative study of the conditions and penalties of various forms of societal action as well as research leading to social action. While most of Lewin's work centred on leadership and management styles, this was not the case for his work on action research. This served as the basis for conventional experiential learning as defined by the cycle of action, reflection, analysis, and assessment (Jowdy et al., 2004; Kolb & Kolb, 2009).

A significant chunk of Dewey and Lewin's theoretical foundation for experiential learning was laid by the work of developmental psychologist Jean Piaget in the first half of the 20th century. The theories of Piaget describe how experience shapes intelligence and links to cognitive development (Jowdy et al., 2004; Kolb, 1984). He held that assimilation, accommodation, and equilibrium were vital steps in the process of intellectual growth and that intelligence was the result of interactions between people and their environment (Jowdy et al., 2004; Piaget, 1952). According to Piaget's views, learning is personalized and self-motivated (Jowdy et al., 2004); hence, activity-based discovery learning is preferred to teacher-centred teaching.

Kelly developed the Personal Construct Theory in the middle of the 1950s, which suggested that people had the freedom to ascribe any meaning they want to events in the world (Kelly, 1991). To be more specific, people must:

- Decide what they want to do
- Commit to the selected action
- Deal with various circumstances during the action
- Decide whether the action is right for them personally
- Assess and make changes as needed. Current experiential learning theory has its roots in this process of creating a personal construct.

Through Kolb's (1984) experiential theory has been assimilated into the teaching process. Kolb created the model based on studies in psychology, philosophy, and physiology and the underlying principles of the learning process. The model unambiguously focuses on grown-up development theories, a typology of personal learning inclinations, and associated knowledge structures from assorted academic fields and occupations.

Applications of this developmental strategy served as the basis for the experiential learning theory, which is applied to education, the workplace, and lifetime learning. According to (Jowdy et al. (2004), it is a multifaceted partnership that involves concrete experience, action, observation, reflections, analysis leading to the creation of abstract notions, and testing novel scenarios. According to Hayes, Sauder, and Mudrick (2018), Sattler (2018), Kolb & Kolb (2009), and Kolb & Kolb (2017), this relationship demonstrates that the learning cycle can begin at any of the circular sites and that it should be viewed as a continuous spiral. Joplin (1981) further classified experiential learning into five phases by developing the four-stage experiential learning paradigm. The five phases are as follows: The focus stage comes first and provides a general overview of the educational objective. The situation in which the student must solve the problem is challenging.

Stage two is the stage where action is demanded. The support and feedback phases that follow provide the student with instructions and details about their activities and what they will do going forward. Debriefing, the final step, allows for the assessment of information that might enhance the recurring cycle. Facilitators and the appropriate activity design are crucial elements of this cycle in order to attain the highest levels of learning and skill development (Joplin, 1981; Newman et al., 2017).

The phases of the experiential learning model (Kolb, 1984) are concrete experience reflective observation, abstract conceptualization and active experimentation. Learners need particular occasions, examples, and the opportunity to participate in events throughout the phase of the concrete experience as s a result, lesson should be applicable to daily life, and role-playing exercises and sample case analyses should be appropriate for the learning approach (Kolb, 1984).

Reflecting on what has been learnt and observed is essential in the learning situation known as reflective observation. This stage involves reflecting on ideas and viewpoints related to the subject, challenging how the facts actually happen, and making choices (Kolb, 1984). Reflective observation should be regarded as the stage in which numerous circumstances that arise during the concrete experience phase are assessed and possible issues are sought for.

During the abstract conceptualization phase, logic, cognition, and concepts are prioritized as opposed to learning from real experiences. The theoretical understanding of the subject must be delivered in a certain manner throughout this phase. In this regard, the teacher's summary and explanations are appropriate (Healey & Jenkins 2000; Kolb, 1984). Students would have the opportunity to implement what they have learned during the active experimentation phase. Participating is becoming more important than watching and listening. According to (Hein & Budny, 2000; Klç, 2002; Kolb, 1984), students who choose this kind of instruction appreciate applying what they have learned. In summary, during the first stage of the learning cycle, students engage with the subjects in real-world settings. Within a questioning framework, the second phase entails gaining various views on the experiences learned. At the third phase, students understand the logical structure of what they learnt through their experiences. The final phase of the learning cycle is the active experimentation.

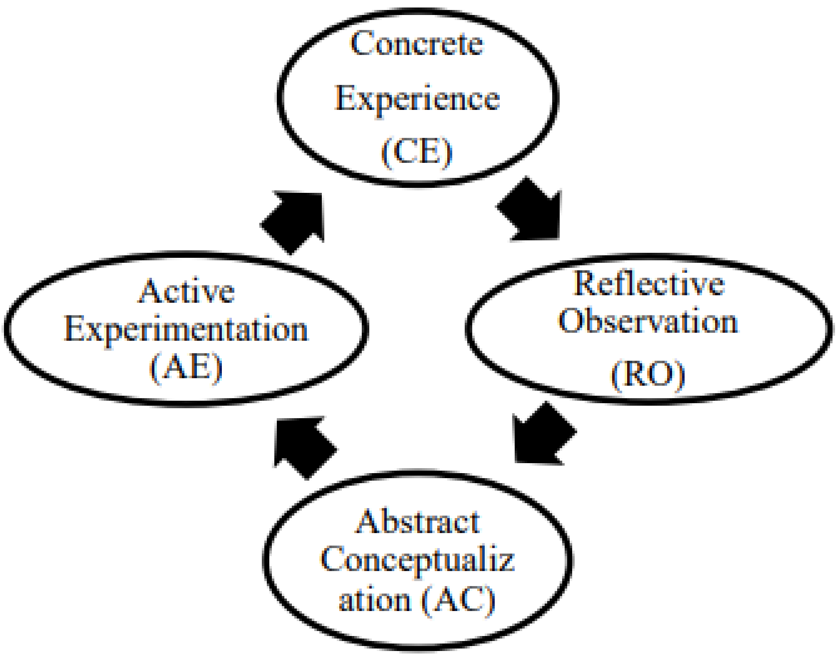

Figure. 1 Kolb Experiential Learning Cycle.

4.METHODS

4.1 Research Approach

The research approach employed for this study is quantitative. Quantitative research aims to find relationships and explain the causes of change in measurable social facts (testing theories) (Sutama, 2015). Bryman (2004) asserts quantitative research usually accentuates quantification in the collection and analysis of data. In quantitative research, data is usually collected through organized surveys, experiments, or observations, and is analyzed using statistical methods to produce objective and numerical results (Creswell & Creswell, 2018). This approach aims to achieve objectivity and generalizability by collecting data from a representative sample and using rigorous statistical techniques (Babbie, 2016).

4.2 Research Design

The study was conducted using a quantitative (quasi-experimental) design; the researcher chose a non-equivalent group since it was impossible to assign and choose the groups at random. Because the participants in the control and experimental groups did not receive the same treatment (the experimental group was taught using Kolb's experiential learning, whereas the control group was taught using the conventional method).

4.3 Sample

The sample size for this study was sixty-seven (67) students. The number of samples which were used for the study falls in line with Yamane (1973) who revealed a formula for calculating the ideal sample size.

$$n = \frac{N}{1 + N\alpha^2}$$

where n = sample size N = population size α = error (0.05) reliability level 95%

$$n = \frac{80}{(1 + 80(0.05)^2} = 66.67$$

$$n \approx 67$$

4.4 Sampling Technique

The researcher used Purposive sampling. Purposive sampling allows the researcher to use his/her choice to select a sample which he/she thinks, that would supply the information needed (Fraenkel & Wallen, 2009).

4.5 Reliability and Validity of the Test

The reliability analysis that was conducted using Cronbach alpha, yielded a value of 0.80, for the pre-test, 0.86 for the post-test. This coefficient indicates the internal consistency of the test items, measuring the extent to which they collectively measure the intended construct. According to George and Mallery (2003), Cronbach Alpha values above 0.7 are generally considered acceptable, suggesting that the current test demonstrates an acceptable level of reliability.

5. FINDINGS

5.1 What is the significant difference in the conceptual knowledge of students taught with experiential and the traditional method?

Table 1: Independent Sample T-Test Pre-Test Scores for Experimental and Control Group

Group	N	Mean	SD	*T*	Df	Sig
Control	35	9.94	2.722	.296	65	.755
Experimental	32	9.57	2.590			

Source: SPSS Output

Comparing the mean scores of the pre-test of the two groups after an independent sample t-test was conducted in the table above, the (Mean = 9.94 and a standard deviation = 2.722) and the (Mean = 9.75 for the experimental group with a standard deviation = 2.590) a t (df) = .0296, p =.755 reveals that there was no significant difference among the two groups before the treatments since they have the same level of mathematical thinking ability.

Table 2: Independent Sample T-Test Post Test Scores for Experimental and Control Groups.

Group	N	Mean	SD	*T*	Df	Sig
Control	35	23.43	7.605	-6.657	65	.000
Experimental	32	36.19	8.082			

Source: SPSS Output.

An independent sample t-test was conducted in the table 2 above, for the control group a (Mean = 23.43 and a standard deviation = .065) and experimental group a (Mean = 36.19 and a standard deviation =8.082) with a t(df)= -6.657, p =0.00

The outcomes show that the post-test results of the two groups differ significantly from one another. The control post-test mean was much lower than the experimental post-test means demonstrating that experiential learning has an impact on students' conceptual knowledge in calculus.

6.DISCUSSIONS

The goal of this study was to examine how experiential learning affected senior high school (SHS) students at Krobo Community Day Senior High School in the Bono East Region of Ghana's their conceptual knowledge of calculus concepts, notably limits of functions and derivatives. As a facilitator, I guided the students in the experimental group through Kolb's (1984) cycle of experiential learning after the introduction of limits of functions. According to Kolb (1984), experiential learning involves concrete experience, reflective observation, abstract conception and active experimentation.

In general, concrete experience necessitates that people actively participate in the activity; reflective observation is the time during which people are expected to develop different perspectives; abstract conceptualization is the acquisition of theoretical knowledge; and active experimentation is the application of the knowledge acquired. In order to achieve permanent and effective learning, the learning cycle must be used in the classroom (Dinçol et al 2011). While the control group received traditional instruction, the experimental group underwent concrete experience, reflective observation, abstract conceptualization, and active experimentation phases of the experiential model, which were implemented with materials and activities for the students and teachers. The pre-test scores of both groups show no significant difference (as shown in table 1) but the post test score shows a significant difference as reported in (table 2). Based on the analysis it can be concluded that experiential learning has a significant influence on students' achievement. The findings of the study are supported by the related research in the literature which reveal the positive effect of experiential learning on academic achievement, meaningful learning and learning outcomes by (Ernst, 2013; Konak et al 2014; Matuso, 2014).

The study also demonstrates that students who received their calculus instruction through experiential learning had a stronger grasp of the subject. The results support earlier study by Coker et al,2017; Ting et al 2023; Hans and Suh, (2023).

In the experimental group, it was found that the experiential teaching approach was quite successful at encouraging students to participate actively and confidently in their education (Akman & Cakir,2023). The addition of hands-on activities helped students strengthen their mathematical modelling skills, which raised their mean score. The study's findings also concur with those of Prashant and Gowri (2020), who found that students' performance is significantly impacted by experiential learning.

7. CONCLUSION

The result of this study indicated that there was a significant difference between the achievement score of students in the control and experimental groups. The means of the test from the independent sample t-test revealed that students taught using Kolb's experiential learning method was higher than those taught traditionally. It also shows that students who were taught using the experiential learning method demonstrated better knowledge and understanding of calculus concepts.

8. RECOMMENDATION.

The findings of this study have raised attention of adopting experiential learning strategy in teaching calculus for Senior High School students than using the traditional method. It is therefore recommended that:

- Schools should be equipped with functional computers and a mathematics laboratory to assist mathematics teachers in incorporating image software into their teaching.
- Experiential learning should be used by mathematics teachers as an effective teaching pedagogy since it can improves learners conceptual knowledge according to the study
- Ghana Education Service (GES) should organize training/workshop on the use of experiential techniques in the teaching and learning of mathematical concepts.
- Mathematics teachers should encourage good and effective discussions and interaction among students in their lessons to create a pleasant learning atmosphere that is more conducive to learning than the traditional instruction.

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