JIGSAW CO-OPERATIVE LEARNING STRATEGY INTEGRATED WITH GEOGEBRA: A TOOL FOR CONTENT KNOWLEDGE DEVELOPMENT OF INTERMEDIATE CALCULUS FOR FIRST YEAR UNDERGRADUATE LEARNERS OF TWO PUBLIC UNIVERSITIES IN ETHIOPIA

by

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submitted in accordance with the requirements for the degree of

DOCTOR OF PHILOSOPHY IN MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION

in the subject

MATHEMATICS EDUCATION

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: Professor Nosisi Nellie Feza

August 2019

DECLARATION

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Exact wording of the title of the dissertation as appearing on the copies submitted for examination:

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I declare that the above dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

_______________ 26 August 2019

SIGNATURE DATE

(SIRAK TSEGAYE YIMER)

ABSTRACT

Intermediate calculus bridges secondary school and advanced university mathematics courses. Most mathematics education research literatures indicated that the conceptual knowledge in intermediate calculus has challenged first year undergraduate mathematics and science learners to a great extent through the lecture method. The content knowledge attained by them has been tremendously decreasing. Negative attitude exhibited by students toward calculus was highly influenced by the lecture method used. Generally, students have not looked at the learning of all mathematics courses offered in universities as normal as other courses. Due to this lack of background conceptual knowledge in learners, they have been highly frustrated by the learning of advanced mathematics courses. Taking the understanding of teaching and learning challenge of conceptual knowledge of calculus into consideration, Ethiopian public universities have been encouraging instructors to devise and implement active learning methods through any professional development training opportunity. The training was aimed to enhance learners' content knowledge and attitude towards calculus. This is one of the main reasons for the motivation of this study that experimental group learners were allowed to be nurtured by the lecture method in their mainstream class, and then also the active learning intervention method integrated with GeoGebra in the mathematics laboratory class. Only conventional lecture method was used to teach the comparison group in both the mainstream and mathematics laboratory class. The purpose of the study was to explore the Gambari and Yusuf (2016) stimulus of the jigsaw co-operative learning method combined with GeoGebra (JCLGS) on statistics and chemistry learners' content knowledge improvement and change of their attitude towards calculus. The post-positivism mixed methods tactic was used in a non-equivalent pre- and post-test comparison group quasi-experimental design. The population of the study was the whole freshman mathematics and science degree program learners of two public universities in Ethiopia

in 2017. Samples of the size 150 in both the experimental and comparison groups were drawn utilizing two-stage random sampling technique. A questionnaire using a Likert-scale on attitudes and an achievement test were sources used for data collection. Data analysis employed descriptive statistics conducting an independent samples t-test and a Two Way ANOVA for repeated measures using SPSS23. Each of the findings on content knowledge, conceptual knowledge, and procedural knowledge development produced through the TWO-Way ANOVA, respectively as $F(1,148)=80.917;\ \eta^2 = .353;\ p<.01$, $F(1,148)=106.913;\ \eta^2 = .419;\ p<.01$, and $F(1,148)=7.328;\ \eta^2 = .047;\ p<.01$, revealed a statistically significant difference between the treatment and comparison groups from pre-test to post-test. These findings show that the experimental group participants were highly beneficial in developing their content knowledge and conceptual knowledge through the active learning approach and technology-based learning strategy using Vygotsky's socio-cultural learning theory. The JCLGS learning environment representing Vygotsky's socio-cultural learning theory modestly influenced the procedural knowledge learning of the experimental group learners'. Although the lecture method affected the comparison group students' knowledge development in calculus during the academic semester, the impact was not comparable to that of the active learning approach and technology-based learning strategy. The major reason for this was the attention and care given to the active learning intervention integrated with GeoGebra by the researcher, data collectors, and research participants. Overall findings showed that the active learning intervention allowed the experimental group students to considerably enhance their conceptual knowledge and content knowledge in calculus. Learners also positively changed their opinion towards calculus and GeoGebra. The intervention was a group interactive environment that allowed students' to be reflective, share prior experience and knowledge, and independent learners. As a matter of fact, educators are advised to model such a combination of active learning approach and technology-

based learning strategy in their classroom instructional setting and practices. Consequently, their learners will adequately benefit to understand the subject matter and positively change their opinion towards university mathematics.

Key words: active learning strategy; attitude; computer-assisted learning; conceptual knowledge; content knowledge; first-year undergraduate university learners; GeoGebra; intermediate calculus achievement; jigsaw co-operative method; knowledge development; procedural knowledge

DEDICATION

This thesis is dedicated in memory of my diligent, courageous, and humble mother Aberash Merga Hurisa. She died 20 years ago just when my eldest son Natoli Sirak was born. My success is unthinkable without her continuous nurturing.

ACKNOWLEDGEMENT

First and foremost, I would like to express my heartfelt thanks to Almighty God for creating me this challenging and marvelous opportunity of PhD study. I am also grateful to Him being my Savior of all physical and psychological conditions to complete this study. It is very important to acknowledge the professional support of the following experts and my wife.

Next, my special thanks go to my supervisor, Professor Nosisi Nellie Feza, for her diligently provided me continuous advices throughout my course of study even in her tight schedule. I also give my appreciation for her humbleness and empathy. She is also rational, punctual, moderator, and interlocutor. Really, I learned a lot, especially how to develop proposal and thesis through her valuable comments.

I would like to forward my gratitude to those instructors, Aman Tunshura, Getinent Worku, Bayissa Degaga, Fekadu Tolosa, and Tsegaye Kebede, who participated from the very beginning of pilot study and the end of main study. They immensely engaged in evaluating the data collection instruments and in collecting data.

I would like to thank my home university and UNISA management for the financial support they provided me.

Last but not least, I would like to thank my wife, Beliyu Azale, who nurtured our three sons without any complain. I would also like to thank for her endurance, prayers, and advices in the development of my thesis from the outset to its completion.

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LIST OF ACRONYMS

CAI	Computer-assisted instruction
CAL	Computer-assisted learning
CAS	Computer Algebra System
CBL	Computer-based learning
CG	Comparison group
CK	Conceptual knowledge
COK	Content knowledge
DV	Dependent variable
EG	Experimental group
EFA	Exploratory Factor Analysis
EUEE	Ethiopian University Entrance Certificate Examination
GRE	Graduate Record Examination
HDP	Higher Diploma Program
IV	Independent variable
JCLGS	Jigsaw Co-operative Learning Group Strategy Integrated with GeoGebra
KMO	Kaiser-Meyer-Olkin
MKO	More Knowledgeable Other
NR	Nonrandom assignment
PCA	Principal Component Analysis
PK	Procedural knowledge
STEM	Science, Technology, Engineering and Mathematics
TBL	Technology-based learning

TLM	Traditional Lecture Method
TPACK	Technological, Pedagogical and Content Knowledge
ZPD	Zone of Proximal Development

OPERATIONAL DEFINITIONS OF THE RESEARCH VARIABLES

The operational definitions of the important variables involved in the research objectives or hypothesis/questions of the study which were supposed to have relative meanings in the context of various research studies are provided below:

Attitude refers to the opinion of first-year undergraduate experimental group Statistics and Chemistry learners in one of the two Ethiopian public universities toward calculus concept learning and GeoGebra as a tool through the JCLGS.

Development is the gradual progress shown on experimental group learners' classroom achievement scores in the learning of intermediate calculus using the JCLGS.

Intermediate calculus is one of the mathematics courses offered either during the first or second semester for the first year undergraduate learners enrolled in the Mathematics, Physics, Chemistry and Statistics departments, in the College of Natural and Computational Sciences of two Ethiopian public universities.

Learners refer to those first-year undergraduate males and females enrolled for intermediate calculus whose age ranges from 18 to 26, in the department of Mathematics, Physics, Statistics and Chemistry, in the College of Natural and Computational Sciences of two Ethiopian public universities.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In most parts of the world, university first year undergraduate mathematics and science learners have enrolled for the course intermediate calculus in their freshman study. According to Othman, Tarmuji, and Hilmi (2017); Yimer and Feza (2019), intermediate calculus is central and very pertinent course in STEM and social science disciplines. Yimer and Feza (2019) argue that calculus diverse ideas have potential to define and model problems that involve change in real life situations. Boz yaman (2019) confirms this argument by stating that calculus is a starting point of making sense of real life situations to students that are science and engineer oriented through mathematics.

Limited knowledge of the proposed strategy in this research observed in educators is a challenge. Yimer and Feza (2019) propose that professional development of educators empowering them with such knowledge and skills involved in the JCLGS will influence classroom practices. This influence will then translate to students' interests and positive attitudes towards calculus. The knowledge gap and the need to explore the possibilities of using the active JCLGS for developing students understanding of calculus drive this study.

The rationale for the study of the proposed innovative strategy was the understanding of teaching and learning challenges that learners experience the hand in-hand conceptual and procedural knowledge development of calculus through the lecture method. Generally, almost all learners have been ignoring the learning of concepts that require them encapsulating the main idea and inadequately poorly perform on quizzes, tests and examinations of conceptual knowledge in calculus by the most commonly used lecture method in classroom instruction at the tertiary level.

Even instructors themselves pass over imparting of conceptual knowledge in calculus lessons. This shows us that teachers' content and pedagogical knowledge needs to be seriously scrutinized. The other reason for calculus learning to be viewed as challenging may be learners are always being confronted with the limit concept at the outset. The limit concept is one of the abstract calculus concepts with fixed and dynamic objects. The study of the notions of continuity, differentiation and integration entirely rely on it. Students could not properly understand the advanced concepts of calculus like continuity in their further study unless they are well-equipped with the pertinent knowledge of the limit concept. The conventional lecture method has not allowed learners' to easily understand and visualize limit concepts through black/whiteboard. As Bezuidenhout (2001); Engelbrecht, Harding, and Potgieter (2005); Kadijević (1999) reported, lecture method has not addressed students' learning of calculus concepts rather it was entirely used to enhance the knowledge of a finite set of procedures of calculus. Jaafar and Lin (2017); Kadijević (1999) also indicated that without knowing the applications, learners merely get into memorization of instrumental skills through solving procedural tasks that involve fully quantified objects by using appropriate remembered rules. In support of this, Khashan (2014) stated that learners have highly focused on procedural knowledge of mathematics, particularly on rational numbers almost ignoring the learning of concepts through lecture method. Awang and Hamid (2015) also explained that most learners had positive opinion towards the procedural knowledge aspects of mathematics, such as rules and formulas as they suppose it can easily be memorized. In line with this, Lim-Teo Suat Khoh (1999) posited that most learners have been challenged by the learning of concepts, definitions, theorems, and proofs. As Younga et al. (2011) reported, learning calculus was difficult for students in Science, Technology, Engineering and Mathematics (STEM) departments.

According to Huang (2011), lecture method made learners to have a negative and moderately positive opinion towards the learning of mathematics, particularly to calculus. Generally, learners was not successful the learning of advanced university mathematics courses due to lack of the necessary prior knowledge and skill of intermediate calculus. Maltas and Prescott (2014); Othman et al. (2017) stated that when learners enter higher education the challenge has become magnified because they initially encounter the learning of limit concepts in calculus which require higher order thinking, abstraction, imagination and visualization. They are expected to construct all limit concepts in their brain during their learning. Of the four knowledge Getie (2013) that Piaget identified, this abstract knowledge that is constructed in our brain is called logico-mathematical or metaphysical knowledge.

Several other factors contribute to learners' learning challenge of conceptual knowledge (CK), procedural knowledge (PK) and content knowledge (COK) in calculus. Of all these factors, the lecture method was the one that predominantly affect university learners' learning of calculus in classroom instruction. Educators need to be motivated by this problem of learning to be careful while selecting an appropriate learning strategy that best suits for the learning of any given calculus lesson. In support of this idea, Arbin et al. (2014) suggested that special attention has to be paid to the appropriate learning strategy(s) that entertain learners' various learning styles, their prior knowledge, and experiences. The conventional lecture method that instructors often employ has contributed to learners' being unable to attain meaningfully in the he learning of calculus. In support of this, Arbin et al. (2014) indicated that the conventional method has not allowed learners to think critically and creatively. This is because the lecture method was used emphasizing the theoretical model of delivering rather than in a visualized, concrete, tangible and practical manner. It has not allowed students to actively participate in the learning to elicit and probe the essence of various calculus concepts and then ultimately own the subject matter/content knowledge. Dhage, Pawar, and Patil (2016) described that the traditional teaching method is usually a teacher-centered method. This means a teacher prepares short notes and presents the lesson only through talk and writes short notes on the black/whiteboard, and students passively listen and take their short notes.

Learners in science, technology, engineering, and mathematics (STEM) departments have been highly challenged with the knowledge of concepts and less with procedural knowledge (PK) learning challenge of calculus. However, intermediate calculus has a wide range of applications in science, engineering, and technology. Learners have not been successful in their field of specialization due to their lack of sufficient knowledge in calculus acquired through the lecture method. To minimize learning difficulty of calculus, the researcher advocates the idea that the active learning approach integrated with technology-based learning intervention should be devised and implemented whenever and wherever possible in calculus classroom instruction. Maltas and Prescott (2014) indicated that politicians, parents, learners, and universities feel bad as to the every year exacerbate of learners' mathematics learning challenge at all levels. Educators need to be more considerate to this learners' learning difficulty towards calculus. The reason is that no one can replace the responsibility and accountability that the instructor has and the vital role played by him/her in respect of classroom instruction. By this reason, mathematics educators have potentially suggested some possible solutions and endeavored to improve the learning challenge. However, the conceptual knowledge in particular the content knowledge learning challenge of intermediate calculus in general has kept up till this day. In this regard, Roschelle, Rafanan, Bhanot, and Estrella (2010) indicated that improving mathematics learning is one of the challenging issues from basic education to tertiary level in the classroom instruction all over the world.

As most mathematics education research literatures pointed out, this learning challenge has likely arisen while learners are running towards making the linkage between knowledge of concepts and procedures in calculus. Arbin et al. (2014); Engelbrecht et al. (2012) indicated the reason that the traditional teaching employed in the tertiary level has entirely been oriented to procedural knowledge development of calculus. It has not yet created a conducive learning environment for learners' to sufficiently acquire conceptual knowledge development by their own initiation and effort without any pressure from the instructor. It has also not assisted learners to gain both conceptual (CK) and procedural (PK) knowledge hand-in-hand. Rather, it has emphasized almost on problem-solving tasks that could be tackled through the application of a finite set of sequences of procedures (Kadijević, 1999). Kadijević (1999) has also discovered a similar idea that the traditional classroom instruction of calculus was often regarded accountable at addressing the procedural knowledge (PK) learning and the corresponding assessment approaches. In line with this, Summit and Rickards (2013) also added that lecture method has encouraged learners to build up rote learning approach. It makes them not to adapt with the situation in the provided problem. Furthermore, they are inflexible who give poor evaluation and judgment to the new learning environment they encounter. Generally, for any problem issue under study learners were unmotivated and uncreative through the lecture method of calculus learning.

As aforementioned, in most mathematics education research literatures one of the major causes for learners' poor performance and achievement of calculus in classroom instruction at the tertiary level is the lecture method of instruction. Learners have also developed a negative attitude towards the course using this teaching method. Crooks and Alibali (2014); Kadijević (1999) mentioned the reason that instructors have used the lecture method emphasizing more on the procedural knowledge and almost neglecting conceptual knowledge development of calculus.

Even the performance and achievement scores on the learning of a finite set of procedures in calculus were not sufficiently addressed. Engelbrecht et al. (2012) also confirmed that procedural skills development has been experienced by both learners and instructors, in many countries of the world, including South Africa and Sweden. Such pedagogical experience of learners and instructors is more serious in Ethiopia. Thus, this is a signal for all instructors to take a closer look at for all possible means that could improve the learning of this type of knowledge by being able to go beyond the lecture method. In doing this, special attention should be given to all those possible favorable circumstances allowing both conceptual (CK) and procedural (PK) knowledge to be developed hand-in-hand.

Crooks and Alibali (2014) reviewed many mathematics education research literatures that deal on how to develop conceptual knowledge (CK) and procedural knowledge (PK). They indicated this issue was challenging within and across different mathematical domains. The predominant challenges were that of aligning the definitions of knowledge of procedures and concepts operationally, conducting their measures, and designing their appropriate learning strategies. This notifies the existence of learning problem of calculus to researchers and instructors. In this regard, Crooks and Alibali (2014); Isleyen and Isik (2003); Rittle-johnson and Schneider (2014) indicated that educators are usually unable to reach consensus in delineating a clear distinction and relation between the two knowledge. Researchers have been challenged while studying the developmental process of conceptual knowledge (CK) and procedural knowledge (PK) knowledge in learners' learning of intermediate calculus.

However, Kilpatrick and Swafford (2001) stated that scholars have nearly agreed that improving mathematics learning requires engaging learners in connecting conceptual (CK) and procedural (PK) knowledge. The prominent scholar, Silver (2013) also pointed out that learners' competence in the domain of mathematics is based on developing and linking their knowledge of concepts and procedures. On the other hand, a few research literatures have revealed that researchers conducted the impact of learning aided with mathematics software packages like Mathematica, Microsoft Mathematics and Sage generally Computer Algebra System (CAS) on learners' knowledge of concepts and procedures improvement. However, Ayub, Sembok, and Luan (2008) indicated there exists inconsistent results in this regard. This means some researchers found that somehow the lecture method favoured the learning of knowledge of mathematics. Others reported as a learning approach supported with a computer software package enhanced learners' mathematical knowledge. Nevertheless, Lavicza (2010); Ocal (2017); Oktaviyanthi (2015); Zulnaidi and Zakaria (2012); Zulnaidi and Zamri (2017) conducted a research on the use of technology that has modestly enhanced learners' mathematical knowledge. They conducted their research without integrating technology with active learning approach. Australia, Malaysia, Singapore, Indonesia, and Turkey are the countries which have more experience in using technology-based calculus learning. The inclusion of technology-based learning in their curriculum has played an important role in the quality of education, particularly in Turkey (Eret, Gokmenoglu, & Engin-Demir, 2013). This could be taken as one of the major contributing factors for Malaysia, Singapore and Indonesia to be viewed as fast-growing countries by the world community. There is a consensus by the world community that quality education is the basis for growth and development of a nation. Currently, Saudi is experiencing at introducing such technology-based learning strategy in the curriculum (Alshehri, 2014). For that matter, Ethiopia is not at all in that track.

To enhance learners' mathematical content knowledge, Ethiopian public universities have been reinforcing instructors through any professional development training opportunity to appropriately devise and implement active learning interventions. The Higher Diploma Program (HDP) is one of the major evidences to that professional training. This was to give awareness for instructors to well-equip them the skill to conduct action research and appropriately devise and implement any innovative learning strategy model in classroom instruction. Through this instructors can experience presenting any subject on the basis of researched instruction. They could be helped to suggest possible remedies for their learners learning challenge of calculus and to the whole constrains in the teaching/learning process of classroom instruction. In the article produced in Turkey by (Othman et al., 2017) also added the idea that innovative teaching and learning strategies should replace the lecture method in any classroom instructional aspects.

Applying innovative learning strategies combined with appropriate mathematical software package in calculus learning in this dynamic digital world is highly essential for classroom instruction. Kandemir and Demirbağ-Keskin (2019) stated that the importance of blending technological tool for teaching/learning of mathematics has become vital for mathematics and science educators. The reason is that learners have the glance at everywhere and any time to various software packages designed for the purpose of education in their day-to-day activities and then helped by it to construct the desired content knowledge. The use of technology-based learning will alleviate learners' knowledge of concepts, procedures, and content learning challenge and negative attitude problem towards calculus if educators wisely apply it in calculus classroom instruction.

However, most instructors have not been applying such kind of learning strategy in their classroom instruction. This may be because of the experience of using lecture method of instruction for many years had influenced them. They might have skill problem of manipulating mathematics software package. They might have negative attitude toward using instructional technology. According to Lavicza (2010), teachers' use of technology particularly Computer Algebra System (CAS) for education could generally be affected by their attitude. Educators are required to pay significant attention while devising and implementing such kind of learning strategy in their teaching and learning endeavor. Active learning approach integrated with technology should be carefully planned, designed, implemented and evaluated. Learners' visualization capacity of calculus concepts could be substantially developed if educators are very attentive in devising technology-based learning at the outset. Innovative learning strategy creates a socially interactive environment for learners to experience knowledge, skill, opinion, and practices sharing to each other through it. According to Ayub et al. (2008), it also alleviates instructors' shortage of time in presenting their lesson and reduce mental work for learners. As Arbini (2016) reported, students can better attain through the use of graphic calculator as one of software packages in their learning of mathematics. Parrot and Leong (2018) also reported that learners' learning difficulty and their negative attitude towards problem-solving techniques of linear equations has improved through the graphing calculator. Learners can take their own initiation how to carry out their learning endeavor through active learning approach combined with technology-based learning.

Educators/instructors must consider themselves as one of the responsible bodies for their learners who create, pave and adjust a conducive learning environment. Through this way, learners can get quality calculus learning in this contemporary world. As a result, learners gradually get enrich in conceptual knowledge. They also become critical, reflective and creative towards calculus learning.

The independent variables of this study were the active jigsaw learning strategy and GeoGebra. It is essential to discuss about them as follows. One of a typical group learning strategies is co-operative learning strategy. It could facilitate learners' multi-faceted learning difficulties of mathematics and could also help to adequately produce their knowledge, skill, and positive opinion. Arbin et al. (2014) reported that learners can be motivated and develop positive opinion towards their learning material through co-operative learning strategy. Sofroniou and Poutos

(2016) argued this idea as students' higher order thinking, group work experience, individual learning, social interaction capacity and ability of minimizing their daily-life problems can highly enhanced. As one type of co-operative learning strategies, jigsaw learning strategy refers to a small group learning strategy in which each member striving to be an 'expert' on any one given learning activity for their common goal success in the absence of competition (Abed, Sameer, Kasim, & Othman, 2019; Orey, 2010; Pilgrim, 2010).

GeoGebra is one of mathematics software packages employed to teach geometry, statistics, calculus and algebra. Alkhateeb and Al-Duwairi (2019) explained that it can empower learners to easily imagine abstract concepts of calculus that is not likely through lecture method. This can be a reality through numerical, symbolical, algebraically, geometrical, and graphical representation and description of the calculus notions under scrutiny.

Knowledge of the JCLGS is very limited for most mathematics educationalists as it can enhance learners' knowledge of concepts and content of calculus to a large extent. Though learners learning challenge generally in mathematics specifically in calculus is almost the same all over the world, developed countries are far better than developing countries at inculcating technology-based learning strategy in their curriculum. Due to the demerit of the use of lecture method and other reasons for the learning problem of calculus, twenty-two, nineteen, and eighteen students in 2015, 2016, and 2017 respectively enrolled in mathematics department in one of the study location. This shows there has been a decreasing trend as to the number of students enrolled in the successive academic year. Maltas and Prescott (2014) reported that in Australia learners' enrollment for advanced mathematics like calculus has decreased in every succeeding academic year.

1.2 Statement of the problem

Intermediate calculus is offered for first-year undergraduate science and mathematics students in their freshman study. Physics, Chemistry, Mathematics and Statistics students enroll for this course in the context of harmonized modular curriculum of Ethiopian public universities. Mazana, Suero Montero, and Olifage (2019) indicated that the success of students should be affected by their opinion towards mathematics and the methods of teaching that instructors employ. Students must accomplish the expected learning outcomes expressed in terms of their behavioral change towards knowledge of concepts in calculus to qualify for degree in the program of study. The aim of any higher institution is to facilitate a conducive learning atmosphere for learners better attain content knowledge of calculus.

Lecture method has not allowed learners to be successfully constructing their knowledge of concepts in calculus. Learners' opinion towards the learning of calculus was not positive. To minimize learners learning difficulty of calculus, almost all instructors have not paid attention to such factors as learners' motivation, interest and attitude; socio-economic status of learners and university, and appropriate learning/teaching strategy while preparing and presenting their lessons. To argue on the importance of some of them, for instance, if learners come from a middle or high-income family they can easily access learning materials or aides, which would, in turn, benefit their learning of calculus. If universities have well-established and furnished classes equipped with various technology, libraries and dormitories and involve high calibre staff, then the learning environment could become conducive and provide quality education and this in turn enhances learners' learning of calculus. In support of this idea, Lee (2012) reported that learner and school socio-economic status considered as well-known demographic factors that strongly impact learners' math performance and achievement. The major factor in classroom instructional setting that needs to be taken into consideration is that of the use of appropriate learning/teaching strategy that could empower learners to elicit and probe the essence of calculus concepts. To fill this knowledge gap, the active learning interventions that heavily borrows and utilizes technology was designed to explore its influence on experimental group students' development in knowledge of concepts, content and procedures, and change in attitude towards calculus.

1.3 Purpose of the Study

The study aims to achieve the following:

- ✓ Explore the influence of the JCLGS with Vygotsky's socio-cultural context learning theory. This exploration aims to use the active learning intervention integrated with technology-based learning to develop learners' understanding, procedural knowledge and application knowledge of calculus. Furthermore, the learners' change of attitude towards calculus and GeoGebra will also be measured after the intervention.

Specific objectives

- ✓ To study conceptual knowledge development of students in both the experimental and control groups
- ✓ To inspect procedural knowledge development of students in both the experimental and control groups
- ✓ To explore the content knowledge development of students in both experimental and control groups
- ✓ To explore the effect of the JCLGS on students' attitudes in the experimental group

1.4 Research Questions

This study responds to the following questions with the aim of achieving its objectives.

- ✓ Does the JCLGS has influence on learners' development of the conceptual knowledge of intermediate calculus?

- ✓ Does the JCLGS has influence on learners' development of the procedural knowledge of intermediate calculus?
- ✓ Does the JCLGS has influence on learners' content knowledge development of intermediate calculus?
- ✓ Does the JCLGS has influence on experimental group learners' change of attitude?

1.5 Statement of the Hypotheses

The following hypothesis statements equivalently express the questions of the study as follows:

Null hypothesis

H_{01}: Learning calculus through JCLGS has the same influence as lecture method on conceptual knowledge.

H_{02}: Learning calculus through JCLGS has the same influence as lecture method on procedural knowledge.

H_{03}: Learning calculus through JCLGS has the same influence as lecture method on content knowledge

Alternative hypothesis

H_{11}: Learning calculus through JCLGS has better influence than the lecture method on conceptual knowledge.

H_{12}: Learning calculus through JCLGS has better influence than lecture method on procedural knowledge.

H_{13}: Learning calculus through JCLGS has better influence than lecture method on content knowledge.

1.6 Rationale of the Study

This study was designed to experiment on knowledge of concepts, procedures and content learning challenges and negative attitude problem towards calculus of the first-year undergraduate mathematics and science learners in two Ethiopian public universities. Most often this challenge emanates from the lecture method that university instructors' used in classroom instruction. Lecture method was not addressing learners' the hand-in-hand development of conceptual (CK) and procedural knowledge (PK) of calculus. To suggest possible solutions for that problem, at the outset the researcher thought about the class size and the available resources such as computers in the mathematics laboratory and identified those instructors able to manipulate GeoGebra. The proportion of the number of computers to the number of students nearly found to be 1:4 or 1:5. Thereafter, the researcher came to speculate such an active learning method that allows learners to learn calculus in a group in the mathematics laboratory class. Proceeding, the researcher selected the JCLGS and developed learning activities that fit to it. Therefore, the designed learning strategy by the researcher was that combines the learning activities prepared by him, the jigsaw learning method and GeoGebra. Vygotsky's social-cultural context learning theory was represented by the JCLGS. Two instructors engaged in the intervention assisting learners to make a jigsaw group consisting of four or five learners to discuss over the learning activities. After having thorough discussion, they moved into using GeoGebra interactively to make clear those abstract notions and concepts. These aspects addressed through learners' representations of the various calculus concepts under study such as numerically, symbolically, algebraically, geometrically and graphically with the assistance of instructors. In succinct terms, this learning strategy designed to point out whether these learning activities have addressed those learners' content knowledge learning challenges of intermediate calculus or not.

1.7 Significance of the Study

The intention of the study was to extend first-year undergraduate program mathematics and science learners' awareness on all about conceptual knowledge (CK), procedural knowledge (PK), content knowledge (COK) and learning calculus using the JCLGS. This means as you all know their mission in the study or after completion is to read, examine, investigate, discover and explore things. If they have the exposure to this paper, it likely helps at least to be familiarized with the essence of these three terms. If they also study further education, they may contribute something new through conducting some sort of research on any one or all of them. Curriculum developers, science and mathematics education policymakers, the expertise of universities, teachers' training colleges and school science and mathematics instructors may model this learning strategy while developing mathematics or science syllabus and presenting their lessons in the classroom instruction. You know that all these stakeholders are the ones who engage in the educational sphere of life. One of their major duties is to look for a suitable learning strategy(s) that appropriately address learners learning of any kind of lesson. Therefore, the findings of this study inform them of the direction on how to devise and implement appropriate active learning methods integrated with technology that allow students to develop knowledge of concepts particularly in calculus generally in mathematics.

1.8 Assumptions

Two research instruments were used in this study to conduct data. They are named achievement test in calculus and Likert-scale attitude questionnaire. This classroom achievement test developed by the researcher and a few of them adapted from the Graduate Record Examination (GRE) and other sources. Though the validity and reliability of it was pilot-tested in the context of this research study, the items taken from the GRE and other sources were assumed as their reliability and validity ensured in other contexts. Awang and Hamid (2015) used, Test of

Mathematics Related Attitudes (TOMRA), which is a modification of TOSRA (Khine, 2013) designed by a distinguished Professor Barry J. Fraser in Macquarie University, in their research study by verifying its reliability and validity. Even if the reliability of the modified TOMRA was ensured through pilot-testing, using principal components analysis (PCA), and validated by three subject experts in the context of this research study, this questionnaire assumed that its reliability and validity ensured in other contexts.

1.9 Limitations

The following conditions can be taken beyond the researcher's control and could have slightly affected the findings and interpretations of the study. The quasi-experimental design was one of the limitations of the study. Because at the outset of the intervention, intact class groups from the two study areas were used for both experimental groups. However, calculus classroom achievement scores of sample participants randomly drawn based on their age, gender and scores of Ethiopian University Entrance Certificate Examination (EUEE) using the codes given to each of them after having collected, organized, and presented. Unfortunately, the violence occurred during data collection around these two study areas of Ethiopia could also be taken as a constraint that might specifically affect the data collection process. The absenteeism and not on time coming of very few participants during the intervention could also be taken as limitations affecting research findings and interpretations. Also, few of the research participants have not become very proficient in GeoGebra within the training period stipulated by the instructors. Extra time was taken in the weekend to equip them well about GeoGebra. The other limitation is that the affirmative action for female students was not implemented in the main study for merely the purpose of motivating them.

1.10 Scope of the Study

There are 44 public universities in Ethiopia of which few are old and a lot of them are newly established. However, the study area was delimited to two public universities. These universities were selected because of their similarities in climatic condition, and academic and administrative structures. Both are second-generation universities financed by the government. The other second-generation universities were not included because of their distant location from these two study sites that entail a considerable amount of research budget if they were considered. The subject area of the study was delimited to intermediate calculus which is one of the fundamental and challenging courses in the tertiary level. Specifically, the subject area was delimited to intermediate calculus of one variable. It is one of the courses given for freshman undergraduate mathematics and science students in the current harmonized modular curriculum of public universities in Ethiopia. The lessons used in the study were the fundamentals of limits, continuity, differentiation, and integration. The study was delimited to knowledge of concepts, procedures, and content development in calculus where knowledge is one aspect of the lowest level of the cognitive domain. The JCLGS was also delimitation to the study as there are several learning strategies that could have been used to improve the learning of intermediate calculus.

1.11 Definition of terms

Attitude refers to a learned, or derived through interaction, or an experienced tendency of a person, to respond positively or negatively manner to some object, situation, concept or another person (Aiken, 1970; Sarmah & Puri, 2014).

Computer-assisted learning (CAL) is defined as the learning procedures and environments used in the learning of subjects like Mathematics, Science, etc., that facilitated through suitable computer software packages (Schittek, Mattheos, Lyon, & Attström, 2001).

Conceptual knowledge (CK) is defined as knowledge of concepts in mathematics with plenty of interrelationships, principles and definitions as well as the understanding of the relationship among mathematical objects (Chinnappan & Forrester, 2014; Hiebert & Lefevre, 1986; Star & Stylianides, 2013).

Content knowledge (COK) refers to knowledge of mathematics that interrelates conceptual knowledge (CK), and procedural knowledge (PK) (Ball, Thames, & Phelps, 2008).

GeoGebra is a mathematics software package used for teaching and learning at all levels (http://www.mediawiki.org).

Jigsaw learning strategy is defined as a small group learning strategy in which each member striving to be an 'expert' on any one given learning activity for their common goal success in the absence of competition (Abed, Sameer, Kasim, & Othman, 2019; Orey, 2010; Pilgrim, 2010).

Procedural knowledge (PK) refers to knowledge of procedures in mathematics such as rules, routines, finite set of steps, formulas and notations used in problem-solving (Chinnappan & Forrester, 2014; Hiebert & Lefevre, 1986; Star & Stylianides, 2013).

1.12 Contribution of the Study to Knowledge

This study adds to the scientific research community understanding on how technology can be blended with active learning interventions in the teaching and learning of mathematics. The study also creates the scientific research community awareness that the JCLGS can enhance students' knowledge of concepts and content, and positively change attitude towards calculus.

1.13 Summary of the Chapter

The problem of the study, the background and justification of the problem, the rationale/motivation of the study, the purpose of the study, the significance and the contribution of the study to knowledge were the major aspects addressed in the chapter.

Outline of all Chapters in the Study to Give an Overview Idea of the Thesis

The essence of Chapter One is dealt in the preceding sections. Outlined below is the overview of the remaining chapters. Chapter Two is about the review of related literature that emphasizes on the seven most important variables involved in the study. They are named the JCLGS and the lecture method as independent variables (IV) while students' knowledge of concepts, procedures and content achievement scores of calculus and their attitude toward calculus as dependent variables (DV). The conceptual review, theoretical framework, empirical review and summary of literature reviewed have also included in it. The theoretical framework was built on those dependent and independent variables. Chapter Three was all about research methodology. Chapter Four was about descriptive and inferential statistical analysis of data and interpretation of results. Chapter five was dealt with the discussion, summary, conclusion and recommendation on the findings of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Overview

This study employed the post-positivism mixed methods approach in a non-equivalent pre-and post-test comparison group quasi-experimental design. According to Johnson and Christensen (2019), the mixed methods paradigm is characterized by critical, analytical, and intensive reviewing of the pertinent, similar and related research literatures. They also pointed out that reviewing research literature, especially for mixed paradigm, helps us to obtain an understanding of something useful about the current state of knowledge in the underlying variables. This, in turn, assists us in realizing what has been done, what was lacking, what needs to be done, close the gap and thereby to add new knowledge. As Nenty (2009) indicated, these things are viewed as important data, input and a source of information that benefits the researcher while writing the methodology and discussing research findings as well as in revising a problem, topic and hypothesis. These aspects can be performed based on other researchers' studies that reflect either their experiences supported with empirical evidence or knowledge of their research results. Nenty (2009) also proposed that other researchers' contribution with desirable design and methods must be taken into consideration to find out what was lacking in their research work. This is the most important way that could help to identify the underlying inconsistencies and the knowledge gap, and then to fill this knowledge gap. The purpose of this research study was a kind of descriptive or explanatory or predictive. It follows confirmatory scientific methods as its research questions expressed in hypothetical statements (Gelo, 2012). These aspects could situate the researcher as a proponent of a post-positivist belief. According to (Gelo, 2012), the knowledge that the researcher strives to add to the scientific community cannot be absolute truth and is instead, only an approximation of reality.

The review process of this study took place based on seven variables. The jigsaw co-operative learning strategy, GeoGebra and the lecture method were the independent variables (IV). Learners' knowledge of concepts (CK) , procedures (PK) and content (COK) achievement scores, and students' opinion towards calculus and GeoGebra were the dependent/problem variables (DV) (Nenty, 2009). According to Bloom's taxonomy of educational learning objectives, knowledge of concepts (CK), procedures (PK) and content (COK) constitute cognitive and psychomotor domains while learners' attitude towards calculus and GeoGebra as an affective domain. As Atanasova-Pachemska, Lazarova, Arsov, Pacemska, and Trifunov (2015); Awang and Hamid (2015); Awang, Ilias, Che Hussain, and Mokhtar (2013); Eyyam and Yaratan (2014) reported, learners achievement and attitude toward mathematics are very common and closely related variables in mathematics education research. They further stated that the better learners achieve in mathematics, the more likely it is that they will have a positive attitude towards mathematics and vice versa.

The technological, pedagogical, and content knowledge domains were applied in the course of implementing this intervention (JCLGS) research project. They have highly benefited in stimulating students in the experimental group (EG) in their calculus learning. According to Voogt, Fisser, Pareja roblin, Tondeur, andBraak (2013), the union of these three knowledge domains is abbreviated as TPACK. These days, the application of TPACK has become a vital issue in the teaching profession. TPACK has played the most important role across the fields of teachers' professional development and technology blending. Thus, the reviewed-related literature, therefore, focused on the meaning and importance of the jigsaw co-operative learning strategy; the disparity, the relationship and ways of developing conceptual knowledge (CK) and procedural knowledge (PK). It also dealt with learners' learning using GeoGebra, generally computer software packages, the role the jigsaw learning strategy and GeoGebra have played and the significance of them in this two knowledge learning of intermediate calculus. The reviewed literatures on the variables were used to develop the theoretical framework of the study.

2.2 Conceptual Review

2.2.1 Conceptual Knowledge (CK) and Procedural Knowledge (PK)

In most mathematics education research literature, for instance, Rittle-Johnson and Alibali (1999); Haapasalo and Kadijevich (2000); Rittle-Johnson, Siegler and Alibali (2001); Rittle-Johnson and Siegler (1998), we can find conceptual knowledge (CK) and procedural knowledge (PK) have been yoked (bi-directional). However, educators have not yet been delineated clear cut distinction and relation between them. Rather they applied them in the context and purpose of their research study. As to the researcher's stance and understanding, conceptual knowledge is deeper in terms of the width and depth in any given mathematical knowledge. Procedural knowledge is a superficial/surface level knowledge. Conceptual knowledge (CK) was viewed as one of the most important quality or type of mathematical knowledge by many scholars. Most mathematics educational research communities have viewed it as knowledge quality, whereas the psychology research community has perceived it as a knowledge type (Star & Stylianides, 2013). According to Star (2005), knowledge quality refers to the way that something is known-essentially and how well it is understood. In contrast, knowledge type merely refers to "what is known." The framework set by mathematics education researchers for mathematical knowledge revealed that conceptual knowledge (CK) can be known deeply or superficially or something between them. Star and Stylianides (2013) refer to knowledge of concepts (CK) as mathematical knowledge involving principles and definitions. Similarly, Chinnappan and Forrester (2014) refer to it the knowledge that deals with understanding the relationships among mathematical objects. Thus, stakeholders such as learners, instructors, researchers, curriculum developers and policymakers need to take a note on those features of conceptual knowledge (CK) that requires some sort of abstraction. In accomplishing their educational mission, they should endeavour to make in-depth understanding of this construct rather than merely memorizing it. The researcher would like to bear in mind that this concept emphasized more deeply in this research study rather than using it superficially. That is, more emphasis given to the use of one of Skemp's levels of learning known as relational learning, though Skemp identified two where the other is instrumental learning (Summit & Rickards, 2013). This discussion reminds us that instrumental learning can be considered as the learning of procedural knowledge while relational/logical learning can be viewed as the learning of conceptual knowledge (Jaafar & Lin, 2017). If you are well-equipped with these characteristics of knowledge, you will become more skilful in selecting the appropriate teaching/learning strategy that best suits for the learning of a given calculus lesson.

Procedural knowledge (PK) is the other most crucial quality or type of mathematical knowledge. As with conceptual knowledge (CK), most mathematical education research community viewed procedural knowledge (PK) as knowledge quality, whereas the psychology research community perceived it as knowledge type (Star & Stylianides, 2013). However, it is most often regarded as superficial or surface-level knowledge. Chinnappan and Forrester (2014); Star and Stylianides (2013) refer to knowledge of procedures (PK) as a mathematical knowledge such as rules, routines, finite set of steps, symbols and notations used in problem-solving. This explanation completely agrees with the one stated in Summit and Rickards (2013) article that, procedural knowledge (PK) refers to the ability to carry out procedures or steps for the learning of mathematics problem. In this article, it is also mentioned that most often learners have been paying more attention to the instrumental/procedural knowledge (PK) learning. According to Jaafar and Lin (2017), learners assume as instrumental learning allows them to derive temporary knowledge with good marks in tests or examinations could be easily achieved. Instructors have encouraged such learning approach through their assessment procedures and pedagogy. Knowledge of pedagogy and content refers to the interconnection between the science of teaching and content knowledge (COK) that teachers can represent in a learner-friendly manner (Ball et al., 2008). However, in Jaafar and Lin article, it recommended that educators should be devoted to applying relational/conceptual knowledge learning in the future. In this research project, procedural knowledge (PK) should be regarded as superficial knowledge as compared to conceptual knowledge (CK). The other aspects of procedural knowledge (PK) could be highlighted in complement with conceptual knowledge (CK) in what follows.

Most research literature in the domain of mathematics and interdisciplinary fields, conceptual knowledge (CK) and procedural knowledge (PK) have been studied in harmony. Some of these researches asserted that conceptual knowledge (CK) needs to be initially instructed and then procedural knowledge could be derived from it through the practice of problem-solving. Others say procedural knowledge (PK) needs to be acquired first and then conceptual knowledge (CK) may be developed in learners' minds through abstraction. A few of them, for instance, Resnick (1987) stated that both conceptual knowledge (CK) and procedural knowledge (PK) must be learned independently. Others described increase in conceptual knowledge (CK) in one's learning subsequently lead to an increase in procedural knowledge and vice-versa. Nevertheless, most research literatures on mathematical learning reported that instructors and learners have been emphasizing more on procedure-based instruction almost ignoring concept-based instruction. This situation would have been taken as one of the reasons for the learning of calculus has become more challenging for learners. The problem was supposed to predominantly emanate from our way of presenting the lesson, which is usually the use of lecture method at the tertiary level. However, the researcher shares the view that concept-based instruction has to be encouraged more in the teaching/learning environment. As to these issues Haapasalo and

Kadijevich (2000) indicated that there exist four distinct theoretical viewpoints. They are named concepts-first views, procedures-first views, inactivation view, and iterative view. However, this research study utilized iterative theory that most often describes the bi-directional relationship between conceptual knowledge (CK) and procedural knowledge (PK). From its theme, you may note that this theory is flexible as to which knowledge is instructed first or the source to another in a given learning/teaching environment. This suggests to the researcher that either knowledge can be instructed first or the source of the other. Several researchers succeeded in using this theory, researching on the two knowledge of mathematics lesson from elementary to the tertiary level.

2.2.2 Test Items Analysis Indices

It is most important to explain about the four-item analysis indices used to ensure the reliability of the calculus diagnostic test, namely difficulty level of an item (P), discrimination index (D), point-biserial coefficient (r_{pbi}) and reliability coefficient index (r_{test}) (Ding & Beichner,2009; Kiliyanni & Sivaraman, 2016). Examining the objectively scored tests such as multiple-choice using these indices in pilot study could improve their quality and accuracy to use them for the main study.

According to Boopathiraj and Challamani (2013); Ding and Beichner (2009), the difficulty level of an item is one of the basic statistics involved in item analysis. Ding and Beichner (2009) defined it as the “measure of the easiness of an item". The item difficulty level also refers to the proportion of the correct responses to the total number of responses (Kiliyanni & Sivaraman, 2016). It is expressed by the formula:

$$P = \frac{N_1}{N} \qquad \text{eq. (1)}$$

where N_1 is the number of correct responses, N is the total number of examinees taking the test (Ding & Beichner, 2009).

The difficulty level of an item is measured in percentage (Boopathiraj & Challamani, 2013). The ideal value is one-half of chance and a perfect score for the true/false items, i.e., 0.75 for this pilot test. Similarly, as each of the multiple-choice stem involves five options in the diagnostic test, the ideal value is around one-half of chance and a perfect score, i.e., 0.6. A p-value above 0.9 indicates that the item can be easily answered. In such a case, the item needs to be revised by the researcher based on the purposes that he/she sets in advance. A p-value below 0.3 represents that the item is a challenging one to answer. In such a case also, the item needs to be reviewed for possible confusing language, whether the item was poorly constructed or not, whether it is to be eliminated in the next examinations and identification of an area for re-instruction. Ding and Beichner (2009) indicate that the acceptable item difficulty value ranges from 0.3 to 0.9 for practical utility.

Ding and Beichner (2009) examined the other type of statistic, which is the item discrimination index that is most widely used for measuring the dichotomous response item. According to Kiliyanni and Sivaraman (2016), the item discrimination index measures the extent to which an item distinguishes how high-achieving learners differ from low-achieving learners. It is defined as the ratio of the difference between the number of correct responses in the top quartile and the number of correct responses in the bottom quartile to one-fourth of the number of students (Kiliyanni & Sivaraman, 2016).” It is given by the formula

$$D = \frac{N_H - N_L}{\frac{N}{4}} \qquad \text{eq. (2)}$$

where N_H denotes the number of correct responses in the top quartile, N_L denotes the number of correct responses in the bottom quartile, N denotes the total number of students (Oosterhof, 2001).

"Quartile involved in the formula can be found by using either an internal criterion or an external criterion" (Ding & Beichner, 2009, p.2). However, in the context of this research study, the internal criterion (students' score on the test) could be considered to be employed. Item discrimination index greater than or equal to 0.3 is a standard value. The generated item is better when the item discrimination value is big.

Brown (2001); Costa, Oliveira, and Ferrão, (2009); Ding and Beichner (2009) indicated that the point-biserial correlation is the third very crucial statistic involved in item analysis. It is defined as the relationship between item score and the total score (Kiliyanni & Sivaraman, 2016). This index is expressed by the formula as

$$r_{pbi} = \frac{\overline{X_1} - \overline{X_0}}{\sigma_x} \sqrt{P(1-P)} \qquad \text{eq. (3)}$$

Ghiselli, Campbell, and Zedeck (1981)

where (Ding & Beichner, 2009) $\overline{X_1}$ denotes the average total score for those who correctly answer it, $\overline{X_0}$ denotes the average total score for those who incorrectly answer the item, σ_x denotes the standard deviation of total scores and P denotes the difficulty index for this item. An acceptable value is $r_{pbi} \geq 0.2$ (Kline, 2015). The higher the value the better it is.

On the other hand, Costa et al. (2009); Ding and Beichner (2009); Ding, Chabay, Sherwood, and Beichner (2006) studied the other statistic used to estimate the measure of the entire test score that is the reliability coefficient index. The Kuder-Richardson Formula 21 (KR-21) is the appropriate statistical tool used to estimate its value that measures the internal consistency of a test. It can be expressed by the formula

$$r_{test} = \frac{K}{K-1}\left(1 - \frac{\sum P_i(1-P_i)}{\sigma_x^2}\right) \qquad \text{eq. (4)}$$

Kuder & Richardson (1937)

where K is the number of test items, P_i is the difficulty index of item i, σ_x is the standard deviation of total score. An acceptable value is $r_{test} \geq 0.7$ (Kuder & Richardson, 1937).

The calculus achievement test scores is a continuous scale of measurement. For the work-out items, two raters were used to ensure the consistency and stability (agreement) of it by measures of inter-rater reliability and inter-rater agreement. Liao, Hunt, and Chen (2010) indicated that the Pearson Product Moment Correlation measures inter-rater reliability. Graham, Milanowski, and Miller (2012) pointed-out that, intra-class correlation coefficient (ICC) can be used for measuring inter-rater agreement. Both obtained using SPSS 23. According to Liao et al. (2010), the Pearson Product Moment Correlation is denoted by r and expressed by the formula:

$$r = \sum_{i=1}^{n} \frac{(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y} \qquad \text{eq. (5)}$$

where $\bar{x}$ and $\bar{y}$ are the sample means, s_x and s_y are the sample standard deviation of the variables X and Y. Graham et al. (2012); Liao et al. (2010) stated that inter-rater reliability index ranges from -1 to 1 and inter-rater agreement index ranges from 0 to 1.

2.2.3 Traditional Lecture Method of Instruction

Yang Li-niang and Deng Jun (2005) defined the traditional lecture method (TLM) as the method that teachers impart knowledge to their students orally and the students sit and listen passively without taking their learning initiatives. In this research project, the conventional lecture method was used to teach intact comparison group (CG) learners. The researcher only made some sort of discussion with the instructors/data collectors on how to administer pre-test, post-test, and collect and organize data. As class begins, both instructors gave course outlines for their learners. After having taught for two weeks, they administered the pre-test calculus diagnostic test for three hours. Thereafter, in the course of the lecture, the two instructors supplied notes on each of the four chapters, worksheets, quizzes and mid-term test to the learners. They also worked on the instructional tasks with the learners following the usual trend of traditional lectures in the universities of the world. The trend has been giving lectures by the lecturers and learners only take short notes and listen to them passively. The instructors also conducted tutorial classes to assist learners to work with worksheets. They also provided feedback on what learners attempted during the class participation, doing class work, home assignments, group work and tests and so on. Two weeks before the end of the academic semester, the instructors administered post-test similar to the pre-test items for three hours. Altogether, all the semester activities and tasks lasted twelve weeks, in which four hours were employed for lectures and two hours for tutorials per week (seventy hours). Finally, at the end of the semester instructors corrected, presented, and organized learners' responses on calculus achievement test in collaboration with the researcher.

2.3 Theoretical Framework

This research project was an intervention study intended to improve learners' content (COK) knowledge of intermediate calculus. Rittle-Johnson and Siegler (1998) suggested the idea that learners' knowledge of concepts (CK) and procedures (PK) of mathematics can be improved through intervention experimental study. The JCLGS with socio-cultural context learning theory by Vygotsky's was used in the intervention. Socio-cultural context learning theory emphasizes the importance of individuals' interaction in the group and community in the context of their learning environment in the development of cognition and in the process of "making meaning"

(Vygotsky, 1980; Wertsch, 1985). Wertsch was one of the propounders of Vygotsky's learning theory. Socio-cultural context learning theory was supposed pertinent to be used in the activities of calculus learning using the JCLGS to upgrade students' interest, attitude, performance and achievement in a socio-cultural learning environment. The JCLGS was the innovative learning strategy applied in the intervention to verify that the learning activities prepared by the researcher address students' styles of learning and interest. The learning theory was also the one compatible with and more suitable for the technology integrated learning environment. The purpose of using the socio-cultural context learning theory is to create favorable circumstances and active interactive social circumstances and thereby to increase learners' capacity to attain and effect the desired cognitive knowledge improvement. According to Amineh and Asl (2015), learners could employ it to inform their previous experiences and knowledge, and the learning experiences obtained using the new interactive learning environment. Socio-cultural context learning theory can assist each learner to provide meaning to the knowledge being developed. This theory was applied based on the JCLGS and lecture method as independent variables. Learners' achievement scores in knowledge of concepts, procedures and content and their responses to the five-points Likert attitude scale questionnaire were dependent/problem variables (DV) (Nenty, 2009).

About the active JCLGS, it is worth noting the following. In respect of the principles of pedagogy, instructors must use a variety of learning activities that entertain different students learning styles to generate the desired learning outcome. In many research literature assertions, the conventional lecture method has not appropriately addressed learners' conceptual knowledge development. In connection with this, National research Council, Cocking, Brown, and Bransford (1999) suggested that one of these learning strategies capable of enhancing these multi-faceted issues is technology-based learning. National research Council, Cocking, Brown, and Bransford have also described as a number of modern educational technologies allow students be participatory in their learning. Even though it was identified that the number of technology used into mathematics learning has been rapidly increasing, Highfield and Goodwin (2008), the situation is not supported by research that is with very limited literature. Lavicza (2010) posited that the use of technology in mathematics education has been slowly increasing. In contrast, there are many literatures that indicate the conventional lecture method was not addressing the learning of conceptual knowledge of calculus. We might have noted that in this twenty-first century there is almost no sphere of life where technology is not intervening. Especially, it has been substantially used in mathematics and science education. Furthermore, National research Council, Cocking, Brown, and Bransford (1999); Kilicman, Hassan, and Husain (2010) suggested the following about instructional technology. Educator must use it wisely for their students attain the desired learning outcome. Instructional technology can create a learning environment by linking the content of the lesson and the computer software package for students to have hands on experience. It allows them to explore and experiment. Learners also realize through utilizing instructional technology what they missed and answered those calculus problems in developing knowledge of concepts, procedures and generally the subject matter (National research Council, Cocking, Brown, & Bransford, 1999; Kilicman, Hassan, & Husain, 2010). The generated knowledge by learners gradually becomes vivid and eventually they will be creative of something novel knowledge. Technology based learning helps learners to easily visualize, understand, and reduce misconceptions of those concepts that challenge them in learning using the conventional lecture method. Moreover, it could facilitate a learning environment that makes learners to relate theory and application of knowledge in real-life problems. That would help them to have power to own their learning in collaboration with peers and then give meaning individually for the generated knowledge. Moreover, the technology assisted learning environment could enable learners to look for their learning without any pressure from the instructor. However, Koehler and Mishra (2009) suggested that instructor or researcher should think in advance to pay attention for those technological tools that suit best for students' learning of a given content as much as possible.

Below a discussion is undertaken on one of the components of the theoretical framework such as socio- cultural context theory of learning mathematics. This theory had sufficiently guided this study. In the discussion of socio- cultural context learning theory, it is now important how human beings perceive knowledge acquisition. Some philosophers thought as knowledge is discovered, given and absolute (Cornelius & Ernest, 1991). Others perceived as knowledge is relative constructed by individuals during interaction with the environment. The construction aspect of knowledge will benefit learners as it represents their logical thinking, understanding, and rationale. Despite of this, socio-cultural context learning theory was used to guide the intervention. Of a number of factors for the selection of this theory, the scarcities of teaching materials like computers, large class size, and learners' different learning styles, abilities, diverse interests and backgrounds were few of them. The nature of the intervention and the abstract nature of limit concepts were the other factors. During the intervention, it was tried the best by the researcher, data collectors and learners to make this theory a reality in learners' discussion of the calculus activities in their group using the innovative learning strategy. Four or five learners constituted the group. In this regard, this circumstance led to associate the socio-cultural context learning theory with the intervention that Vygotsky's emphasizes its significance in cognitive development. Amineh and Asl (2015) confirm this argument by stating that learners need to experience a move from social constructivism to constructivism (individual) in the devised socio-cultural context learning environment.

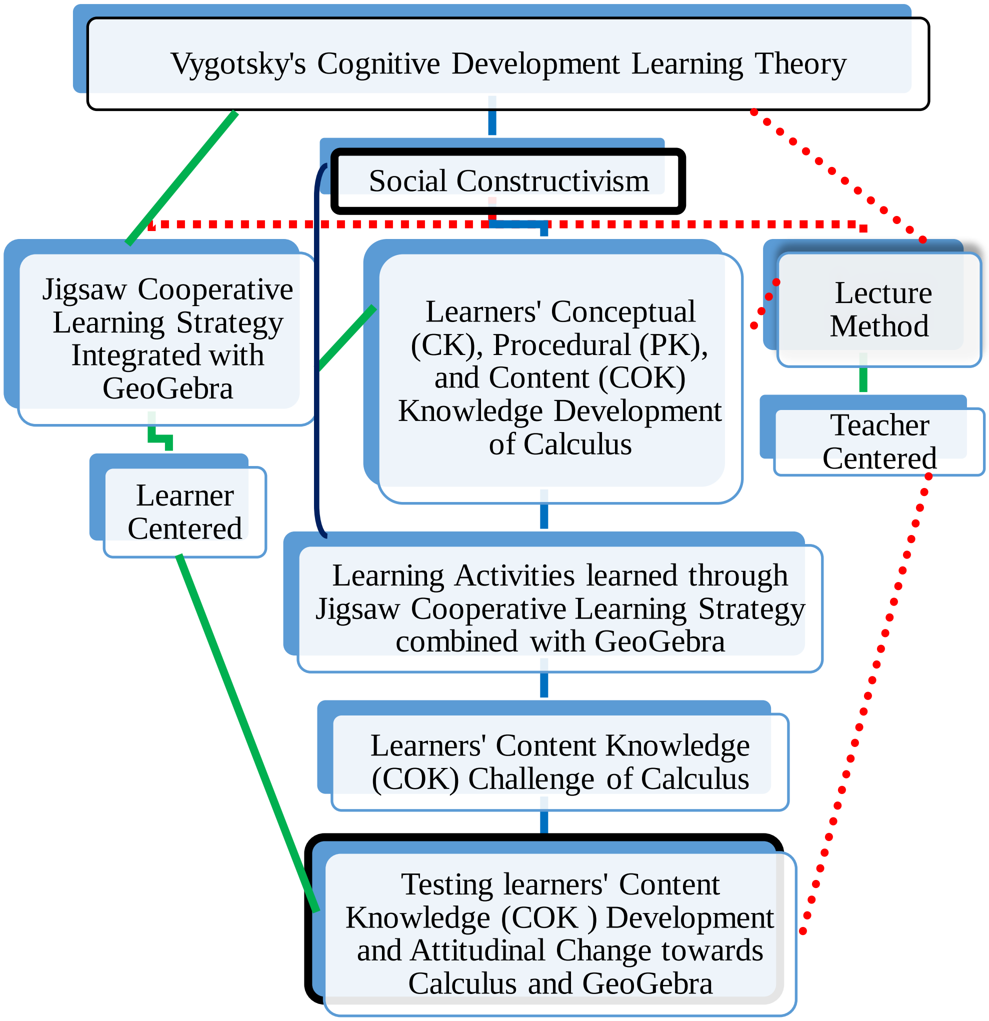
According to Mcmahon (1997), in the socio-cultural learning environment culture and context play an important role in learners' knowledge construction and also they are able to understand what is going on in the group or community or society. The researcher, Amineh and Asl (2015) and Vygotsky (1980) were also in support of this argument. As Vygotsky stated, learning is inherently social in the development of cognitive domain that need to be carried out through discourse. This means learners to gain the desired knowledge they must go through socially driven learning. There are two main principles by Vygotsky's that teacher/instructor should note in the process of cognitive development. These are more knowledgeable other (MKO) and the zone of proximal development (ZPD). In group learning, in relative to others one who has better or best opinion, knowledge and skill under the given social learning environment of a certain subject/course is termed as more knowledgeable other (MKO). Siyepu (2013, p.3) defined the zone of proximal development as "the disparity between learners performance on learning tasks with and without other assistance."

Pedagogy and socio-cultural theory were used hand-in-hand to address the effective use of the JCLGS in learners' content knowledge development. To enrich learners understanding the meaning and importance of the learning environment, the socio-cultural theory allows them to interact with classmates and the instructor as facilitator (Amineh & Asl, 2015; Orey, 2010). Community, culture and context need to play as mediation in the learning process for learners' development of skill, attitude and knowledge through their interaction (Amineh & Asl, 2015; Orey, 2010). As Amineh and Asl argued, constructivism (individual) and social constructivism can minimize the weakness of conventional teaching. Piaget, Vygotsky, and Perkins also supported this idea.

Furthermore, Orey (2010) suggested that we should take note on those main points on which Vygotsky's theory had relied on. Students' culture, history and their social interaction are very essential for the attainment of cognition in Vygotsky's stance (Amineh & Asl, 2015). According to Hoover (1996), students' prior knowledge should be taken into consideration by the facilitator while presenting his/her lesson. New knowledge can be generated through prior knowledge. Learning needs to be addressed actively for students' to reconcile their understanding of their lesson in striving to adapt the new learning circumstance.

Given the socio-cultural theory, learners can be successful the production of appropriate knowledge by interacting with the instructor and the devised learning situation. For this be attained, instructors should be a facilitator, consultant, and coach (Cobb & Bauersfeld, 1995). The facilitator provides guidance, help, advice and support for learners to obtain understanding of the subject matter while a teacher covers the content under consideration by lecturing (Amineh & Asl, 2015). In line with this, Cobb and Bauersfeld (1995) indicated that learners learn lessons actively and independently when teaching is facilitated, guided and supported by instructor. They learn lessons without their participation if the instructor lectures. Such kind of instructor experience as facilitator will make learners be completely involved in the study in a democratic and interactive way (Gray, 1997). Roth (1999) suggested that the learning environment must be used in a social aspect enabling students be freely interact. Through this social interaction environment that students can make sense of their peers and generate knowledge. Social learning environment also challenges their thinking. In this way learners can become independent thinker, problem solver and learner in a learner-centered learning environment.

The relationship among the ontological and epistemological philosophical assumptions and socio-cultural learning theory can consolidate the theoretical framework of the study. Keep in mind that reality is the cornerstone of ontology while knowledge for epistemology (Gelo, 2012; Gray, 2013; Saunders, Lewis, & Thornhill, 2009). Reality, knowledge and learning are the building blocks underlying in the assumptions of socio-cultural learning theory (Kim, 2001). In the formulation of socio-cultural learning theory assumptions, reality comes first. Social constructivists view reality as relative that humans can construct through their daily life (Amineh & Asl, 2015; Orey, 2010). Kukla (2013) also proposed that individuals in the group or society must run toward discovering the realities of the physical world through their interaction. Members in the social group learning are concerned for producing the knowledge of interest in their interaction in the learning circumstances (Kim, 2001). According to social constructivists, learning must be undertaken through social process to achieve the intended learning outcome (Amineh & Asl, 2015; Orey, 2010). They say learning has taken place when learners discuss lessons together with the facilitator, learning material and social environment as well as among them. They also argue that learners must be engaged in social activities like interaction and collaboration to be successful in their learning (Amineh & Asl, 2015). The ontological and epistemological perspectives of this study can be summarized as follows. Reality is not absolute or given that should be discovered rather learners can construct it in their interaction. Knowledge is a social product that an individual would take his/her own share. Learners and instructors must view learning as a social process that it needs to be constructed by them in their interaction and collaboration in a given learning environment. Social learning comes before knowledge development (Orey, 2010). Hence, the points discussed above under theoretical framework played a crucial role in this study to affect its completion and they are concisely depicted as follows.



Caption

Expected strong relationship between the components in the Model.

Expected almost weak relationship between the components in the Model.

Social constructivism learning theory highly involved in the development as well as implementation of the learning activities.

Figure 2.1: Theoretical Framework (Imenda, 2014)

In Figure 2.1 shown above, the findings had shown that the intervention with Vygotsky's learning theory highly benefited learners' content knowledge development and positively changed their attitude toward calculus. Although the conventional lecture method also affected comparison group learners' content knowledge development, the effect is incomparable to that of the intervention applied on the experimental group. This situation reminds educators to minimize the use of the obsolete traditional lecture method and rather magnify the use of the active learning technology blending intervention and the social interactive learning environment in classroom instruction.

2.4 Empirical Review

2.4.1 Jigsaw Co-operative Learning Strategy and GeoGebra in the Learning of Calculus

2.4.1.1 Jigsaw Co-operative Learning Strategy

One of typical active learning strategies used to teach calculus is the co-operative learning strategy. The jigsaw learning strategy is one of co-operative learning strategies. This study employed the jigsaw method combined with GeoGebra. As most research literature, for instance, Sofroniou and Poutos (2016) reported co-operative learning strategy enhances students' analytical and critical thinking, team-work spirit, independent learning, the development of interaction capabilities, and acquiring methods of solving classroom or application problems. According to Arbin, Ghani, and Hamzah (2014), co-operative learning strategy could make learners to be motivated and to have a positive attitude towards the learning material they come across. However, instructors/educators have limited knowledge to include this learning strategy in the lesson they impart. Instead, they most often use the conventional lecture method.

In the study conducted by Dhage, Pawar, and Patil (2016) on a sample of 20 engineering students, it is suggested that a research should be conducted to make a comparison between the effect of the traditional lecture method and active learning method in students learning. Such an active learning method that needs to come into comparison with the passive lecture method is the jigsaw learning strategy. The aim is to create on students' critical thinking and creativity and then apply what they learned in their day-to-day activities. In this same article, it also reported that the traditional teaching method should be transformed into any active learning method. This idea also agree with the idea suggested by (Othman et al., 2017) as innovative learning strategy must overtake the role of the conventional teaching and learning models in classroom instruction.

Gull and Shehzad (2015) conducted a study to examine the effect of jigsaw II method on students' achievement in the subject of Education. The sample size was 63 female students enrolled in grade 12 of a public college. The pre- and post-test control group quasi-experimental design was used. The data were analyzed using the paired sample t-test and independent samples t-test. The finding showed that there is a significant difference between experimental group and comparison group in post-test scores. Students enrolled in the subject Education positively achieved using Jigsaw II. The other co-operative learning strategy, namely STAD and TGT, used in this same study had also contributed for students learning to be successful in the subject Education.

Sengul and Katranci (2012) conducted a research to investigate the benefit of jigsaw method on nineteen 6^{th} grade students in Kocaeli in three lessons of 'sets'. A qualitative paradigm was used. The data were descriptively analyzed. The results showed that students enjoyed and understood the subject matter in 'sets' learning using jigsaw method

A research on the effect of jigsaw co-operative learning strategy on the achievement, knowledge retention, and attitude toward this learning strategy of 80 final-year Vietnamese mathematics students was conducted by (Tran & Lewis, 2012). The experimental group and control group were matched groups each with 40 students. The quasi-experimental design was used. The data were analyzed by ANOVA, ANCOVA, and MANOVA. The findings revealed that the experimental group perceived the jigsaw method more co-operative and student-centered. The knowledge retention and achievement of the experimental group was significantly larger than the comparison group.

Abed et al. (2019) conducted a study to explore the effect of the predictive power of jigsaw strategy on low proficient students' proficiency in mathematics and on their mathematics achievement of grade-two students enrolled in 2017-2018. The sample size was 80 in both the experimental and comparison group. Explanatory research design was used. Data were analyzed by independent samples t-test. The findings showed that the experimental group students achieved more in mathematics than the control group. Experimental group students changed their attitude positively towards mathematics lessons.

2.4.1.2 GeoGebra

In this modern world, mathematics software packages have played a multi-faceted role in education sphere of life. Next, the extent to which how people in different areas of the teaching and learning of mathematics have used them would explicitly be detailed. It would also be tried to exhaustively review the distinct features and categories of learning with computer software package as a tool. It may be helpful to say something useful about the overview of the current state of knowledge. It would further enable us to be reminded of the influence they have and the role they have played in the teaching and learning of calculus.

GeoGebra is one type of computer software packages used for teaching and learning mathematics at all levels. GeoGebra was employed in this study as a tool in the devised learning strategy in learners' calculus learning. Researchers obtained remarkable results that GeoGebra benefited for the successful attainment of students in different areas of mathematics. The empirical results indicated in some research literature are evidence to that.

Saha, Ayub, and Tarmizi (2010) conducted their research to examine the effect of GeoGebra on students' co-ordinate geometry achievement. Both the experimental group and control group comprised 53 participants. The non-equivalent post-test only control group quasi-experimental design was used. Data were analyzed using independent samples t-test. The findings showed that the experimental group taught with GeoGebra achieved more than the comparison group taught through the traditional teaching method.

A research was conducted by Zakaria (2012) to identify the effect of GeoGebra on high school students' procedural and conceptual knowledge of function according to group and gender. The experimental group comprised 138 participants. The participants in the control group were 146. A non-equivalent pre- and post-test control group quasi-experimental design was used. Data were analyzed using T-test, One-Way ANOVA and Two-Way ANOVA. The results revealed that there was a statistically significant difference in students' conceptual knowledge and procedural knowledge achievement based on their group. The results showed that there was no a statistically significant difference in students' conceptual knowledge and procedural knowledge achievement based on their gender.

Simulation is one kind of dynamic multimedia computer software programs. It is highly interactive with several features under user control. Most often, simulation has been implemented in close connection with modelling while dealing with a certain system. De Jong (2011, p.446) refers to computer simulation as a "computer program that has as their core a computational model of a system or a process". Scholars have been using it for many purposes in several situations in different spheres of life, especially in science education.

Simulation as a particular case of computer-assisted instruction (CAI) approach employed and played a very important role generally in the learning of science particularly in mathematics. In this regard, Ayub et al. (2008) have revealed that effective use of computer software packages introduce both learners and instructors with a new and better way of learning and teaching than that of the conventional lecture method. They have also indicated that these tools can be used interactively. It also helps to visualize calculus concepts and thereby enhance learners' understanding and reduce the burden in instructor explanation. In this same research article, they suggested that further analysis should be conducted on the influence which computer-assisted instruction (CAI) has on learners' knowledge development. Keengwe and Georgina (2013); Eyyam and Yaratan (2014) forwarded a supporting idea that the intention of integrating technology in learning is not yet to enhance pedagogy. Rather technology has to be considered as a tool for delivery, and should also be viewed as a means to enhance learning. A quite similar idea has been reflected in Oktaviyanthi and Supriani (2015) article that, technology is considered as a tool in the learning of mathematics. Some of the main benefits would be visualizing something abstract, representation of mathematical objects, exploring the purpose and interactive media. Moreover, Zulnaidi and Zakaria (2012) have analyzed the use of GeoGebra in the learning and teaching function can somehow improve students' knowledge of concepts (CK) and procedural knowledge (PK). Similarly, Takači, Stankov, and Milanovic (2015) reported the use of GeoGebra in learners' learning of calculus can be more effective and efficient than that of learning with the lecture method. Furthermore, Awang and Zakaria (2012) has also researched learners' conceptual knowledge (CK) and procedural knowledge (PK) understanding of integral calculus through learning using technology. Eventually, they suggested such experience of using technology in the learning and teaching of other calculus topics to be devised and implemented in a better way in the future.

Chen and Howard (2010) indicated that generally learning supported with technology particularly with computer simulation, can enhance learners' performance, creativity, and achievement in STEM learning. It also helps them to have a positive perception and attitude towards science. Also, Buteau, Muller, Marshall, Sacristán, and Mgombelo (2016) conducted their research on learners' appropriate use of computer programming as a tool in the learning of mathematical concepts. They suggested that learners need to be involved from the establishment until the implementation of every aspect of a computer interactive software package. It allows them to develop experience in constructing their mathematical knowledge. Ultimately, this enables them to own the learning. Even though the review of related literature discussed above has shown that learners exposed to the learning of mathematics with technology benefit more understanding than those instructed with traditional lecture method, there are some relevant research studies sometimes exhibiting the opposite findings. For instance, Lee (2012); Zulnaidi and Zakaria (2012) reported that, there is some sort of inconsistency in this regard.

2.5 Computer-based Learning

In this contemporary lifestyle, one's life is linked to technology. Computer-based technology is one that mostly we come across in the course of our day-to-day activities. It has especially played a very great role in the education sphere of life and specifically in teaching-learning activities. However, especially developing countries have not experienced using computer technology (graphing calculators) in mathematics classroom (Alacaci & McDonald, 2012). In connection with this, Lee (2012) has shown that computer technology used in class-room instruction since the 1990s. In this regard, Crook (2005); Eyyam and Yaratan (2014) reported, there is limited research on CBL. Highfield and Goodwin (2008) also reviewed recent studies on mathematics education and technology research journals over the last five years. They found out that technological tools in mathematics learning, particularly early mathematics learning have had potential affordances and the number of journals has been increasing rapidly. But this was not supported by evidence-based research. In this same review, it attested that the publications focused on mathematics learning and technology limited in quantity and scope. Lavicza (2010) stated that the use of technological tools in mathematics learning increased slowly. The theme in Barron, Kemker, Harmes, and Kalaydjian (2003) was also in support of this idea saying as few large-scale studies examined the effects of CBL activities on math performance. Lee also added that the findings on the incorporation of computer technology in math classrooms were inconsistent. This means that no significant differences observed in learners' achievement between those who participated in CBL activities and those taught with the traditional lecture method. In this same article, it indicated that some other studies shown these major inconsistencies. Thus, Lee recommended that follow-up research should be considered to see the extent whether the learning activities involved in it affected math major choices or not. The reason is that these activities are essential to college learners majoring in mathematics.

Also, Samuelsson (2007) indicated that some researchers have argued that computer programs can create opportunities for learners' mathematics learning conditions to be changed. Others argued that learners' mathematical skills may be affected by computer programs. Wan Salleh and Sulaiman (2013); Zulnaidi and Zakaria (2012) suggest that instructors need to be motivated to use technology whenever appropriate for any given lesson in calculus. The use of it has now been rapidly increasing. As compared to innovative learning strategy with computer software package, there is a lot of empirical evidence that the conventional lecture method has inappropriately addressed learners' performance and achievement of content (COK) knowledge in calculus. Most of the time, instructors used the conventional lecture method to teach procedural knowledge (PK). As in mathematics education research literature indicated, even it was inappropriately addressed the procedural knowledge development (PK) of calculus. Due to the arguments made and based on the various reviewed research literature, the need to examine the influence of the JCLGS on students' knowledge of concepts (CK), procedures (PK), and content (COK) development, and their attitude towards intermediate calculus and GeoGebra was designed.

2.6 Importance of Computer-assisted Instruction in Calculus Learning

Computer-assisted instruction is a process used in the teaching and learning activities that include various forms of technology-based learning (TBL). Instructors used it for different purposes in the delivery of lessons requiring various learning styles in calculus. According to Geban, Askar, and Özkan (1992); Eyyam and Yaratan (2014), computer-assisted instruction allows different learner types, such as slow, medium, and active, to be motivated and assists them to acquire the desired knowledge as much as possible in a balanced way. In support of this, Gunbas (2015) stated that computer-assisted instruction has been facilitating, directing, and helping learners' by decreasing the burden of their mental work. This is through creating a conducive learning environment to solve a given problem using appropriate procedures. Gunbas (2015) also pointed out that CAI involves various delivery means and learning environments like a simulation of lessons in calculus. Furthermore, Gunbas (2015) reported that in CAI learning environments, learners identify what knowledge and skill is applicable in their day-to-day activities. It assists them to be motivated and interested in solving problems. Arslan (2003) also indicated that CAI helps learners to frequently deal with a given learning activity through their initiative without external imposition. Forcier and Descy (2007), pointed out that in computer-assisted instruction (CAI), learners can specifically master previously learned skills through problem-solving learning environments. According to Camnalbur and Erdogan (2008), the analysis of the results of multiple studies verified that learners were more academically successful using computer-assisted instruction learning procedures than the traditional lecture method. Specifically, computer-assisted instruction (CAI) is found to be a more effective learning strategy in learners' academic achievement in the mathematics problem-solving environment (Bintaş & Çamli, 2009).

2.7 Computer-assisted learning of Calculus

Computer-assisted learning (CAL) of calculus can be considered as a particular case of computer-assisted instruction (CAI). Schittek, Mattheos, Lyon, and Attström (2001) refer to computer-assisted learning (CAL) as the learning procedures and environments used in the learning of subjects like Mathematics, Science, etc., that facilitated through suitable computer software packages. They also called it "Computer Based Instruction", or "Computer-Aided Learning", or "Computer-Aided Instruction". However, the interaction aspect was more of a benefit for this research. Of all the multiple levels that computers possess, the following two were more emphasized and implemented in this study. As Schittek et al. (2001) stated, computers can assist learners to interact with notes, handouts and assignments, and expected learning-outcomes in the syllabus. The other is that computers can host the interaction of learners with facilitator/teacher, classmates, and learning environments.

As mentioned in the previous section, this research was intended to examine the influence of the JCLGS through problem exploration before instruction on learners' knowledge, skill and attitude development of intermediate calculus. This is because limited use of computer-assisted learning (CAL) in learners' calculus learning has existed as indicated in several studies. For instance, as Hohenwarter, Hohenwarter, Kreis, and Lavicza (2008) indicated, the process of embedding technology in the teaching and learning of calculus is slow and complex. However, Eyyam and Yaratan (2014) indicated that technology has numerous benefits in mathematics education. Moreover, Caligaris, Schivo, and Romiti (2015) have shown that a significant difference is still noticed that the potential of information technology contributes to meaningful calculus learning.

2.8 Summary of Literature Reviewed

From most of the reviewed literatures, instructors/teachers have used the traditional teaching in different specific lessons of mathematics from elementary to tertiary level in classroom instruction. Because of repeated use of this obsolete and passive traditional method, students' mathematical knowledge attainment has been enormously decreasing. In some situations, GeoGebra and jigsaw learning strategy were separately used by instructors in specific lessons of mathematics to make students' learning active. Both GeoGebra and jigsaw learning strategy have enhanced students' knowledge in specific lessons of mathematics. However, no research literature reported the importance of jigsaw learning strategy combined with GeoGebra alleviating students' content knowledge (COK) learning challenge of intermediate calculus. This was taken as one of the knowledge gaps for this research to be studied. This study was intended to examine the importance of the JCLGS using socio-cultural context learning theory on students' content knowledge (COK) development of calculus.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Philosophical Assumptions and Theoretical Perspectives

The pertinent and appropriate philosophical assumptions and theoretical perspectives compatible with any educational and social sciences research should first be looked at as a component of research methodology. As Saunders et al. (2009) indicated in their research ‘onion’ schema, the philosophical assumption is the first layer that needs to be pointed out in the research methodology as part of a thesis/dissertation. Generally, the schema displays where educational or social science researchers should start and end their research and then thereby give an overview idea for readers about research methodology. Accordingly, the study employed the post-positivist philosophy, deductive approach, quasi-experiment, mixed methods, longitudinal research (pre- and post-intervention over a semester), calculus classroom achievement test and five-points Likert scale attitude questionnaire (instruments of data collection). The detail of research methodology such as the ontological and epistemological philosophical stance, research approach (deductive), research strategy (a non-equivalent pre-and-post-test comparison group quasi-experimental design), paradigm (mixed methods), time horizon/number of times over which data are gathered (longitudinal), techniques and procedures of data collection and analysis (population, sampling procedure, sample, context and participants, interventions used, instruments employed, estimating validity and reliability of instruments in pilot study, means of data preparation and means of data collection), and ethical issues are explicitly explained in later sections (Nenty, 2009; Saunders et al.,2009). According to Morgan, Leech, Gloeckner, and Barrett (2012), the quasi-experimental design used in this study is also called repeated measures design. Morgan Leech, Gloeckner, and Barrett also described such design is common in longitudinal and intervention research.

As a consensus from the research community, the process of every research study emanates from looking for the research problem(s) by the researcher. The researcher can identify and find the problem(s), as well as the topic compatible with it, using the following as his/her main sources of information. According to Singh (2006), these are personal experiences of the researcher in the field of education, deciding field of investigation, reviewing critically pertinent, related and available research literatures, new innovations, technological changes, curricular developments, consulting supervisors, experts in the field and most experienced persons in the field, and so on. To answer such a research problem(s), several issues need to be taken into account. One of these essential issues is to be aware that the intended research study goes along with appropriate philosophical schools of thought or worldviews and theoretical perspectives as a component of research methodology.

3.2 Educational Research Paradigms

Educational research paradigm has two major components, named quantitative and qualitative. There is also a third educational research paradigm, known as mixed approach encompassing the characteristics and methods of these paradigms that scholars have formulated very recently. As specified by Gelo (2012); Castellan (2010); Johnson and Christensen (2019); Yilmaz (2013), each of them possesses its characteristics, components, standards, ontological, and epistemological philosophical assumptions, methodology, and theoretical perspectives. As described by Gelo (2012), these are some of the main underlying issues that a researcher needs to take into consideration. This helps him/her to select the appropriate research method(s) in the research proposal phase before entering to conduct the thesis phase. Gelo (2012); Castellan (2010); Johnson and Christensen (2019); Yilmaz (2013) suggested that the research methods could be viewed as those technical procedures that a researcher follows for implementing both paradigms in the implementation of the research process. They also indicated that the research paradigms with corresponding philosophical assumptions and theoretical perspectives derive the methods and drive their application. Though these paradigms are not mutually exclusive, this research study is intended to be guided by mixed methods research paradigm. The reason is that the devised statements of hypothesis describe consisted the JCLGS and content (COK) knowledge development.

Gelo (2012); Castellan (2010); Yilmaz (2013) stated the various types of philosophical assumptions of a research paradigm such as positivist, post-positivist, interpretive-constructivism, and so on, from their ontological, epistemological, and methodological stances. Gelo indicated that the quantitative research approach is characterized by positivism or post-positivism whereas Castellan (2010); Yilmaz (2013) suggested that only positivism characterizes it. According to Castellan (2010); Yilmaz (2013), positivism is one of the schools of thought that believes physical and social reality exist independent of people intelligence. This means that the researcher cannot categorize the data collected by their similarities, construct the theme, put his view on an interpretation, and show empathy towards research participants. Rather he/she could analyze, and then find the results only based on the raw data obtained from observation or experimentation without applying subjective judgment. This perspective is most often recommended to be used in true or pure experimental methods (Gelo, 2012). Gelo (2012, p.118) indicated that post-positivism is similar to positivism but "it still contemplates reality, but affirm that this is only imperfectly/probabilistically apprehensible." In other words, post-positivism refers to a belief that physical and social realities are not completely independent of us. Castellan (2010); Yilmaz (2013) were in support of this idea that the post-positivists cannot observe the world as outsiders, rather they consider themselves as part of it. The ontological stance of the researcher would be to view knowledge as something that could be discovered (realist/objectivist) or constructed (constructionist), or both. This perspective is precisely said to be critical realist ontology (Gelo, 2012). This means that no reality exists completely independent of our senses. As a branch of philosophy, ontology refers to “the study of nature of reality” (Gelo, 2012; Gray, 2013; Saunders et al., 2009, p.110).The epistemological stance of the researcher could be empiricist, or interpretive, or both. Epistemology simply refers to “the study of nature of knowledge” (Gelo, 2012; Gray, 2013; Saunders et al., 2009, p.112). Since this research was based on the socio-cultural context learning theory, the knowledge developed by learners is the one constructed through social interaction with each other and with the surroundings in the designed learning environment. Learning is social by its very nature. Despite that, most quantitative researchers come up with the assumption that objective reality is out there to be discovered, therefore, the researcher cannot add his opinion, feeling, attitude and belief on the collected data of the research under consideration (Gelo, 2012; Castellan, 2010; Yilmaz, 2013).

The theoretical perspective inculcated in the researcher’s mind about the mixed research paradigm was based on the six most important variables. They are generally considered as the corner-stone of this research study, particularly building blocks of the hypotheses. Thus, each informed hypothesis attempted to explain the relationship among the JCLGS, conventional lecture method, learners’ conceptual knowledge, procedural knowledge and content knowledge achievement scores. The other variable was students’ opinions to the five points Likert type attitude scale. Since the hypotheses were stated in the beginning, while developing the research proposal, the quantitative research thesis component was processed using deductive reasoning (Creswell & Creswell, 2017). Because deductive scientific approach initially begins with a theory/hypothesis, and then goes through using particular situations towards data collection processes, the hypothesis would eventually be tested whether the data support it or reject or confirm or modify the hypothesis (Gelo, 2012; Creswell & Creswell, 2017; Yilmaz, 2013). The groups, independent (IV) and dependent (DV) variables involved in this research project are depicted in a figurative form (see Figure 3.1).

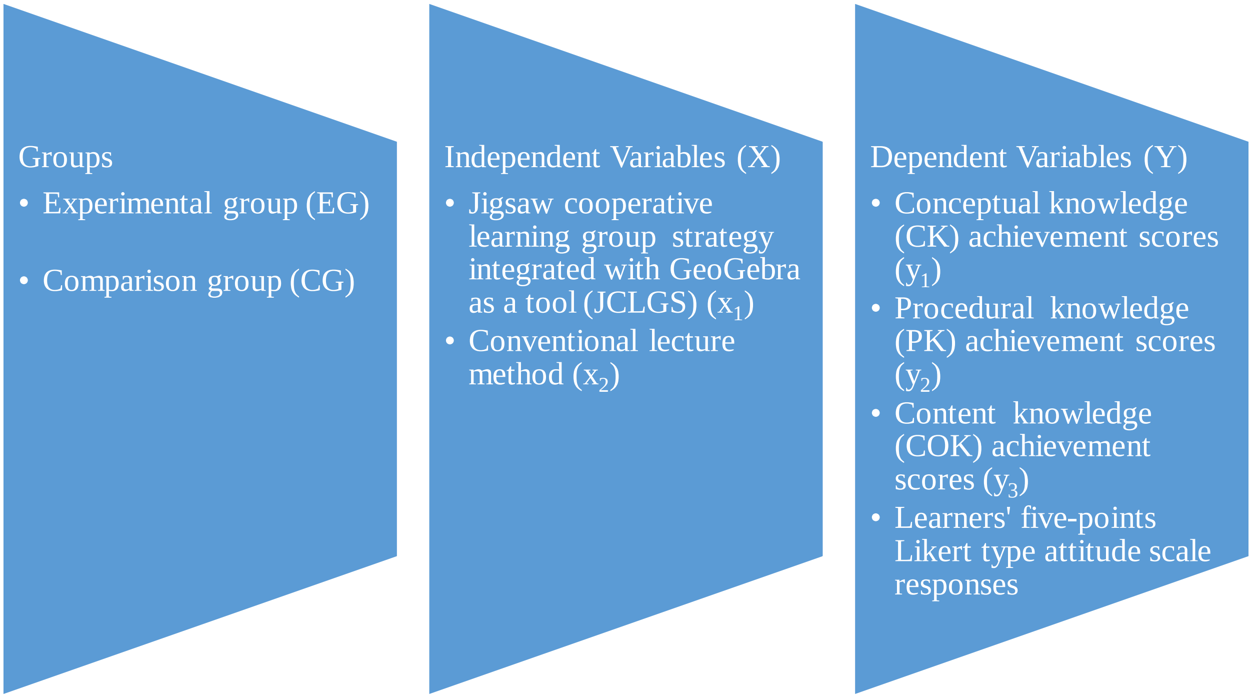


Figure 3.1: Groups, DV and IV of the Study

In terms of research processes, the deductive approach implies that the research should be undertaken with the intent of testing hypotheses, rather than developing them. In so doing, the researcher has to state a hypothesis almost at the beginning of the proposal writing and then proceed with conducting data collection to test it. Finally, he/she should reflect on its confirmation or disconfirmation, based on the inferential statistics results (Creswell & Creswell, 2017). Thus, in succinct terms, as this study utilizes the procedures of mixed research paradigm, the researcher has taken into consideration the deductive approach and then goes along with the following stages.

✓ stating the hypothesis(s) and research question(s);

- ✓ defining those variables (or constructs) contained in hypotheses or research questions, or seeking an acceptable definition from the literature;
- ✓ administering appropriately instruments to use in measuring or observing knowledge, skills, attitudes or behaviors of participants;
- ✓ finally collecting scores on these instruments; and
- ✓ testing the hypotheses and research questions, using the data collected to confirm or disconfirm the hypothesis (Creswell & Creswell, 2017).

In conclusion, the deductive approach tells you where hypotheses in a quantitative research study are placed. It can also be depicted visually as follows.

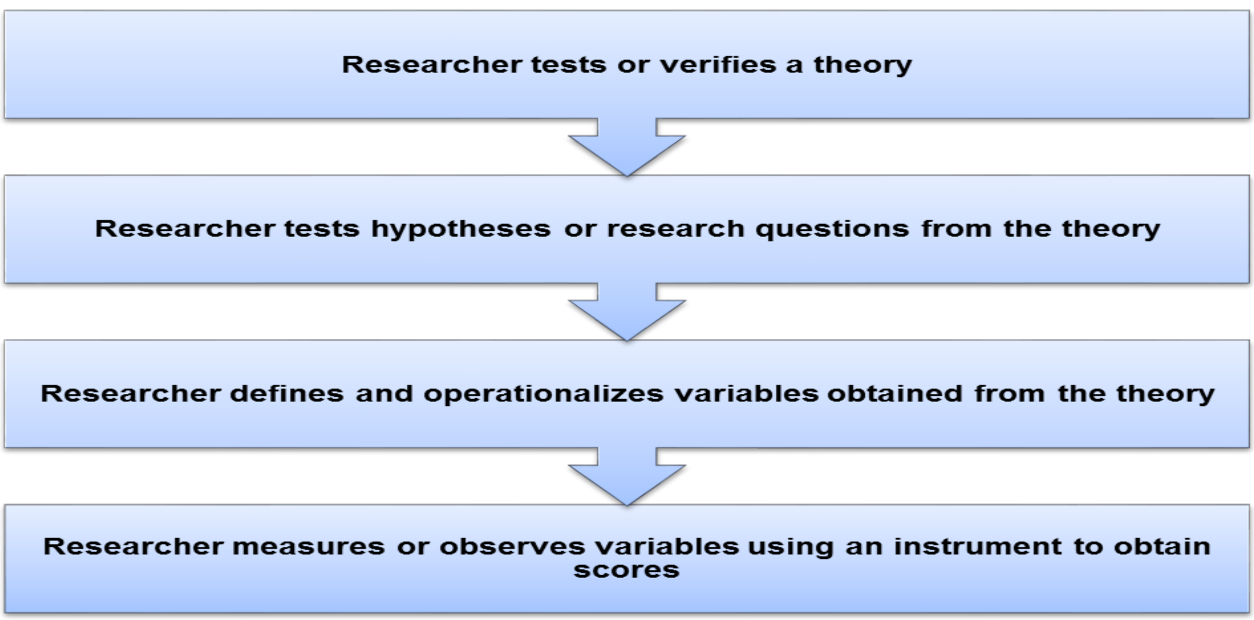


Figure 3.2: Deductive approach (Creswell & Creswell, 2017)

In this regard, Gray (2013) has suggested a set of principles or allied ideas that must initially be elaborated before testing them empirically. Accordingly, in the context of this research project, all about governing a set of constructs such as the JCLGS and students' conceptual knowledge (CK), procedural knowledge (PK), and content knowledge (COK) achievement scores have been discussed in the review of related literature. This issue was implemented before proceeding to the actual conducting of the thesis phase, as this is one of the main principles that we had to follow in carrying out mixed methods research.

Hence, the points discussed above have been taken as the main ones about the philosophical and theoretical assumptions employed. Therefore, these fundamental and important aspects guided the processes of data collection, analysis of data and interpretation of the results of this study.

3.3 Research Design

This research study employed a non-equivalent pre-test and post-test comparison group quasi-experimental design (Yimer, 2016) as depicted in Figure 3.3.

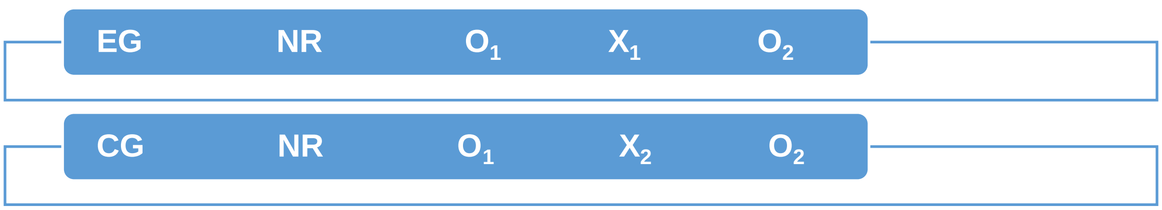


Figure 3.3: Non-equivalent Pre-test and Post-test CG Quasi-experimental Design (Yimer, 2016)

Where NR designates sample participants drawn through non-random assignment, learners' pre-test scores of treatment (EG) and comparison (CG) groups denoted by O_1, X_1 denotes the JCLGS employed to stimulate treatment group (EG), X_2 represents the lecture method applied on control group (CG) and O_2 denotes learners' post-test achievement scores of experimental (EG) and comparison (CG) groups.

According to Johnson and Christensen (2019), the quantitative paradigm can be divided into experimental and non-experimental research methods. According to Castellan (2010), the experimental method is typically distinguished, as the researcher has control over one or more independent variables. Castellan (2010); Johnson and Christensen (2019) also mentioned that it is mainly of three types; true experimental, quasi-experimental and pre-experimental method. Furthermore, Castellan asserted that true experimental method is uniquely characterized by its random assignment of sample participants into experimental and control groups. It is also used to investigate the cause-effect relationship between variables. Quasi-experimental does not involve the technique of random assignment of participants, but rather employs intact groups. As with true experimental design, quasi-experimental design can also be employed to confirm the cause-effect relationship between variables, especially on humans (Fraenkel & Wallen, 2009). However, this can be done through paying special attention to those extraneous variables that equally bring rival explanations with that of the independent variable in the conclusion of the study (Castellan, 2010; Johnson & Christensen, 2019).

The researcher selected the quasi-experimental design instead of the pure experimental design as he cannot control all confounding continuous variables. As university students have already admitted to the research universities by the Ministry of Education (MOE) and also the universities assigned these learners to their departments, random assignment of learners into experimental and comparison groups is not ethical. At the outset, this led not to necessitate applying random assignment in classifying individual participants to comparison and experimental instead existing groups were employed. Therefore, as it is indicated in many kinds of literature, for instance, Fraenkel and Wallen (2009), the quasi-experimental design has become the appropriate research design whenever the researcher gets into challenge of using random assignment techniques. The study designed to responding the research questions expressed in hypothetical statements, the essential data conducted through tests, and questionnaires had also considered as the main reason in using the quasi-experimental design

(Castellan, 2010). The similarities of the two study areas/universities was also the other reason (see Table 3.1).

Table 3.1: Some Common Attributes of the Two Research Universities

Academic Factors
Local and expatriate staff of both universities has similar profiles as their employment is undertaken by the Ethiopian Federal Government Ministry of Education (MOE) as per universities yearly plan and request.
Both universities possess only one general library which is not digital.
Both universities admit learners with almost the same educational background based on their Ethiopian University Entrance Certificate Examination (EUEE) score results.
Both universities use the same harmonized modular curriculum.
Both universities have only one mathematics laboratory with a very limited number of computers.
Administrative Factor
Both universities have one president.
Both universities have four vice presidents namely Academic, Administrative, Research and Business.
The College of Natural and Computational Sciences of both universities from which the target population considered and the sample participants for both experimental and comparison group drawn, have one dean and two vice deans (academic, and research and community service).
Both universities provide service for café and no-café (supplied pocket money) learners.
Other Factors (geographical, demographic, etc.)

Both universities are of the second generation.
Both universities are all financed by Government.
Both universities are located in the Western part of Ethiopia.
Both universities have the same climatic condition.
Both universities are located in the Oromia regional state in which most people speak the Oromia language having almost the same values, culture and history, are the habitants.

Source: Researcher's own survey

Using the quasi-experimental design, for example, Rutten, Van Joolingen, and Van Der Veen (2012); Zulnaidi and Zakaria (2012) have successfully obtained remarkable findings in their research study. Similarly, the research conducted by Arbin et al.(2014) could be taken as the other instance for which this design has been used effectively.

As to the quality of the research findings, the achievement test consisted of three items, named true/false and multiple choice items (closed-ended), and work-out items (open-ended), was pilot tested. The Kuder-Richardson formula 21 (KR-21) internal consistency measure of the first part and second part was found to be 0.7 and 0.9, respectively. These values represent an acceptable value. The Cronbach alpha reliability coefficient value of work-out items (open-ended) determined as 0.87, which is also an acceptable value. The second instrument Likert-scale attitude questionnaire was also pilot-tested and Cronbach's alpha reliability coefficient value obtained as 0.9, which is of a very high acceptable value. Overall, coefficient values ensure the reliability of the research findings. Both research instruments were validated by three-course experts. Instructors engaged in nurturing the learning of experimental group and teaching comparison group learners' had the same educational status and similar years of service. Learners enrolled in the departments of Statistics and Chemistry in both universities had on average similar scores around 300 out of 700 in the Ethiopian University Entrance Certificate

Examination (EUEE). This means that potential confounding extraneous variables, if any, very weakly influenced the response variables.

3.4 Population of the Study

The target population for the pilot study was the whole freshman undergraduate science and mathematics students in one of the two Ethiopian public universities who enrolled for calculus. The two public universities of Ethiopia were the study areas, generally located west of Ethiopia, particularly west of Oromia. Seventy five Statistics and 70 Chemistry learners, of which 83 was male and 62 female, with ages ranging between 18 and 26 for the intact experimental group, voluntarily participated for the main study. Forty three Statistics and 60 chemistry learners, of which 56 was male and 47 female with ages ranging between 18 and 25 for the intact control group voluntarily, participated. As mentioned in the preceding section, these two study areas were quite similar. Despite this, intact learners in one of the two universities were chosen as a comparison group, while the other as an experimental group.

3.5 Sampling Procedure

The sample for the main study was drawn by a two-stage random sampling method (Johnson& Christensen, 2019; Fraenkel & Wallen, 2009) for the thesis phase. At the outset, cluster random sampling was used to select randomly Statistics and Chemistry departments from science and mathematics departments in both Ethiopian public universities. Based on intact group participants' age, gender and scores of Ethiopian University Entrance Certificate Examination (EUEE) and using the codes given to each participant in the collected data, lottery method was used to draw 75 samples for the experimental group from 145 chemistry and statistics learners in one of the two universities and 75 samples for comparison group from 103 chemistry and statistics learners in the other university. These samples were used to collect data on calculus classroom achievement test. Before the pre-test, 72 samples for the experimental group were drawn by simple random sampling technique from 145 chemistry and statistics learners to collect data on learners' attitude questionnaire.

3.6 The Sample

3.6.1 For Pilot Study (Calculus Diagnostic Test and Learners' Attitude Questionnaire)

A sample of 30 participants (16 males and 14 females) was randomly drawn from the 84 existing statistics class students sat for calculus diagnostic test. Ten were low achievers. Ten were medium achievers. The remaining ten were high achievers. A reliability test for calculus diagnostic test was conducted using these samples.

Two hundred ninety eight mathematics and science students were the samples of the study (192 males and 106 females) was selected from one of the two universities who enrolled for calculus. The construct validity was conducted using Likert-scale attitude questionnaire in the pilot study. Their age ranges from 18 to 25. Strongly disagree=1, disagree=2, neutral=3, agree=4, and strongly agree=5 were the scales used in the instrument. This instrument was an adaptation of TOMRA which is a modification of TOSRA (Fraser 1981; Khine, 2013), developed by a distinguished Professor Barry J. Fraser in Macquarie University, Australia. The reliability of this similar research tool was reported by Awang and Hamid (2015) reported in their study.

3.6.2 For Main Study (Calculus Achievement Test and Learners' Attitude Questionnaire)

One hundred fifty were samples for the main study. These samples were used to collect data on calculus classroom achievement test. The comparison group comprised 75 samples (30 females and 45 males). Eighteen to twenty-five was the age range. The remaining 75 samples (50 males and 25 females) made up the experimental group (EG). Eighteen to twenty four was their age range. The proportion of males to females in both groups was similar. The age range for both groups was almost the same. Similarity of groups in age and gender was important to control extraneous variables that equally bring rival explanations with that of the independent variable in using a quasi-experimental design. Seventy two samples for the experimental group were drawn by simple random sampling technique from 145 chemistry and statistics learners to collect data on learners' attitude questionnaire. The sampling frame for this study comprised all learners who voluntarily participated.

3.7 Context and Participants

The education system of Ethiopia was classified into different stages: kindergarten (4 -6 years); primary education (7 -14 years) with two cycles, named first cycle (7 -10 years) and second cycle (11 -14 years); secondary education (15 -18 years), with two cycles, named first cycle (15 - 16 years) and second cycle, preparatory school (17 -18 years) (Federal Democratic Government of Ethiopia, 1994) as well as the highest stage the undergraduate and graduate programs (college and university). Each stage was aimed at different goals. The research participants were whole science and mathematics students of the study locations who enrolled for calculus course. However, the introductory of basic calculus learning begins in the second cycle of secondary education, i.e. grade twelve, with the informal notion of limit discussing the procedural aspect (or computational) and certain applications of differentiation and integration. Conceptual knowledge of calculus learning manifests in the undergraduate program of higher education, involving the dynamic, together with the formal notion of the limit of a function at a point. Therefore, it is at this turning point, that most learners' calculus learning gets challenged. The reason is that mostly the dynamic notion of limit appears with such phrases "approaches to", "tends to" or "closer to" and "as small as we please" which are usually difficult for students to visualize them through traditional lecture method (Tall & Razali, 1993). The other learners' challenge is also that of the formal notion of limit, which entails given any sufficiently small real number "ε", requiring to find some small real number "δ" depending on "ε". Hence, this study was devised to explore the influence of the JCLGS on freshman undergraduate students' content knowledge (COK) development of calculus and then to minimize their learning challenges.

3.8 Intervention

At the beginning of the intervention, the researcher conducted training for one week with two instructors. They had MSc degree in Mathematics. This initial group of instructors had 24 and 7 years teaching experience, respectively. They took training on the JCLGS and learning activities of calculus. These calculus learning activities were prepared by the researcher. The JCLGS was devised to explore these activities had addressed students' learning problems of calculus or not. The initial group instructors were skilful with the free open-source mathematics software package, GeoGebra. Following, two cluster departments named Statistics and Chemistry from both research project universities were randomly selected. As per the permission of the head of the Department of Mathematics in one of the two Ethiopian public universities, the initial group of instructors was assigned for the experimental group (Statistics and Chemistry learners). The second group of instructors with Master of Science Degree in Mathematics had 26 and 9 years experience in teaching, respectively. Similarly, the second group of instructors was assigned for the comparison group (Statistics and Chemistry learners) in the second university.

When class begins, the initial group instructors was moved to give training on basic notion of GeoGebra for 16 hours (four weeks) to the experimental group learners, in laboratory of mathematics (2 hours in a week). There were 2 intact laboratory classes for Chemistry and Statistics learners in the experimental group. Side-by-side, experimental group learners learned intermediate calculus in the mainstream class through the conventional method. Altogether, the experimental group learners learned the intermediate calculus course for 4 hours in mainstream class and 2 hours in laboratory/tutorial classes in a week. Comparison group learned in their mainstream and tutorial class through the conventional lecture method. Next, pre-test was administered on knowledge of concepts, procedures and content for experimental group and comparison group students by their instructors for three hours. The adapted and pilot-tested learners' attitude questionnaire was also administered in this same session, only for 72 randomly experimental group learners. The calculus classroom achievement test had three parts. The first and second parts were of the closed-ended type, of which twenty true-false items and thirty multiple-choice items and the third part was open-ended type containing five work-out questions.

The constructed items covered such topics as limits, continuity, derivatives, and integration of a function at a point. The researcher developed these items based on lecture notes, hand-outs, modules, and reference books. This set of items were designed and constructed by paying special attention to conceptual knowledge (CK) and procedural knowledge (PK) aspects. Likert-scale questionnaire was used for the main study consists of 28 items.

Following this, the treatment group went to discuss calculus using the JCLGS for 12 weeks (24 hours) in the laboratory class, together with lecture methods in a normal class. The conventional lecture method in both mainstream and tutorial classes was used for comparison group learners until the end of the semester. During the intervention, class exercises, home exercises and hand-out, two mid-tests, one home assignment and sample of miscellaneous questions on the classroom achievement test were supplied for intact experimental group learners. Learners in both groups took post-test as with the pre-test, for three hours at the end of the semester. As with the pre-test session, Likert-scale questionnaire was administered to only 72 treatment group learners in the post-test session. The intervention was conducted to stimulate treatment samples and thereby to explore the influence of it on their knowledge of concepts, procedures and content improvement as compared to the lecture method.

3.8.1 Jigsaw Co-operative Learning Strategy Integrated with GeoGebra as a Tool

The JCLGS was employed in the mathematics laboratory and tutorial sessions to nurture experimental group (EG) learners' learning of calculus. This was focused more on conceptual (CK) knowledge development of calculus. The intervention was facilitated by the initial group instructors assigned for experimental group learners. One of the initial group instructors had taught in high school, college and university. The other instructor in the initial group instructors had taught only in university. The learning activities were discussed by the experimental group learners in their jigsaw group interactively with each other and they eventually came to a consensus to what they agreed on. If they came across an abstract calculus object, they tried visualizing symbolically, algebraically, geometrically, and graphically and calculus means using GeoGebra. Both instructors had been guiding, helping, assisting, facilitating, and motivating the learners to utilize their learning. They used the same course outline, hand-out, worksheets, pre- and post-test questions, quizzes, tests, and learning activities in the laboratory session, and attitude questionnaire. In the course of the intervention, experimental group learners shared their experiences using the JCLGS on the learning activities. Initial group instructors provided feedback on what learners attempted during class participation and in doing class work, homework/assignments, group work and tests. The initial group instructors also taught the experimental group learners using the lecture method in the mainstream class.

The process of the JCLGS in the mathematics laboratory class was generally structured and implemented using socio-cultural context learning theory by Vygotsky's in the way shown in Figure 3.4.

Figure 3.4: Structure of the Process in JCLGS (Orey, 2010)

GeoGebra applet was used to illustrate the geometrical interpretation of the formal $(\varepsilon - \delta)$ definition of limit of a function f at a point/number x_0 is shown in Figure 3.5.

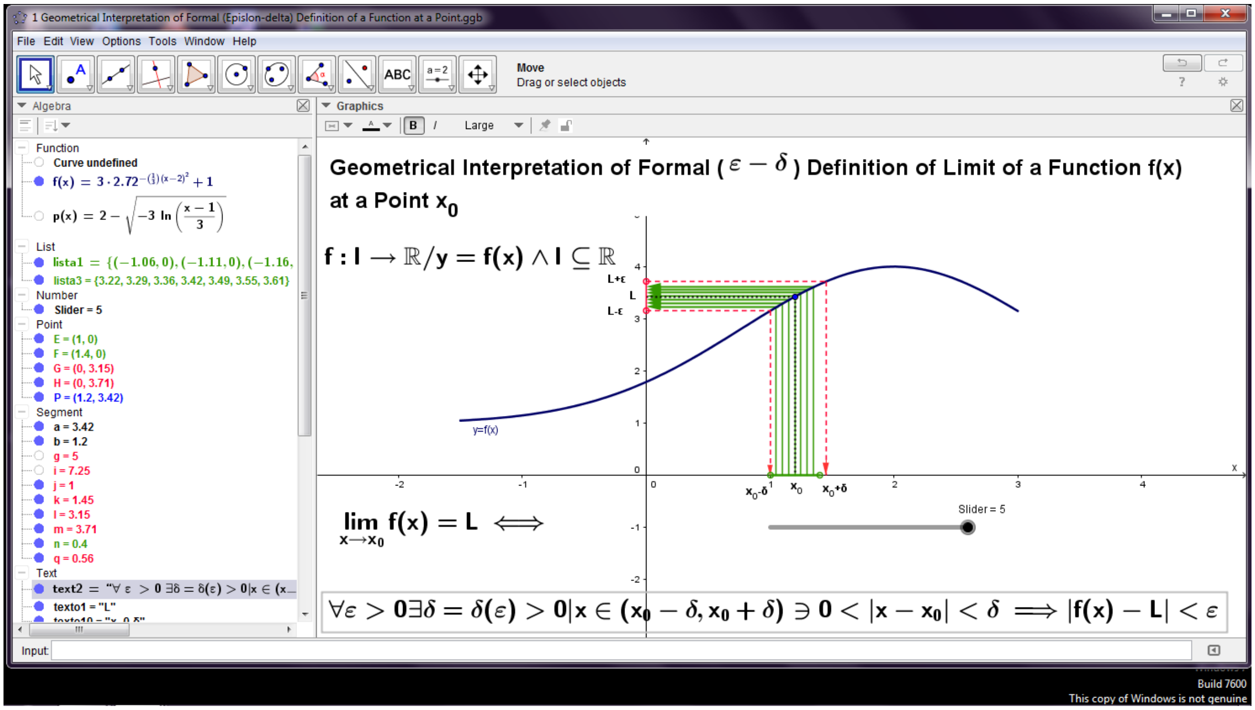


Figure 3.5: GeoGebra Applet on Formal Definition of Limit

Example on area problem using $f(x) = x^3$, $g(x) = 8x$ and $h(x) = 8$ that learners tried, is shown in Figure 3.6.

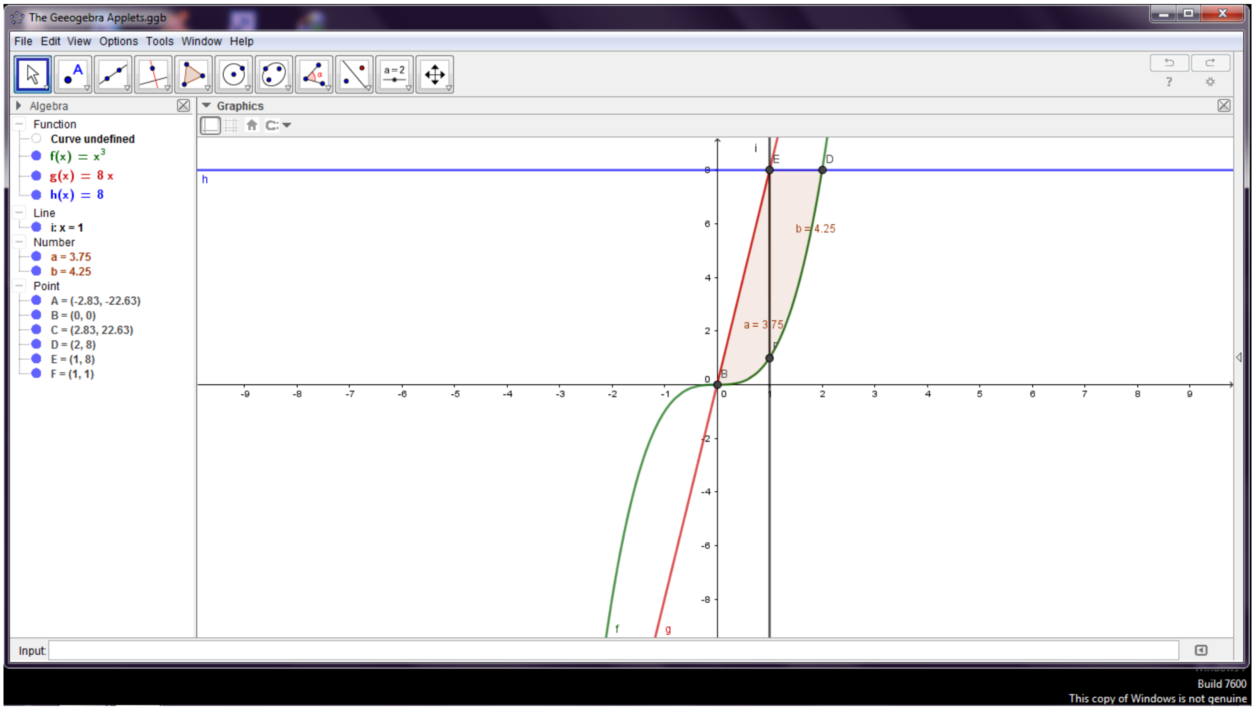


Figure 3.6: Learners' Attempt on the Area Problem in the Mathematics Laboratory Session

The learning activities on the intermediate calculus developed by the researcher are appended (see Table H2 in Appendix H). Along with these learning activities, the fundamental functions of one variable were provided for students to pay special attention in their interaction (see Table H3 in Appendix H).

3.9 Instrumentation

3.9.1 Intermediate Calculus Classroom Achievement/Diagnostic Test

Two instruments were used for this study, namely the calculus diagnostic/achievement test and the five-points Likert-scale questionnaire. Quantitative data were collected using achievement/diagnostic test (Johnson & Christensen , 2019). The topics were limits, continuity, derivatives and integration. Almost all were constructed from learning materials. Special attention was paid to knowledge of concepts and procedures while designing and constructing it. The bi-directional approach due to Kridler (2012); Chinnappan and Forrester (2014) was applied as much as possible, to balance these two knowledge learning. The items were developed through going back and forth. The operational definitions of knowledge of concepts and procedures were stressed. The nature of the psychological construction or characteristics being measured (nature of items in the test) was ensured using the Bloom's taxonomy of educational learning objectives theory (Fraenkel & Wallen, 2009). Adebule (2009) suggested an important idea that instructors should employ different test types rather than essay/workout items of achievement tests at a time. As the number of students in higher institutions is rapidly increasing all over the world, such variety of items in achievement test can easily be managed in the construction and administration of them. By Adebule's suggestion and Ethiopian public universities evaluation trend involving varieties of items, achievement test consisted of closed-ended and open-ended items were used. The work-out part had 5 items. The multiple-choice part had 30 items. The true-false part had 20 items. They were used in the pilot and main (pre- and post-test) study.

3.9.2 Learners' Attitude towards Calculus and GeoGebra Questionnaire

The Likert-scale questionnaire was the second instrument. Such survey questionnaire is called a delivery-and-collection questionnaire (Saunders et al., 2009). As the name indicates, this questionnaire was administered by distributing the questionnaire and collecting the responders from each sample. They indicated that it is most often used in descriptive or explanatory (analytical) research. This questionnaire was used as this study is explanatory research designed to investigate cause-and-effect relationships. It was adapted from a pre-existing TOMRA/TOSRA questionnaire developed by Fraser (1982). There were items were five criterions, namely view normality of mathematics (N), mathematics inquiry (I), adoption of mathematics (A), enjoyment of mathematics lessons (E) and learners' attitude towards calculus. The reliability of this instrument was verified by (Awang & Hamid, 2015) in their research study. A pilot-test was also conducted to ensure the validity and reliability of this instrument in the context of the current study. This instrument consisted of fifty items. The number of items was reduced to twenty-eighty variables through a pilot study. These variables were also employed to explore treatment group students' change in opinion towards calculus over a semester during main (pre-and post-test) study.

3.10 Validity and Reliability

3.10.1 Overview of Validity

One of the most important concepts used to estimate what it was supposed to measure about a research instrument is validity (Johnson & Christensen, 2019; Saunders et al., 2009; Fraenkel & Wallen, 2009). It is of two types, namely internal and external validity. As the study was a comparative study, the internal validity procedures could assist the researcher to make sure to draw right inferences based on the data collected. It can be validated through three testing techniques named content related, construct related and criterion-related evidence (Fraenkel & Wallen, 2009). Of all these evidences, content validity is the one that most applied in the achievement test. According to Fraenkel and Wallen (2009), firstly the subject experts provided comment on content-related evidence of validity. In selecting, the educational background, skill and experience of the experts should be taken into account as much as possible. As Fraenkel and Wallen (2009) also suggested, evaluating the adequacy of sample questions, whether achievement test meet the proposed definition of measurements and the objective of the study or not. Also, whether the instrument is based on the syllabus, evaluating the format of the test and appropriateness of language are also included as additional tasks. The face validity techniques were used to assess these aspects. The coefficient index (r) was used to analyze the correlation. As Fraenkel and Wallen (2009) suggested, Bloom's taxonomy of educational learning objectives theory is utilized to ensure the construct-related evidence of items. The validity of Likert-scale questionnaire could analogously be verified as that of the classroom achievement test.

3.10.2 Content/Face Validity of the Calculus Classroom Achievement Test

The researcher prepared the calculus achievement test based on Bloom's taxonomy of educational learning objectives theory. He was permitted by Mathematics Department head to obtain opinions from instructors/experts in evaluating face/content validity. The application was requested by specifying the names of three experienced and skilful instructors of the department. In the application, benchmark points were indicated so that the evaluators could be guided by them. Some of the evaluation aspects that were given due consideration were the adequacy of sample questions (level of difficulty) and whether the proposed objectives of the research was based on the syllabus (content) or not. The letter of permission was appended with this research thesis report (see Appendix G). Accordingly, the experts suggested their opinion in the way shown below.

The comments were minor on the instruction in part one of the tests such as miss-spelt words and phrases either to be included or excluded at the outset. Proceeding, each of the twenty items under this part was thoroughly assessed by correcting miss-spelt words and notations. Also, the instructors remarked that one of the items was not objective focused and then suggested it be excluded. They also identified how each question was constructed to measure knowledge of concepts (CK) and procedures (PK). Next, evaluators commented the instruction of the second part. Each item and corresponding possible alternatives were also evaluated by experts. These were typographical errors, improper writing of mathematical symbols or notations, formation and appearance of distracters. Each question was assessed as it represents knowledge of concepts (CK), procedures (PK) or content (COK). Finally, the experts evaluated the third. Overall, they checked the coverage of the syllabus in the instrument. The researcher corrected some of the comments forwarded by course experts.

Table 3.4: Table of Specification/Test Blue Print for Content Validity (Bloom's Taxonomy)

Topics	Questions								
	True-false			Multiple-choice			Work-out/Open-ended		
	CK	PK	COK	CK	PK	COK	CK	PK	COK
Limits	4	3	7	6	7	13	1	1	2
Continuity	5	1	5	8	2	9	2	1	3
Derivative	11	4	11	9	7	15	2	2	4
Integral	1	-	1	-	1	1	-	1	1

CK=Conceptual Knowledge, PK=Procedural Knowledge, COK=Content Knowledge

3.10.3 Overview of Reliability

The other concept used together with validity to assess stability of an instrument is reliability. The consistency of responses can also be evaluated through it (Fraenkel &Wallen, 2009). The level of reliability testing is of three types such as test-retest, equivalent form and internal consistency methods (Yimer, 2016). However, the equivalent-forms reliability or internal consistency reliability method introduces a small standard error of measurement (Yimer, 2016). The reliability of the achievement test in the pilot-test was estimated by the internal consistency method due to lack of resources (Yimer, 2016). Only once a single test was administered to participants. The correlation between the item score and the total test score was evaluated by computing the reliability coefficient (Kiliyyani & Sivaraman, 2016). The Kuder-Richardson Formula 21 (KR-21) was used to check the internal consistency reliability of both multiple-choice and true/false items (Kuder & Richardson, 1937). Cronbach's alpha (α) coefficient was calculated to ensure the reliability coefficient of workout items which should be at least 0.7 (Arbin et al., 2014; Kuder & Richardson, 1937; Zulnaidi & Zakaria, 2012) for the calculus achievement test.

3.10.3.1 Item-analysis of True-false, Multiple-choice and Work-out Items

At the outset, the researcher was looking for a department in the location of the study offering calculus in the semester he planned to undertake the item-analysis. The researcher was permitted by the head as per his application and then assigned to freshman statistics students. When the researcher entered the class at 'day one class one' he gave a course outline and informed the students that he was going to undertake the pilot test. Afterwards, he came to deliver the course (Math1041) by providing worksheets for every four chapters, conducting the tutorial class by especially giving more attention to female learners and administered two tests on true/false, multiple-choice and workout items on chapter one and two. There was a trend of providing affirmative action for female students all over the public universities of Ethiopia. The reason was to empower female learners to look for their knowledge. The researcher also gave sample questions for both female and male students that would help them to be prepared for chapters three and four. Keep in mind that the structures of the content in the assessment involved in both the two tests and sample questions were quite similar to the diagnostic test. At the end of the academic semester, the researcher administered 20 true/false, 30 multiple-choice and 5 workout items which cover the whole four chapters in the course. Fortunately, this was agreed with the trend followed by the quality education and audit office of the university, that final examination of each course should include at least three types of item questions. The number of learners who sat for the final examination was 84. Finally, the researcher entered the sample data into SPSS 23.0 to estimate the reliability indices of both objective type tests.

3.11 Item Analysis Results of True-false Items

3.11.1 Discussion on Item Analysis of True-false Items

As reported by Ding and Beichner (2009), the difficulty index of each item was found to be in the acceptable range [0.30, 0.90]. The average item difficulty level for all items was also included in this range. On the other hand, the discrimination index of each of the twelve items was found in the standard range [0.30, 1.00] while for the eight items were not in the range (Boopathiraj & Challamani, 2013; Ding & Beichner, 2009). Item 14 got a negative discrimination index it was rejected in the main research data collection. In the main data collection, items with low item discrimination value (7) were corrected. The average item discrimination index for all items was a somewhat satisfactory value of 0.38. More than half of the items nearly had point-biserial correlation coefficients lies in [0.20, 1.00]. The point-biserial correlation coefficients of nine items were low. Overall items fairly had average value, 0.26 and acceptable. Cronbach's alpha value of the first part was found to be 0.7, which is applicable for group assessment (Kuder &Richardson, 1937).

The sample data and results obtained on true/false items are depicted in tabular form (see Tables I5, I6 in Appendix I) and Table 3.6.

Table 3.7: Descriptive Statistics for Learner' Pilot Test Scores of True-false Items

n	M	SD
30	14.30	3.334

Based on Table I5 and I6 in Appendix I and Table 3.7, results on estimates of the four basic statistics (item difficulty level index=0.72, item discrimination index=0.38, reliability index of item score=0.26 and reliability index of the total test score=0.7) for each item and the entire test score of the true-false test items are also depicted in tabular form (see Table I8 Appendix I).

3.12 Item Analysis Results of Multiple-choice Items

3.12.1 Discussion on Item Analysis of Multiple-choice Items

The multiple-choice items had difficulty items, as their item difficulty indices were below the lower limit of the range. These items were seven in number. The item difficulty index of the remaining twenty-three questions belonged to the specified range [0.30, 0.90] as examined by (Boopathiraj, 2013; Ding & Beichner, 2009). The average value of 0.45 was a good and acceptable one. The discrimination index of five items had values below the range while the remaining twenty-five questions had item discrimination values that lied in the acceptable range [0.30, 1.00] as reported by (Boopathiraj & Challamani, 2013; Ding & Beichner, 2009). However, items 28 and 30, out of the five items were associated with item discrimination value 0. High achievers from low achievers were not differentiated by these two questions. Thus, this suggested that they must be removed from this collection of items. The average value was 0.61 which is good value. Each of the items had good point-biserial correlation coefficient index that belonged to the range [0.20, 1.00], except five of the items (Boopathiraj & Challamani, 2013; Brown, 2001; Ding & Beichner, 2009). Two of them were the ones mentioned above with item discrimination value 0. The average value was 0.46 which is good value. Finally, the Cronbach's alpha value of the second part was found as 0.91, which is very high. Therefore, generally, these indices suggest to the researcher that this part of the test would likely be employed in the main research data collection process.

The sample data and results obtained on multiple-choice items are displayed in tabular form (see Table J9 and J10 in Appendix J) and Table 3.11.

Table 3.11: Descriptive Statistics for Learner' Pilot Test Scores of Multiple-choice Items

n	M	SD
30	13.37	7.304

Just as the true/false items, based on Table J9, J10 in Appendix J and Table 3.11, results on estimates of the four basic statistics (item difficulty level index=0.45, item discrimination index=0.61, reliability index of item score=0.46 and reliability index of the total test score=0.9) for each item and the entire test score of the multiple-choice items are also represented in tabular form (see Table J12 Appendix J).

3.13 Item Analysis of Workout Items/Open-ended

Work-out items are considered as a subjectively scored test. Due to this, internal consistency analysis technique used for subjective test is different from that of the objectively scored tests even though both measures were targeted at addressing the same issue. The two raters corrected the workout items using a common answer key. The instructor and researcher (raters) had similar experiences. Both taught similar courses during that semester. The purpose of the analysis was to reduce personal biases.

The sample data and results obtained on important information on the workout items are depicted (see Table K13 Appendix K) and (see Table 3.14 and 3.15).

Table 3.14: Descriptive Statistics for Learners' Pilot test Scores of the Work-out Items

		M		SD	
n	Question	Rater 1	Rater 2	Rater 1	Rater 2
30	Q_1	1.2833	1.1833	1.15731	1.13322
30	Q_2	0.8667	0.8167	0.85029	0.82507
30	Q_3	1.5667	1.4500	1.27126	1.23108
30	Q_4	1.0000	.9667	1.0000	0.9906
30	Q_5	.5667	.5167	1.2228	1.1779

Table 3.15: Inter-rater Reliability Estimate of the Work-out Items

	Pearson's Product Moment Index
Question	Rater 1 and Rater2
Q_1	0.984
Q_2	0.984

Q_3	0.981
Q_4	0.992
Q_5	0.987

Correlation is significant at the 0.01 level (2-tailed).

The inter-rater reliability index of the sample data on each of the five workouts item questions is very high (see Table 3.15). This implies that the scores that raters rated on the same learner were consistent. It also tells us high-achiever learners received high scores, while low achievers received low scores. This characteristic of the workout items could qualify it to be used in the main study data collection process.

Table 3.16: Inter-rater Agreement Estimate of the Work-out Test Items

	Intra-class Correlation Coefficient (ICC)	
Question	Single Measures	Average Measures
Q_1	0.981	0.990
Q_2	0.982	0.991
Q_3	0.976	0.988
Q_4	0.992	0.996
Q_5	0.986	0.993

One way random effects model where people effects are random.

Each work-out item had very high inter-rater agreement index (see Table 3.16). The values were in the acceptable range. Therefore, they characterized the workout test items. Cronbach's alpha reliability coefficient value for the third part was found as 0.87 and acceptable medium value.

3.14 Content/Face Validity of Learners' Attitudes Questionnaire

The three experienced and skilful instructors, who evaluated content validity of the classroom achievement test, also forwarded their usual constructive comments to ensuring the content validity of the second instrument. The evaluators had commented individually not in a group. Accordingly, each instructor had evaluated starting from the instruction through each item of the questionnaire, such things like misspelt words and phrases, improperly constructed sentences, identifying vocabularies not easily understandable in the phrase or sentence and generally appropriateness of language. They also commented on the context in which each item was intended to address. The questionnaire formats like the clarity of printing, font size and line spacing adequately assessed. After looked at the comments suggested, the researcher had corrected so that the respondents in the main data collection process easily understand it and thereby to obtain the appropriate data.

3.15 Construct Validity of Learners' Attitudes Questionnaire

3.15.1 Construct Validity of Learners' Attitude Questionnaire for Pilot Study

In one of the two Ethiopian public research areas/universities, the questionnaire was administered to 298 entire mathematics and science learners by their respective lecturers. One hundred ninety two of them were male and 106 were females. Their ages ranges from 18 to 25. The learners were those who enrolled in the intermediate calculus.

Table 3.17: Frequency Distribution for Respondents' Department and Gender

	Gender		
	Male	Female	Total
Department	Freq (%)	Freq (%)	Freq (%)
Mathematics	32 (10.74)	16 (5.37)	48 (16.11)
Physics	35 (11.74)	17 (5.7)	52 (17.44)
Chemistry	50 (16.78)	27 (9.06)	77 (25.84)
Chemistry Laboratory	20 (6.71)	17 (5.70)	37 (12.41)
Statistics	55(18.46)	29 (9.73)	84 (28.19)
Total	192 (64.43)	106 (35.57)	298 (100)

Thereafter, the collected data in the survey were input into SPSS 23. Each variable had a mean value greater than equal to 3.00. This observation was important to use exploratory factor analysis. Demircioglu, Aslan, and Yadigaroglu (2014) indicated that exploratory factor analysis (EFA) is one of the multivariate analysis techniques used for such purpose. The construct validity was ensured using the principal component factor analysis (PCFA) with varimax rotation as the variables were independent or uncorrelated. The principal component analysis is one of the basic exploratory factor analysis (EFA) techniques. The PCFA was used to identify those common factors predominate students' opinion. In doing this, Yong and Pearce (2013) suggested that large sample size is one of the most important factors in factor analysis. Demircioglu et al. (2014) also supported this idea. Generally, cognitive and behavioral sciences research literatures were also in support of this argument. Yong and Pearce (2013) reported that the proportion of the number of respondents to variables should be at least 10:1. This means that for 20 variables, at least 200 samples need to be employed. The number of samples used in the current study was medium-sized. Bartlett test of Sphericity and Kaiser-Mayer-Olkin Measures (KMO) are the appropriate indices for small-or medium-sized samples (Demircioglu et al., 2014) to decide the data are suitable for factor analysis or not. It encourages us to assess the conformity of the variables for factor analysis. As most research literatures on factor analysis study suggested, when the significant level (p-value) of Bartlett's test of sphericity test is at the 0.05 level or better and the Kaiser-Mayer-Olkin (KMO) value is greater than or equal to 0.6 we say that data are suitable for factor analysis.

Table 3.18: KMO and Bartlett's Test

Kaiser-Meyer-Olkin	Bartlett's Test of Sphericity		
Measure of Sampling Adequacy	Approx. Chi-Square	df	Sig.
0.849	6654.583	1225	.000

The results shown in Table 3.18 the values were appropriate in the pilot-test. Furthermore, Demircioglu et al. (2014); Yong and Pearce (2013) suggested that the correlation between the scale items is the other index that should be verified in factor analysis. This value was determined by the most often widely used reliability testing tool, Cronbach's alpha (Demircioglu et al., 2014). It was found that .89 was a highly acceptable, reliable and valid value.

Scree plot and Eigenvalues were also considered very important phenomenon. According to Cohen et al. (2007); Demircioglu et al. (2014); Yong and Pearce (2013), they can be used to determine how many underlying (latent) factors to retain. Kaiser's criterion is one of the criteria that decided by Eigenvalues whose value is 1 or above 1. The graph of the scree plot with Eigenvalues against the component/factor numbers is displayed in the figurative form (See Figure 3.7).

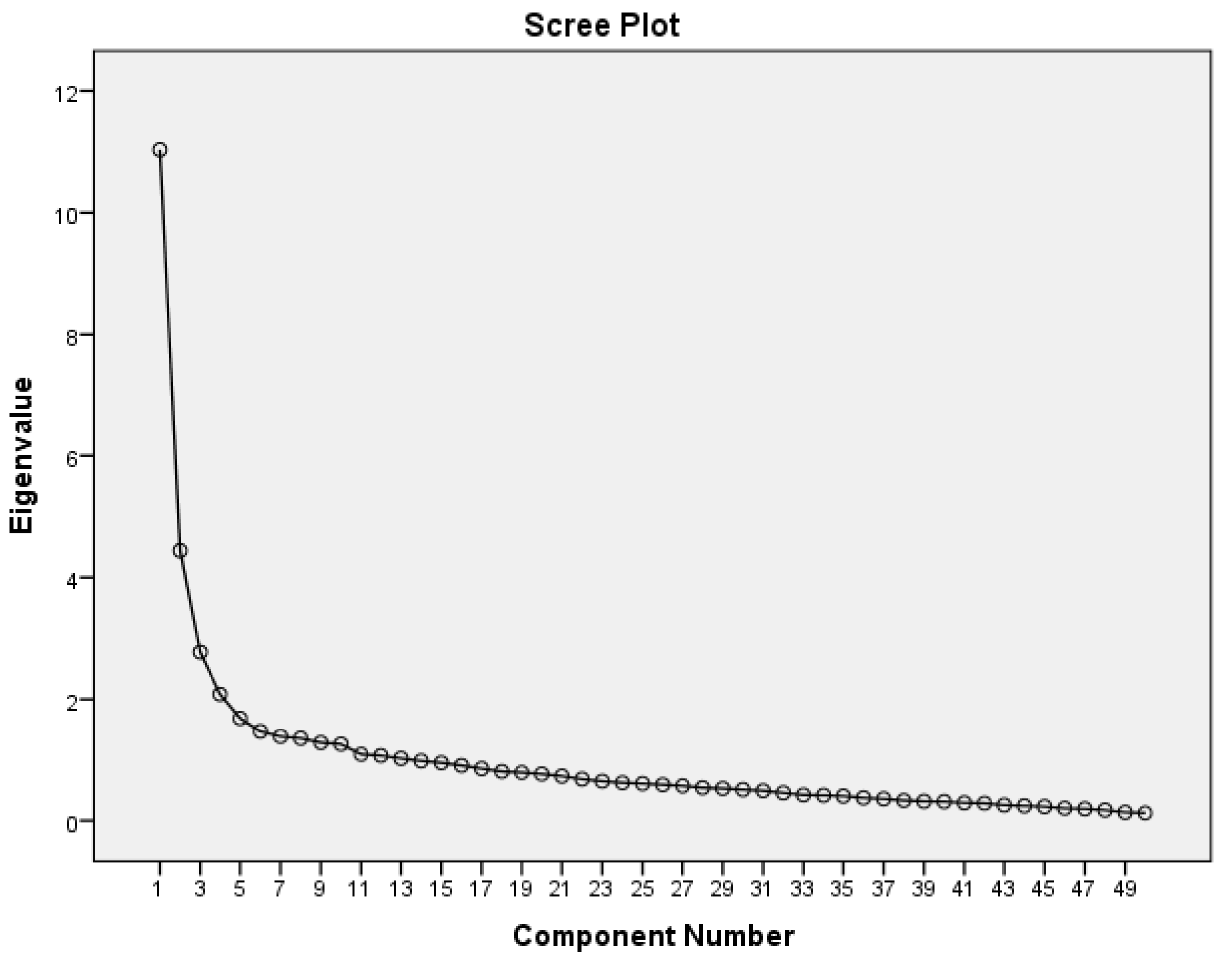


Figure 3.7: Scree Plot Graph

Yong and Pearce (2013) stated the decision to the cut-off point of factor loadings and the number of factors is usually left for the researcher to use his professional skill. For this reason, the cut-off point for factor loadings was estimated to be 0.4. As suggested by Yong and Pearce (2013), the scree plot graph was used to decide on the five factors. The fifth point (factor) along the graph from left to right is an inflexion point where the graph exhibited a change in the concavity. To the left of this inflexion point, the graph is concave upward. To the right of this point, the graph is concave downward. The number of sub-criteria/variables included by these five factors is 45. The Eigenvalues of the factors 1, 2, 3, 4 and 5 were 11.993, 6.754, 6.190, 2.09 and 2.04, respectively. 23.98%, 13.51%, 12.38%, 4.18% and 4.08% indicated the percentage of variances explained by each of the factors. 58.13% explained the total percentage of variance. The values .792, .783, .797, .813 and .815 were Cronbach's alpha value on each of the factors (internal consistency). The value .89 was the total Cronbach's alpha value on the entire instrument.

The researcher further examined giving a closer look at the five factors obtained above to reduce them. Criterions highly influenced learners' attitude were normality of mathematics (N), which is F_1 and enjoyment of mathematics lessons (E), which is F_2 and learners' attitude towards calculus, which is F_3. The pilot study findings were similar to (Awang et al., 2013). It consisted of 28 items with their corresponding factor loadings (see Table L20 in Appendix L). These things alerted the researcher to identify students' interest and attitude toward calculus in conducting his main study and presenting the course content through active learning strategy. For instance, the instructor may employ different learning strategies that would enhance the learning of calculus interesting, satisfactory, and easy.

In conclusion, this pilot test helped the researcher to devise and then to take the appropriate remedial action for learners to better learn the content material. In particular, it had highly facilitated the application of the JCLGS undertaken in the main study data collection process in intervention.

3.15.2 Reliability Coefficient Values of Learners' Attitude Questionnaire for Main Study

The data were collected from 72 randomly selected experimental group (EG) on the five-points Likert-scale questionnaire. The data collection process took place at two points in time over a semester. At the beginning of a semester (pre-intervention), the first data set was collected. At the end of a semester (post-intervention), the second data set was conducted from the same group using the same questionnaire in the pre-test. The questionnaire consisted of 28 items of which 8 were normality attitudes, 10 were enjoyment attitudes and 10 were learners' attitude towards calculus and GeoGebra.

It is now worth to have an idea about the reliability coefficient values of Likert-scale attitude questionnaire in pre- and post-intervention.

Table 3.21: Cronbach's Alpha Reliability Coefficients

	Cronbach's Alpha	
Attitude Constructs	Pre-intervention	Post-intervention
Normality	.911	.803
Enjoyment	.947	.844
Attitude towards calculus and GeoGebra	.874	.793
Overall Attitude	.970	.934

The reliability coefficient values in pre-intervention shown in Table 3.21 were in the acceptable range of which two were of very high (.911 and .947) and the other one was medium (.874) for each attitude criterion. The overall attitude questionnaire had also very high value of 0.970. In post-intervention also acceptable reliability coefficient values were observed in the same instrument as with pre-intervention. Therefore, it can be said that the reliability coefficient values were consistent at two different points in time (pre- and post-intervention) as with the pilot test.

3.16 Data Collection Procedures

The study employed the achievement test and Likert-scale attitude questionnaire to collect data. Both instruments were used to ensure reliability and validity. The main data collection process used the corrected instrument by the researcher in the pilot-test. The instructions were clearly stated. The language was made simple for students to easily understand the questions. The appropriate printing size was used, specifically misspell words, phrases and sentences were carefully edited. The researcher and each respective instructor assessed other factors affecting the data collection such as the weather, classroom size and facilities, such as chairs and desks. For the weather, morning time was used as the afternoon time was hot during winter. The instructors tried their best utilizing the available facilities in the universities be helped by them to get appropriate data from participants. The researcher and instructors also informed research participants as their responses not related to grades. This means the information that students were providing, was only used for research purpose. Research participants completed both instruments in pre- and post-intervention sessions. The research participants' responses to the classroom achievement test were corrected by the researcher and data collectors/instructors. The researcher and data collectors/instructors had carried-out the correction by taking into consideration the purpose of the study. Finally, the desired data on the classroom achievement test were obtained based on conceptual knowledge score out of 45%, procedural knowledge score out of 28% and content knowledge score out of 100%. The researcher prepared, described and organized data on Likert-scale questionnaire. Data-collection for the thesis phase was processed at two different points in time (pre-test & post-test) over an academic semester (longitudinal) in 12 weeks.

3.17 Ethical Considerations

Two Ethiopian public universities were the study areas of this research project. The whole first year undergraduate learners in the department of Mathematics, Physics, Statistics, and Chemistry who enrolled for calculus were considered as a target population. UNISA received the letters of permission from both universities. Despite that, UNISA where the researcher has studied his

PhD had provided the ethics approval for the study on 20/07/2016. The letters of consent from the two research locations and ethical clearance are appended at the end of this research thesis (see Appendix D and F).

3.18 Data Preparation

One of the research instruments, the achievement test consisted of three parts with 55 questions. The first part had 20 true/false items (closed-ended), the second part 30 multiple-choice items (closed-ended) and the third part 5 workout items (open-ended). Each part had got items used to measure three dependent variables such as knowledge of concepts (CK), procedures (CK) and content (COK) achievement scores. Part one consisted of 15 conceptual (CK), 2 procedural (PK) and 20 content (COK) knowledge items. Part two consisted of 26 conceptual (CK), 18 procedural (PK) and 60 content (COK) knowledge items. Part three consisted of 4 conceptual (CK), 8 procedural (PK) and 20 content (COK) knowledge items. Knowledge of concepts (CK) was scored out of 45%, knowledge of procedures (PK) out of 28%, and content knowledge (COK) out of 100%. Learners' responses on the first and second part were scored by the respective instructors (data collectors) using the answer key. The average scores on the responses rated by the researcher and data collectors were calculated on part three.

The second instrument had 28 five points Likert-scale items, of which 15 were positively worded statements and 13 were negatively worded statements. The experimental group (EG) attitudinal change was explored using this instrument. Learners' response rates for the positively worded statements were entered into SPSS 23.0 without making any transformation. A transformation was made on negatively worded statements in such a way that learners' response rate of 1 was input as 5, 2 as 4, 3 as it is, 4 as 2 and 5 as 1.

3.19 Procedures for Hypothesis Testing

The procedures followed in testing the hypotheses or answering research questions of this study are concisely depicted in Table 3.22 shown.

Table 3.22: Hypothesis Testing Procedures

Null Hypotheses (H_0)
H_{01}: Learners who learn calculus using the JCLGS demonstrate the same conceptual knowledge (CK) as learners who learn without it.
H_{02}: Learners who learn calculus using the JCLGS demonstrate the same procedural knowledge (PK) as learners who learn without it.
H_{03}: Learners who learn calculus using the JCLGS demonstrate the same content knowledge (COK) as learners who learn without it.
Constructs
Cognitive, psychomotor and affective
Learning theories
calculus conceptual (CK), procedural (PK) and content (COK) knowledge; and attitudinal change
Instructional strategy theories
Jigsaw co-operative learning strategy integrated with GeoGebra as a tool (JCLGS), traditional lecture method
Types of Variables

Independent Variable (IV)	Jigsaw co-operative learning strategy integrated with GeoGebra as a tool (JCLGS)
	Traditional lecture method
Dependent Variable (DV)	Learners' conceptual knowledge (CK) achievement scores in calculus
	Learners' procedural knowledge (CK) achievement scores in calculus
	Learners' content knowledge (COK) achievement scores in calculus
	Learners' attitudinal change towards calculus/mathematics and GeoGebra (five-points Likert type scale)
Level of Measurement of Dependent Variable (DV)	
Ratio measure (achievement scores ranging from 0 to 100)	
Ordinal measure (five-points Likert type scale ranging 28 to 140)	
Statistical Design (Two groups: Experimental vs Comparison)	
Assumption Pre-test: Experimental group=Comparison group (Data support H_0.) Pre-test to Post-test: Experimental group>Comparison group (Data do not support H_0.)	
Statistical test	

Descriptive analysis, Independent-samples t-test and Two-Way ANOVA for repeated measures

CHAPTER FOUR

DATA ANALYSIS AND RESULT INTERPRETATION

4.1 Descriptive and Inferential Statistical Tools for Data Analysis

Presenting and describing the collected data sets using the appropriate descriptive statistics, carrying out the presentation of each hypothesis in line with the analysis of the corresponding data, obtaining findings based on descriptive and inferential analyses, interpreting the generated results and eventually answering the research hypothesis/question are major concerns of this chapter. The purpose of descriptive analysis is to represent the collected data with appropriate descriptive statistics and then based on that to give descriptive analysis. The inferential statistical techniques could specify the appropriate test of the level of statistical significance, effect size measure and confidence interval used in fitting the model like mean, variance, and etc. to the collected data. Descriptive and inferential statistical tools should be applied by giving due emphasis to the following major quantitative research analysis procedures. According to Cohen et al. (2007), these are the purpose of the analysis, the data are parametric or not parametric, the nature of data (nominal, ordinal, interval or ratio) and number of groups in the sample. It also needs to be checked whether the data meet the requirement of the underlying assumptions in the various inferential statistical tests. The other issue was to verify whether the samples were independent or related to each other. Despite this, the purposes of data analysis of this study were to test the three null hypotheses using inferential analysis. The fourth research question that could not be converted into hypothesis form was analyzed through descriptive analysis. The three null hypotheses built on the dependent variables such as learners' knowledge of concepts (CK), procedures (PK) and content (COK) achievement scores in calculus. The parametric test was employed as the data were a continuous scale of measurement that represented learners' calculus classroom achievement scores on CK, PK and COK. Also, the data had to satisfy the underlying assumptions criterion in the parametric test which must be checked later on. The hypotheses were tested to ensure the statistical significant of pre-test mean score difference between the experimental (EG) and comparison (CG) group and to assess mean score incremental change through pre-test to post-test. The 95% level of statistical significance (α=0.05) was the one most commonly and widely used in mathematics education research. However, because of the care and attention given to the intervention by the researcher, data collectors/instructors and research participants, this study employed 99% (α=0.01) level of statistical significance. The five points Likert-scale of experimental group responses constituted the dependent variable of the fourth research question. Peteros, Columna, Etcuban, Almerino, and Almerino (2019) indicated that learners attitude affect their achievement scores of mathematics and vice-versa. That is the reason this research project intended to study these constructs jointly which were the components of the theoretical framework. Bear in mind that, this study involved one continuous variable, one nominal variable (instructional method/independent), one ordinal variable (dependent), two experimental conditions/factors and two different groups of participants. This led to the use of a particular case of parametric test that is an independent-samples t-test and two-way ANOVA for repeated measures procedures used by (Kandemir & Demirbağ-Keskin, 2019).

4.2 General Description of Data

The overview descriptions of the collected pre-and-post-test data on a continuous dependent variable are presented in tabular forms (see TableM1, Table M2, Table M3, Table M4, Table M5, and TableM6 in Appendix M).

4.3 Answering Research Question

The fourth research question was not transformed into a hypothesis form. Firstly, answers for it are presented by making rigorous descriptive analysis as follows. The intention of including the fourth research question in this study was to find out whether learners' calculus achievement scores were related to their attitude or not. It is stated as follows:

Does the JCLGS has influence on treatment group learners' change of attitude towards calculus and GeoGebra?

Descriptive analysis was performed in terms of mean as the sample size was relatively large for the distribution of data gets to tend to normality by the Central Limit Theorem. The second reason was that the collected data on Likert scale were assumed as interval. As the results are shown in Table 4.7, all the mean values for each variable except one in the pre-intervention were below neutral scale (3). The weighted mean was also below neutral. This implies that almost all sample participants had not perceived the life condition of mathematician as quite similar to others. This led them to view as the learning of calculus/mathematics was not as normal as other courses. In contrast, in the post-intervention, each participant's opinion towards each variable had a mean value by far bigger than the neutral scale. The weighted mean was also bigger than the neutral scale. Participants were very positive towards learning calculus in the post-intervention. They had become perceiving mathematician who lead his/her life in quite similar to another person life. In sum, they had positively changed their attitude as they can learn calculus/mathematics in the way they learn other subjects. This was due to learners' use of calculus learning activities prepared by the researcher in which they had learned them with the aid of the intervention (JCLGS) using socio-cultural context learning theory. Consequently, at least learners had minimized their phobia towards the learning of calculus/mathematics course during the post-intervention.

Table 4.7: Descriptive Statistics for Normality Attitude

Normality Attitude	Pre-intervention	Post-intervention

	M	SD	M	SD
Mathematicians are about as fit and healthy as other people.	2.83	.934	3.79	1.244
Mathematicians do not have enough time to spend with their families.	2.25	.960	4.58	1.071
Mathematicians like sports as much as other people do.	2.46	.838	4.62	.863
Mathematicians are less friendly than other people.	2.56	.977	4.58	1.045
Mathematicians can have a normal family life.	2.53	.978	4.62	.941
Mathematicians do not care about their working conditions.	4.18	.565	4.45	.872
Mathematicians are just as interested in art and music as others are.	2.47	.855	4.53	1.100
If you met a mathematician, he/she would probably look like anyone else you might meet.	2.24	1.204	4.21	1.087
Weighted mean	2.29		4.42	

Detailed descriptive analysis in terms of frequencies or percentages on these same data on each normality attitude item based on Table 4.8 can be given as follows.

Table 4.8: Frequency Distribution for Normality Attitude (N)

Normality (N)	Pre-intervention	Post-intervention

	Frequency (%)					Frequency (%)				
	SA	A	N	D	SD	SA	A	N	D	SD
Mathematicians are about as fit and healthy as other people.	5 (6.9)	10 (13.9)	26 (36.1)	30 (41.7)	1 (1.4)	32 (44.4)	5 (6.9)	28 (38.9)	2 (2.8)	5 (6.9)
Mathematicians do not have enough time to spend with their families.	4 (5.6)	4 (5.6)	8 (11.1)	46 (63.9)	10 (13.9)	60 (83.3)	4 (5.6)	2 (2.8)	2 (2.8)	4 (5.6)
Mathematicians like sports as much as other people do.	4 (5.6)	3 (4.2)	16 (22.2)	48 (66.7)	1 (1.4)	58 (80.6)	5 (6.9)	6 (8.3)	2 (2.8)	1 (1.4)
Mathematicians are less friendly than other people.	7 (9.7)	4 (5.6)	11 (15.3)	50 (69.4)		60 (83.3)	3 (4.2)	3 (4.2)	3 (4.2)	3 (4.2)
Mathematicians can have a normal family life.	6 (8.3)	6 (8.3)	9 (12.5)	50 (69.4)	1 (1.4)	59 (81.9)	6 (8.3)	2 (2.8)	3 (4.2)	2 (2.8)
Mathematicians do not care about their working conditions.	10 (13.9)	11 (15.3)	6 (8.3)	45 (62.5)		16 (22.2)	55 (76.4)			1 (1.4)
Mathematicians are just as interested in art and music as	3	7	12	49	1	58	4	4	2	4

other people are.	(4.2)	(9.7)	(16.7)	(68.1)	(1.4)	(80.6)	(5.6)	(5.6)	(2.8)	(5.6)
If you met a mathematician, he/she would probably look like anyone else you might meet.	5 (6.9)	8 (11.1)	8 (11.1)	29 (40.3)	22 (30.6)	36 (50.0)	26 (36.1)	3 (4.2)	3 (4.2)	4 (5.6)

The results shown in Table 4.8 revealed that participants on the first item of normality attitude responded by agreeing 20.8%, neutral 36.1% and disagreeing 43.1% in the pre-intervention while 51.4% agreed, 38.9% were neutral and 9.7% disagreed in the post-intervention. The percentage of participants responded to agreeing in the post-intervention was higher than those participants who responded to agreeing in the pre-intervention. This led to deduction of that positive attitudinal change observed in students as the result of using the JCLGS in their calculus learning. This means that learners were nurtured by the JCLGS through the guidance and assistance of their instructors. These aspects thereby made learners, in the course of intervention change their attitude towards mathematicians as they are fit and healthy as other people.

On the second item, participants responded by 11.1% agreeing, 11.1% remaining neutral and 77.8% disagreeing in the pre-intervention, while 88.9% agreed, 2.8% were neutral and 8.3% disagreed, in the post-intervention. The number of participants that responded by agreeing in the post-intervention was also very large compared to those respondents agreeing in the pre-intervention. Participants who responded to neutral were few in both pre- and post-intervention as compared to the first item. A remarkable positive attitudinal change exhibited by most participants, due to the intervention to this item. It means the intervention allowed learners to change their opinion that mathematicians were very serious in budgeting their time.

Participants' response to item three were 9.7% in agreement, 22.2% neutral and 68.1% disagreeing in the pre-intervention, while 87.5% agreed, 8.3% were neutral and 4.2% disagreed in the post-intervention. The percentage of responding participants agreeing on post-intervention were substantially higher than those respondents agreeing in the pre-intervention. Most participants had also experienced a considerable positive attitudinal change in respect to item three, because of the use of the intervention in their calculus learning. In the course of the intervention, learners had come to perceive mathematicians as they were normal as any other people who appropriately use their leisure time to other extracurricular activities.

Participants' response to item four was 15.3% in agreement, 15.3% neutral and 69.4% disagreeing on pre-intervention while 87.5% agreed, 4.2% were neutral and 8.3% disagreed in the post-intervention. The percentage of participants responding in agreeing on post-intervention was higher than those who responded in agreeing to the pre-intervention. Most participants changed their attitude positively to item four. Mathematicians had smoothly communicated with their learners when the learning of intermediate calculus undergone using the JCLGS integrated with GeoGebra as a tool.

On the fifth item, participants responded to 16.7% agreeing, 12.5% being neutral and 70.8% disagreeing in the pre-intervention, while 90.3% agreed, 2.8% were neutral and 6.9% disagreed in the post-intervention. A few numbers of participants in both pre- intervention (9) and post-intervention (2) responded to being neutral. However, the number of participants who responded by agreeing to the post-intervention was high. From this, it can be inferred that almost all participants had shown a positive attitudinal change as the result of intervention in respect of this item. During the intervention, learners had derived a positive attitude that led them to perceive mathematicians were who lead their family life in a normal way.

Participants' responses to item six was in agreement 29.2%, 8.3% neutral and 62.5% disagreeing, in the pre-intervention, while 98.6% agreed and 1.4% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was higher than those who responded by agreeing in the pre-intervention. Almost all participants had exhibited positive attitudinal change towards item six. During the intervention, learners had perceived that mathematician were careful and attentive to their working environment.

On the seventh item, participants responded in 13.9% agreeing, 16.7% neutral and 69.4% disagreeing in pre-intervention while 86% agreed, 5.6% neutral and 8.4% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was higher than those responding by agreeing in the pre-intervention. Few numbers of participants in both pre-intervention (12) and post-intervention (4) responded to being neutral. However, the number of participants responding by agreeing in post-intervention was high. From this, it can be deduced that participants have shown positive attitudinal change due to the intervention in respect of this item. The intervention had influenced learners to perceive that mathematicians enjoyed in art and music.

Participants' response to item eight was 18.1% agreed, 11.1% was neutral and 70.8% disagreed during pre-intervention, while 86.1% agreed, 4.2% neutral and 9.7% disagreed in the post-intervention. The percentage of participants responding by agreeing in the post-intervention was higher than those responding by agreeing in the pre-intervention. Most participants had exhibited a considerable positive attitudinal change in respect of this item. Learners viewed mathematician as simple man as any other person

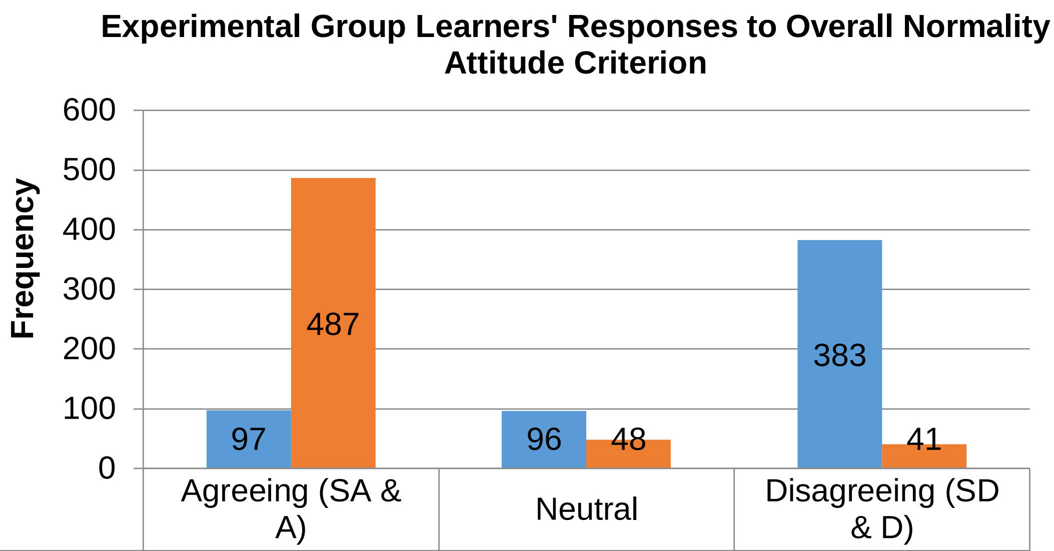
Overall, most participants had shown a positive attitudinal change in response to the eight normality attitude items. They viewed the learning of intermediate calculus as normal as other courses. They had become to develop a positive attitude towards those who study mathematics (mathematician), viewing them as normal as other persons.

Table 4.9: Frequency Distribution for Overall Normality Attitude (N)

Pre-intervention Frequency (%)			Post-intervention Frequency (%)		
A	N	D	A	N	D
97 (16.8%)	96 (16.7%)	383 (66.5%)	487 (84.5%)	48 (8.3%)	41 (7.1%)

Note: A= Agreeing (Strongly Agree and Agree Responses); N= Neutral (Neutral Responses); D= Disagreeing (Strongly Disagree and Disagree Responses)

The number of participants responding by agreeing was 84.5% on overall normality attitude in post-intervention which was bigger than those responding by agreeing, 16.8%, in pre-intervention. Generally, this showed learners viewed intermediate calculus as normal as other courses in learning it through the JCLGS. The frequency distribution is equivalently depicted graphically as follows.



	Agreeing (SA & A)	Neutral	Disagreeing (SD & D)
Pre-intervention	97	96	383
Post-intervention	487	48	41

Figure 4.1: Bar graph to Overall Normality Attitude Responses

Data on enjoyment attitude can be analyzed in terms of mean as follows. As the results are depicted in Table 4.10, the pre-intervention mean value on the entire criterion was below the neutral scale except one with nearly a neutral mean value. Therefore, the weighted mean was also less than the neutral scale. At the outset of the intervention, learners had not likely felt good on calculus/mathematics learning. Overall, they disliked mathematics/calculus lessons. In contrast, the mean value on each item in the post-intervention was by far greater than the neutral scale. The weighted mean was too. Consequently, learners had improved their attitude in such a way that they viewed the learning of calculus as easy, enjoyable and interesting. This was due to the influence of the jigsaw learning strategy and GeoGebra grounded in socio-cultural context learning theory on learners' leaning of calculus.

Table 4.10: Descriptive Statistics for Enjoyment Attitude

Enjoyment	Pre-intervention	Post-intervention

	M	SD	M	SD
Mathematics/calculus lessons are fun.	2.81	.898	4.67	.582
I do not like mathematics /calculus lessons.	2.43	.962	4.50	1.113
Universities should have more mathematics /calculus lessons each week.	2.24	.459	4.33	1.113
Mathematics/calculus lessons bore me	1.74	1.501	4.24	1.316
Mathematics/calculus is one of the most interesting courses in the programme.	3.03	.374	4.49	1.088
Mathematics/calculus lessons are a waste of time.	2.53	1.150	4.47	.571
I enjoy going to classes where mathematics/calculus lessons are presented.	2.49	1.007	4.19	1.328
The material (content) covered in mathematics/calculus lessons is uninteresting.	1.72	1.416	4.21	1.087
I look forward to mathematics/calculus lessons.	2.06	1.174	4.33	.712
I would enjoy university more if there were no mathematics/calculus lessons.	2.36	.810	3.97	1.244
Weighted mean	2.34		4.36	

Descriptive analysis in terms of frequencies or percentages on these same data on each enjoyment attitude item based on Table 4.11 can be carried out as follows.

Table 4.11: Frequency Distribution for Enjoyment Attitude

Enjoyment (E)	Pre-intervention Frequency (%)					Post-intervention Frequency (%)				
	SA	A	N	D	SD	SA	A	N	D	SD
Mathematics/calculus lessons are fun.	6 (8.3)	5 (6.9)	30 (41.7)	31 (43.1)		32 (44.4)	5 (6.9)	28 (38.9)	2 (2.8)	5 (6.9)
I do not like mathematics /calculus lessons.	6 (8.3)	4 (5.6)	7 (9.7)	53 (73.6)	2 (2.8)	57 (79.2)	4 (5.6)	5 (6.9)	2 (2.8)	4 (5.6)
Universities should have more mathematics /calculus lessons each week.	1 (1.4)		15 (20.8)	56 (77.8)		50 (69.4)	5 (6.9)	9 (12.5)	7 (9.7)	1 (1.4)
Mathematics/calculus lessons bore me.	11 (15.3)	2 (2.8)	1 (1.4)	1 (1.4)	57 (79.2)	51 (70.8)	3 (4.2)	7 (9.7)	6 (8.3)	5 (6.9)
Mathematics/calculus is one of the most interesting courses in the university.	1 (1.4)	3 (4.2)	65 (90.3)	3 (4.2)		55 (76.4)	7 (9.7)	3 (4.2)	4 (5.6)	3 (4.2)
Mathematics/calculus lessons are a waste of time.	12 (16.7)	1 (1.4)	1 (1.4)	57 (79.2)	1 (1.4)	55 (76.4)	16 (22.2)		1 (1.4)	
I really enjoy going to classes where mathematics/calculus	7	6	2	57		48	7	6	5	6

lessons are presented.	(9.7)(8.3)(2.8)(79.2) (66.7) (9.7) (8.3) (6.9) (8.3)
The material (content) covered in mathematics/calculus lessons is uninteresting.	7 7 1 1 56 36 26 3 3 4 (9.7)(9.7)(1.4)(1.4)(77.8) (50.0)(36.1)(4.2) (4.2) (5.6)
I look forward to mathematics/calculus lessons.	5 6 3 32 26 32 34 4 2 (6.9) (8.3) (4.2) (44.4)(36.1)(44.4)(47.2)(5.6) (2.8)
I would enjoy university more if there were no mathematics/calculus lessons**.**	5 11 56 52 16 4 (6.9) (15.3) (77.8) (72.2) (22.2) (5.6)

As the results are shown in Table 4.11, it can be observed that participants to the first item on enjoyment attitude responded to 15.2% agreeing, 41.7% being neutral and 43.1% disagreeing in the pre-intervention, while 51.3% agreed, 38.9% were neutral and 9.7% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was moderately higher than their agreeing response in pre-intervention. Even though a lot of participants in both pre- and post-intervention responded to neutral, it was observed that learners had shown positive attitudinal change as a consequence of the intervention. An average number of learners in the post-test had viewed intermediate calculus learning as fun using the JCLGS.

On the second item, participants responded by 13.9% agreeing, 9.7% being neutral and 76.4% disagreeing in the pre-intervention, while 84.7% agreed, 6.9% were neutral and 8.3% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was very high compared to their agreeing response in the pre-intervention. Few participants in the pre-test (7) and post-test (5) responded to being neutral compared to the first item. A remarkable positive attitudinal change was exhibited by most participants, through using the intervention in respect of this item. Learning with the JCLGS allowed learners to develop positive behavior towards intermediate calculus.

Participants' responded to item three were 1.4% agreeing, 20.8% neutral and 77.8% disagreeing in the pre-test while 76.4% agreed, 12.5% were neutral and 11.1% disagreed in the post-intervention. The number of participants who responded by agreeing in the post-intervention was higher than their agreeing responses in the pre-intervention. Most participants had also experienced a considerable positive attitudinal change concerning item three. Most learners had avoided a phobic character towards the learning of calculus/mathematics.

Participants responded to item four with 18.1% agreeing, 1.4% neutral and 80.6% disagreeing in pre-intervention while 75% were in agreement, 9.7% being neutral and 15.3% disagreeing in the post-intervention. The number of participants responding by agreeing in post-intervention was higher than those learners responded to agreeing in pre-intervention. Most participants had exhibited a considerable positive attitudinal change in respect of item four. Most learners viewed mathematics lessons attractive.

On the fifth item, participants responded with 5.6% agreeing, 90.3% neutral and 4.2% disagreeing in the pre-intervention while 86.1% agreed, 4.2% were neutral and 9.7% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was higher than their agreeing response in the pre-intervention. Most participants (65) were responded to neutral in the pre-intervention, while fewer in number in post-intervention. However, the number of participants responding by agreeing to the post-intervention was high.

From this, it can be inferred that participants had shown positive attitudinal change towards this item as the result of the intervention. Most learners had an interest in the learning of intermediate calculus with the JCLGS.

Participants' responses to item six were 18.1% agreed, 1.4% neutral and 80.6% disagreed in pre-intervention, while 98.6% agreed and 1.4% disagreed in post-intervention. You can see that no one responded to being neutral in the post-intervention. The number of participants responding to agreeing in the post-intervention was substantially higher than their agreeing response in the pre-intervention. Therefore, participants exhibited a highly positive attitudinal change in respect of item six. This means almost all learners perceived intermediate calculus lessons as being very valuable and applicable in different spheres of real-life.

On the seventh item, participants responded 18% agreeing, 2.8% neutral and 79.2% disagreeing in the pre-intervention, while 76.4% agreed, 8.3% were neutral and 15.3% disagreed in the post-intervention. A few number of participants in both pre-intervention (2) and post-intervention (6) responded neutral. However, the number of participants responding to agreeing in the post-intervention was high. It can be concluded that most participants had shown a positive attitudinal change as the result of intervention to this item. They viewed learning intermediate calculus with the JCLGS as enjoyable.

Participants' responded to item eight was 19.4% agreeing, 1.4% neutral and 79.2% disagreeing in the pre-intervention, while 86.1% agreed, 4.2% were neutral and 9.7% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was higher than their agreeing response in the pre-intervention. Most participants had exhibited a considerable positive attitudinal change to item eight. They perceived the learning activities included in the learning material as pertinent and important.

On item nine participants responded 15.2% agreeing, 4.2% neutral and 80.6% disagreeing in the pre-intervention, while 91.6% agreed, 5.6% were neutral and 2.8% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was higher than their agreeing response in the pre-intervention. As to this item, few numbers of participants in both pre-and post-intervention responded neutral. However, the percentage of participants responding to agreeing in the post-intervention was high. Therefore, almost all participants had shown positive attitudinal change to this item. They had interested to what is going to be presented in the designed learning environment.

Participants' responded to item ten were 6.9% agreeing, 15.3% neutral and 77.8% disagreeing in the pre-intervention, while 94.4% agreed and 5.6% were neutral in the post-intervention. The number of participants responding agreeing in the post-intervention was substantially higher compared to their agreeing responses in the pre-intervention. Almost all participants showed a positive attitude in their response to this item. They were aroused even to learn other mathematics in the future by the initiation they received from the learning environment used.

Overall, most participants exposed to the intervention considerably changed their attitude positively as to the enjoyment of intermediate calculus lessons. In other words, they almost viewed the learning of intermediate calculus enjoyable using the JCLGS. Therefore, the conducted analysis implied that the JCLGS was appropriately used in addressing the learning activities to be very enjoyable for experimental group learners. It allowed them to successfully perform and achieve in a devised learning environment and to develop a positive attitude.

Table 4.12: Frequency Distribution for Overall Enjoyment Attitude (E)

Pre-intervention	Post-intervention

Frequency (%)			Frequency (%)		
A	N	D	A	N	D
95 (13.19%)	136 (18.89%)	489 (67.92%)	591 (82.08%)	69 (9.58%)	60 (8.33%)

The percentage of participants responding agreeing to overall enjoyment attitude was 82.08% in post-intervention which was substantially higher than those in pre-intervention, 13.19%. This generally indicated that learning calculus with the JCLGS as enjoyable, interesting and easy. This frequency distribution was equivalently depicted graphically as follows.

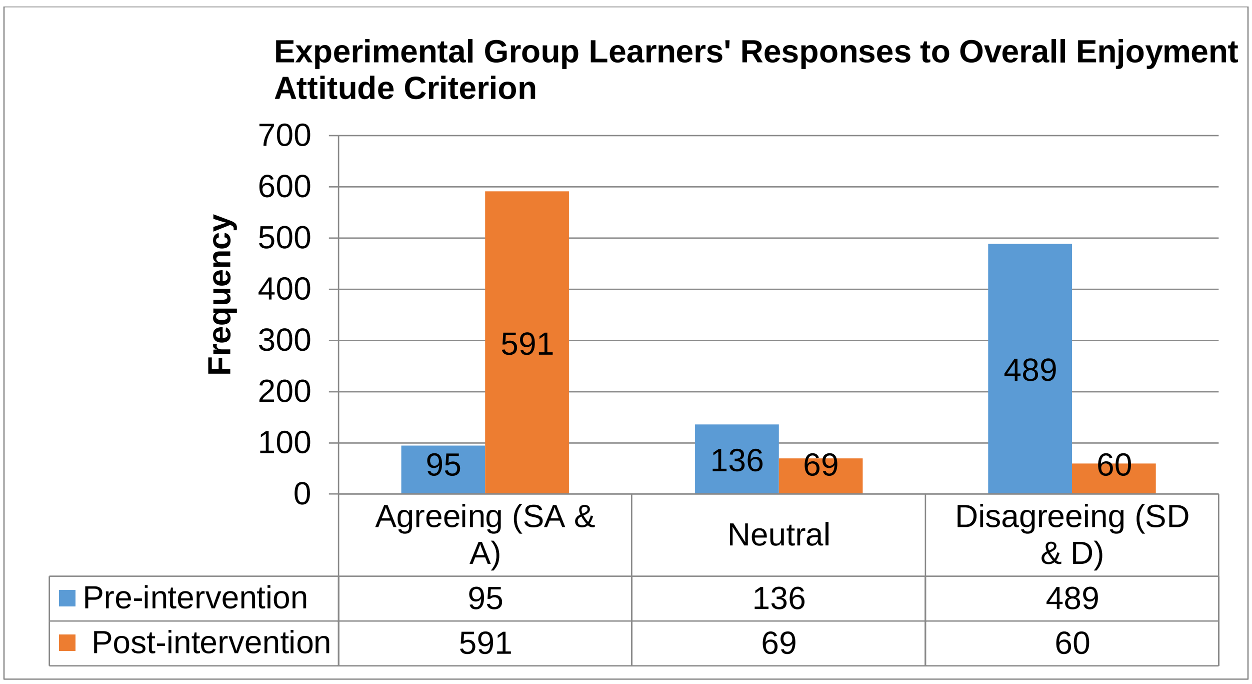


Figure 4.2: Bar graph to Overall Enjoyment Attitude

Data on students' attitude towards calculus and GeoGebra can be analyzed in terms of mean. Table 4.13 revealed that students' response to a few variables in the pre-intervention had a mean value by far less than the neutral scale. The mean values on each criterion were almost equal to the neutral scale. The weighted mean was too. It can be deduction that learners might have not been exposed to or they might have not familiarized to or they might have had a negative attitude to calculus and GeoGebra. In the post-intervention, the mean value on each value and the weighted mean were by far higher than the neutral scale. So, learners showed an improvement of opinion in the pre-test to post-post period to calculus.

Table 4.13: Descriptive Statistics for Attitude towards Calculus and GeoGebra

Attitude towards Calculus and GeoGebra	Pre-intervention		Post-intervention	
	M	SD	M	SD
I enjoy working with calculus problems through learning integrated with GeoGebra as a tool.	3.04	.426	4.64	.512
The use of GeoGebra as a tool in calculus learning cannot benefit you visualizing concepts and developing knowledge.	3.10	.653	4.50	.872
Representing calculus concepts in multiple ways of using GeoGebra as a tool enhances your learning.	2.99	.205	3.79	1.244
I do not like learning calculus linked with real-life problems using GeoGebra as a tool.	1.75	1.508	4.56	1.071
Learning calculus using GeoGebra as the tool makes knowledge of concepts and procedures/steps to be easily understood.	3.07	.306	4.6	.863
GeoGebra is not a good tool for calculus learning.	3.25	.810	4.58	1.045
Learning calculus using GeoGebra as a	3.22	.633	4.62	.941

tool reduces my mental work (cognitive load).				
Learning calculus with the aid of a computer software package as a tool does not economize time.	1.71	1.347	4.57	.709
GeoGebra is a valuable tool for calculus learning.	2.44	1.209	4.53	1.100
Using GeoGebra as a tool cannot encourage The creative learning environment of calculus.	3.11	.545	4.13	1.174
Weighted mean	2.76		4.45	

Descriptive analysis in terms of frequencies or percentages on these same data on each attitude item towards calculus and GeoGebra based on Table 4.14 can be performed.

Table 4.14: Frequency Distribution for Data on Attitude towards Calculus and GeoGebra

Attitude towards calculus and GeoGebra as a tool	Pre-intervention Frequency (%)					Post-intervention Frequency (%)				
	SA	A	N	D	SD	SA	A	N	D	SD
I enjoy working with calculus problems through learning integrated with GeoGebra as a tool.	2 (2.8)	2 (2.8)	65 (90.3)	3 (4.2)		47 (65.3)	24 (33.3)	1 (1.4)		
Using GeoGebra as a tool in calculus learning cannot	4	5	59	2	2	50	12		6	4

benefit in visualizing concepts and developing knowledge.	(5.6) (6.9) (81.9) (2.8) (2.8) (69.4) (16.7) (8.3) (5.6)
Representing calculus concepts in multiple ways using GeoGebra as a tool enhances your learning.	1 69 2 32 5 28 2 5 (1.4) (95.8) (2.8) (44.4) (6.9) (38.9) (2.8) (6.9)
I do not like learning calculus linked with real-life problems using GeoGebra as a tool.	11 2 2 57 60 4 2 2 4 (15.3) (2.8) (2.8) (79.2) (83.3) (5.6) (2.8) (5.6) (2.8)
Learning calculus using GeoGebra as a tool makes knowledge of concepts and procedures/steps to be easily understood.	1 3 68 58 5 6 2 1 (1.4) (4.2) (94.4) (80.6) (6.9) (8.3) (2.8) (1.4)
GeoGebra is not a good tool for calculus learning.	11 58 2 1 60 3 3 3 3 (15.3) (80.6) (2.8) (1.4) (83.3) (4.2) (4.2) (4.2) (4.2)
Learning calculus using GeoGebra as a tool reduces my mental work (cognitive load).	6 6 58 2 59 6 2 3 2 (8.3)(8.3)(80.6)(2.8) (81.9) (8.3) (2.8) (4.2) (2.8)
Learning calculus with the aid of GeoGebra as a tool does not	6 5 6 55 49 16 6 1 (8.3)(6.9)(8.3) (76.4)(68.1) (22.2) (8.3) (1.4)

economize time.	
GeoGebra is a valuable tool for calculus learning.	4 5 6 1 26 26 58 4 4 2 4 (5.6)(6.9)(8.3)(1.4)(36.1) (44.4)(80.6)(5.6) (5.6) (2.8) (5.6)
Using GeoGebra as a tool cannot encourage creative learning environment of calculus.	5 65 2 35 25 2 4 6 (6.9) (90.3) (2.8) (48.6) (34.7) (2.8) (5.6) (8.3)

In the results shown Table 4.14, participants to the first item responded with 5.6% agreeing, 90.3% neutral and 4.2% disagreeing in the pre-intervention while 98.6% agreed and 1.4% disagreed in the post-intervention. The number of participants responding to agreeing in the post-intervention was higher than their agreeing responses in the pre-intervention. This implies that learners attitude had changed positively to this item. Almost all learners enjoyed working with intermediate calculus problems using the JCLGS.

On the second item, participants responded 12.5% agreeing, 81.9% neutral and 5.6% disagreeing in pre-intervention, while those responding to agreeing were 86.1%, neutral 8.3% and disagreeing 5.6% in post-intervention. The number of participants responding to agreeing in the post-intervention was also very high compared to their agreeing responses in the pre-intervention. Hence, learners had developed the positive attitude as a result of the intervention. GeoGebra had helped most learners to easily visualize the abstract concepts of calculus.

Participants' responses to item three were 1.4% agreeing, 95.8% neutral and 2.8% disagreeing in pre-intervention, while 51.4% agreed, 38.9% were neutral and 9.7% disagreed in post-intervention. The number of participants responding in agreeing in the post-intervention was moderately higher than their agreeing responses in the pre-intervention. Therefore, the average number of participants had exhibited a positive attitudinal change to item three. Learners had used GeoGebra to represent various calculus notions in a variety of ways, such as numerically or geometrically or graphically or algebraically or calculus means.

Participants' responses to item four were 18.1% agreeing, 2.8% neutral and 79.2% disagreeing in pre-intervention, while 88.9% agreed, 2.8% were neutral and 8.3% disagreed in post-intervention. The number of participants responding to agreeing after the intervention was higher than their agreeing responses in the pre-intervention. Thus, this implied that most participants had shown a positive attitudinal change to item four. Most learners had used GeoGebra as a tool to solve problems related to real life.

On the fifth item, participants responded with 5.6% agreeing and 94.4% neutral in pre-intervention while 87.5% agreed, 8.3% were neutral and 4.2% disagreed in post-intervention. The number of participants responding to agreeing in post-intervention was higher than their agreeing responses in pre-intervention. A few numbers of participants responded neutral in post-intervention. From this, it can be inferred that there was a very big change in most learners' attitude observed towards this item. GeoGebra has helped most learners to easily grasp concepts and procedures using the built-in functions interface in it.

Participants' responses to item six were 15.2% agreeing, 80.6% neutral and 4.2% disagreeing in pre-intervention while 87.5% agreeing, 4.2% neutral and 8.3% disagreeing in post-intervention. The number of participants responded agreeing in post-intervention was higher than their agreeing responses in pre-intervention. Most participants highly exhibited a positive attitudinal change to this item. They perceived GeoGebra was a good tool for calculus learning.

On the seventh item, participants responded 16.6% agree, 80.6% neutral and 2.8% disagreeing in pre-intervention while 90.3% agreeing, 2.8% neutral and 6.9% disagreeing in post-intervention. The number of participants responded agreeing in post-intervention was higher than their agreeing responses in pre-intervention. However, a large number of participants responded neutral in pre-intervention and least number in post-intervention. From this, it can be concluded that almost all participants showed a positive attitudinal change as the result of intervention to this item. GeoGebra helped most learners to visualize especially graphs that might not be possible learning it with black or whiteboard. GeoGeba assisted learners to reduce their cognitive load.

Participants’ responses to item eight were 15.3% agreeing, 8.3% neutral and 76.4% disagreeing in pre-intervention while 90.3% agreeing, 8.3% neutral, and 1.4% disagreeing in post-intervention. The number of participants responding agreeing in post-intervention was higher than their agreeing responses in pre-intervention. Almost all participants had exhibited a considerable positive attitudinal change to item eight. Both learners and instructors viewed the use of GeoGebra as a tool as it save time in the teaching and learning of calculus.

On item nine participants responded 12.5% agreeing, 50.0% neutral, and 37.5% disagreeing in pre-intervention while 86.1% agreed, 5.6% neutral, and 8.3% disagreed in post-intervention. The number of participants responding by agreeing in post-intervention was higher than their agreeing responses in pre-intervention. Therefore, most participants showed positive attitudinal change as the result of intervention to this item. GeoGebra was viewed a valuable tool in learners’ learning of calculus.

Participants’ responses to item ten were 6.9% agreeing, 90.3% neutral and 2.8% disagreeing in the pre-intervention, while 83.3% agreed, 2.8% were neutral, and 13.9% disagreed in the post-intervention. The number of participants responding by agreeing in the post-intervention was substantially higher than their agreeing responses in the pre-intervention. Thus, this indicated that most participants exhibited a considerable positive attitudinal change in respect of this item. Learners were encouraged to a large extent, to be creative and innovative in their endeavors using GeoGebra in their learning of intermediate calculus.

Consequently, learners' use of the JCLGS could be viewed as GeoGebra had contributed much in their overall positive attitudinal change towards intermediate calculus. This means it allowed them to perceive the learning of calculus as normal as other courses. They also viewed GeoGebra as enjoyable and interesting as well as easier in learning it through using the JCLGS.

Table 4.15: Frequency Distribution for Overall Attitude towards Calculus and GeoGebra

Pre-intervention Frequency (%)			Post-intervention Frequency (%)		
A	N	D	A	N	D
79(10.97%)	486 (67.5%)	155 (21.53%)	612 (85%)	60 (8.33%)	48 (6.67%)

The number of participants responding agreeing to the overall attitude towards calculus and GeoGebra was 85% in post-intervention substantially higher than those responded 10.97% in pre-intervention. This indicates that learners had positive opinion towards the learning of calculus and GeoGebra. Graphical representation of the frequency distribution is depicted as follows.

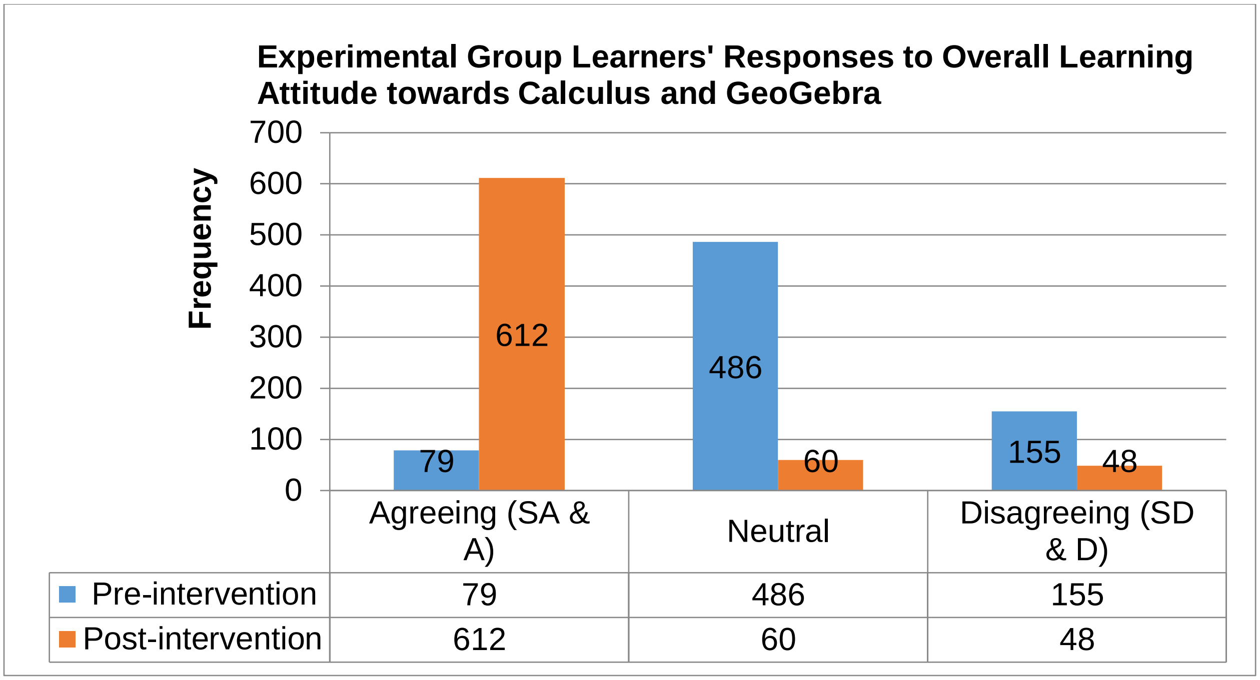


Figure 4.3: Bar graph to Attitude towards Calculus and GeoGebra

In sum, the number of participants responding agreeing to every item involved in all the three attitude criteria was sufficiently large in the post-intervention compared to their responses in the pre-intervention.

Table 4.16: Frequency Distribution to Overall Attitudes

	Overall Attitudes					
	Pre-intervention			Post-intervention		
	Frequency (%)			Frequency (%)		
Attitude Constructs	A	N	D	A	N	D
Normality(N)	147 (27.43%)	90 (15.63%)	339 (58.85%)	437 (74.13%)	54 (9.38%)	85 (14.76%)

Enjoyment (E)	95 (13.19%)	136 (18.89%)	489 (67.92%)	591 (82.08%)	69 (9.58%)	60 (8.3%)
Attitude towards Calculus and GeoGebra	79 (10.97%)	486 (67.5%)	155 (21.53%)	612 (85%)	60 (8.33%)	48 (6.67%)
Overall	321 (15.93%)	712 (35.32%)	983 (48.76%)	1640 (81.35%)	183 (9.08%)	193 (9.57%)

The corresponding graphical representation of the experimental group (EG) learners' responses to normality, enjoyment and learners' attitude towards calculus and GeoGebra is shown as follows.

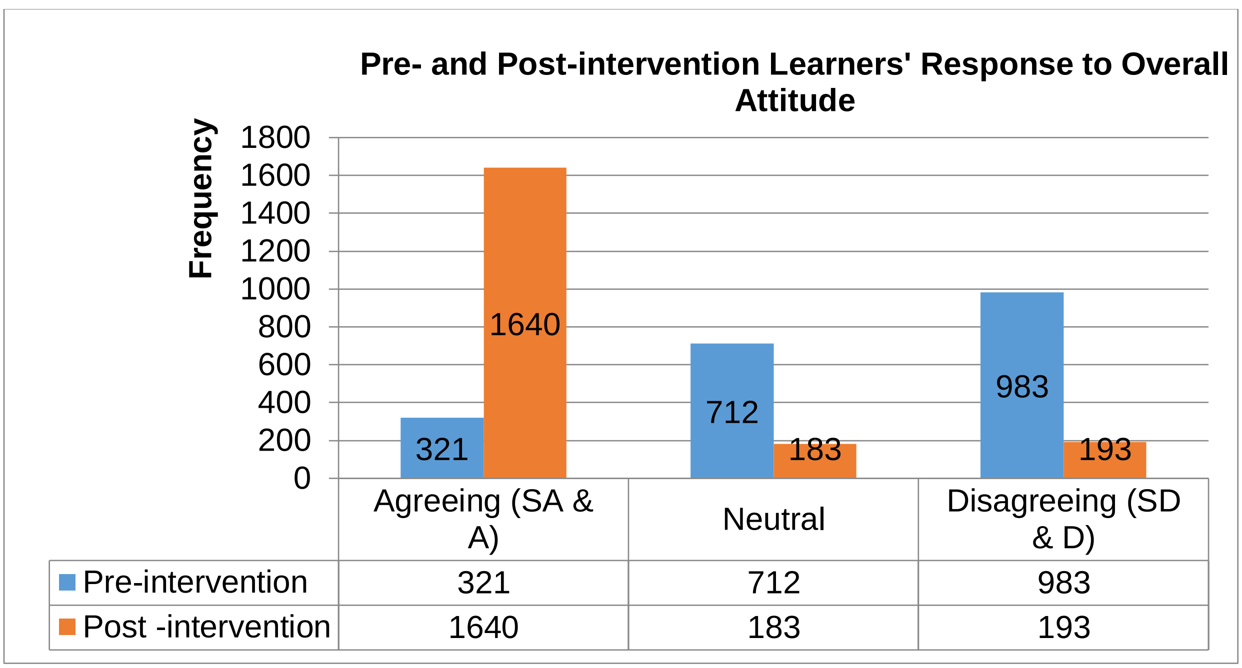


Figure 4.4: Bar graph to Learners Responses to Overall Attitudes

The overall pre-intervention descriptive statistics results related to each learners attitude criterion in the treatment group towards calculus and GeoGebra is depicted (see Table 4.17).

Table 4.17: Frequency Distribution for Pre-test EG Learners' Overall Attitudes

	Overall Attitudes		
	Pre-intervention		
	Scales		
Criterion of Attitude	A	N	D
Normality (N)	147	90	339
	(27.43%)	(15.63%)	(58.85%)
Enjoyment (E)	95	136	489
	(13.19%)	(18.89%)	(67.92%)
Attitude towards Calculus	79	486	155
and GeoGebra	(10.97%)	(67.5%)	(21.53%)
Overall	321	712	983
	(15.93%)	(35.32%)	(48.76%)

Note: A= Agreeing (Strongly Agree and Agree Responses); N= Neutral (Neutral Responses); D= Disagreeing (Strongly Disagree and Disagree Responses)

When the results shown in Table 4.17 on the pre-intervention was examined, the percentage of learners responded by disagreeing to each attitude criterion and overall attitude was bigger than to those who responded by agreeing. This survey implied that at the outset most experimental group students' opinion towards the learning of calculus/mathematics and GeoGebra was not that positive.

The overall post-intervention descriptive statistics results related to each learners attitude criterion in the experimental group towards calculus and GeoGebra is displayed (see Table 4.18).

Table 4.18: Frequency Distribution for Post-test EG Learners' Overall Attitudes

	Overall Attitudes Post-intervention Scales		
Criterion of Attitude	A	N	D
Normality(N)	437 (74.13%)	54 (9.38%)	85 (14.76%)
Enjoyment (E)	591 (82.08%)	69 (9.58%)	60 (8.3%)
Attitude towards Calculus and GeoGebra	612 (85%)	60 (8.33%)	48 (6.67%)
Overall	1640 (81.35%)	183 (9.08%)	193 (9.57%)

From the results shown in Table 4.18, in post-intervention the percentage of most learners responded by agreeing to each attitude criterion and overall attitude, was higher than those responded by disagreeing. This observation implied that during the intervention most students' opinion towards the learning of intermediate calculus/mathematics and GeoGebra was positive.

4.4 Hypothesis-by-Hypothesis Analysis of Data and Interpretation of Results

Before dealing with the analysis of data and interpretation of results carried out on calculus classroom achievement test scores in line with each null hypothesis, it was obligatory to argue on the reason why the independent-samples t-test and Two-Way ANOVA for repeated measures techniques had to be applied. It was also necessary to verify whether the underlying assumptions required by these tests had to meet by the collected data or not.

Data on calculus classroom achievement test for the main research study were conducted in an academic year program (10 weeks). When data are collected in this way, student t-test or/and One or Two-Way ANOVA are the suitable and widely used parametric test statistics to test changes over time (Saunders et al., 2009). To use them, there are very few basic and crucial underlying assumptions that our data should have to meet (Cohen et al., 2007; Green, Salkind, Samuel, & Salkind, 2005; Saunders et al., 2009). As data collection procedures of this study employed two experimental conditions/factors, two different groups of participants and one dependent variable measured at two different points in time (pre-test and post-test), Green et al.(2005) suggested the mean score differences between the two groups and the variances can be tested using the appropriate statistical tools such as the independent-samples t-test and Two-Way ANOVA for repeated measures. One of the experimental conditions was the JCLGS employed to stimulate the experimental group samples and the other was the conventional lecture method used to teach comparison group samples. To discuss more on how to use these tests, the following issues had to be checked. That is, the collected data had met a normal distribution, homogeneity of variances, randomly selected sample unit, scores independent of each other on the dependent variable, and data measured at least at interval level are some of them (Field, 2009).

To start with, each case was randomly drawn from the population from which the sample was taken for both groups. The collected data were of ratio-scale of measurement that represented students' knowledge of concepts (CK), procedures (PK), and content (COK) scores. The score of each sample was independent of each other, as it constituted two different independent groups, named experimental and comparison groups. Field (2009) and Pallant (2010) suggested that the skewness and kurtosis values can be used to test normality for each pair of data set and the Kolmogorov-Smirnov test while equality/homogeneity of variances by Levene's test. Normality of each pair of data set using graphs (histogram with normal curve and Q-Q plots) and skewness and kurtosis values were first tested.

Bear in mind that, each null hypothesis involved two independent variables, one dependent variable measured at two points in time (pre-test and post-test) and two experimental conditions. The JCLGS and the traditional lecture method were the independent variables of each null hypothesis. Experimental and comparison groups were the experimental conditions. The first null hypothesis H_{01} was stated as:

$H_{01:}$ Learning calculus through JCLGS has the same influence as lecture method on conceptual knowledge.

To take a glimpse of the idea about the distribution of students' pre-test conceptual knowledge scores of the experimental and comparison groups, look at the histograms shown.

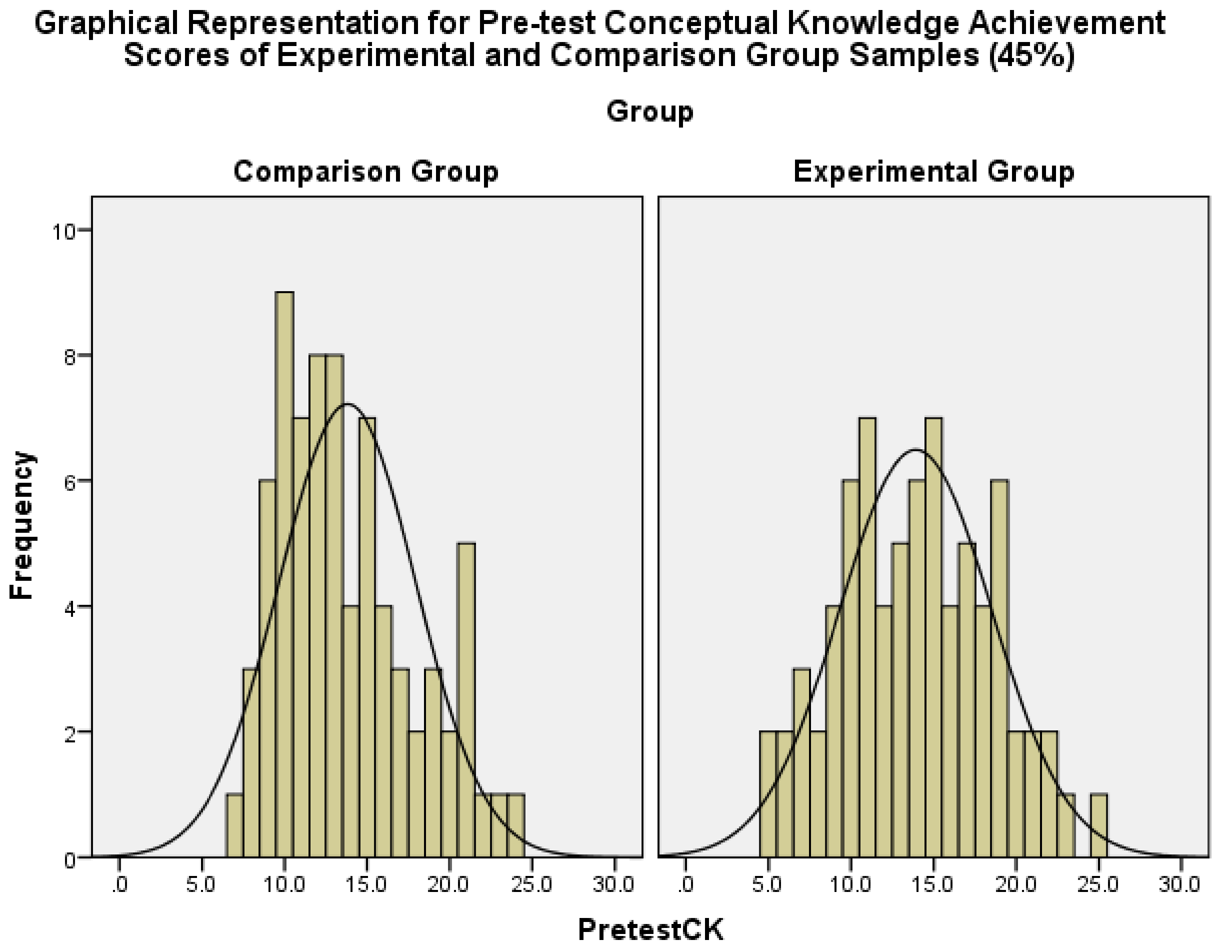


Figure 4.5: Histogram with Normal curve for Pre-test CK Achievement Scores

The shapes of both graphs shown in Figure 4.5 indicate that both distributions of scores were reasonably normal. The skewness (.109) and kurtosis values (-.586) for the distribution of the experimental group and skewness (.624) and kurtosis values (-.476) for the distribution of the comparison group were also in support of the normality of both distributions as these values were relatively close to zero (Field, 2009) as shown in Table 4.19.

Table 4.19: Descriptive Statistics for Pre-test CK Achievement Scores

	Pre-test	
Statistics	Comparison Group	Experimental Group

Valid	75	75
Missing	0	0
Mean	13.800	13.906
Std. Error of Mean	.478	.531
Median	13.00	14.00
Variance	17.162	21.221
Mode	10.00	11.00[a]
Std. Deviation	4.142	4.606
Skewness	.642	.109
Kurtosis	-.476	-.586
Range	17.00	20

Multiple modes exist. The smallest value is shown.

The pre-test samples data for experimental and comparison group on conceptual knowledge was examined using boxplots as follows.

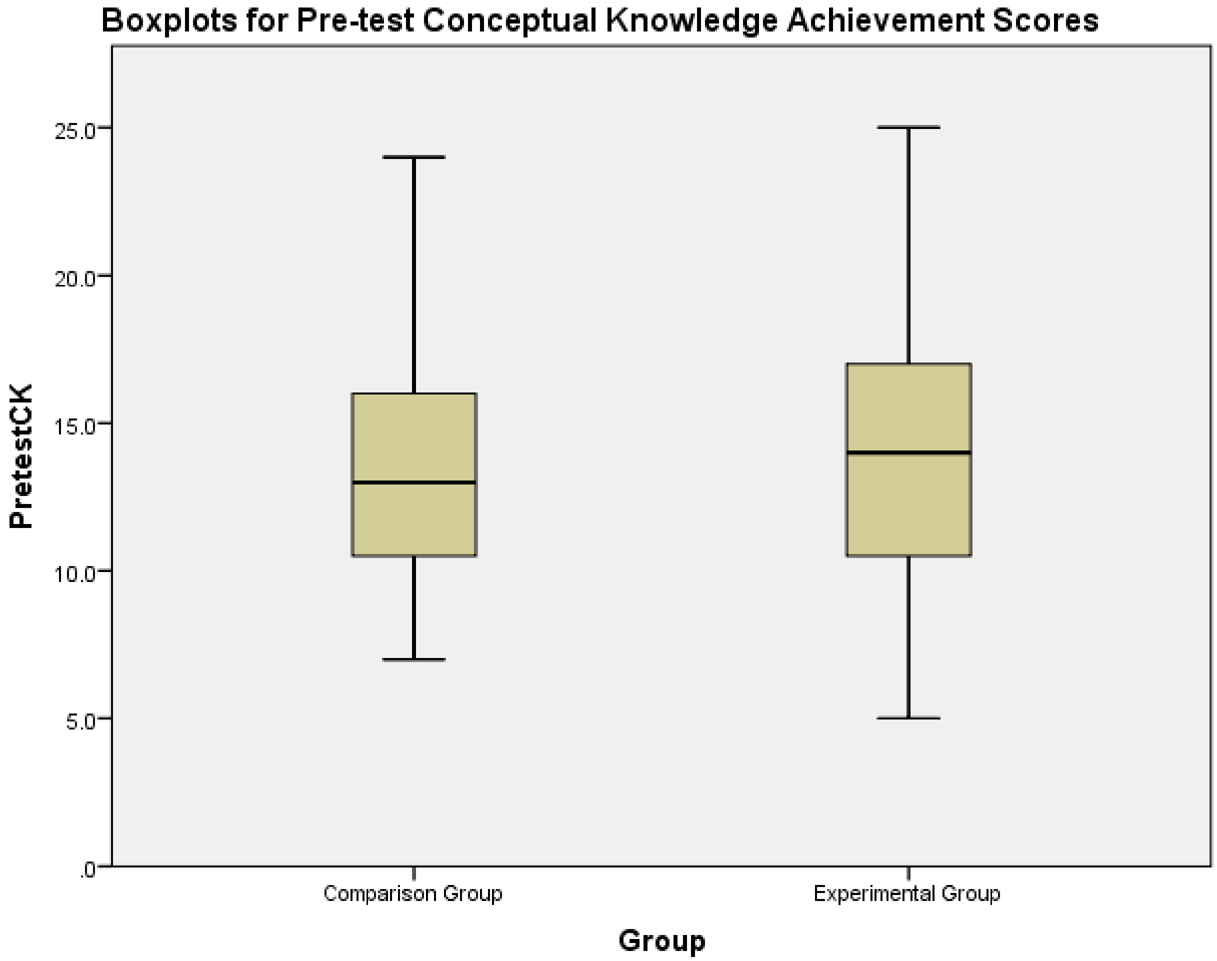


Figure 4.6: Boxplots for Distributions of Pre-test CK Achievement Scores

All points inside each of the boxes and whiskers are shown in Figure 4.6 represented the corresponding distribution of scores for comparison and experimental group samples. You can see that these distributions of scores for both comparison and experimental group samples were quite similar. These boxplots also indicated that there were no outlier scores in both distributions.

It is also very vital to examine the normality of conceptual knowledge scores of both groups in pre-test using Q-Q plots because they would make the issue of normality more illustrative.

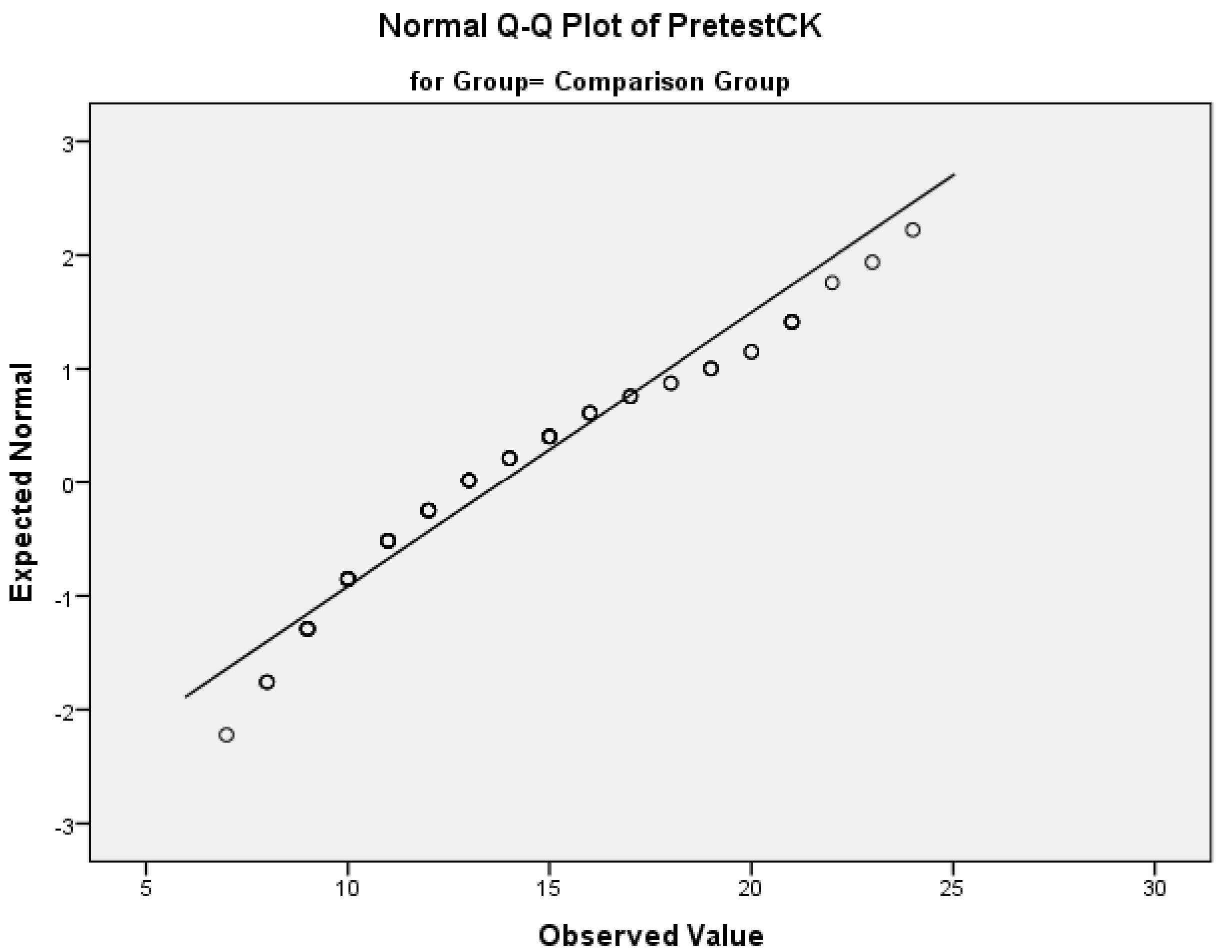


Figure 4.7: Q-Q plot for Pre-test CK Achievement Scores of CG

As shown in Figure 4.7, some of the data points lie on a straight line. Several of the data points were located very close to the line. A few of them were a bit far from the line. This shows that by the Central Limit Theorem when the sample size is large, the distribution reasonably tends to normality. This means that the non-linearity of a few data points do not affect the data analysis in an independent sample t-test and Two-Way ANOVA for repeated measures.

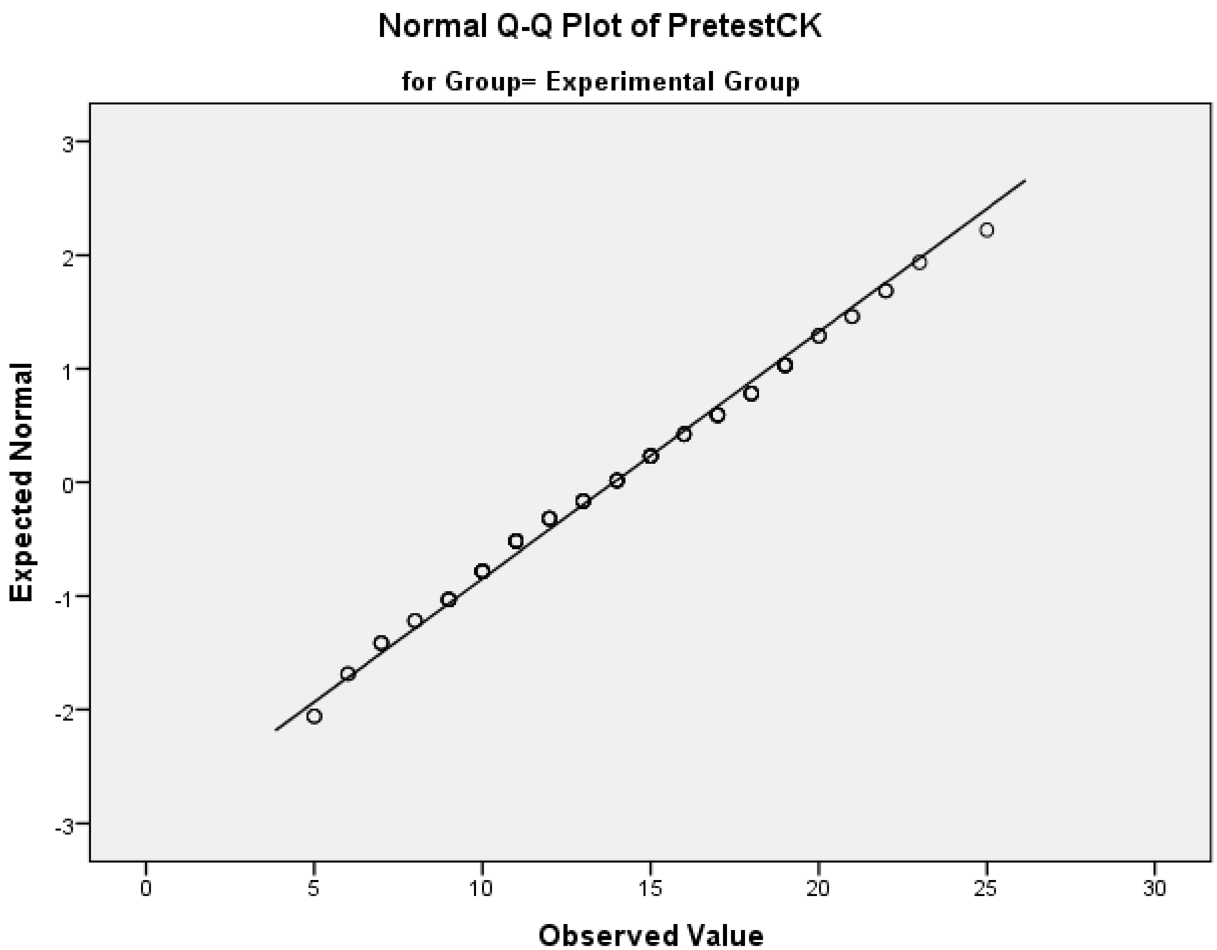


Figure 4.8: Q-Q plot for Pre-test CK Achievement Scores of EG

Almost all data points nearly lay on a straight line (see Figure 4.8). This showed that the distribution was normal.

The normality of knowledge of concepts of the experimental and comparison groups scores was also further examined using Kolmogorov-Smirnov Normality Test.

Table 4.20: Kolmogorov-Smirnov Normality Test for Pre-test CK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.

CK	EG	.083	75	.200*	.986	75	.553
	CG	.137	75	.001	.943	75	.002

*. This is a lower bound of true significance. a. Lilliefors Significance Correction

The normality of the distribution of scores can be determined based on the significance value (Sig.) using Kolmogorov-Smirnov test value (Pallant, 2010). The non-normality of a distribution can be indicated by significance value less than .05 (significance) while normality by significance value more than 0.05 (non-significance).

Keeping this in mind, Field (2009); Green et al. (2005) indicated that D denotes the Kolmogorov-Smirnov test statistic and reported together with the degree of freedom (df), and significance level (sig.). Accordingly, the results on the pre-test conceptual knowledge scores of the experimental and comparison groups was respectively, $D(75)=.200, p>0.05$ and $D(75)=.001, p<0.05$ by Kolmogorov-Smirnov test. Thus, the distribution of data on students' conceptual knowledge scores of the experimental group was fairly normality while the comparison group was not normality. However, by the Central Limit Theorem when the sample size was large , the sampling distribution for students' conceptual knowledge scores of the comparison group tends normality (Field, 2009; Green et al., 2005; Pallant, 2010).

Homogeneity of variances for pre-test data on conceptual knowledge was analyzed as follows.

Table 4.21: Independent-samples t-test for Pre-test CK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
CK	EG	75	13.907	4.606	.875	.351	148	.149	.882	.00014
	CG	75	13.800	4.142						

*p<0.01

Based on the results shown in Table 4.21, the homogeneity of the variances of the populations from which the sample groups were drawn can be examined. As Green et al. (2005) suggested, F denotes Levene's test and described together with a degree of freedom and reported as $F(df_1, df_2)$=value, sig. Thus, the results on learners' pre-test conceptual knowledge scores of experimental and comparison groups was observed to be *F(1,148)=.875, p=.351>.01* by Levene's test. This shows the equality of the variances of the dependent variable for the two populations was attained.

The effect size values shown in Table 4.21 were calculated by the eta squared formula. Eta squared and Cohen's d are the appropriate statistical tools used to find the effect size value for independent samples t-test (Cohen et al., 2007; Field, 2009; Green et al., 2005; Pallant, 2010) . The range of eta squared value is 0 to 1 (Cohen et al., 2007; Pallant, 2010). Cohen's d value can be interpreted as 0-.20= weak effect, .21-.50 =modest effect, .51-1.00 =moderate effect and >1.00 =strong effect (Cohen et al., 2007). As Cohen et al. (2007) and Pallant (2010) indicated, Cohen (1988) provided guidelines to be used for the interpretation of eta squared value as .01 =small effect, .06 =moderate effect and .14 =strong effect. Cohen's d can be given by the formula Cohen et al. (2007) as:

$$d = \frac{MeanDifference}{SD_{pooled}} orconciselyd = t\sqrt{\frac{n_1+n_2}{n_1 n_2}} \qquad \text{eq. (6)}$$

Where SD_{pooled} denotes pooled standard deviation and given as;

$$SD_{pooled} = \sqrt{\frac{(n_1-1)SD_1^2+(n_2-1)SD_2^2}{n_1+n_2-2}}.$$

As indicated in Cohen et al. (2007) and Pallant (2010), eta squared can be calculated by the formula for independent-samples t-test

$$Etasquared = \frac{t^2}{t^2+(n_1+n_2-2)}$$ or for paired sample t-test

$$Etasquared = \frac{t^2}{t^2+(n_1-2)} \qquad \text{eq. (7)}$$

where t =the t-value calculated by SPSS, n_1 =sample size for group one and n_2=sample size for group two.

The effect size of the mean difference between pre-test conceptual knowledge scores of experimental and comparison groups was calculated using eq. (7) as eta square was equal to *.00014*. This effect size value represents a very small effect as suggested by (Cohen et al., 2007; Pallant, 2010). According to Cohen et al. (2005), this value implies that there was no statistically significant mean difference between pre-test conceptual knowledge achievement score of the experimental group (*M=13.907, SE=.531*), and the comparison group (*M=13.800, SE=.478*); *t(148)=.149, p>.01,eta squared=0.00014*, 99% CI [-1.76, 1.97]. The mean difference was 0.107 which is very small. The data were in favour of the null hypothesis H_{01}. Therefore, this result can be interpreted as at the outset of the main research study, learners in treatment and comparison groups had almost the same conceptual knowledge level.

Table 4.22 depicts the gender-wise descriptive statistics for learners pre-test conceptual knowledge achievement scores.

Table 4.22: Descriptive Statistics for Pre-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Conceptual	EG	27	13.704	4.0650
	Knowledge	CG	30	13.500	4.4315
Male		EG	48	14.021	4.9228

	CG	45	14.000	3.9772

The mean score difference 0.204 between pre-test mean conceptual knowledge score of females in the experimental group (M=13.704, SD=4.0650) and the comparison group (M=13.500, SD=4.4315) shown in Table 4.22 was small. The mean score difference 0.021 between pre-test mean conceptual knowledge score of males sample of the treatment group (M=14.021, SD=4.9228) and the comparison group (M=14.000, SD=3.9772) was also very small. Therefore, in the pre-intervention sample participants in both groups had the same conceptual knowledge level in gender-wise. This background information showed the similarity of the two groups about the conceptual knowledge in gender-wise had played an important role in the quasi-experimental design.

Figural representations of the pre-test results would also help us to assess the extent of the variation between the two groups and other related issues of the data. Bar graph representations with error bars for mean scores on pre-test conceptual knowledge scores for experimental (EG) and comparison (CG) groups based on gender were shown in Figure 4.9.

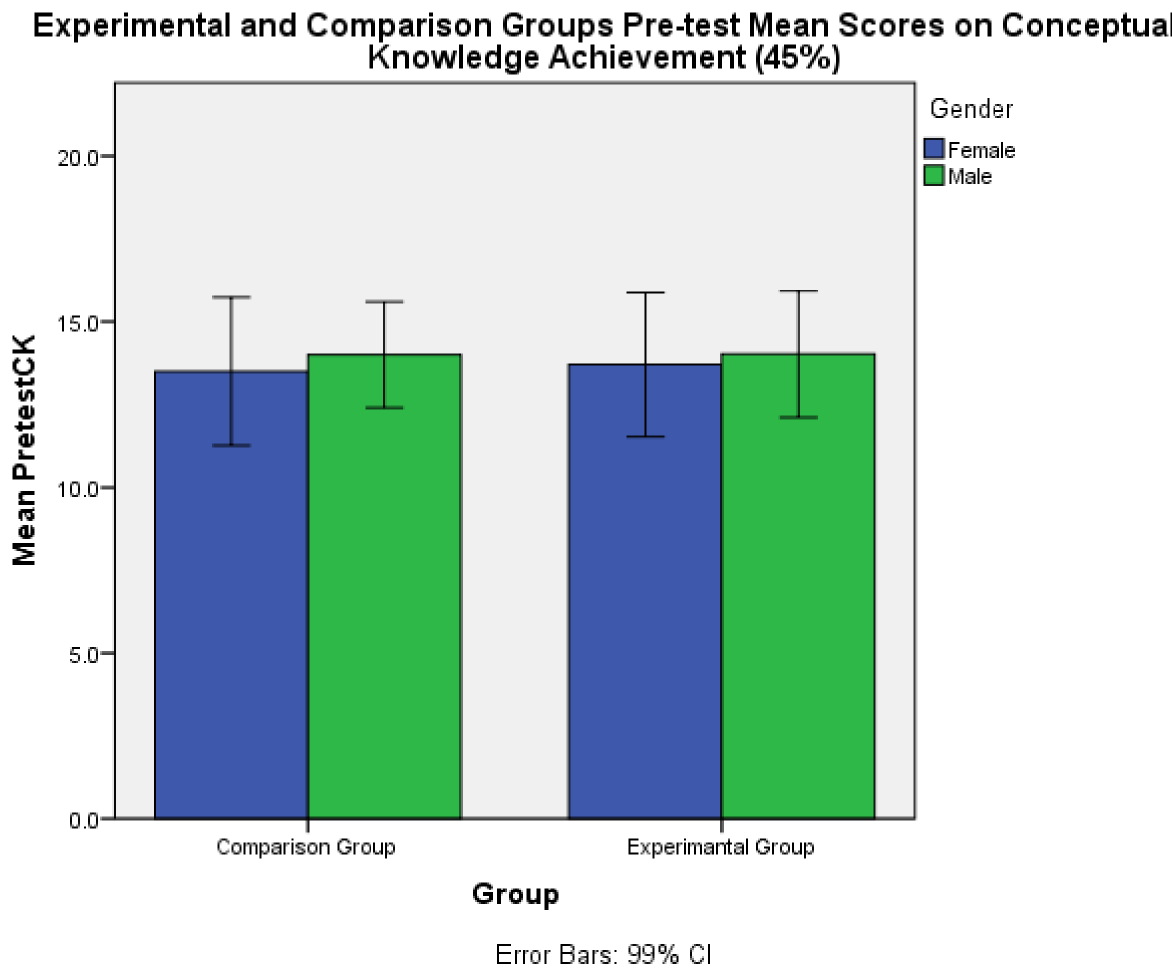


Figure 4.9: Bar graphs for Pre-test CK Achievement Scores Based on Gender

It can be seen from Figure 4.9 that females in both groups had nearly equal mean scores on pre-test conceptual knowledge achievement scores. Similarly, the mean scores of males in both groups were also approximately the same. In sum, mean scores on conceptual knowledge scores of the whole sample in both groups had been nearly equal. Therefore, gender was not taken as a covariate for this case.

Polygonal representations together with error bars of mean scores on pre-test conceptual knowledge scores for both experimental (EG) and comparison (CG) Groups are depicted in Figure 4.10.

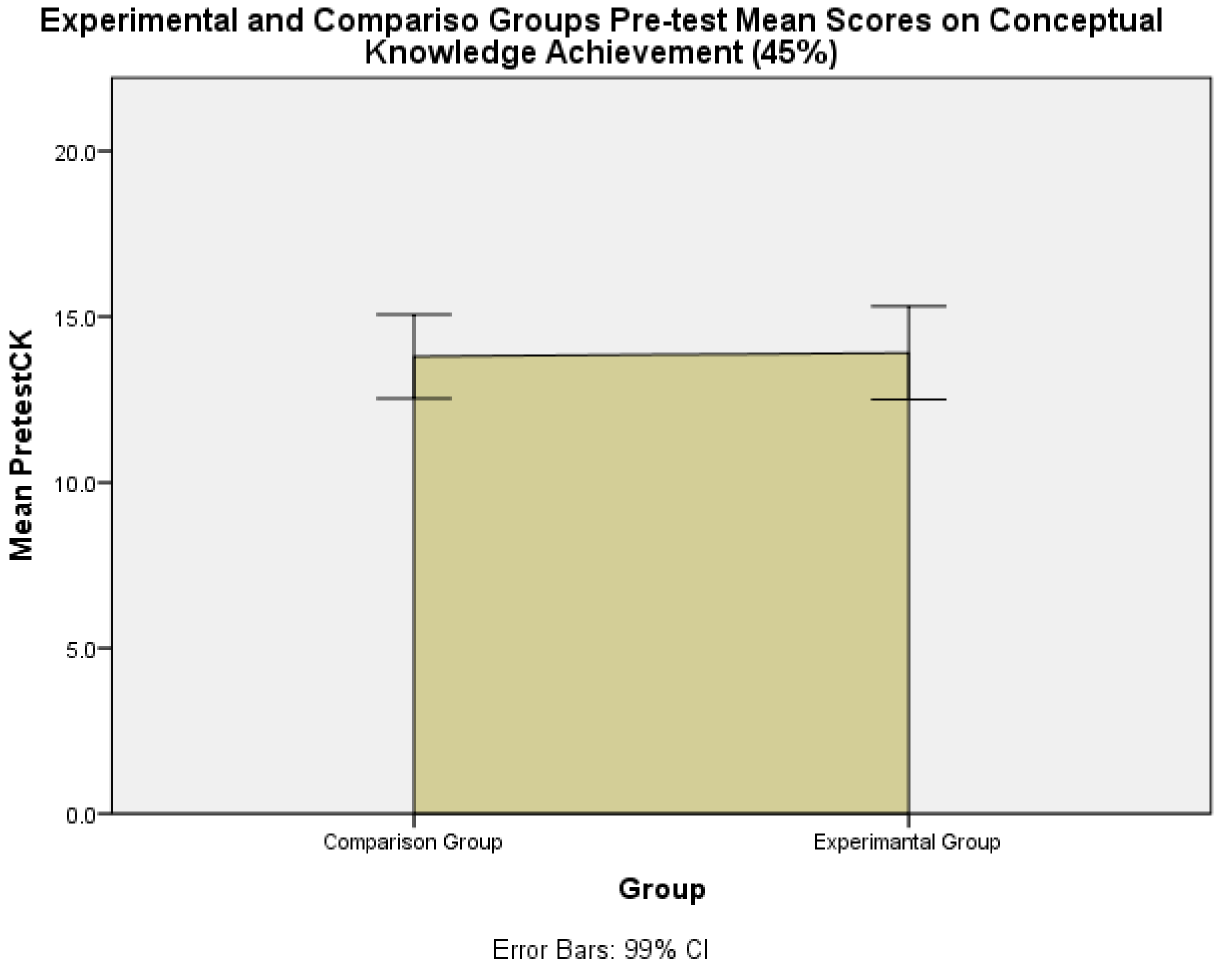


Figure 4.10: Frequency Polygons for Pre-test CK Achievement Scores

From Figure 4.10, it can easily be seen that the mean score of pre-test conceptual knowledge achievement scores for experimental group samples was almost the same as the comparison group mean score.

As with the pre-test, for each pair of post-test data the normality was firstly tested using graphs (histogram with a normal curve, boxplots and Q-Q plots) and skewness and kurtosis values as follows.

Histograms for post-test conceptual knowledge scores of experimental and comparison groups are shown in Figure 4.11.

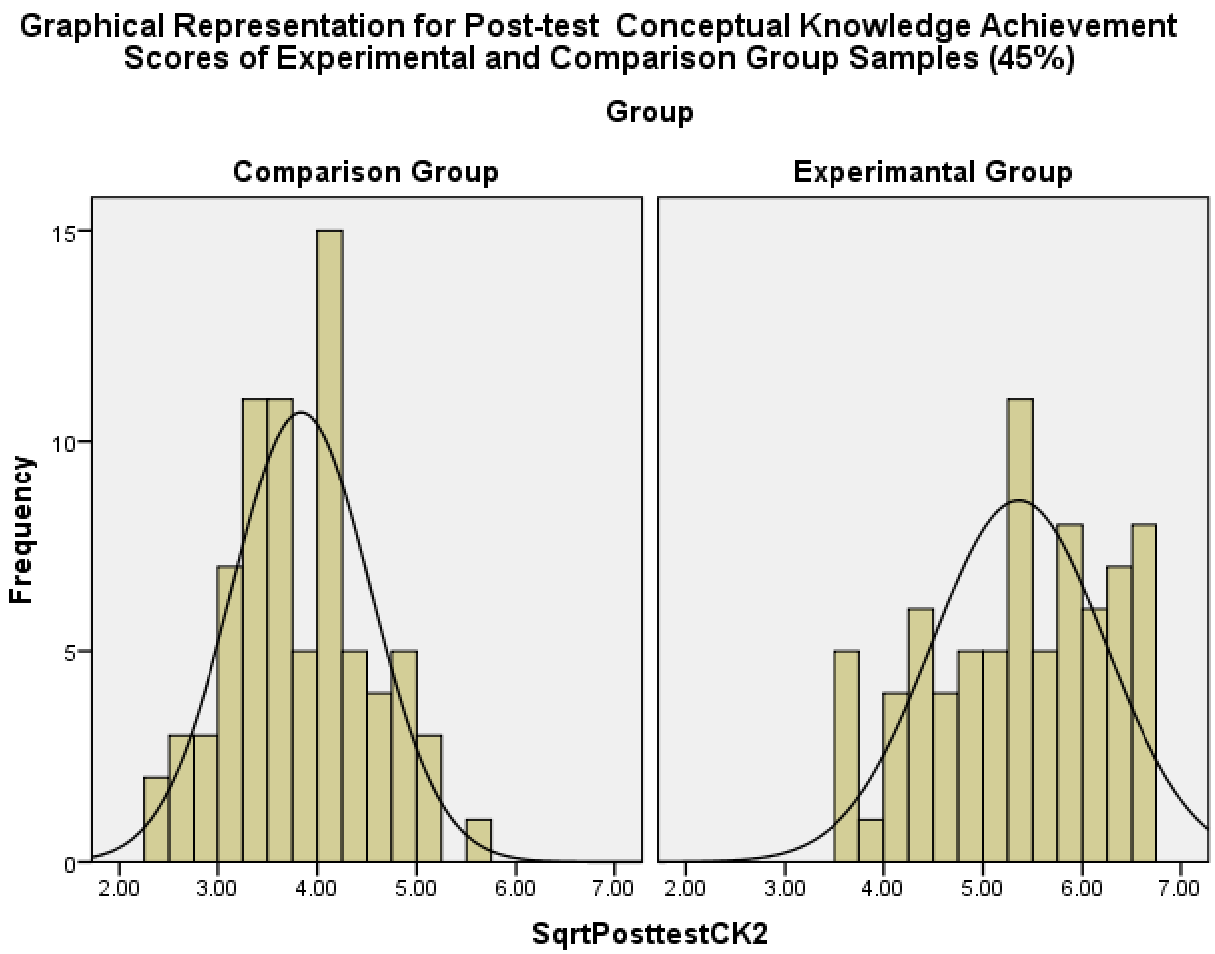


Figure 4.11: Histogram with Normal curve for Post-test CK Achievement Scores

The shapes of both graphs in Figure 4.11 indicate that both distributions of scores were reasonably normal. The skewness value (-.296) and kurtosis value (-.822) for the distribution of the experimental group sample, and skewness (.164) and kurtosis values (-.369) for the distribution of the comparison group sample shown in Table 4.23 were also in support of the normality of both distributions, as these values are relatively close to zero (Field, 2009).

Table 4.23: Descriptive Statistics for Post-test CK Achievement Scores

	Post-test	
Statistics	Comparison Group	Experimental Group

Valid	75	75
Missing	0	0
Mean	15.206	29.480
Std. Error of Mean	.633	1.058
Median	15.00	29.00
Variance	.490	.760
Mode	13.00[a]	28.00
Std. Deviation	5.482	9.162
Skewness	.164	-.296
Kurtosis	-.369	-.822
Range	25.50	32.00

Multiple modes exist. The smallest value is shown.

The post-test samples data for experimental and comparison group on conceptual knowledge were further examined using boxplots as follows.

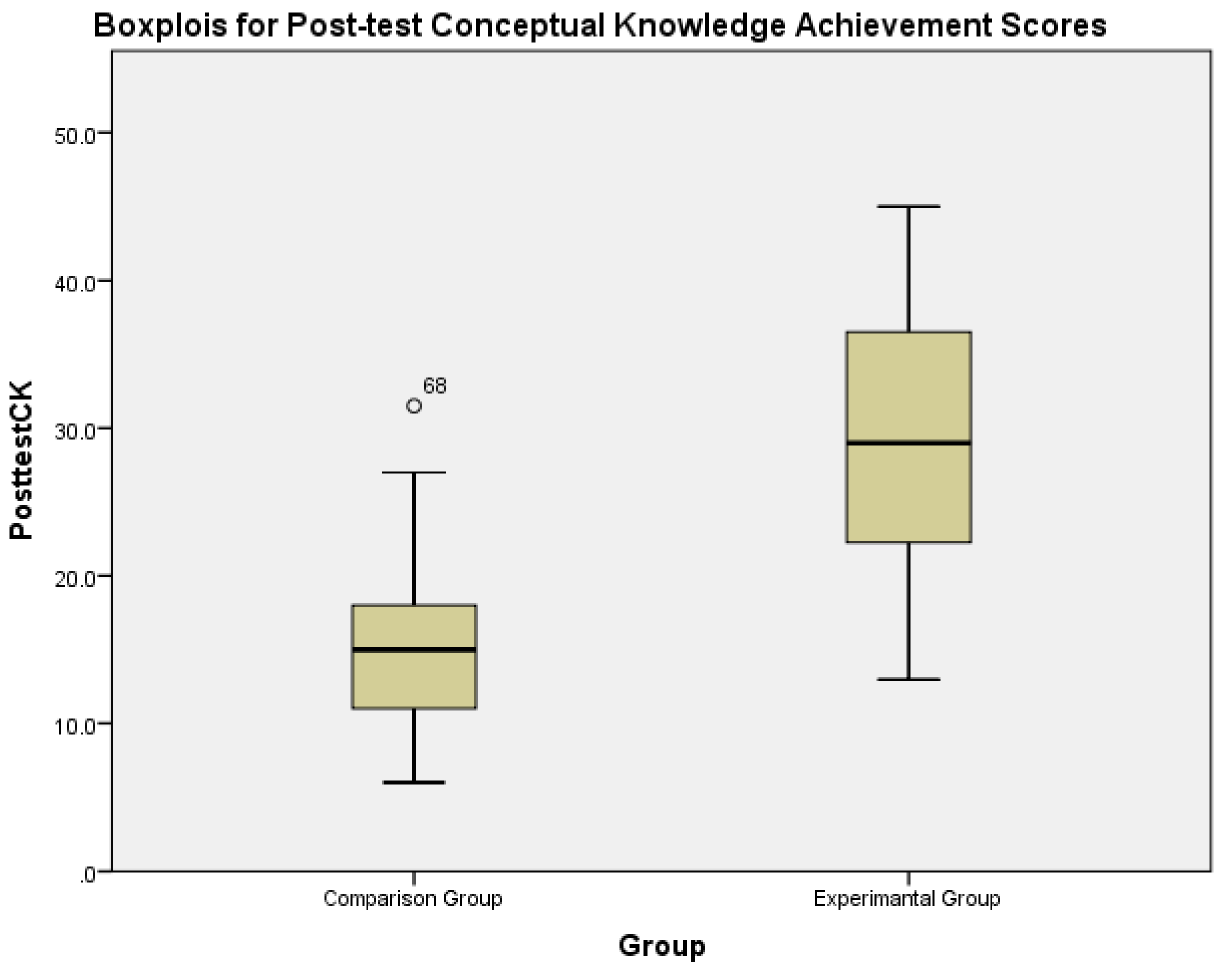


Figure 4.12: Boxplots for Distributions of Post-test CK Achievement Scores

The outcomes shown in Figure 4.12 represented as the experimental group samples distribution of scores on post-test conceptual knowledge achievement scores were quite different from the comparison group. This means that from the appearance of both boxplots, higher values were scored by most participants in the experimental group while lower values were scored by most participants in the comparison group. The boxplot for comparison group distribution scores had one outlier. The boxplot for experimental group distribution scores had no outlier. However, the outlier on the comparison group data was not affected the analysis of data.

The Q-Q plots further illustrated the normality of post-test data as follows.

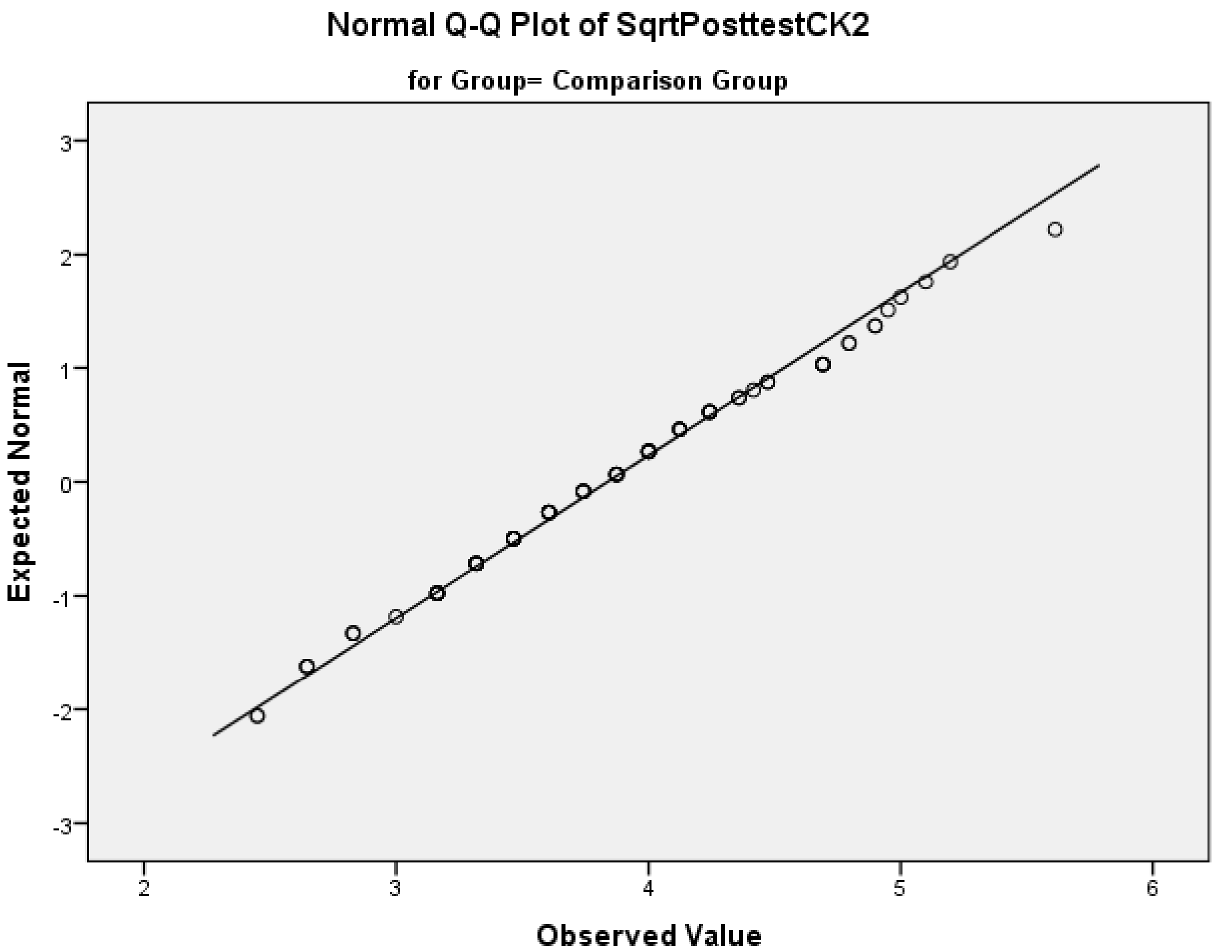


Figure 4.13: Q-Q plot for Post-test CK Achievement Scores of CG

Almost all data points shown in Figure 4.13 lay on a straight line so that the data were reasonably normal.

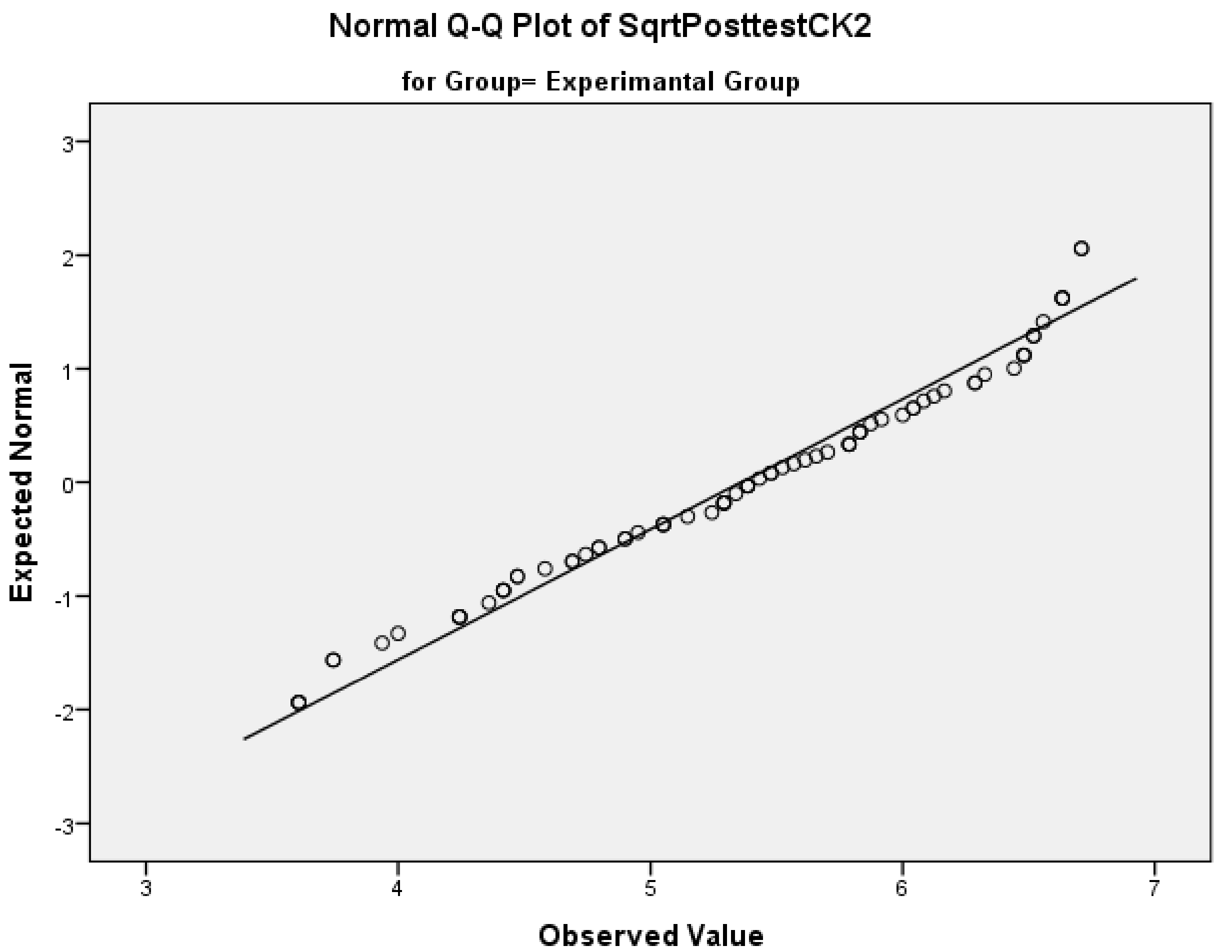


Figure 4.14: Q-Q plot for Post-test CK Achievement Scores of EG

Almost all data points shown in Figure 4.14 nearly lay on a straight line except a few showing that normality of the distribution of scores.

Analysis of the normality of post-test data was carried-out using Kolmogorov-Smirnov test based on Table 4.24 as follows. In so doing, square root transformation has been made on post-test conceptual knowledge (CK) achievement scores data.

Table 4.24: Kolmogorov-Smirnov Normality Test for Post-test CK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.

CK	EG	.075	75	.200*	.961	75	.021
	CG	.070	75	.200*	.987	75	.627

*. This is a lower bound of true significance. a. Lilliefors Significance Correction.

In the results in Table 4.24, the Kolmogorov-Smirnov statistics of learners' post-test conceptual knowledge achievement scores of the treatment and comparison groups were respectively observed as $D(75)=.200$, $p>0.05$ and $D(75)=.200$, $p>0.05$. The dependent variable for both experimental and comparison group was reasonably normally distributed.

In quite analogous to the pre-test data, equality of variances for post-test data was examined based on Table 4.25 as follows.

Table 4.25: Independent-samples t-test for Post-test CK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
CK	EG	75	29.480	9.162	4.575	.034	148	11.795	.000*	.48
	CG	75	15.207	5.482						

*p<0.01

By the Levene's test statistic results shown in Table 4.25, the data on post-test conceptual knowledge achievement scores between the experimental and comparison group was found as $F(1,148)=9.162$, $p=.034>.01$. The equality of variances for the dependent variable of both populations was attained.

As shown also in Table 4.25, the effect size value of the mean difference between the two groups on post-test conceptual knowledge achievement scores was *eta squared=.48*. This value indicated a strong effect induced from the application of the intervention to experimental group learners in their conceptual knowledge development of calculus. This means this figure represents a very large-sized effect (Cohen et al., 2007; Pallant, 2010) implying that there was a statistically significant mean difference between experimental group (*M=29.480, SE=.100*) and comparison group (*M=15.207, SE=.080*); *t(148)=11.795, p<.01, eta squared=.48,* 99% CI [1.185, 1.859], with a mean difference of 14.273. The data were in favour of the alternative hypothesis H_{11}. Therefore, this result can be interpreted as learners in the experimental group that were nurtured with the JCLGS benefited much in developing their conceptual knowledge of calculus.

Table 4.26 depicts the gender-wise descriptive statistics of learners post-test conceptual knowledge achievement scores.

Table 4.26: Descriptive Statistics for Learners Post-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Conceptual	EG	27	24.852	8.4430
	Knowledge	CG	30	14.150	5.1043
Male		EG	48	32.083	8.5747
		CG	45	15.911	5.6672

The observed mean score difference, 10.702, between post-test mean conceptual knowledge achievement score of females of the experimental group (M=24.852, SD=8.4430) and comparison group (M=14.150, SD=5.1043) shown in Table 4.26 was big. Similarly, the mean score difference, 16.172, between post-test mean conceptual knowledge achievement score of males of the experimental group (M=32.083, SD=8.5747) and comparison group (M=15.911, SD=5.6672) was also big.

Bar graph representations with error bars for mean scores of post-test conceptual knowledge scores of experimental (EG) and comparison (CG) groups samples based on gender were shown in Figure 4.15.

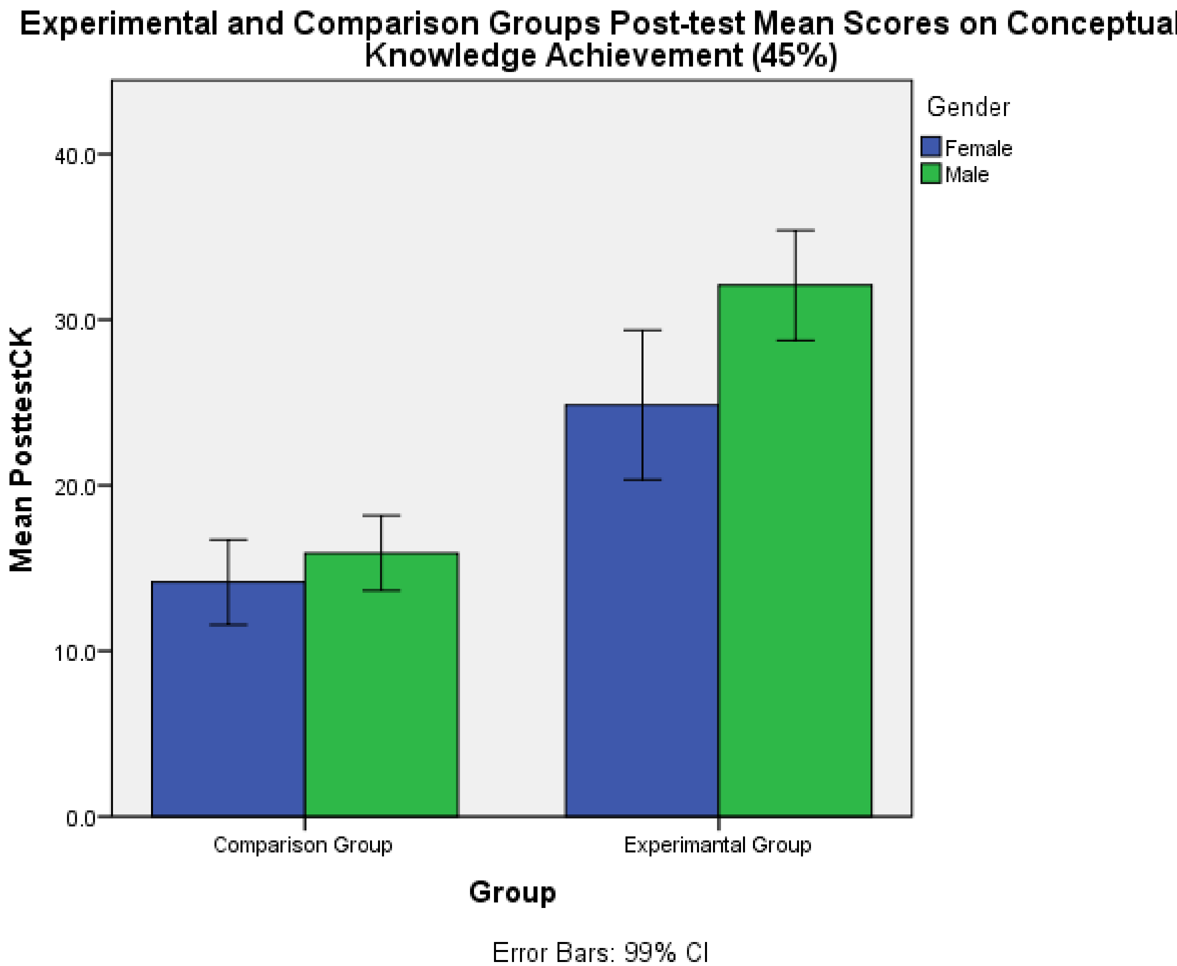


Figure 4.15: Bar graphs for Post-test CK Achievement Scores based on Gender

We can see from Figure 4.15 that the female mean score of post-test conceptual knowledge scores in the experimental group was very high compared to the comparison group. Analogously, the male mean score on this same dependent variable in the experimental group was very big compared to the comparison group. Thus, it can be deduced that the experimental group total sample mean score on conceptual knowledge development was higher than the comparison group.

Polygonal representations with error bars of mean scores on post-test conceptual knowledge scores for experimental (EG) and comparison (CG) Groups are depicted in Figure 4.16.

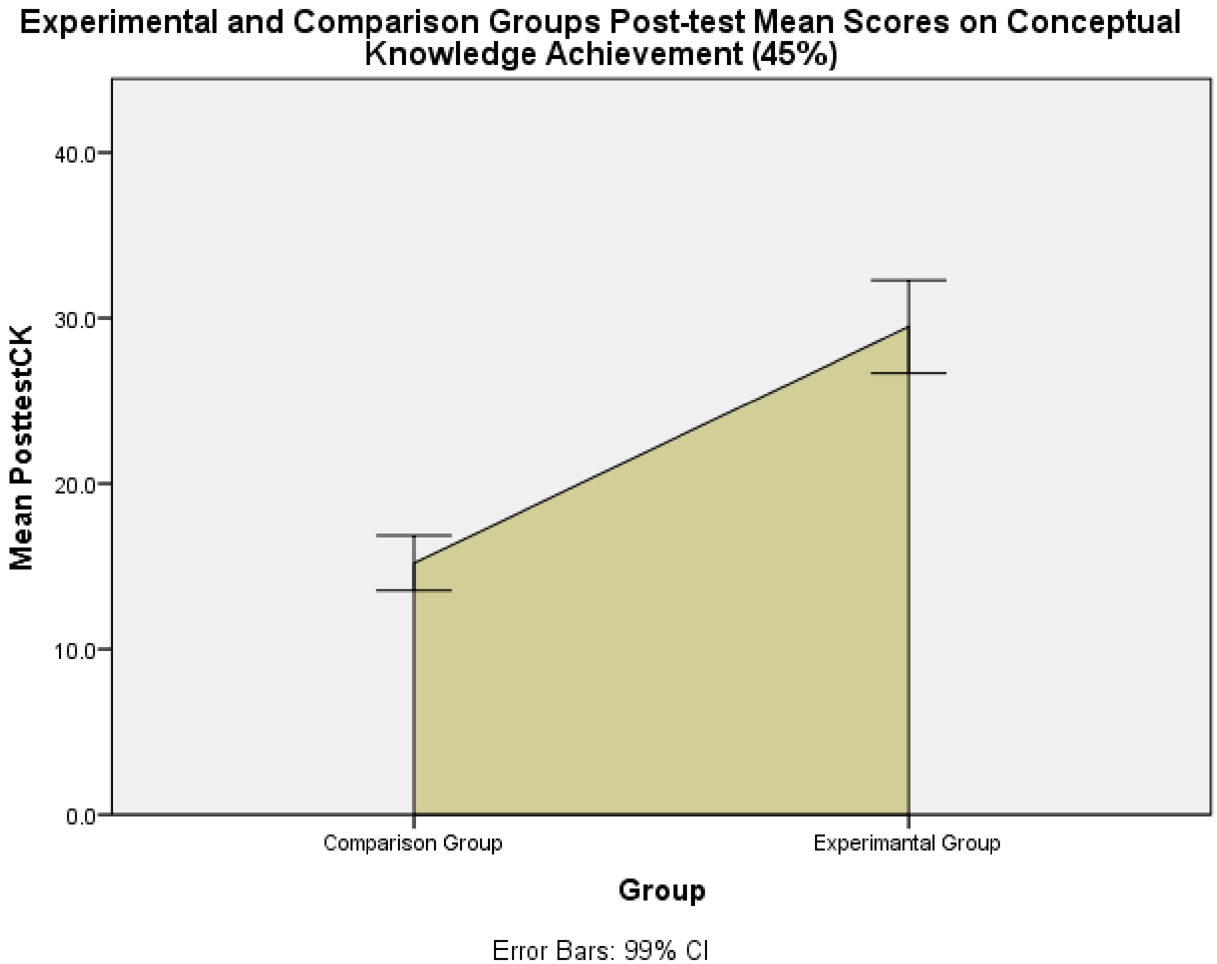


Figure 4.16: Frequency Polygons for Post-test CK Achievement Scores

From Figure 4.16, the mean score difference on post-test conceptual knowledge achievement scores between the experimental group and comparison group was very big.

As the underlying assumptions were met by the collected data for both experimental and comparison groups, the null hypothesis was also analyzed using Two-Way ANOVA for repeated measures and the corresponding results interpreted. The Two-Way ANOVA for repeated measures was used to determine whether the pre-test to post-test mean scores increment in calculus classroom achievement test of learners between the experimental group and comparison group was statistically significantly different or not. In other words, the aim was to identify whether the influence of the intervention (JCLGS) on experimental group learners' knowledge development of calculus was meaningful or not.

The null hypothesis H_{01}involved two independent variables, one dependent variable measured at two points in time (pre-test and post-test) and two experimental conditions. The JCLGS and the traditional lecture method were the independent variables of the null hypothesis H_{01}. Treatment and comparison groups were the experimental conditions.

Two-Way ANOVA for repeated measures analysis was carried out on H_{01} by first presenting the appropriate descriptive statistics of pre-test and post-test conceptual knowledge achievement scores of learners in both experimental and comparison groups. This helped us to make an initial inspection to judge the influence of the independent variables looking at the pattern of these statistics (Pallant, 2010).

Table 4.27: Descriptive Statistics for Pre-test and Post-test CK Scores

		Pre-test		Post-test	
Group	n	M	SD	M	SD
EG	75	13.906	4.606	29.480	9.162
CG	75	13.800	4.142	15.206	5.482

The extent as to which the mean incremental difference between learners in the experimental and comparison groups from pre-test to post-test on conceptual knowledge scores of calculus was statistically significant can be inspected using the line graph shown in Figure 4.17.

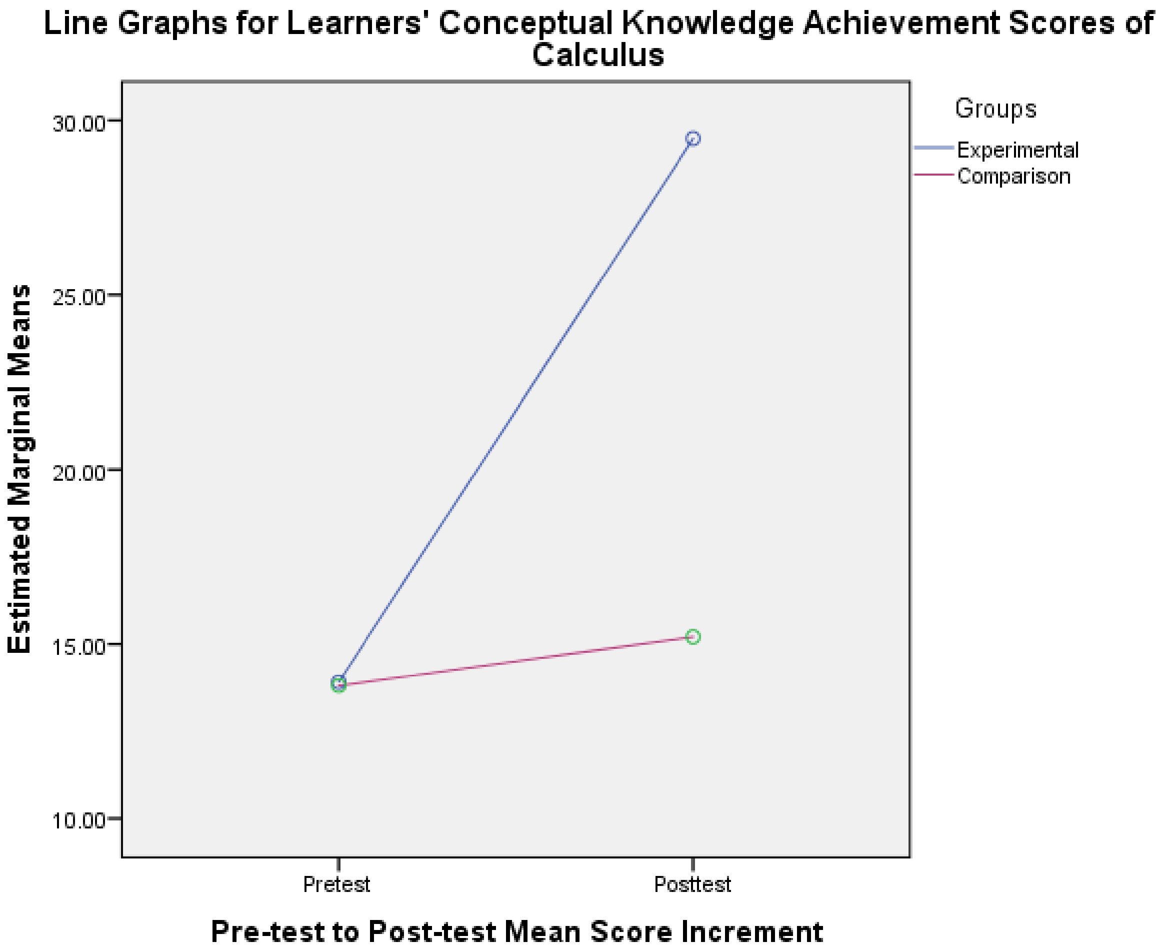


Figure 4.17: CK Development of Calculus for EG and CG

From Figure 4.17, the mean score on pre-test conceptual knowledge achievement scores of learners in the experimental group who learned calculus with the JCLGS was M=13.906. The mean on post-test was M=29.480. The mean score increment was 15.574. The mean score on pre-test for comparison group learners taught with the conventional lecture method was M=13.800. The mean on post-test was M=15.206. The mean score increment was 1.406. The increment for the experimental group was substantial as compared to the comparison group after the intervention. Whether this big incremental difference was statistically significant or not could be further justified using the Two-Way ANOVA for repeated measures analysis procedures. The results of Two-Way ANOVA for repeated measures analysis are shown in Table 4.28.

Table 4.28: ANOVA Results for Pre-test and Post-test CK Scores of the EG and CG

Source of Variance	Sum of Squares	df	Mean Score	F	$\boldsymbol{\eta^2}$	p
			Between Groups			
Group	5406.008	1	5406.008	131.84	.471	.000*
Error	6068.467	148	41.003			
			Within Groups			
Pre-Post Test Measures	3877.208	1	3877.208	110.158	.427	.000*
Pre-Post test*Group	3763.021	1	3763.021	106.913	.419	.000*
Error	5209.147	148	35.197			

*p<.01

Table 4.28 shows that there was a statistically significant mean incremental difference in experimental and comparison groups students' conceptual knowledge development of calculus after the intervention. The effect of pre-test and post-test conducted on learners of both experimental and comparison groups in their conceptual knowledge development of calculus was statistically significant [$F(1,148)=106.913; \eta^2 = .41; p<.01$]. The effect size value $\eta^2 = .419$ was represented a very large effect (Cohen et al., 2007; Pallant, 2007). Therefore, learners in the experimental group substantially benefited in developing conceptual knowledge of calculus by exposure to the JCLGS grounded in Vygotsky's socio-cultural learning theory as compared to the comparison group that was taught calculus by using the conventional method

The second null hypothesis was H_{02} posited as:

$H_{02:}$ Learning calculus through JCLGS has the same influence as lecture method on procedural knowledge. Learners' procedural knowledge achievement scores of calculus were the dependent variable of H_{02}.

Histograms for pre-test procedural knowledge scores of experimental and comparison groups are depicted as follows.

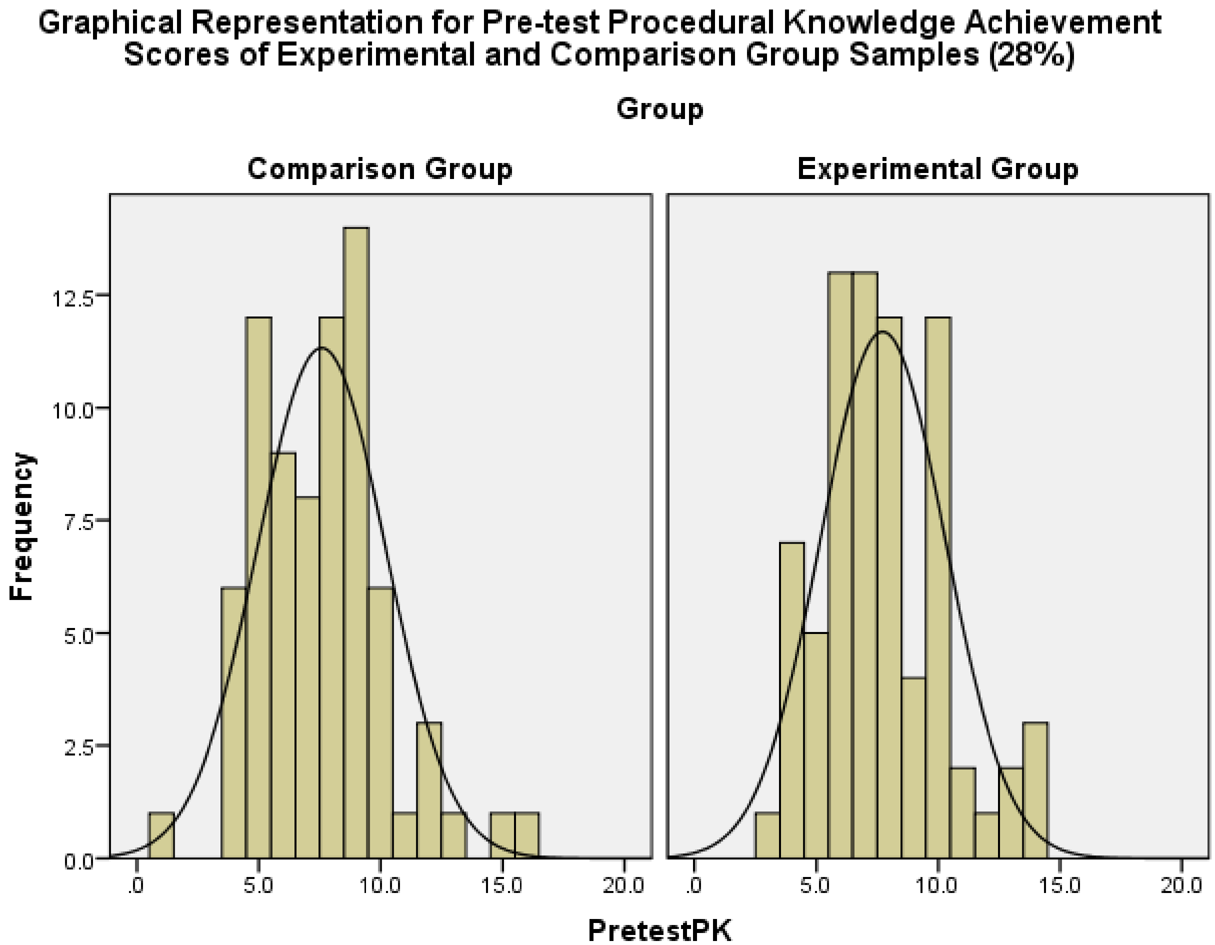


Figure 4.18: Histogram with Normal curve for Pre-test PK Achievement Scores

The shapes of both graphs shown in Figure 4.18 indicate that both distributions of scores were reasonably normal. The skewness (.579) and kurtosis values (.063) for distribution of the experimental group, and skewness value (.600) and kurtosis value (1.069) for distribution of comparison group samples shown in Table 4.29 were also in support of the normality of both distributions, as these values were relatively close to zero, except the kurtosis value (1.069) (Field, 2009). The kurtosis value (1.069) cannot be viewed as a problem for analysis because the sample size was large, as it was greater than 30. According to Field (2009); Saunders et al.

(2009), the central limit theorem states that as the sample size gets larger (greater than 30), the more the distribution scores of the sample gets close to normality distribution. This means that if the sample size gets larger, then whether the population from which the sample is drawn has a normal distribution or normal shape or not, will at times not bother us.

Table 4.29: Descriptive Statistics for Pre-test PK Achievement Scores

	Pre-test	
Statistics	Comparison Group	Experimental Group
Valid	75	75
Missing	0	0
Mean	7.573	7.720
Std. Error of Mean	.305	.295
Median	8.00	7.00
Variance	6.978	6.556
Mode	9.00	6.00[a]
Std. Deviation	2.641	2.560
Skewness	.600	.579
Kurtosis	1.069	.063
Range	15.00	11.00

Multiple modes exist. The smallest value is shown.

In connection with normality testing, examining the outlier scores that may affect the mean and variance that was to be fitted for each collected data by boxplots is very essential.

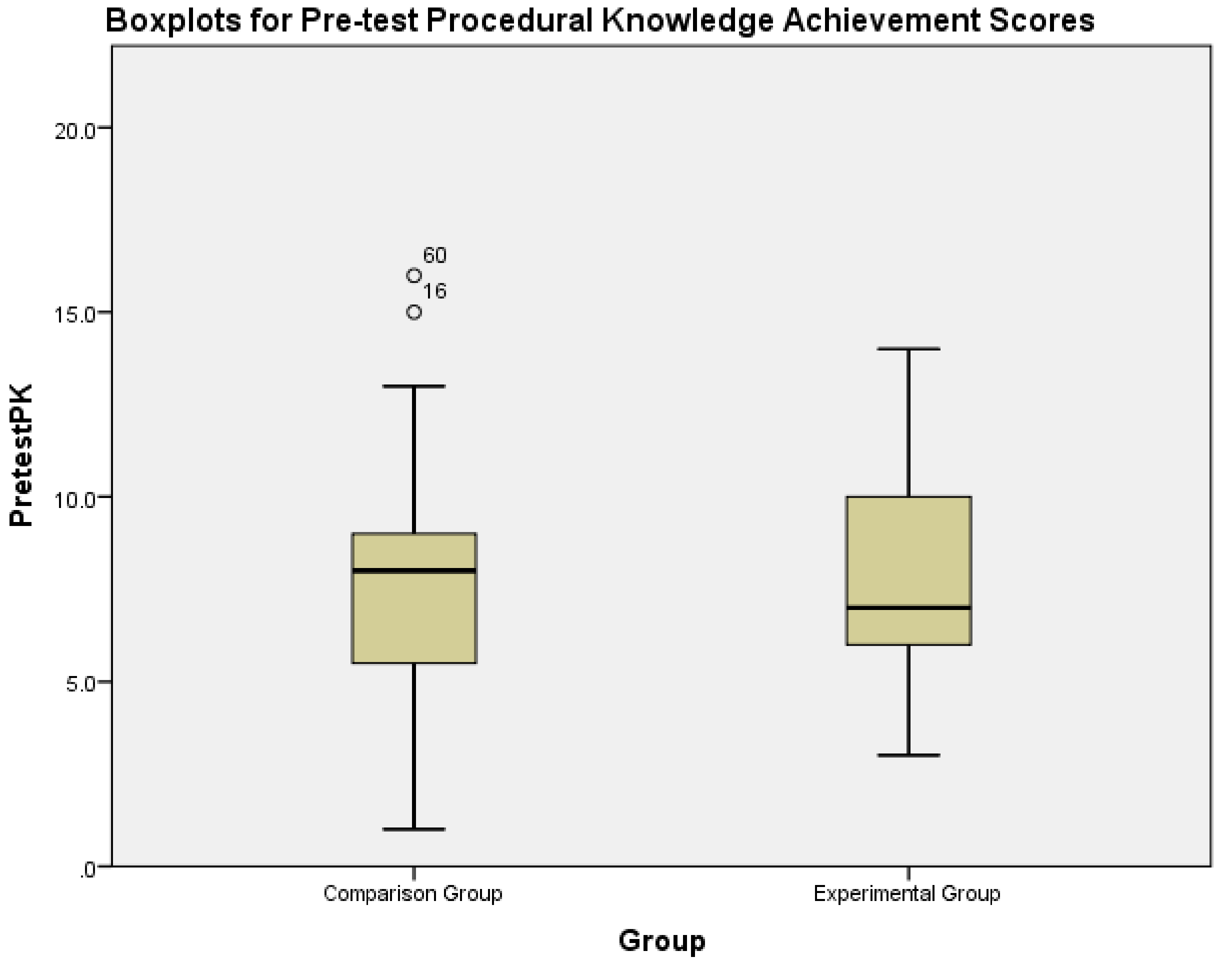


Figure 4.19: Boxplots for Distributions of Pre-test PK Achievement Scores

The scores for both experimental and comparison groups sample on pre-test procedural knowledge achievement scores shown in Figure 4.19 had appeared to be similar. The boxplot for distribution scores of the comparison group had come with two outliers which were not extreme points and were not affecting the analysis of data. However, the experimental group sample distribution had no outlier scores.

It is important to examine the normality of data on pre-test procedural achievement scores of both groups using Q-Q plots because they would make the issue of normality more illustrative.

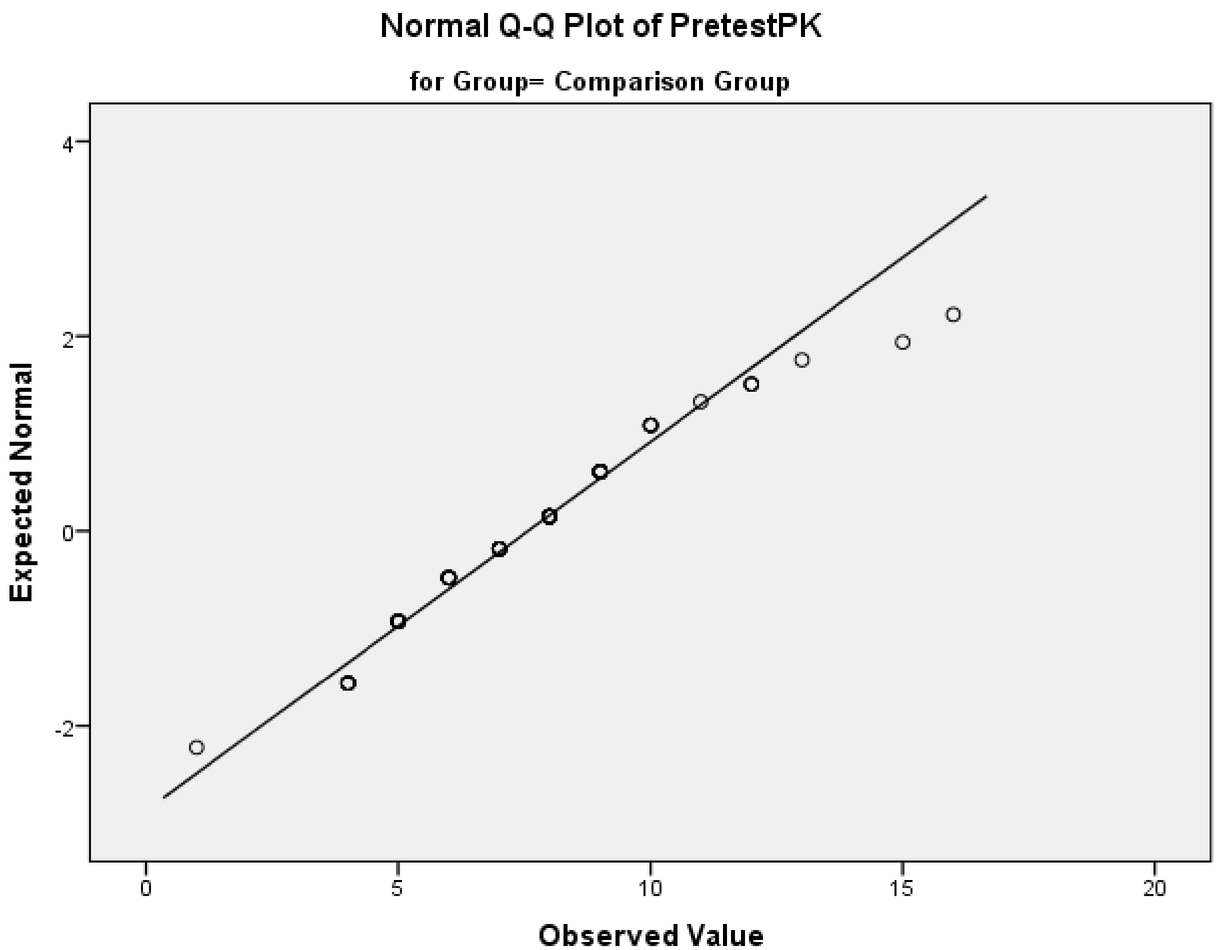


Figure 4.20: Q-Q plot for Pre-test PK Achievement Scores of CG

By the Central Limit Theorem when the sample is large the data points shown in Figure 4.20 indicate normality of the distribution (Field, 2009).

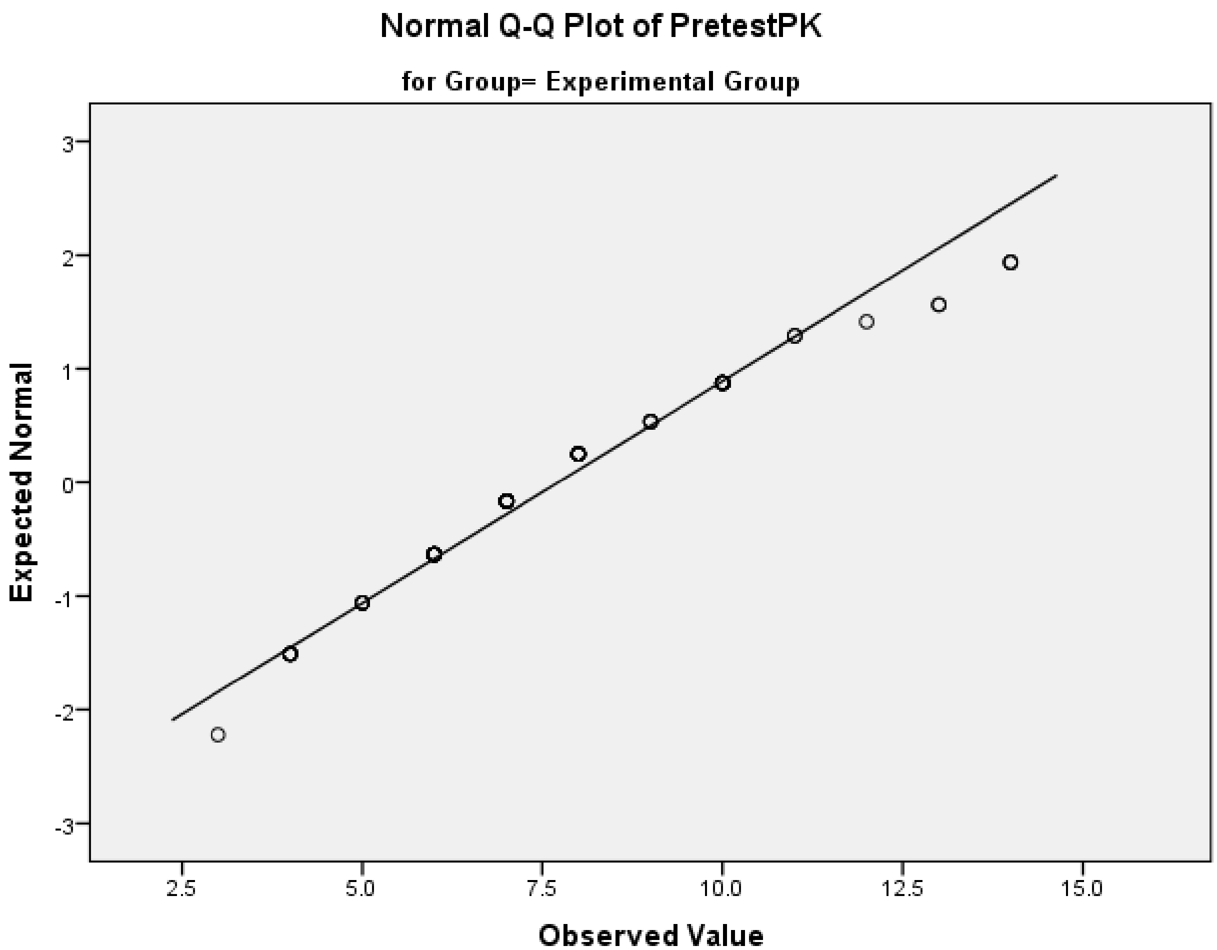


Figure 4.21: Q-Q plot for Pre-test PK Achievement Scores of EG

By the Central Limit Theorem when the sample is large the data points shown in Figure 4.21 indicate normality of the distribution (Field, 2009).

Table 4.30: Kolmogorov-Smirnov Normality Test for Pre-test PK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.
PK	EG	.136	75	.001	.949	75	.005
	CG	.121	75	.008	.953	75	.008

*. This is a lower bound of true significance. a. Lilliefors Significance Correction.

The results for the pre-test procedural knowledge scores of both groups were observed respectively, *D(75)=.001, p<0.05* and *D(75)=.008, p<0.05* by the Kolmogorov-Smirnov test, it follows that the dependent variables in both experimental and comparison groups were not normal. However, by the Central Limit Theorem when the sample is large both sampling distributions are likely normal distribution.

Table 4.31: Independent-samples t-test for Pre-test PK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
PK	EG	75	7.720	2.560	.026	.872	148	.345	.730	.00080
	CG	75	7.573	2.641						

*p<0.01

The results on learners' pre-test data of the procedural knowledge scores of experimental and comparison groups was *F(1,148)=.026, p=.872>.01* by Levene's test. In this case, the variances of the dependent variable for the two populations were equal.

The effect size of the mean difference between the pre-test procedural knowledge score of learners in the experimental and comparison groups was computed using eta squared formula as .00080. This value also represented a very small-sized effect (Cohen et al., 2007; Pallant, 2010). In this case, there was also no statistically significant difference between the mean pre-test procedural knowledge achievement scores of the experimental group (*M=7.720, SE=.295*) and mean pre-test procedural knowledge achievement scores of the comparison group (*M=7.573, SE=.305*); *t(148)=.345, p>.01, eta squared=.00080,* 99% CI [-.96, 1.25] with mean difference 0.147.This implies that the data supported the null hypothesis H_{02}. Therefore, this result can be interpreted as at the outset of the main research study, learners in both experimental and comparison groups had almost the same procedural knowledge level.

Table 4.32 depicts the gender-wise descriptive statistics for learners pre-test procedural knowledge achievement scores.

Table 4.32: Descriptive Statistics for Learners Pre-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Procedural	EG	27	7.000	2.4337
	Knowledge	CG	30	7.333	2.6824
Male		EG	48	8.125	2.5651
		CG	45	7.733	2.6320

In light of gender, the mean score difference 0.333 between the pre-test mean procedural knowledge achievement score of females in the comparison (M=7.333, SD=2.6824) and experimental group (M=7.000, SD=2.4337) shown in Table 4.32 was very small. The mean score difference 0.392 between the pre-test mean procedural knowledge achievement score of males of the experimental (M=8.125, SD=2.5651) and comparison group (M=7.733, SD=2.6320) was also very small. From this observation, it could be inferred that learners in both groups had quite similar procedural knowledge level in the pre-intervention in gender-wise. This could be taken as the other important background information that shows the similarity of the two experimental groups of learners in procedural knowledge (PK) for quasi-experimental design employed.

Bar graph representations with error bars of mean scores on pre-test procedural knowledge achievement scores, for experimental (EG) and comparison (CG) groups samples based on gender, are shown in Figure 4.22.

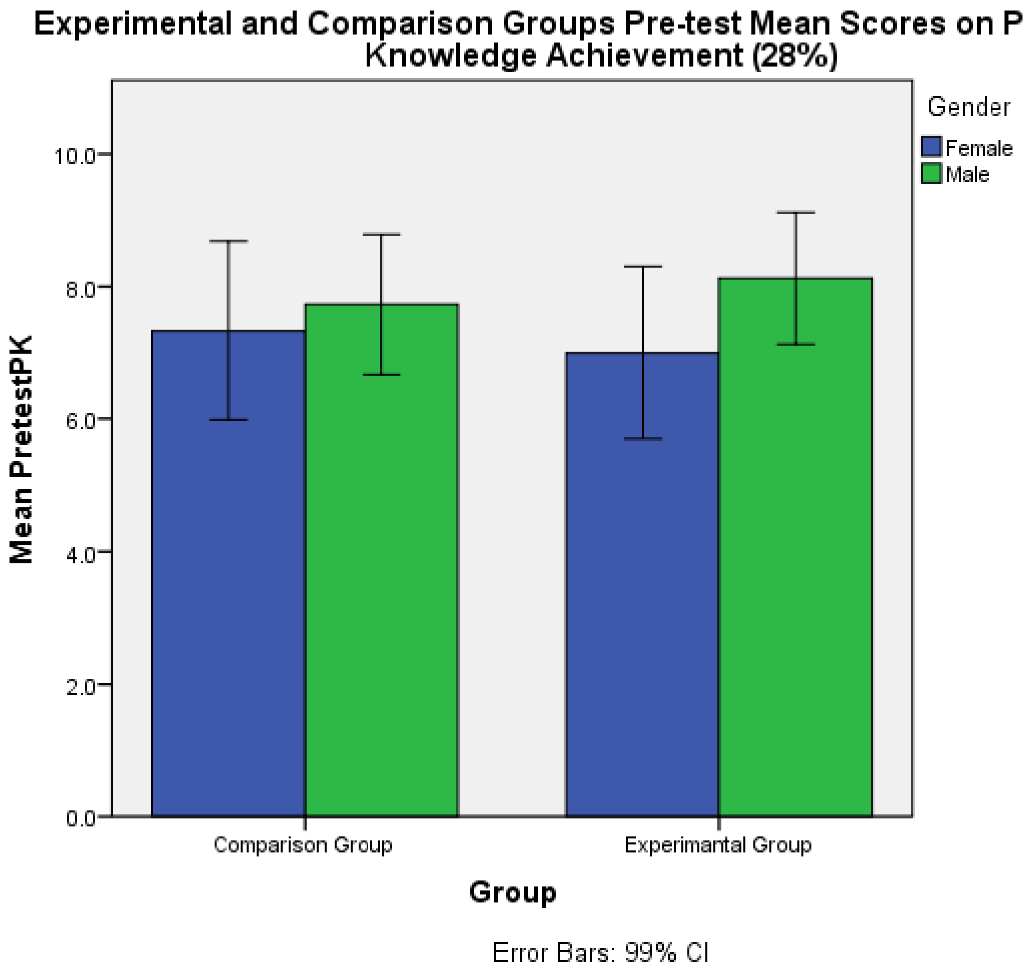


Figure 4.22: Bar graphs for Pre-test PK Achievement Scores based on Gender

As with the bar graph for means pre-test scores on conceptual knowledge, Figure 4.22 yielded that females mean scores for both groups on pre-test procedural knowledge achievement scores were nearly the same. Similarly, males in the experimental group and comparison group also had almost the same mean score on this same variable. Therefore, it can be inferred that the mean score of all samples (males and females), on this same variable of both experimental and comparison groups, were nearly the same. Therefore, in this case, also gender was not taken as a covariate.

Polygonal representations with error bars of mean scores on pre-test procedural knowledge scores for experimental (EG) and comparison (CG) groups were depicted in Figure 4.23.

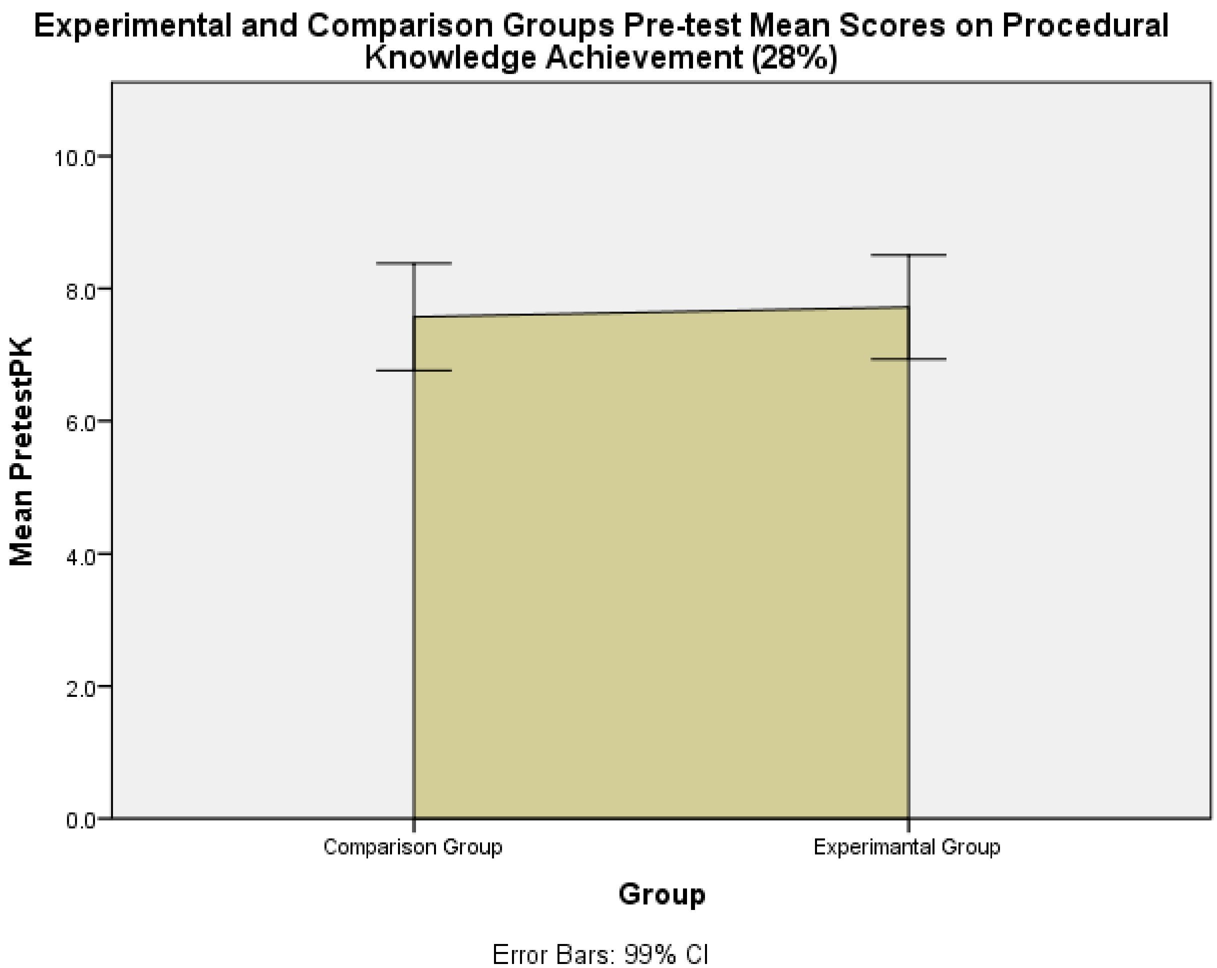


Figure 4.23: Frequency Polygons for Pre-test PK Achievement Scores

From Figure 4.23, the mean score of experimental group learners on pre-test procedural knowledge achievement scores was nearly the same as the mean score of comparison group sample.

Histograms for post-test procedural knowledge achievement scores are depicted in the following way.

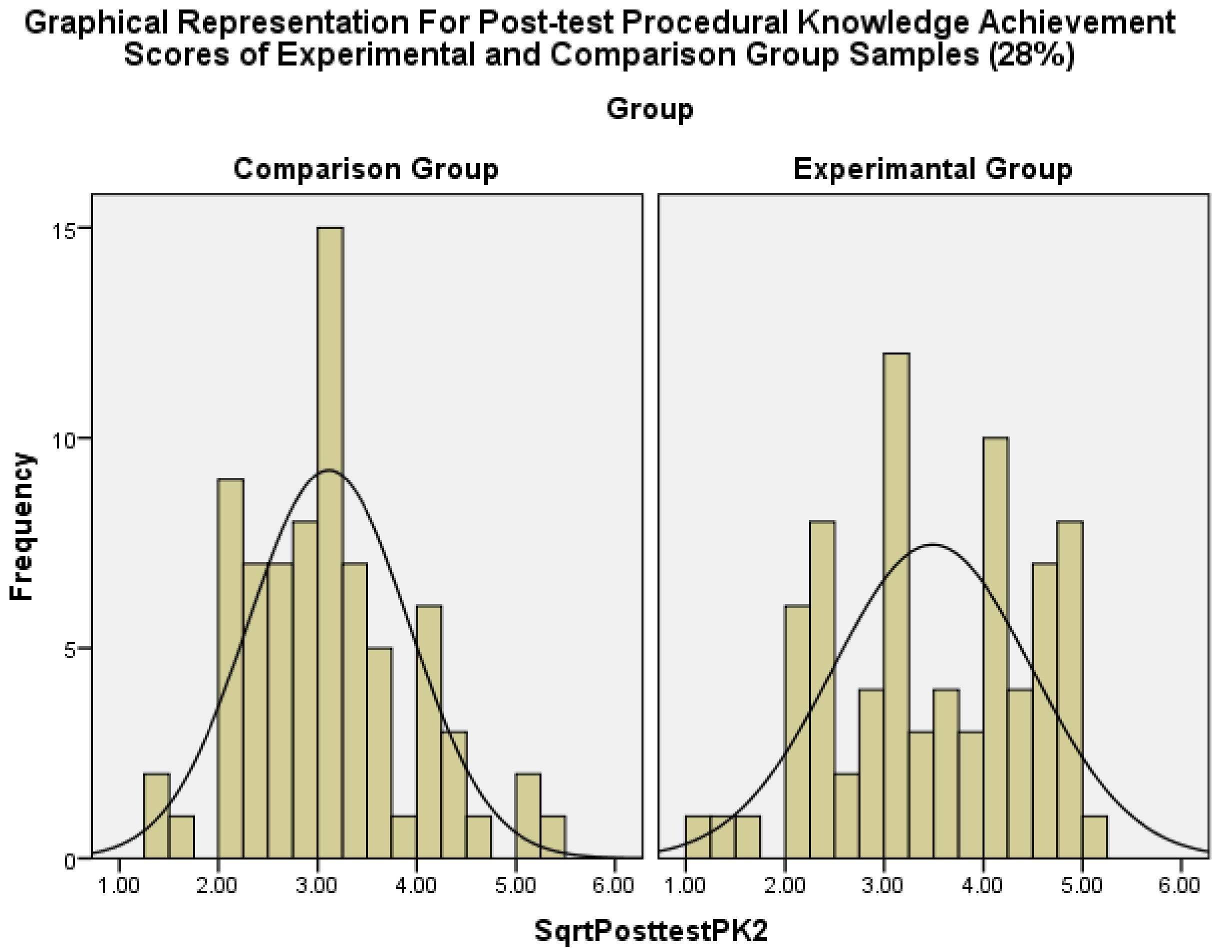


Figure 4.24: Histogram with Normal curve for Post-test PK Achievement Scores

The shapes of both graphs shown in Figure 4.24 indicate that both distributions of scores were reasonably normal. The skewness value (-.268) and kurtosis value (-.893) for the distribution of the experimental group sample and skewness value (.596) and kurtosis value (.367) for the distribution of the comparison group sample shown in Table 4.33 were also in support of the normality of both distributions as these values were relatively close to zero (Field, 2009).

Table 4.33: Descriptive Statistics for Post-test PK Achievement Scores

	Post-test	
Statistics	Comparison Group	Experimental Group
Valid	75	75
Missing	0	0
Mean	10.320	13.153
Std. Error of Mean	.634	.786
Median	9.00	12.00
Variance	.657	1.007
Mode	10.00	6.00[a]
Std. Deviation	5.497	6.811
Skewness	.596	-.268
Kurtosis	.367	-.893
Range	26.00	24.00

Multiple modes exist. The smallest value is shown.

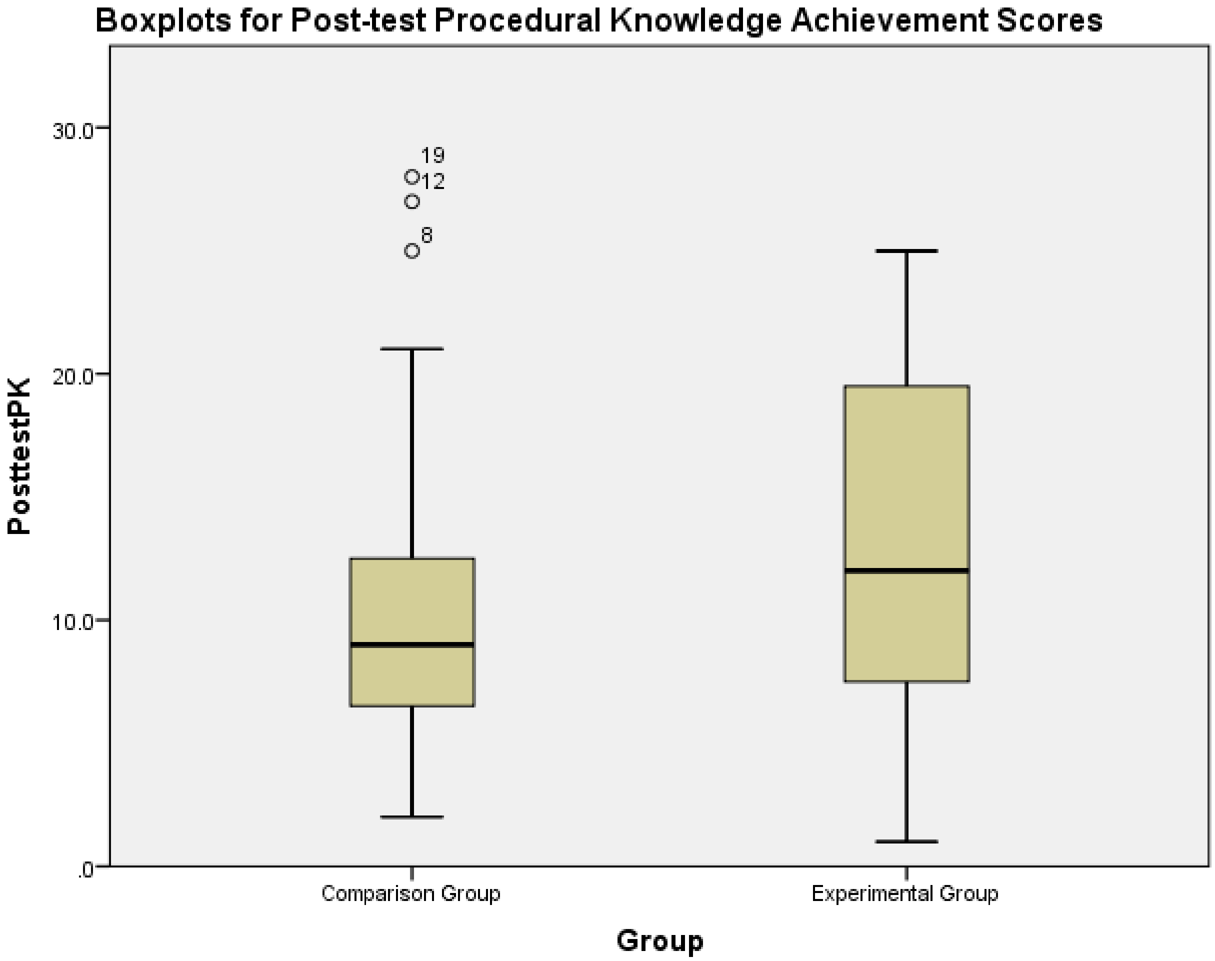


Figure 4.25: Boxplots for Distributions of Post-test PK Achievement Scores

The results shown in Figure 4.25 indicate that both the experimental and comparison group samples distribution scores appeared to be different. This means that most cases/units in the experimental group scored higher values, while lower values were scored by the comparison group. The boxplot corresponding to the comparison group had three outlier scores, which were not extreme points. Data analysis was not affected by these scores. Experimental group distribution scores had no outliers.

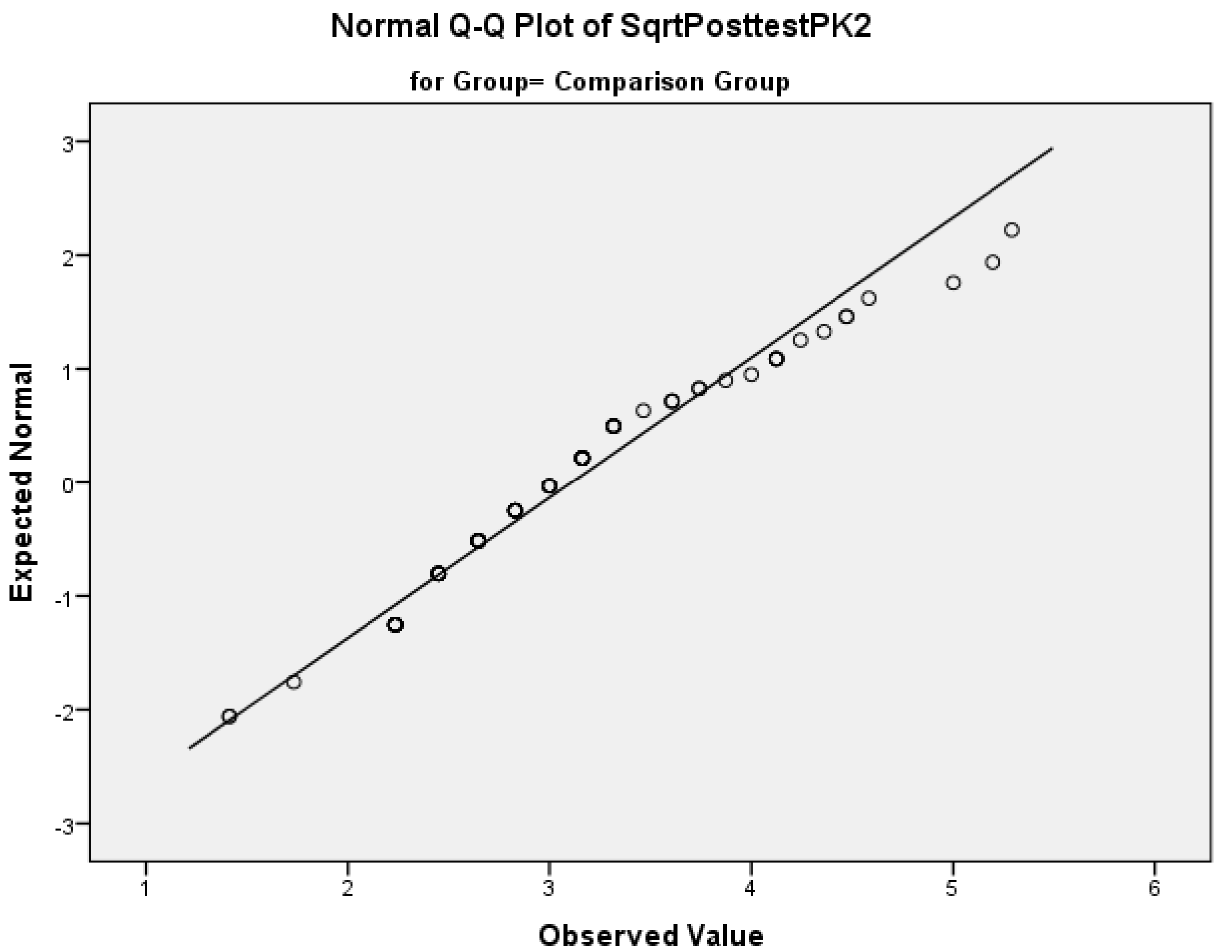


Figure 4.26: Q-Q plot for Post-test PK Achievement Scores of CG

Several of the data points shown in Figure 4.26 nearly lay on a straight line. A few of them were a bit distant from the line. By the Central Limit Theorem when the sample size was large the distribution was reasonably normality (Field, 2009).

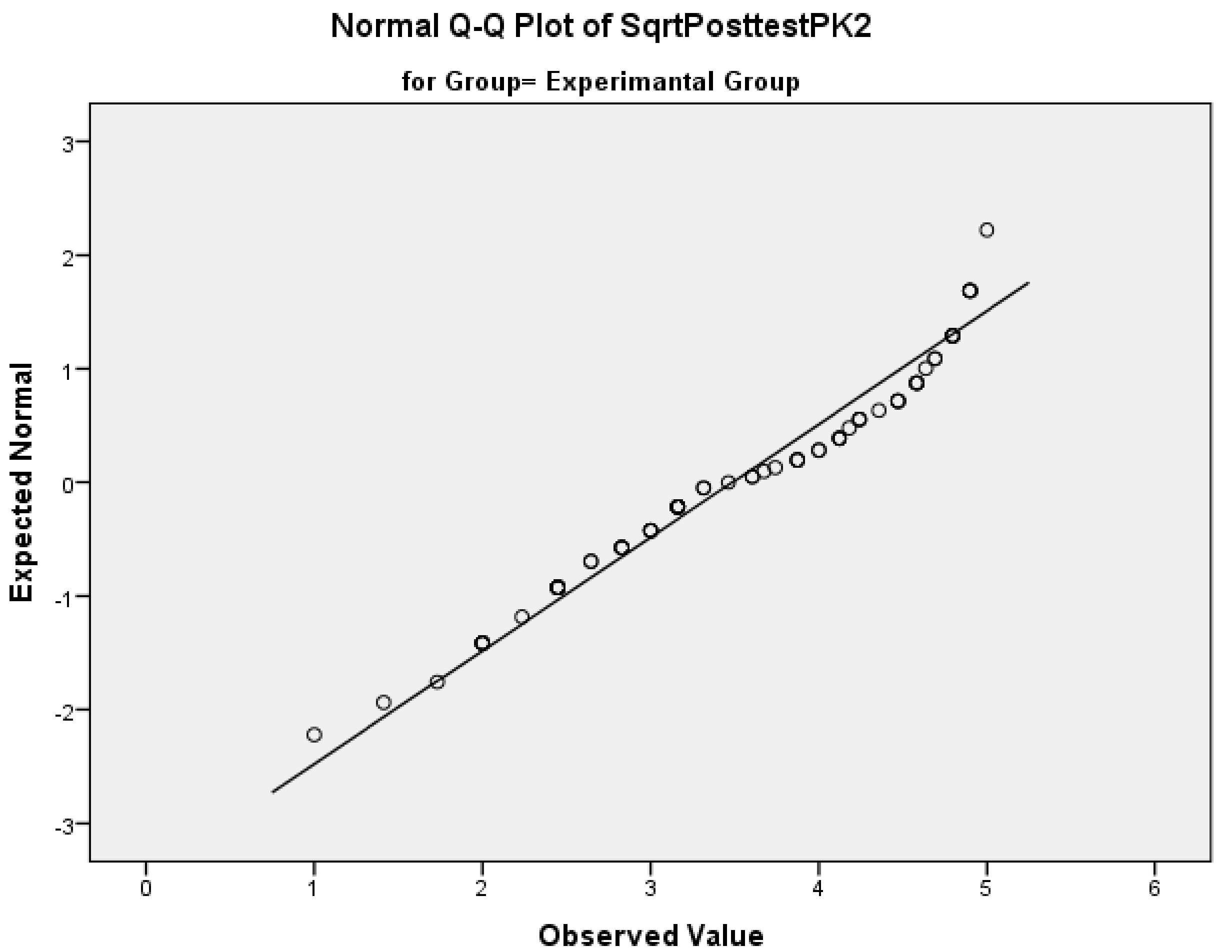


Figure 4.27: Q-Q plot for Post-test PK Achievement Scores of EG

Several of the data points shown in Figure 4.27 nearly lay on a straight line. A few of them were a bit far from the line. By the Central Limit Theorem when the sample size was large the distribution was reasonably normality (Field, 2009).

Square root transformation has been made on post-test procedural knowledge (PK) achievement scores data.

Table 4.34: Kolmogorov-Smirnov Normality Test for Post-test PK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.

PK	EG	.110	75	.025	.952	75	.007
	CG	.133	75	.002	.959	75	.016

*. This is a lower bound of true significance. a. Lilliefors Significance Correction.

The Kolmogorov-Smirnov test statistics of post-test procedural knowledge achievement score of the treatment and comparison groups were respectively observed as *D(75)=.025, p<0.05* and *D(75)=.002, p<0.05*. The dependent variable for both experimental and comparison groups was non-normal. However, by the Central Limit Theorem when the sample size was large, the non-normality sampling distribution can tend to normality.

Table 4.35: Independent-samples t-test for Post-test PK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
PK	EG	75	13.150	6.811	8.897	.003	148	2.532	.012*	.042
	CG	75	10.320	5.497						

*p<0.01

The results on data of post-test procedural knowledge scores of experimental and comparison groups was obtained as *F(1,148)=8.897, p=.003<.01* by Levene's test statistic. The variances for the dependent variable of both populations were not equal.

Based on the square root transformation made on post-test procedural achievement scores data, the variance ratio for the post-test procedural knowledge scores was 1.53. This variance ratio value for this case was reasonably less than the critical value for the associated sample size (75) per group. This implies that the variance was reasonably equal for this case.

The effect size value of the mean difference between experimental and comparison groups on the post-test procedural knowledge achievement scores was calculated as *eta squared=.042*. This value represents a modest effect (Cohen et al., 2007). It implies that there was a statistically significant mean difference between experimental (*M=13.153, SE=.115*) and comparison groups (*M=10.320, SE=.093*); *t(148)=2.532, p<.01, eta squared=.042*, 99% CI [-.011, .765], with a mean difference of 2.8333. The effect of the intervention was not that much big on learners' procedural knowledge development even though the data supported the alternative hypothesis H_{12}. Thus, the result can be interpreted as the JCLGS influenced experimental group learners' procedural knowledge development with modest effect in intermediate calculus.

Table 4.36 depicts the gender-wise descriptive statistics for learners post-test procedural knowledge achievement scores.

Table 4.36: Descriptive Statistics for Learners Post-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Procedural	EG	27	10.796	6.3644
	Knowledge	CG	30	9.333	5.8917
Male		EG	48	14.479	6.7564
		CG	45	10.978	5.1808

The mean score difference, 1.463 between post-test mean procedural knowledge achievement score of females sample of the experimental group, (M=10.796, SD=6.3644) and the comparison group, (M=9.333, SD=5.8917) shown in Table 4.36 was small. The mean score difference, 3.501, between the post-test mean procedural knowledge achievement score of males sample of the experimental group, (M=14.479, SD=6.7564) and the comparison group, (M=10.978, SD=5.1808) was modest.

Bar graph representations with error bars for mean scores on post-test procedural knowledge achievement scores for experimental (EG) and comparison (CG) groups based on gender are shown in Figure 4.28.

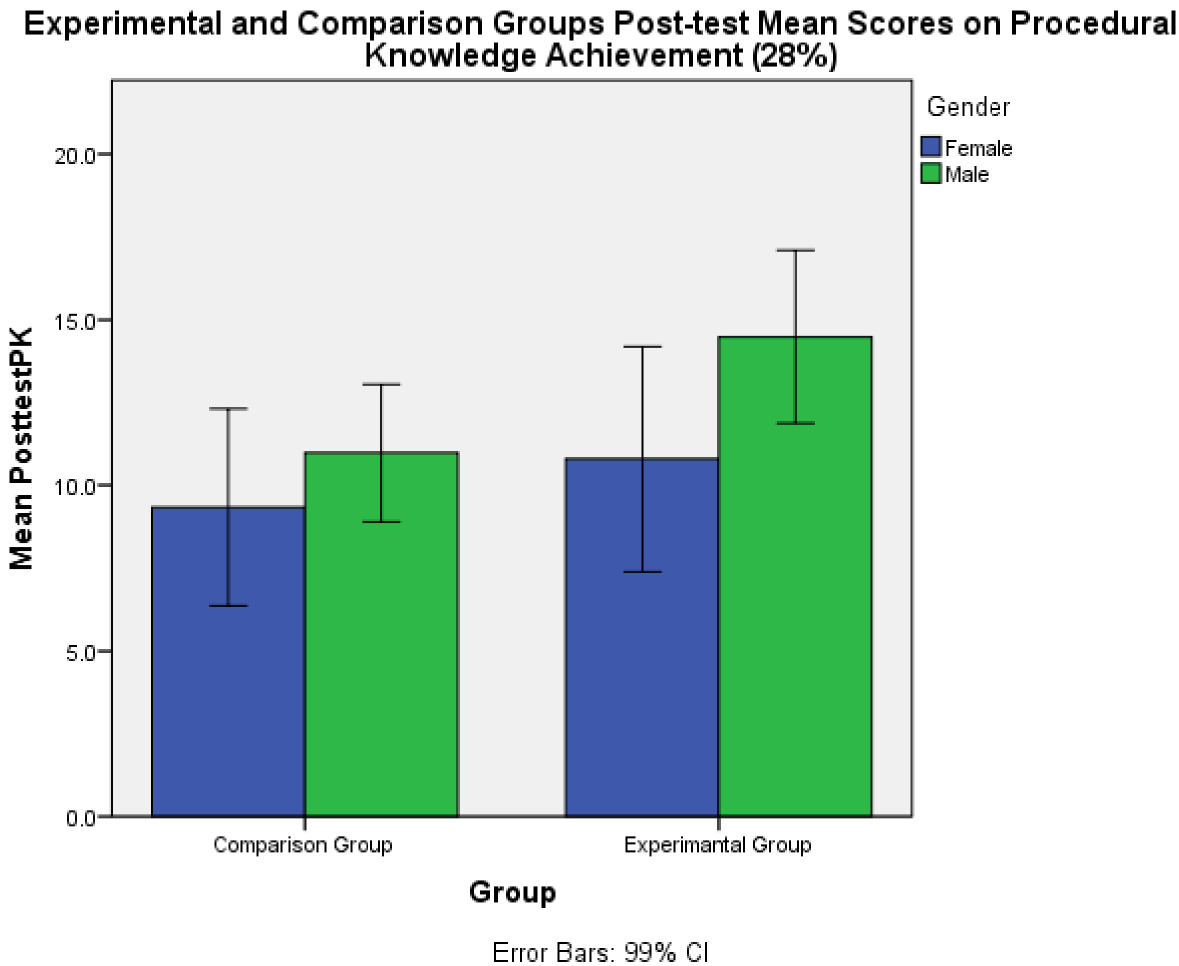


Figure 4.28: Bar graphs for Post-test PK Achievement Scores based on Gender

It can be seen from Figure 4.28 that females sample in the experimental group on post-test procedural knowledge achievement scores had got a mean score which was modestly higher than the comparison group. Also, males sample in the experimental group on post-test procedural knowledge achievement scores had got a mean score which was higher than the comparison group. Hence, in aggregate experimental group sample mean score (male and female) was higher than the comparison group.

Polygonal representations with error bars of mean scores on post-test procedural knowledge achievement scores for experimental (EG) and comparison (CG) Groups are depicted in Figure 4.29.

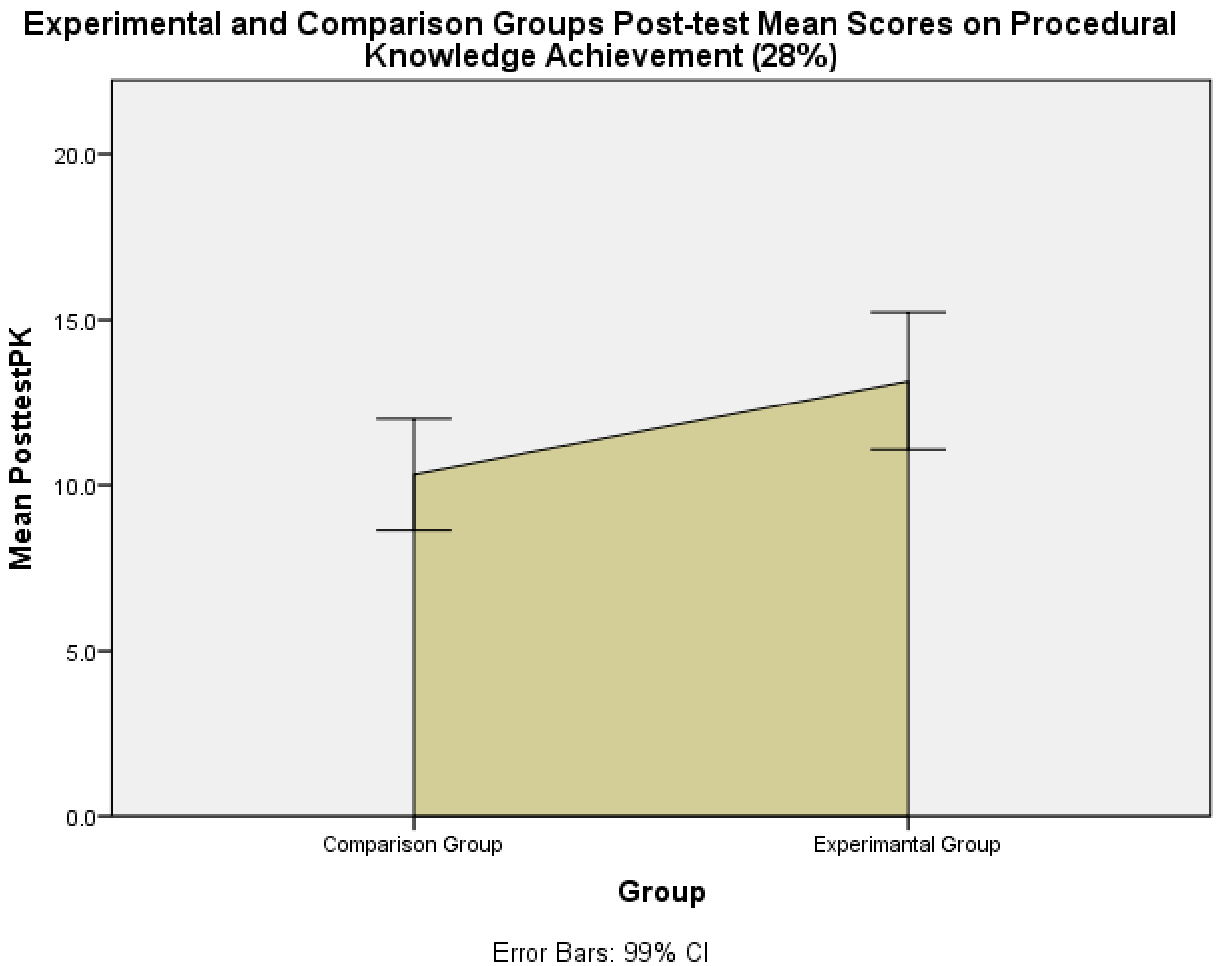


Figure 4.29: Frequency Polygons for Post-test PK Achievement Scores

From Figure 4.29, a modest mean score difference on post-test procedural knowledge achievement scores was observed between the two groups.

As the collected data on procedural knowledge achievement scores for both experimental and comparison group had met the underlying assumptions, the null hypothesis $H_{02}$was also analyzed using Two-Way ANOVA for repeated measures.

The appropriate descriptive statistics of pre-test and post-test procedural knowledge achievement scores of learners in both experimental and comparison groups are shown in Table 4.37.

Table 4.37: Descriptive Statistics for Pre-test and Post-test PK Scores

		Pre-test		Post-test	
Group	n	M	SD	M	SD
EG	75	7.720	2.560	13.153	6.811
CG	75	7.753	2.641	10.320	5.497

The degree as to which the mean incremental difference was statistically significant between learners in the experimental and comparison groups from pre-test to post-test on procedural knowledge achievement scores of calculus can be imagined using the line graph shown in Figure 4.30.

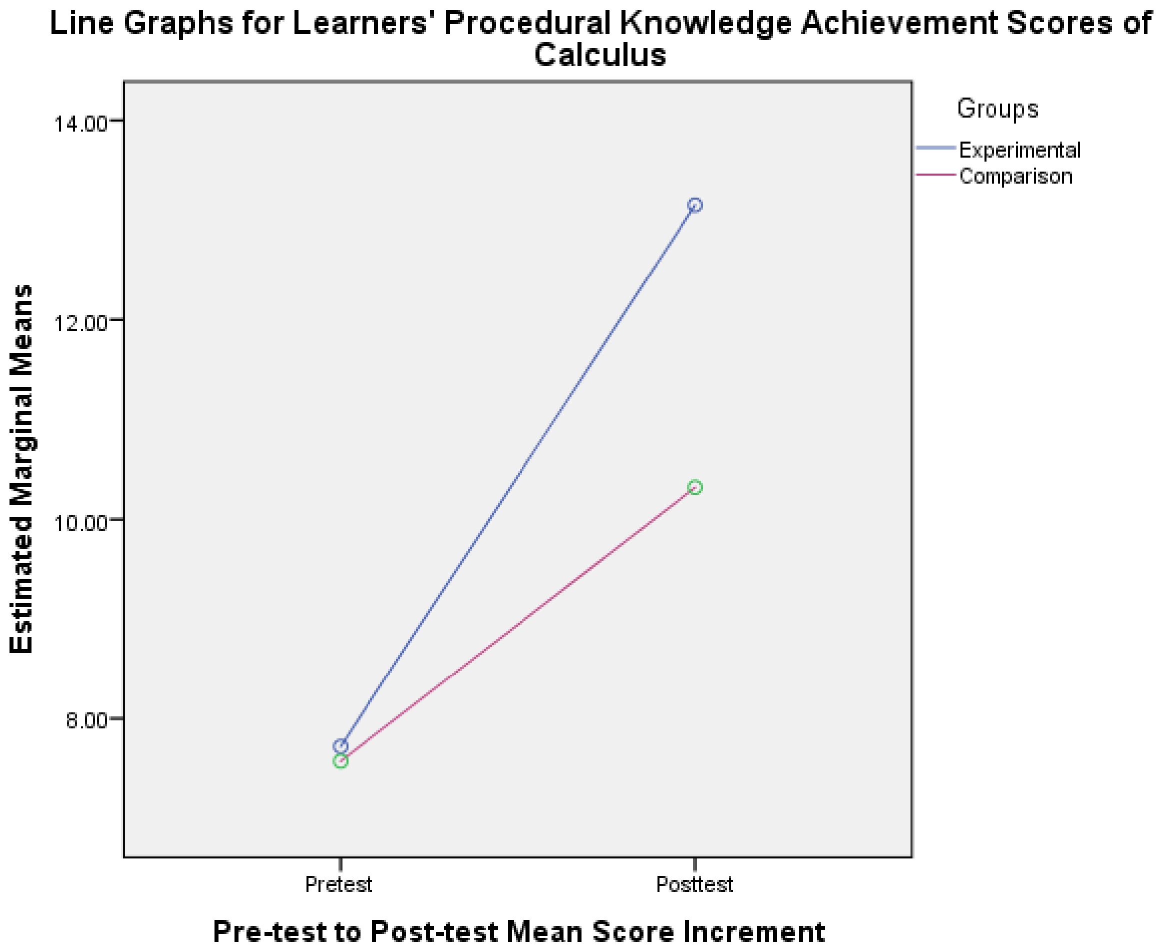


Figure 4.30: PK Development of Calculus for EG and CG

From Figure 4.30, the mean score on pre-test conceptual knowledge achievement scores of learners in the experimental group who learned calculus with the JCLGS was M=7.720. The mean on post-test was M=13.153. The mean score increment was 5.433. The mean score on pre-test for comparison group learners taught with the conventional lecture method was M=7.753. The mean on post-test was M=10.320. The mean score increment was 2.567. The increment for the experimental group was modest compared to the comparison group after the intervention. Whether this mean incremental difference was statistically significant or not could be justified using the Two-Way ANOVA for repeated measures analysis. The results of Two-Way ANOVA for repeated measures analysis are shown in Table 4.38.

Table 4.38: ANOVA Results for Pre-test and Post-test PK Scores of the EG and CG

Source of Variance	Sum of Squares	df	Mean Score	F	η^2	p
			Between Groups			
Group	1254.607	1	1254.607	47.160	.242	.000*
Error	3937.247	148	26.603			
			Within Groups			
Pre-Post Test Measures	166.507	1	166.507	9.015	.057	.003*
Pre-Post Test*Group	135.341	1	135.341	7.328	.047	.008*
Error	2733.527	148	18.470			

*p<.01

Table 4.38 showed that there was a statistically significant mean incremental difference in learners' procedural knowledge development of calculus between the treatment and comparison groups after the intervention. The effect of pre-test and post-test conducted on learners of both experimental and comparison groups in their procedural knowledge development of calculus was statistically significant [*F(1,148)=7.328;* $\eta^2 = .047$*; p<.01*]. According to Cohen et al. (2007) and Pallant (2007), the effect size value $\eta^2 = .047$ lies between a small and moderate effect. This implies that learners in the experimental group gained a small amount of procedural knowledge of calculus after the intervention as compared to the comparison group.

The third null hypothesis was H_{03} stated as:

$H_{01:}$ Learning calculus through JCLGS has the same influence as lecture method on content knowledge. The dependent variable in H_{03} was learners' content knowledge achievement scores of calculus.

Histograms for pre-test content knowledge achievement scores of experimental and comparison groups are displayed as follows.

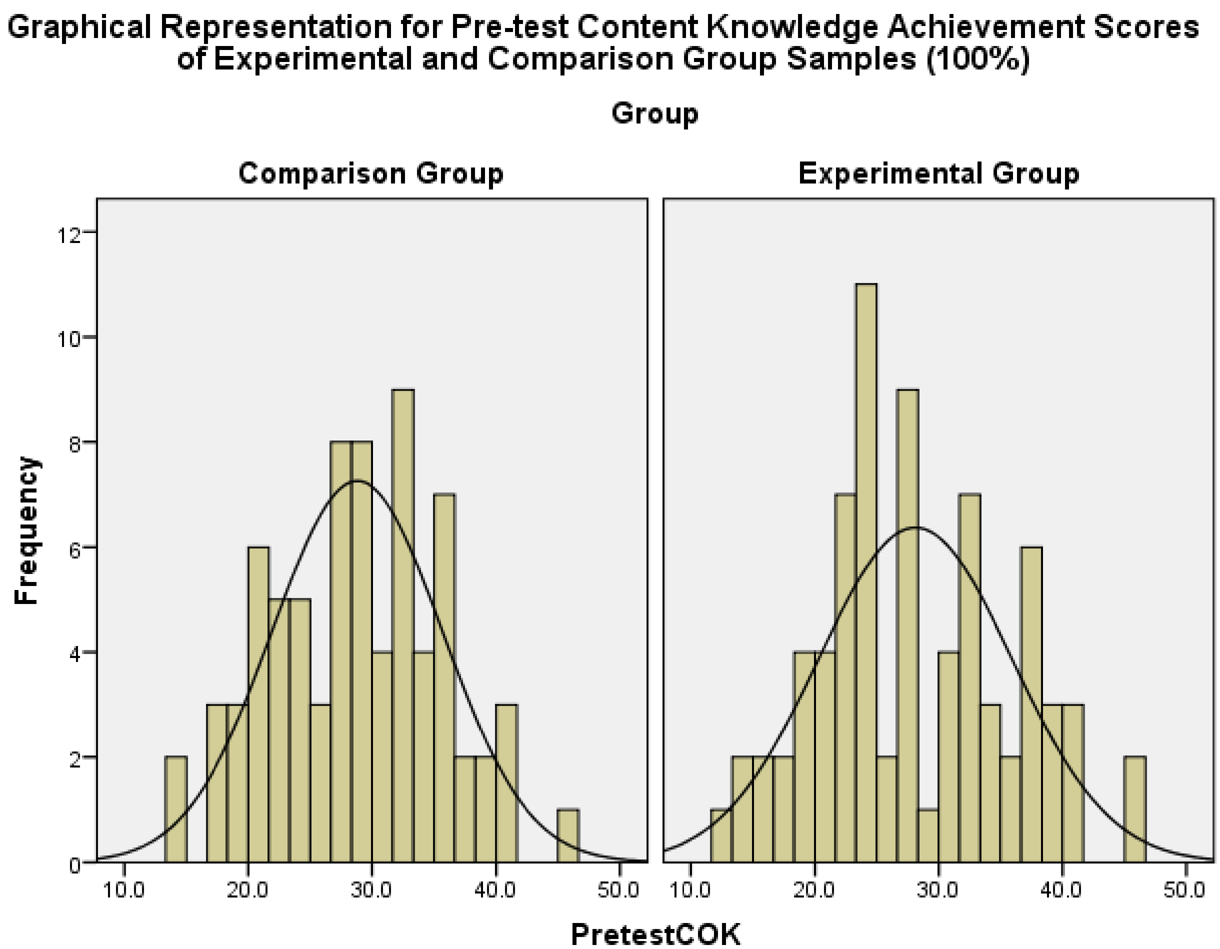


Figure 4.31: Histogram with Normal curve for Pre-test COK Achievement Scores

The shapes of both graphs in Figure 4.31 show that both distributions of scores were reasonably normal. The skewness (.268) and kurtosis values (-.553) for the distribution of the experimental group and skewness value (.075) and kurtosis value (-.403) for the distribution of the comparison group sample shown in Table 4.39, were also in support of the normality of both distributions as these values were relatively close to zero (Field, 2009).

Table 4.39: Descriptive Statistics for Pre-test COK Achievement Scores

	Pre-test	
Statistics	Comparison Group	Experimental Group
Valid	75	75
Missing	0	0
Mean	28.786	28.105
Std. Error of Mean	.793	.903
Median	29.00	27.30
Variance	61.235	47.184
Mode	29.00[a]	24.00
Std. Deviation	6.869	7.825
Skewness	.075	.268
Kurtosis	-.403	-.553
Range	32.50	33.10

Multiple modes exist. The smallest value is shown

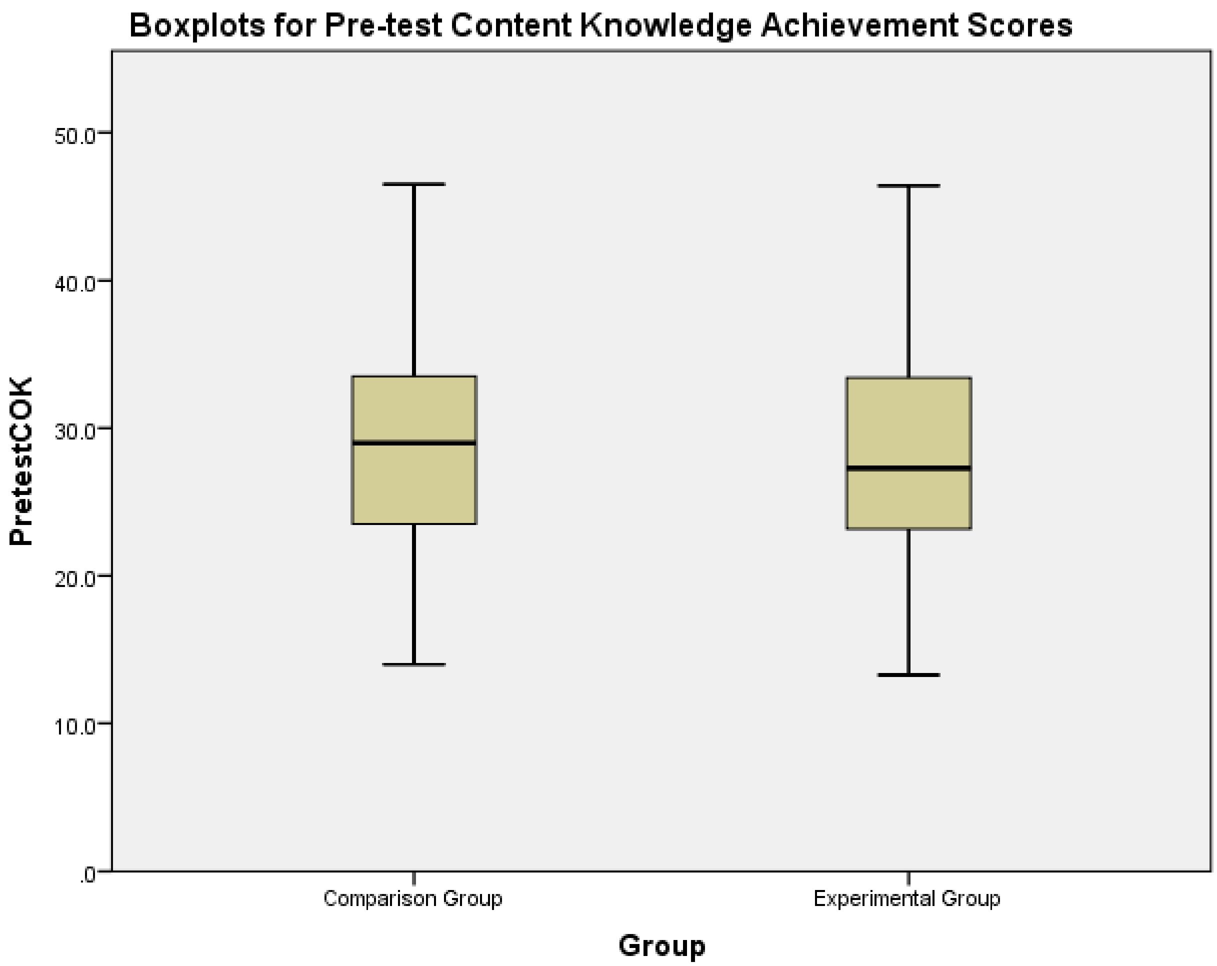


Figure 4.32: Boxplots for Distributions of Pre-test COK Achievement Scores

You can observe from the outcomes shown in Figure 4.32 that distributions of scores for both groups' sample were quite similar. There were no outlier scores in both distributions.

It is essential to examine the normality on pre-test content knowledge achievement scores of both groups using Q-Q plots because they would make the issue of normality more illustrative.

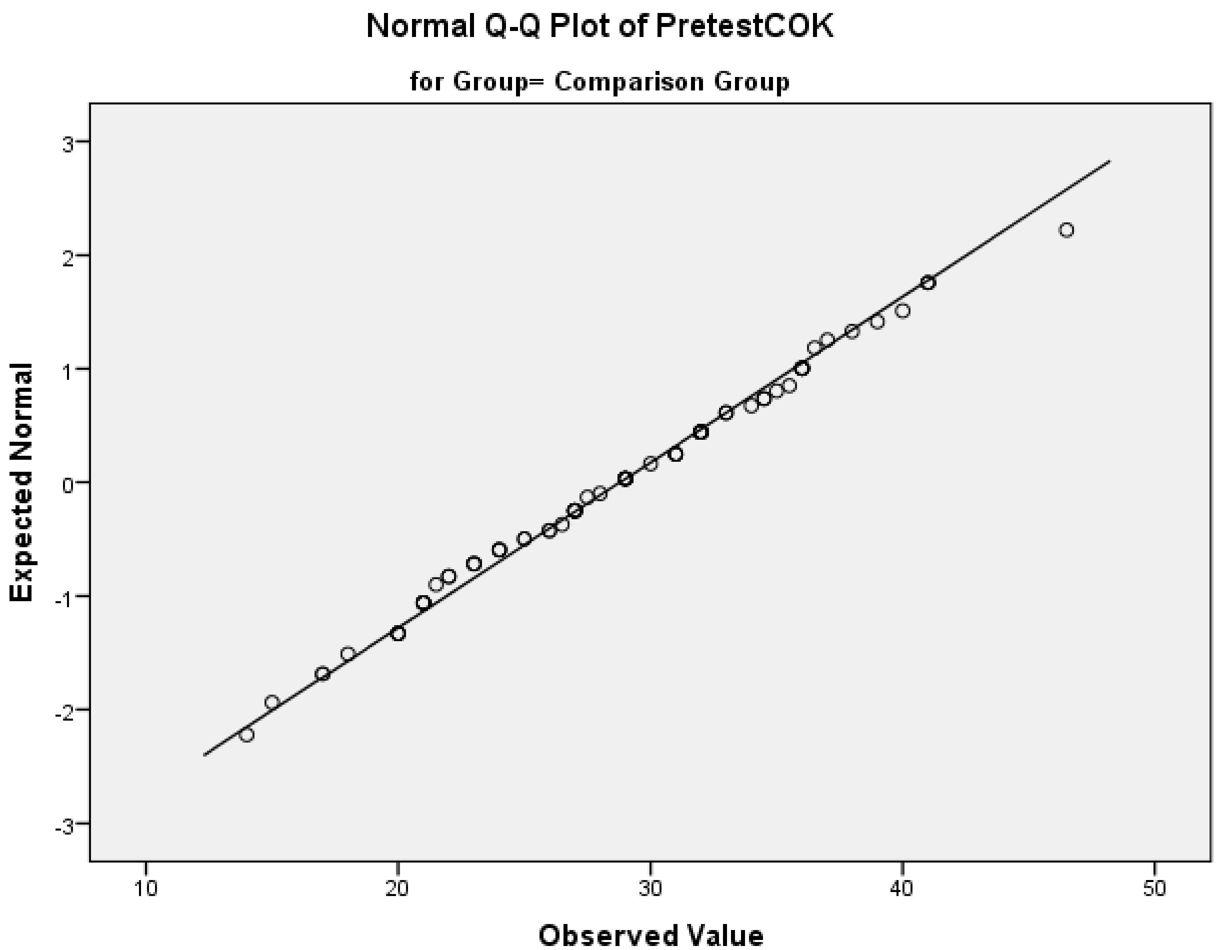


Figure 4.33: Q-Q plot for Pre-test COK Achievement Scores of CG

Almost all data points shown in Figure 4.33 nearly lay on a straight line showing normality of the distribution scores.

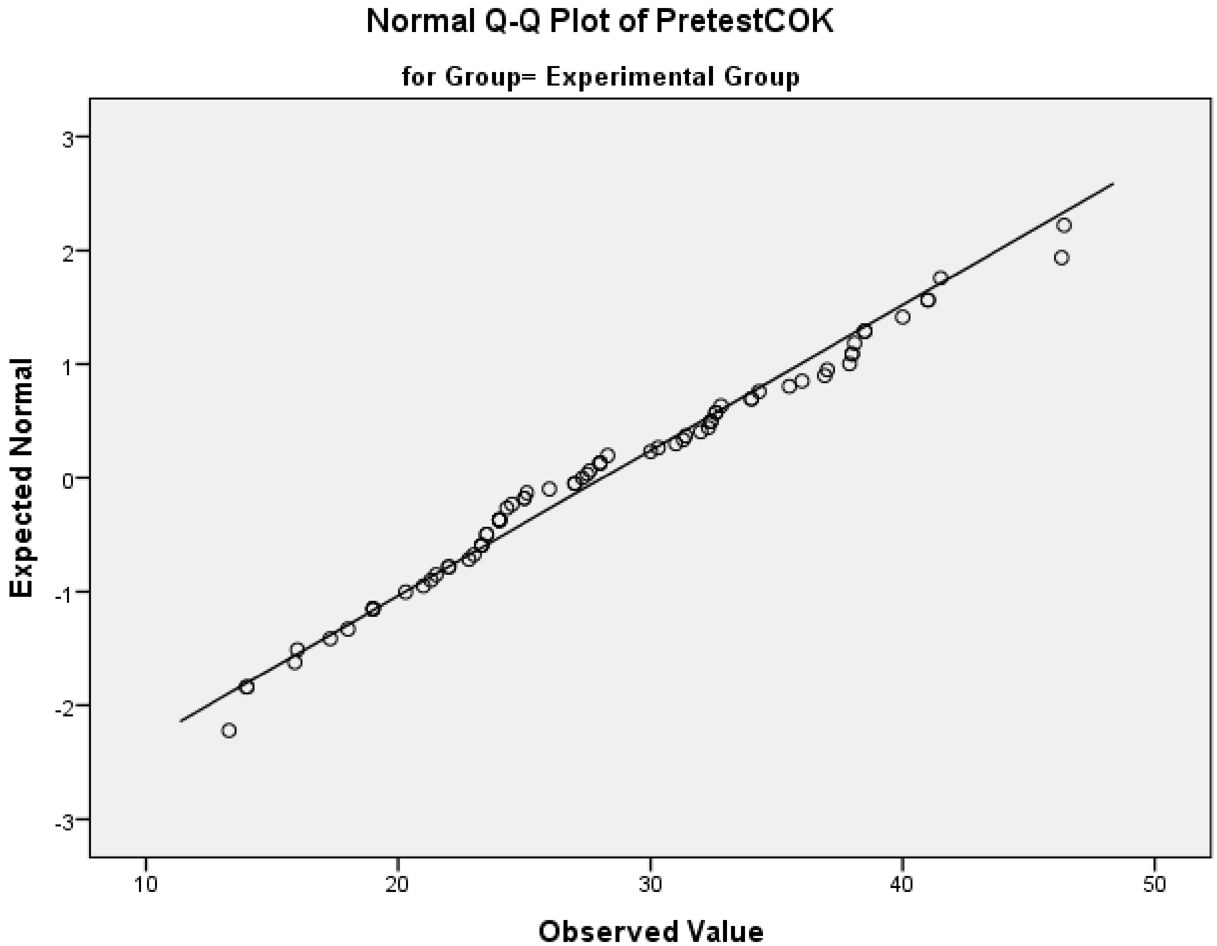


Figure 4.34: Q-Q plot for Pre-test COK Achievement Scores of EG

Almost all data points shown in Figure 4.34 nearly lay on a straight line except a few showing that normality of the distribution scores.

Normality for each pair of pre-test data was tested using the Kolmogorov-Smirnov test as follows.

Table 4.40: Kolmogorov-Smirnov Normality Test for Pre-test COK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.
COK	EG	.103	75	.048	.978	75	.206

	CG	.053	75	.200*	.990	75	.798

*. This is a lower bound of true significance. a. Lilliefors Significance Correction.

The results on the pre-test content knowledge scores of the experimental and comparison groups were, respectively, D(75)=.048, $p<0.05$ and D(75)=.200, $p>0.05$ by the Kolmogorov-Smirnov test , data on learners' content knowledge achievement scores of the experimental group was non-normal while the comparison group was normal. However, by the Central Limit Theorem, the non-normality sampling distribution can become normality as the sample size was large.

Table 4.41: Independent-samples t-test for Pre-test COK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
COK	EG	75	28.105	7.825	1.782	.184	148	-.567	.572	.0021
	CG	75	28.787	6.869						

*p<0.01

By Levene's test, the results on learners' pre-test content knowledge achievement scores of experimental and comparison groups data were observed as *F(1,148)=1.782, p=.182>.01* by Levene's test. Thus, the variances of the dependent variable for the two populations were equal.

The effect size of the mean difference between the pre-test content knowledge achievement score of learners in the experimental and comparison groups was calculated as *eta squared=.0021*. This value represented a very small-sized effect (Cohen et al., 2007; Pallant, 2010). As Green et al. (2005) suggested, this effect size value indicated that there was no statistically significant mean difference between the pre-test content knowledge achievement score of learners in the experimental group (*M=28.105, SE=.903*) and the comparison group (*M=28.787, SE=.793*); *t(148)=-.567, p>.01,eta squared=.0021*, 99% CI [-3.81, 2.45], with a mean difference of 0.681.

The data were in favour of the null hypothesis H_{03}. Hence, this result can be interpreted as at the outset of the main research study those learners in treatment and comparison groups had almost the same content knowledge level.

Table 4.42 depicts the gender-wise descriptive statistics on learners pre-test content knowledge achievement scores.

Table 4.42: Descriptive Statistics for Learners Pre-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Content	EG	27	26.222	7.2576
	Knowledge	CG	30	27.500	6.9145
Male		EG	48	29.165	8.0058
		CG	45	29.644	6.7795

As to gender, the mean score difference 1.278 between pre-test mean content knowledge achievement score of females sample of the comparison group (M=27.500, SD=6.9145) and the experimental group (M=26.222, SD=7.2576) shown in Table 4.42 was small. The mean score difference 0.479 between pre-test mean content knowledge achievement score of males sample of the comparison group (M=29.644, SD=6.7795) and the experimental group (M=29.165, SD=8.0058) was also very small. Due to this observation, students in both the experimental and comparison groups had the same content knowledge level in the pre-intervention in gender-wise. The similarity of the two experimental groups of learners in content knowledge (COK) in calculus in the pre-test had played an important role in the non-equivalent pre-test and post-test comparison group quasi-experimental design used.

Bar graph representations with error bars of mean scores on pre-test content knowledge achievement scores for experimental (EG) and comparison (CG) groups sample based on gender are shown in Figure 4.35.

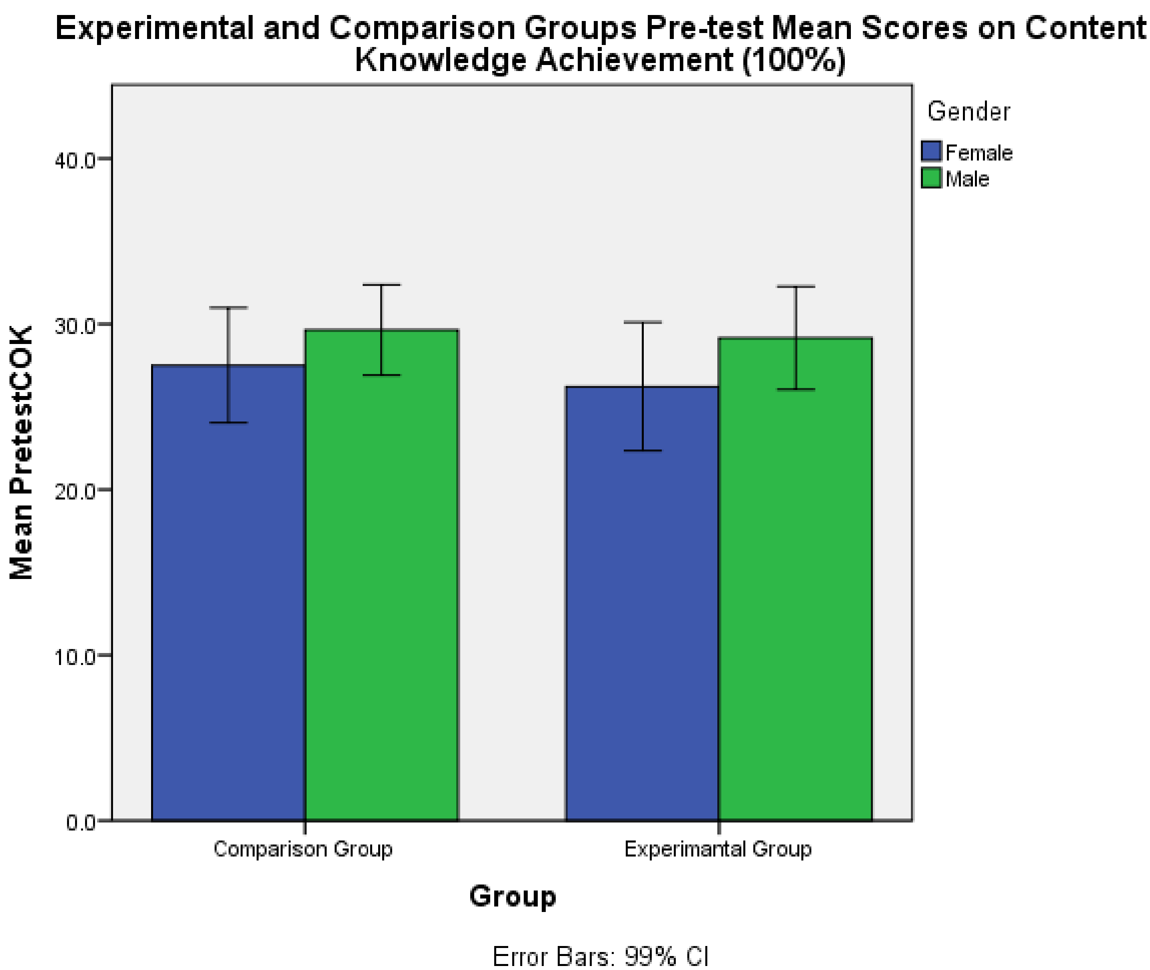


Figure 4.35: Bar graphs for Pre-test COK Achievement Scores Based on Gender

From Figure 4.35, the mean scores on pre-test content knowledge scores of female samples in both groups were nearly equal. Similarly, males in both groups had also nearly the same mean scores on this same variable. Therefore, in aggregate samples (males and females) mean score on pre-test content knowledge achievement scores of both experimental and comparison group was nearly equal. Therefore, gender was not taken as a covariate.

Polygonal representations with error bars of mean scores on pre-test content knowledge scores, for both experimental (EG) and comparison (CG) Groups are displayed in Figure 4.36.

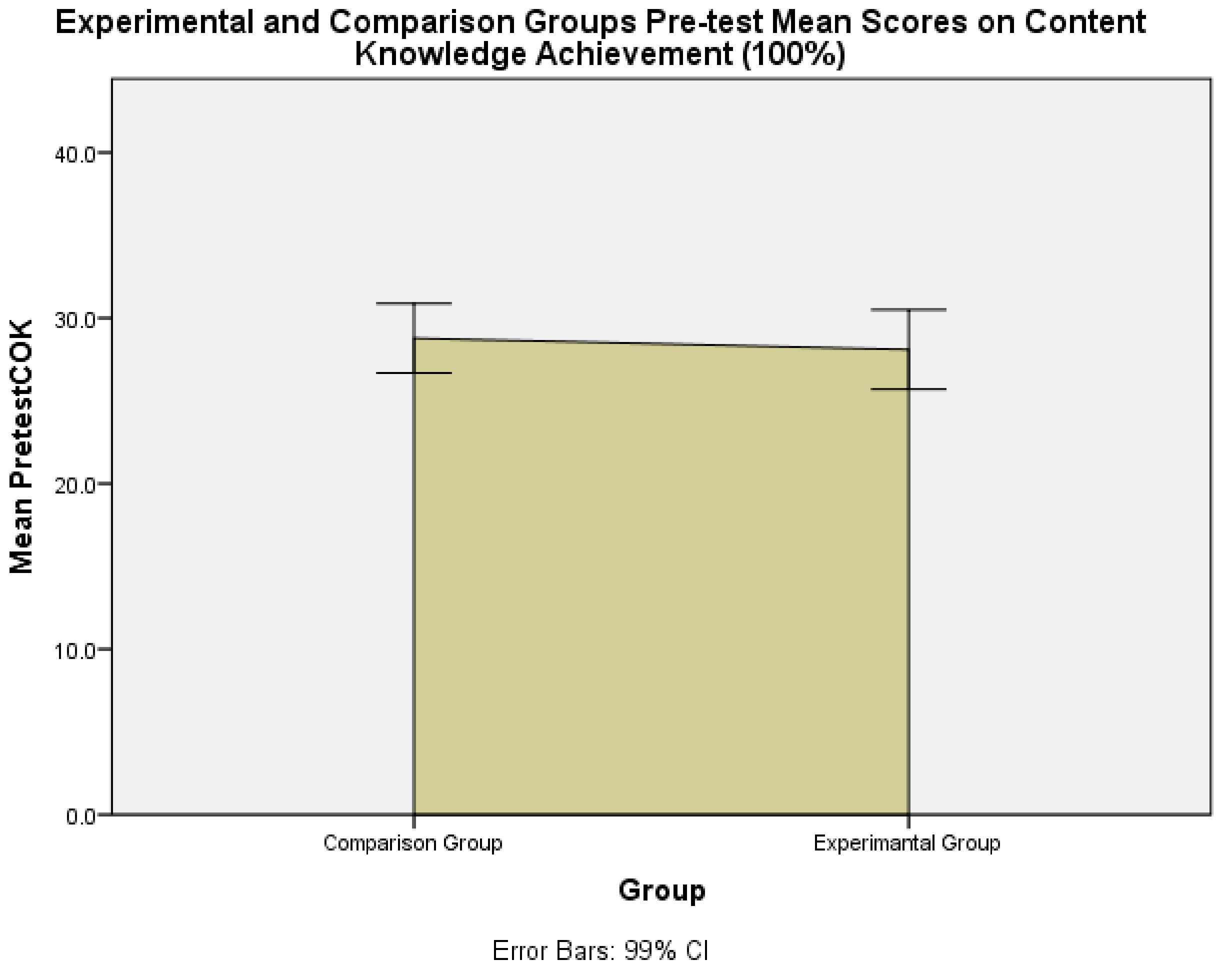


Figure 4.36: Frequency Polygons for Pre-test COK Achievement Scores

From Figure 4.36, learners' mean score differences in pre-test content knowledge achievement scores between the two groups were approximately equal.

Histograms for post-test content knowledge achievement scores are depicted as follows.

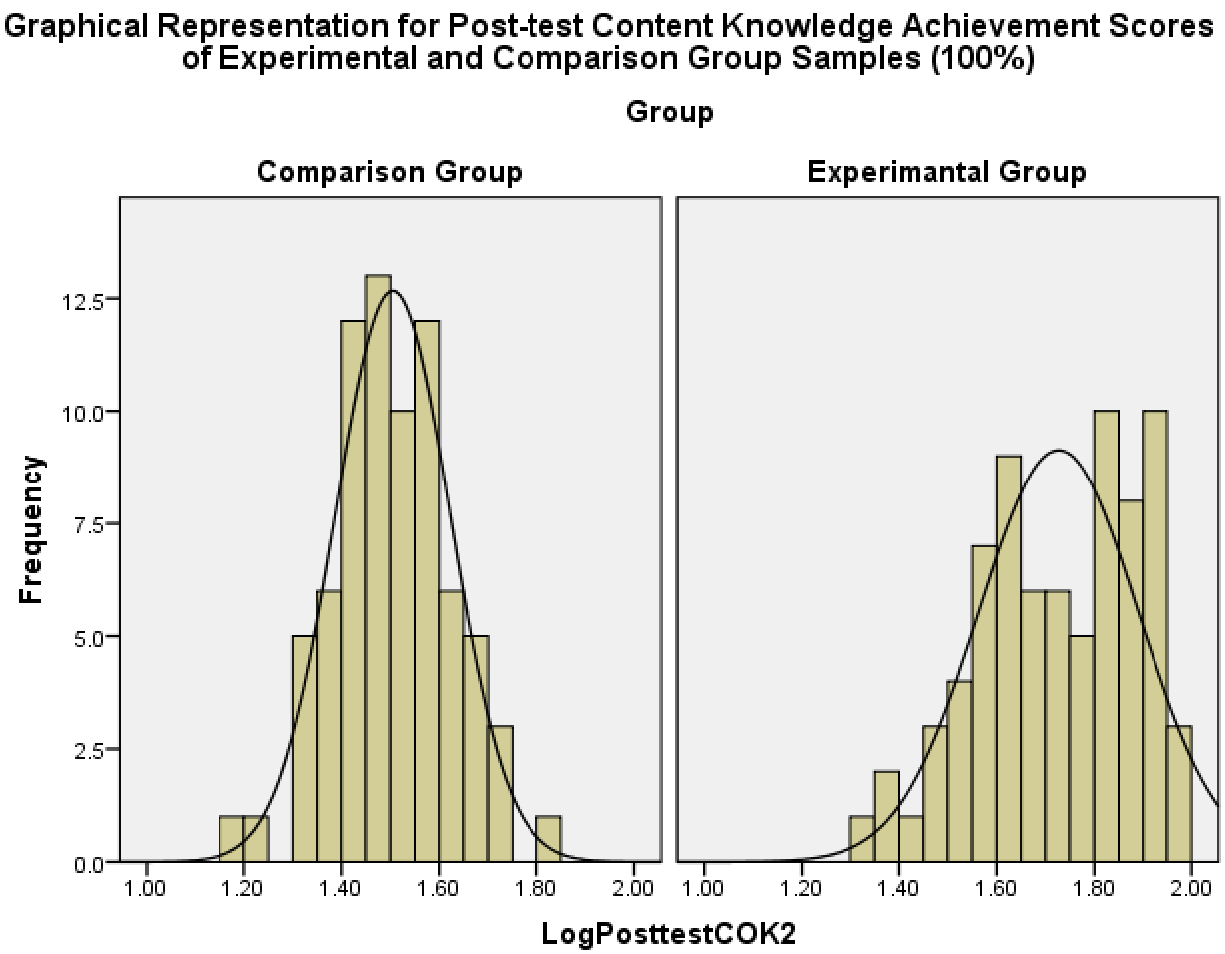


Figure 4.37: Histogram with Normal curve for Post-test COK Achievement Scores

The shapes of both graphs in Figure 4.37 indicate that both distributions of scores were reasonably normal. The skewness (-.360) and kurtosis values (-.801) for the distribution of the experimental group, and skewness (.019) and kurtosis values (.361) for the distribution of the comparison group shown in Table 4.43 were also in support of the normality of both distributions as these values were relatively close to zero (Field, 2009).

Table 4.43: Descriptive Statistics for Post-test COK Achievement Scores

	Post-test	
Statistics	Comparison Group	Experimental Group

Valid	75	75
Missing	0	0
Mean	33.166	56.977
Std. Error of Mean	1.066	2.315
Median	31.00	54.00
Variance	.014	.027
Mode	36.00	43.00[a]
Std. Deviation	9.238	20.048
Skewness	.019	-.360
Kurtosis	.361	-.801
Range	49.50	75.50

Multiple modes exist. The smallest value is shown.

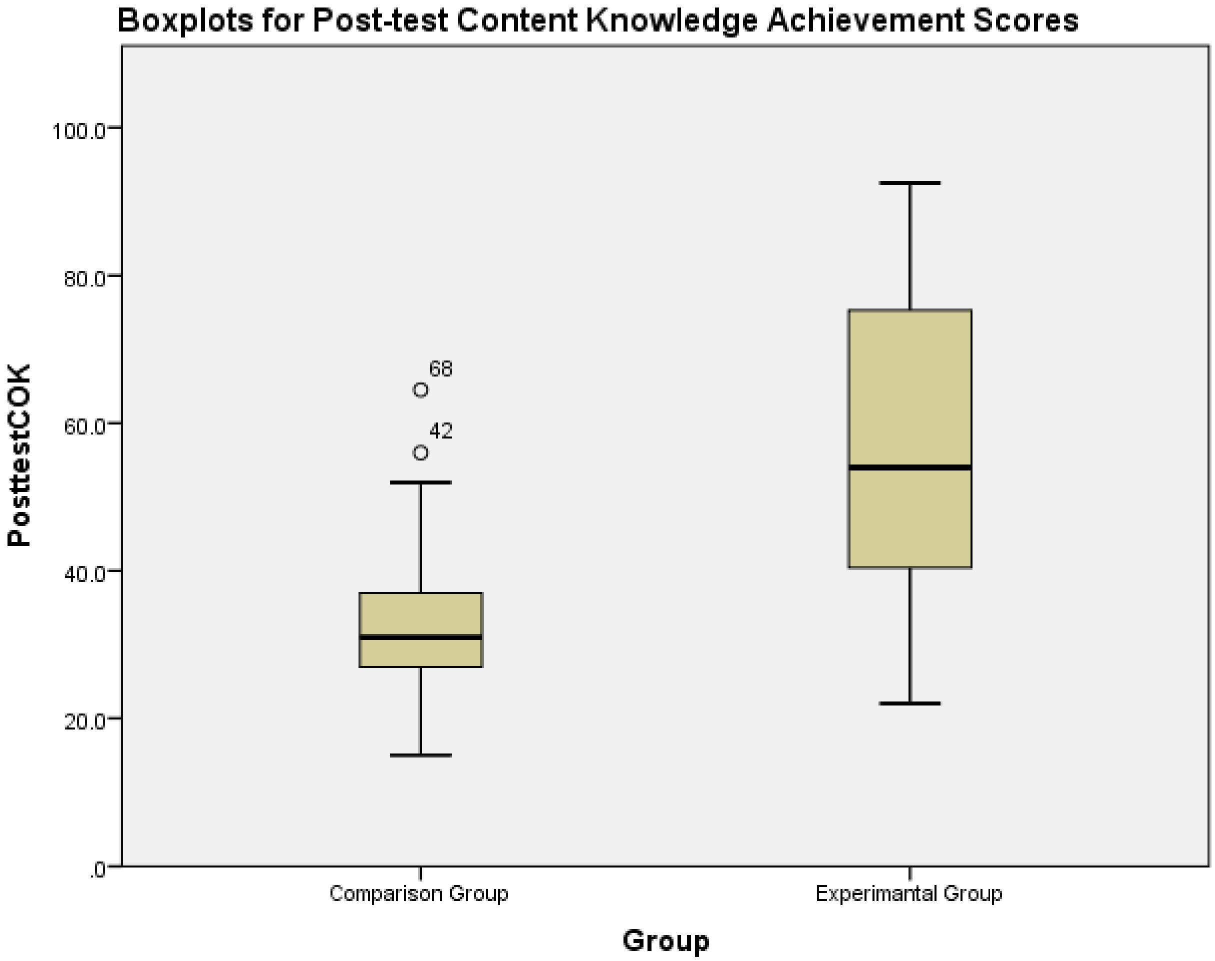


Figure 4.38: Boxplots for Distributions of Post-test COK Achievement Scores

The results in Figure 4.38 revealed that the experimental group samples distribution scores were quite different from the comparison group. This means that a lot of cases/units in the experimental group scored higher values, while lower values were scored by a lot of units in the comparison group. The boxplot that corresponds to the comparison group had come up with two outlier scores which were not affecting the analysis of the data. The experimental group distribution scores had no outlier scores.

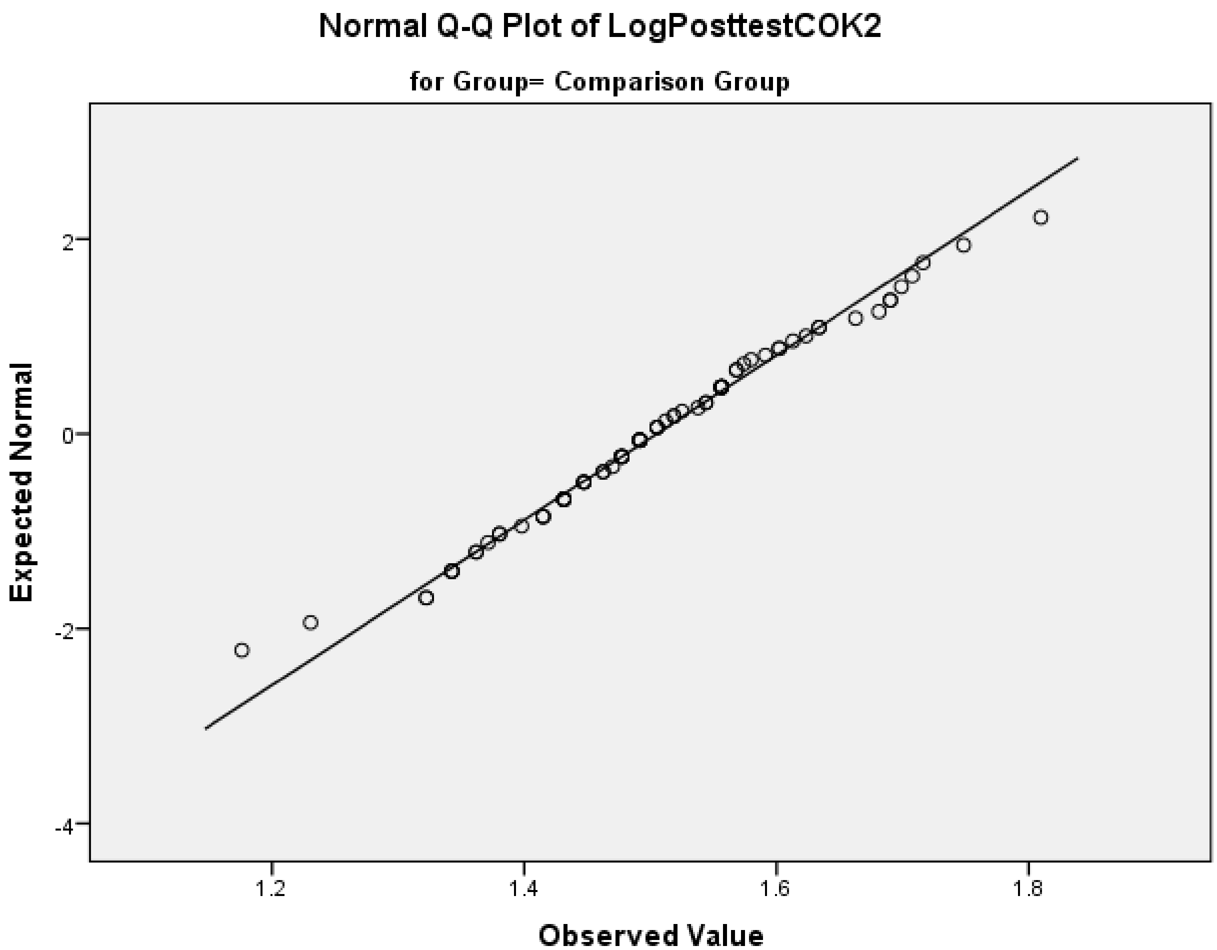


Figure 4.39: Q-Q plot for Post-test COK Achievement Scores of CG

Almost all data points shown in Figure 4.39 lay on a straight line except a few. By the Central Limit Theorem when the sample size was large the distribution had reasonably normality (Field, 2009).

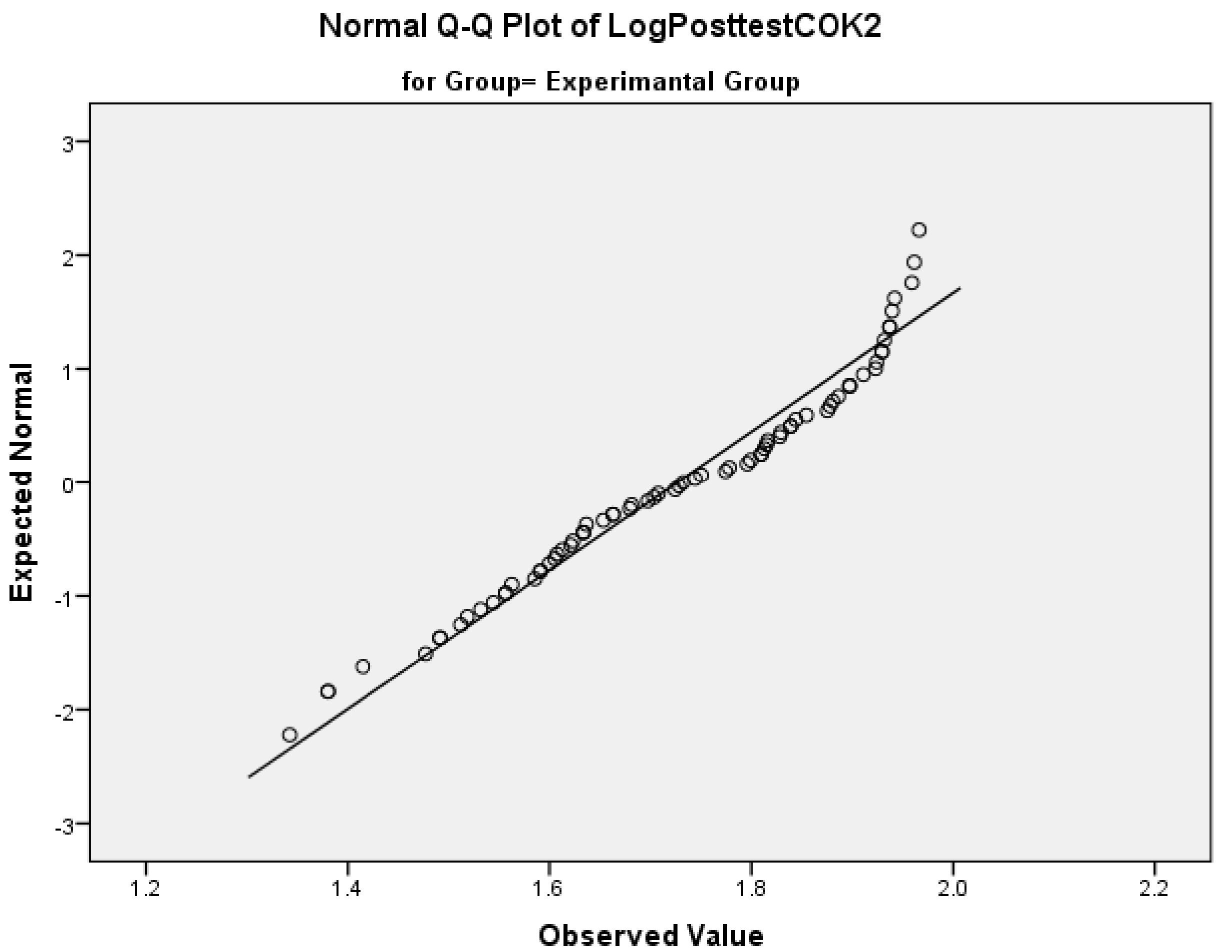


Figure 4.40: Q-Q plot for Post-test COK Achievement Scores of EG

Almost all data points shown in Figure 4.40 lay on a straight line except a few. By the Central Limit Theorem when the sample size was large the distribution had reasonably normality (Field, 2009).

Log transformation has been made on post-test content knowledge (COK) achievement scores data.

Table 4.44: Kolmogorov-Smirnov Normality Test for Post-test COK Scores

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Variable	Groups	Statistic	df	Sig.	Statistic	df	Sig.

COK	EG	.107	75	.035	.952	75	.007
	CG	.065	75	.200*	.991	75	.874

*. This is a lower bound of true significance. a. Lilliefors Significance Correction.

By the Kolmogorov-Smirnov test, the results on post-test content knowledge scores of the treatment and comparison groups were respectively observed as D(75)=.035, $p<0.05$ and D(75)=.200, $p>0.05$. The dependent variable for comparison group was normal while for experimental group was not normal. However, overall by the Central Limit Theorem when the sample size is large, the non-normality sampling distributions observed in each case can get close to normal (Field, 2009).

In quite analogous to the pre-test data, homogeneity of variances for post-test data was examined based on Table 4.45 as follows.

Table 4.45: Independent-samples t-test for Post-test COK Scores

					Levene's Test					
Variable	Groups	n	M	SD	F	Sig.	df	t	p	Eta squared
COK	EG	75	56.977	20.048	14.471	.000	148	9.516	.000*	.38
	CG	75	33.167	9.238						

*P<.01

By the Levene's test statistics, the results on post-test content knowledge achievement scores of experimental and comparison groups data were observed as $F(1,148)=14.471, p=.000<.01$. The equality of variances for the dependent variable of both populations was attained. According to (Field, 2009), when the variances for the response variable of both populations are not equal, it should be interpreted based on the variance ratio (Hartley's F_{max}) and the sample size. The reason is that large samples can be taken as a guarantee for Levene's test to be significant for small variation in group variances (Field, 2009). The variance ratio value needs to be less than the critical values accessible in a table published by Hartley (Field, 2009). Based on the log transformation made on post-test content knowledge achievement scores data, the variance ratio for the post-test content knowledge achievement scores was 1.92. This variance ratio value was reasonably less than the critical value for the associated sample size (75) per group. This implies that the variance was reasonably equal.

The effect size of the mean difference between the experimental and comparison groups on the post-test content knowledge achievement scores was computed as *eta squared=.38*. This value represents a strong effect Green et al. (2005) implying that there was a statistical significance mean different between experimental (*M=56.977, SE=.018*) and comparison groups (*M=33.167, SE=.013*); *t(148)=9.516, p<.01, eta squared=.38*, 99% CI [.161, .282], with a mean difference of 23.810. The data were in favour of the alternative hypothesis H_{13}. Therefore, this result can be interpreted as learners in the experimental group nurtured with the JCLGS benefited to a large extent developing their content knowledge of intermediate calculus. In summary, learners were focused on conceptual knowledge of calculus with the JCLGS. Consequently, this in turn substantially contributed to their content knowledge development.

Table 4.46 depicts the gender-wise descriptive statistics for learners post-test content knowledge achievement scores.

Table 4.46: Descriptive Statistics for Learners Post-test Scores Based on Gender

Gender	Variable	Group	n	M	SD
Female	Content	EG	27	48.985	17.9677
	Knowledge	CG	30	30.467	6.9925
Male		EG	48	61.473	19.9235

	CG	45	34.967	10.1502

From Table 4.46, the mean score difference, 18.518, between the posttest mean content knowledge achievement score of females sample of the experimental group, (M=48.985, SD=17.9677) and comparison group, (M=30.467, SD=6.9925), was very big. Similarly, the mean score difference, 26.506, between the post-test mean content knowledge achievement score of males sample of the experimental group, (M=61.473, SD=19.9235) and comparison group, (M=34.967, SD=10.1502), was also big.

Bar graph representations with error bars for mean scores on post-test content knowledge achievement scores for experimental (EG) and comparison (CG) groups sample based on gender are shown in Figure 4.41.

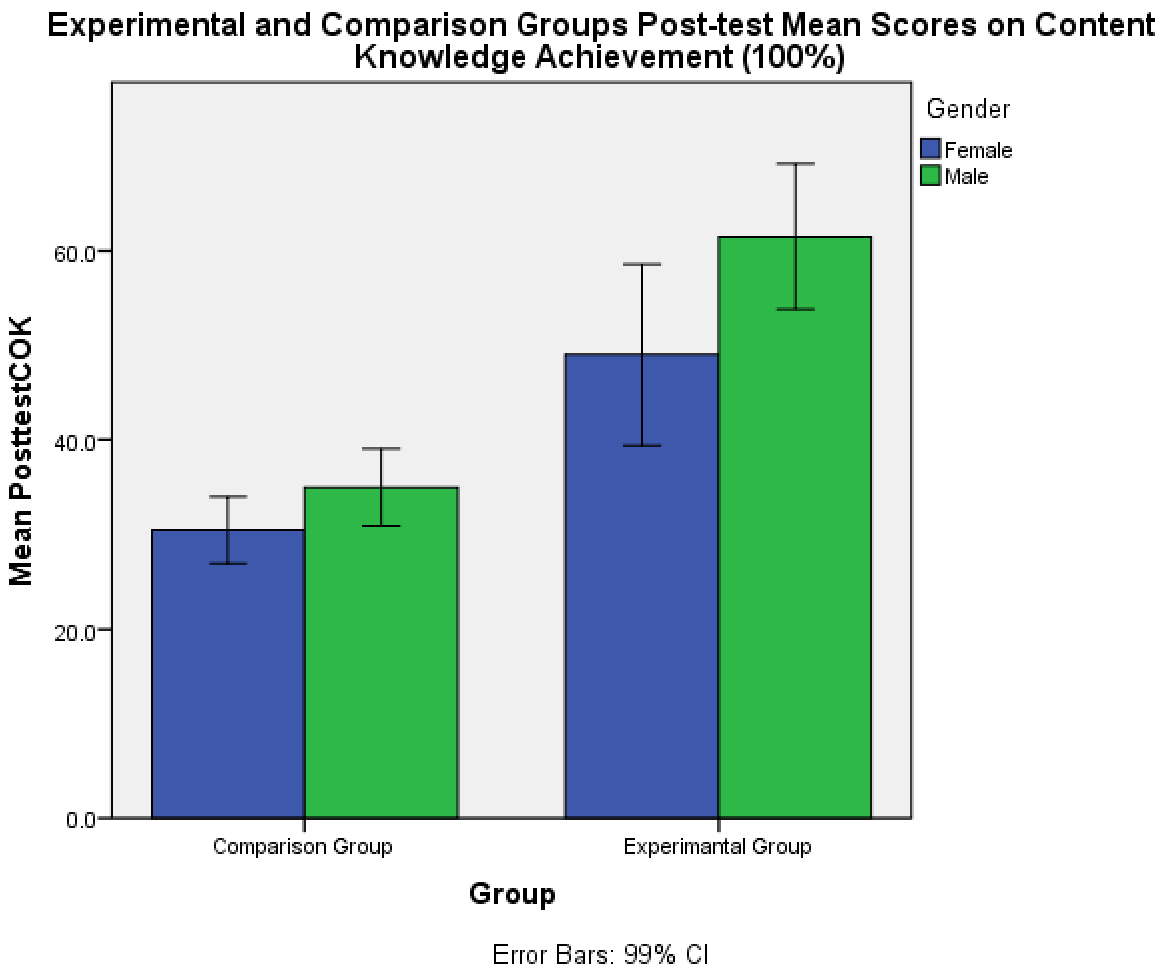


Figure 4.41: Bar graphs for Post-test CK Achievement Scores based on Gender

As can be seen in Figure 4.41, the mean score of female samples in the experimental group on post-test content knowledge achievement scores were by far higher than the mean score of the comparison group. Experimental group males sample mean score on post-test content knowledge achievement scores were also larger by far than the male mean score of the comparison group. In sum, the experimental group total sample (males and female) had got a mean score which is by far higher than the mean score of the comparison group.

Polygonal representations with error bars for mean scores on post-test content knowledge achievement scores for experimental (EG) and comparison (CG) Groups are depicted in Figure 4.42.

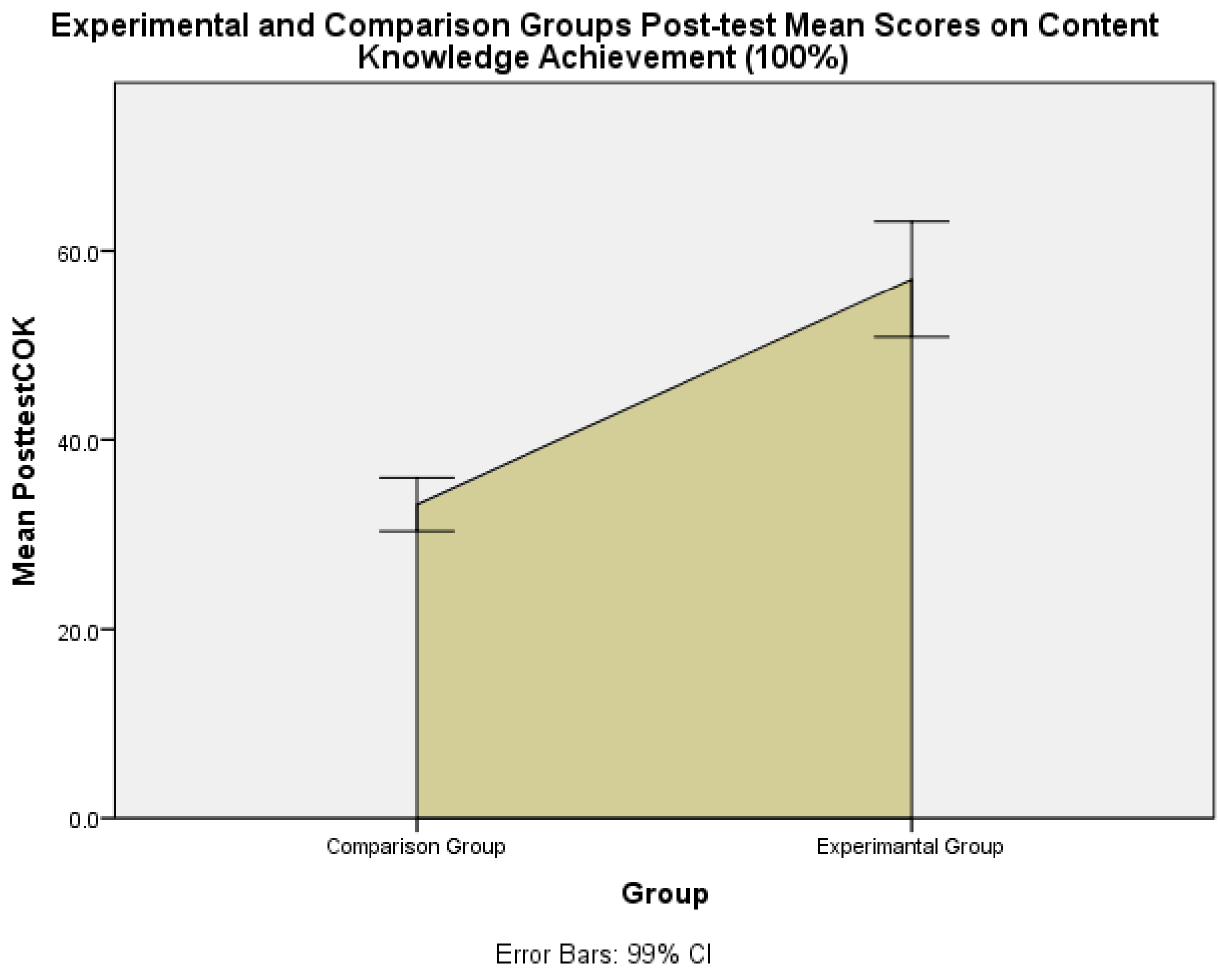


Figure 4.42: Frequency Polygons for Post-test COK Achievement Scores

The experimental group sample mean score on post-test content knowledge achievement scores was by far higher than the mean score of the comparison group.

As the collected data for treatment and comparison groups had met the underlying assumptions, the null hypothesis $H_{03}$was analyzed using Two-Way ANOVA for repeated measures.

The appropriate descriptive statistics of pre-test and post-test content knowledge achievement scores of learners in both experimental and comparison groups are shown in Table 4.47.

Table 4.47: Descriptive Statistics for Pre-test and Post-test COK Scores

		Pre-test		Post-test	
Group	n	M	SD	M	SD
EG	75	28.105	7.825	56.977	20.048
CG	75	28.786	6.869	33.166	9.238

The graph shown in Figure 4.43 could also give us some insight how much the mean incremental difference was statistically significant difference between learners in the experimental and comparison groups from pre-test to post-test on content knowledge achievement scores of calculus.

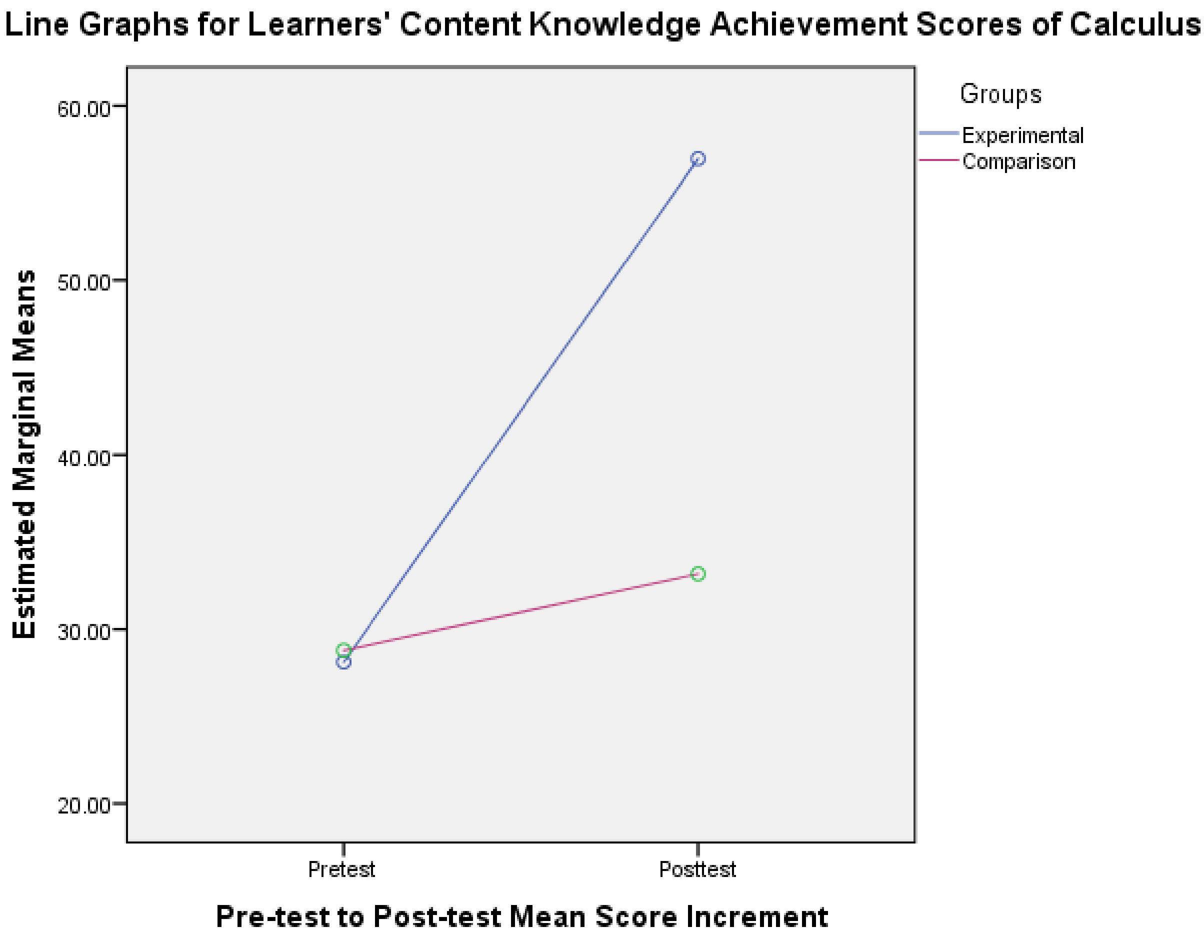


Figure 4.43: COK Development of Calculus for EG and CG

Figure 4.43 revealed that the mean score on pre-test content knowledge achievement scores of learners in the experimental group who learned calculus with the JCLGS was M=28.105. The mean on post-test was M=56.977. The mean score increment was 28.873. The mean score on pre-test for comparison group learners taught with the conventional lecture method was M=28.876. The mean on post-test was M=33.166. The mean score increment was 4.29. The increment for the experimental group was big compared to the comparison group after the intervention. Whether this mean incremental difference was significant or not could be statistically justified using the Two-Way ANOVA for repeated measures analysis. The results of Two-Way ANOVA for repeated measures analysis are shown in Table 4.48.

Table 4.48: ANOVA Results for Pre-test and Post-test COK Scores of the EG and CG

Source of Variance	Sum of Squares	df	Mean Score	F	η^2	p
			Between Groups			
Group	20731.791	1	20731.791	130.500	.469	.000*
Error	23511.830	148	158.864			
			Within Groups			
Pre-Post Test Measures	10030.614	1	10030.614	72.163	.328	.000*
Pre-Post Test*Group	11247.339	1	11247.339	80.917	.353	.000*
Error	20571.793	148	138.999			

*p<.01

The results in Table 4.48 showed that the mean incremental difference in learners' content knowledge development of calculus in the treatment and comparison groups was statistically significant after the intervention. The effect of pre-test and post-test conducted on learners of both experimental and comparison groups in their content knowledge development of calculus was statistically significant [$F(1,148)=80.917; \eta^2 = .353; p<.01$]. Cohen et al. (2007) and Pallant (2010), the effect size value $\eta^2 = .353$ represents a very large effect. Therefore, learners in the experimental group generated a large amount of calculus content by exposure to the JCLGS grounded in socio-cultural context learning theory compared to the comparison group.

4.5 Summary of Findings

In the pre-intervention data analysis results on learners' attitudes questionnaire, most research participants had a negative attitude towards the learning of calculus/mathematics. In this same session, most learners' achievement scores were below average on calculus diagnostic test. This shows that how learners' negative attitude on the learning of calculus had related to their poor performance of calculus and vice-versa. In the post-intervention, the data analysis findings on learners' attitude questionnaire showed that most experimental group learners had a positive attitude towards the learning of calculus. These learners had scored higher marks (above average) on their knowledge of procedures in calculus, especially on conceptual knowledge and content knowledge as compared to the comparison group learners. This implies that how learners' positive attitude toward the learning of calculus had an impact on their achievement and vice-versa. According to Peteros et al. (2019), learners' attitude affects their achievement scores of mathematics and vice-versa. Therefore, during the intervention the JCLGS positively changed learners' attitude towards calculus and also enhanced their performance.

CHAPTER FIVE

DISCUSSIONS, SUMMARY, CONCLUSIONS and RECOMMENDATIONS

5.1 Discussion

This chapter is devoted to the discussion of each research finding as per the research question and each hypothesis, associating the findings of this study to some of the findings from the reviewed literatures, summary of the research work, implications of the findings, presenting a comprehensive conclusion to the researcher's thoughts on the problem and significance of the research findings, and making recommendations based on research findings and suggesting for future related studies to be conducted to contribute additional solutions to the same problem in the current research project (Nenty, 2009). The theory(s) that underlie the problem of this research project and the researcher's experience supported with empirical evidence are also discussed.

In chapter one reasons for the need to study this research were mentioned. One of the research problems was that first year undergraduate mathematics and science learners had been challenged by conceptual knowledge of calculus to a great extent through the conventional method of instruction. In connection to this idea, Gambari and Yusuf (2016) reported that learners' poor performance on science is due to teachers' use of poor instructional strategies and teacher-centered method in teaching the abstract concepts of science. The content knowledge attained by them had been tremendously decreasing. Mathematics and science learners had not positively perceived the learning of calculus through the lecture method. Generally, they had not looked at the learning of mathematics courses offered in universities as normal as other courses. To alleviate this problem, students' attitudes toward calculus, the lecture method, the JCLGS, knowledge of concepts, procedures and content were thought by the researcher as components of the theoretical framework of the study. The research problem was setup in terms of one research question involving learners' attitudes toward calculus as dependent variable and three distinct hypotheses.

In respect of the research question, in the pre-intervention findings most experimental group learners' attitude towards the calculus learning was not positive in their opinion and feeling responses to the questionnaire. In this same session, all students except one student in both experimental groups had scored below average mark in the conceptual knowledge, procedural knowledge and content knowledge in calculus diagnostic test. These findings implied that learners' negative attitude toward calculus is related to their poor performance of calculus and vice-versa. This agree with the findings in (Atanasova-Pachemska et al., 2015; Awang & Hamid, 2015; Awang, Ilias, Che Hussain, & Mokhtar, 2013; Eyyam & Yaratan, 2014). Atanasova-Pachemska et al., (2015) stated that the less positive attitude learners towards the learning of calculus/mathematics have the less likely they achieve better and vice-versa. In the post intervention findings, most experimental group learners had positively changed their opinion towards calculus. The use of the JCLGS for calculus learning was enjoyable and interesting for learners. They perceived learning calculus through the JCLGS as normal as other courses. In this same session, most experimental group learners scored higher marks in conceptual knowledge, procedural knowledge and content knowledge in calculus classroom achievement test. These findings showed that the more positive attitude learners towards the learning of calculus have the more likely they perform better and vice-versa. The reason for experimental group learners' changed positively in attitude and better performance in calculus was most likely the influence of the JCLGS using socio-cultural context learning theory on their calculus learning during the intervention. The other reason was the quality of the research instruments used to collect data. Mazana, Suero Montero, and Olifage (2019) and Gambari and Yusuf (2016) pointed-out that the instructional strategies that teachers use in classroom instruction and opinion of students to mathematics learning influence their retention and performance. Awang and Hamid (2015) used similar learners' attitudes questionnaire toward calculus. They found out that some of the research participants had changed their attitude towards calculus. However, the findings of the current study on this similar instrument were remarkable. This shows that the quality of the adapted questionnaire used in this study was high.

As to the null hypotheses H_{01}, H_{02} and H_{03}, the pre-intervention findings showed that learners in both experimental groups had similar poor knowledge of concepts, procedures and content of calculus. Specifically regarding to the null hypothesis H_{01}, the post intervention findings revealed that the experimental group were highly successful in improving their knowledge of concepts in calculus as compared to the comparison group. This was due to learners appropriately used the JCLGS with Vygotsky's theory in their calculus learning. Although the conventional method also affected comparison group in enhancing their conceptual knowledge development from pre-test to post-test over a semester as well, this was not comparable to that of the extent the JCLGS influenced experimental group. This was because during the intervention the experimental group learners were allowed to actively participate in their mathematics laboratory/tutorial class to work with the learning activities prepared by the researcher using the JCLGS. Through this learning environment, they had learned concepts of intermediate calculus independently, collaboratively and interactively in their respective jigsaw groups. Every group consisted of four or five students in which one of the members in each group was a relatively better scorer (more knowledgeable student) selected based on his/her pre-test result. Vygotsky's social constructivist learning theory of mathematics was applied in their group learning during the intervention. In the process of the application of intervention, each instructor guided the individual learner or each group, on that bit of mathematical objects (symbol, notion, concept and etc.) they were unclear with. Also, GeoGebra as a tool helped learners to visualize those abstract mathematical entities like the limit concept. This was carried out representing each object of calculus in multiple ways such as symbolically, numerically, geometrically, algebraically/formula and graphically as appropriately as possible.

In the post-test, males within the treatment group; and across experimental and comparison groups had performed better towards conceptual knowledge compared to females within the experimental group; and across experimental and comparison groups. However, both male and female learners within the comparison group equally achieved in their conceptual knowledge of calculus in the pre-test and post-test. As data collectors/instructors and researcher assessed, the disparity in performance of males and females in the post-test was the following. Males were more proficient than females in manipulating GeoGebra during mathematics laboratory class in trying to be clear with the abstract calculus concepts. The other one might be due to that of the affirmative action (giving tutorial class) set by the Federal Democratic Republic of Ethiopia Ministry of Education (MOE) only the purpose of motivating female learners in public universities was not applied.

As compared to other research findings, for instance, Ocal (2017) that used only GeoGebra in learners application of derivative and Zakaria (2012) in learners learning of function, the effect of this intervention in the current study with effect size value $\eta^2 = .419$ on knowledge development of calculus concepts by students was very remarkable. In support of the finding of the current study Gambari and Yusuf (2016) found that computer assisted jigsaw II co-operative strategy benefitted physics students to better perform on abstract concepts. The intervention also allowed experimental group in developing positive opinion towards calculus and GeoGebra. The reason for this was the use of an innovative learning strategy that gave power for learners to be more conceptual in their learning of intermediate calculus. The obtained effect size value $\eta^2 = .419$ can be taken as one justifying parameter that measured the strength of the impact of the

JCLGS on knowledge development of calculus concepts by students. The JCLGS was a kind of innovative learning strategy integrated activities of learning in calculus prepared by the researcher, the jigsaw learning strategy and GeoGebra used in mathematics laboratory class and the lecture method in the mainstream class.

With regard to the null hypothesis H_{02}, in the post-intervention the experimental group had improved their procedural knowledge to a modest extent, as the result of the JCLGS influenced their learning of calculus. The lecture method also affected the comparison group in enhancing their knowledge of procedures. But, the amount that the JCLGS influenced experimental group was larger than the lecture method influenced comparison group. However, the effect size value $\eta^2 = .047$ on procedural knowledge in this study was bigger than, for instance, the finding in Ocal (2017) or smaller than Zakaria (2012). In the findings of most reviewed related literature and this study, the effect of the traditional lecture method in learners' procedural knowledge development of calculus is quite similar. In the post-test, males within the experimental group; and across the experimental and comparison groups out-performed towards procedural knowledge compared to females within the experimental group; and across the experimental and comparison groups. Males and females within the comparison group had uniformly performed on procedural knowledge development of calculus in the pre-test and post-test. Because of this, it was challenging to give a clear-cut statement on what the finding of the current study on procedural knowledge of calculus contributed to research. Learners could have developed more experience in using the traditional teaching to their procedural knowledge development in school mathematics.

As to the null hypothesis H_{03}, as with conceptual knowledge development of calculus by students, the experimental group highly developed their content knowledge of calculus as the result of the influence of the JCLGS with Vygotsky's learning theory. The lecture method also affected the comparison group in improving content knowledge through pre-test to the post-test period over a semester. But, this effect was incomparable to that of the extent the JCLGS influenced experimental group learners. The reason used to justify the findings of this study on conceptual knowledge development of calculus can also hold for the findings on content knowledge development of calculus. In the post-test males out-performed on content knowledge compared to females within the experimental group; and across the experimental and comparison groups. Males and females within the comparison group achieved approximately equal in both the pre-test and post-test. In this same study, the effect of the intervention on content knowledge of calculus comes next to the effect on conceptual knowledge and before procedural knowledge. The overall post-test findings showed the better learners achieve especially in their conceptual knowledge and content knowledge the most likely positive attitude they have towards the calculus and vice-versa, through the JCLGS with socio-cultural context learning theory. In sum, the theoretical components and data collection instruments substantially benefited the experimental group. The difference shown in the finding of this study on students' knowledge development of procedures in calculus as compared to other related studies was not meaningful. Due to this inconsistency, on the finding of procedural knowledge the researcher had a reservation to decide what contributed to knowledge.

5.2 Summary

These days we live in a world that is ever advancing in digital technology. Generally very few, if any, university learners in the context of Ethiopia were exposed to the innovative learning strategy model combined with appropriate software packages in the learning of mathematics. Gambari & Yusuf (2016) was in support of this argument that teachers have often employed poor instructional strategies and teacher-centered methods in teaching the abstract concepts of science like physics. Even most instructors do not have such awareness about the features and importance of learning strategy blended with instructional technology. In the Ethiopian public universities context, such learning/teaching model has not yet been implemented. Even other countries of the world, for instance, Turkey, have not seriously used it in the classroom instruction. In connection to this idea, in the case study by (Othman et al., 2017) from Turkey suggested that innovative learning strategy that able to enhance students' interest and positive attitude need to replace the conventional teacher-centered method in classroom instruction. However, learners have been learning all about calculus using the conventional lecture method. Because of this, they viewed challenging the learning of calculus and also derive a negative opinion towards calculus. They have not looked at calculus learning as normal as other courses. Learners even perceived life condition of mathematics educators as not normal as another person. Generally, learners dislike the learning of mathematics courses offered in universities. Generally, learners experienced a phobic character in learning any mathematics course. As to researcher teaching experience and observation, learners have not meaningfully achieved in calculus learning using the lecture method. Most mathematics education research literatures conducted on the teaching/learning of calculus were in support of the idea that learners were not successful in learning calculus, generally other mathematics courses through lecture method. In contrast, the importance of the learning strategy that combines the jigsaw learning strategy and GeoGebra as a tool (JCLGS) in learners' learning of calculus has not yet reported in mathematics education research literatures.

At the outset of the intervention, the two research instruments were pilot-tested to verify their validity and reliability. During the intervention, the experimental group was taught using the lecture method in the normal class and in parallel nurtured with the JCLGS in the mathematics laboratory class. The comparison group was taught only through the conventional lecture method in the mainstream and mathematics laboratory class. The end of the intervention, the post-test was conducted. The data collected on the achievement test and the five points Likert-scale questionnaire were analyzed by using descriptive statistics, an independent-samples t-test and Two-Way ANOVA for repeated measures using SPSS 23. The data analysis results were interpreted.

The following points could attribute to the new knowledge that this study adds to research: The researcher prepared his learning activities on basics of intermediate calculus by Ethiopian Harmonized Modular Curriculum for B.Sc Degree Program in Mathematics (2013) for public universities. These learning activities were designed in such a way that involved more conceptual knowledge of calculus. Learners used the JCLGS to work with the learning activities in their jigsaw group in the laboratory of mathematics. The findings of this study on the use of the JCLGS showed that learners had developed more conceptual knowledge (CK) than procedural knowledge (PK) in calculus. It is evident that the JCLGS for which the researcher designed and the data collectors/instructors implemented was one of the decisive factors that allowed learners to give appropriate meaning, interest and positive attitude to what they learned in classroom instruction. The findings of the study are stated as follows:

- ✓ The JCLGS influenced students' knowledge development of concepts (CK) on calculus compared to those taught with a conventional lecture method, to a large extent. This was because the mean post-test conceptual knowledge achievement score of the experimental group and the comparison group was statistically significant difference. Moreover, the mean incremental difference from pre-test to post-test on conceptual knowledge of calculus between the experimental and comparison groups was statistically significant. The strength of this difference was determined by the magnitude of effect size value $\eta^2 = .419$. This value represented a very strong effect (Pallant, 2010).

- ✓ The JCLGS had a modest influence on the treatment group procedural knowledge (PK) development of intermediate calculus compared to those taught with the conventional lecture method. The effect size value $\eta^2 = .047$ that measured group difference represented a small effect (Pallant, 2010).
- ✓ The JCLGS benefited treatment group content knowledge (COK) development of calculus to a large extent compared to those in the comparison group taught with the lecture method. The effect size value $\eta^2 = .353$ represented a very strong effect (Cohen et al., 2007; Pallant, 2010).
- ✓ The JCLGS also influenced the experimental group improving their opinion positively towards calculus and GeoGebra, apart from their subject matter knowledge development.

5.3 Implications

The findings of this study may benefit stakeholders engaged in the mathematics and science education sphere of life in a way that:

- ✓ It extends undergraduate mathematics and science learners, Ethiopian mathematics and science educators and generally the scientific research community awareness towards conceptual knowledge (CK), procedural knowledge (PK) and content knowledge (COK) in intermediate calculus. This means scholars know that undergraduate mathematics and science learners' mission in the study or after completion is to read, examine, investigate, discover and explore things. If they have the exposure to this thesis, it will help them, at least, to be familiarized with the meaning of the terms such as conceptual knowledge (CK), procedural knowledge (PK) and content knowledge (COK). If they will also study further education (MA, PhD), they may contribute something new knowledge by conducting some sort of research on any one or all of them.

- ✓ Curriculum developers in the Federal Democratic Republic of Ethiopia Ministry of Education (MOE), science and mathematics education policymakers, universities and colleges instructors and school science, and mathematics teachers may utilize it while designing, implementing, and delivering mathematics syllabus/lessons. All these stakeholders are the ones who engage in education activities. One of their major duties is to look for a suitable teaching/learning model that enhances learners' learning of any kind of mathematics and science lesson. Therefore, the findings of this study informs them the direction on how to devise appropriate active learning strategy integrated with technology that enables learners better perform on conceptual knowledge (CK) and content knowledge (COK) in the lesson they are interested in.
- ✓ It may influence the scientific research community to look for solutions to related studies using a new learning model/approach.

5.4 Conclusion

The intent to minimize the learning challenge of knowledge of concepts (CK), procedures (PK) and content (COK) in calculus of freshman undergraduate mathematics and science learners of two public universities in Ethiopia, intervention study was designed. It was also needed in this same design to observe their attitudinal change towards intermediate calculus in learning it using the intervention. The intervention used was JCLGS. It applied to those learners in the treatment group. In contrast, learners in the comparison group were taught using the conventional method. As the result of the careful designing and implementation of the intervention by the researcher and data collectors/instructors and sharing of responsibility by research participants for their learning, it was found that the JCLGS substantially influenced more learners' conceptual knowledge (CK) and content knowledge (COK). Learners understanding and interest towards calculus also increased. The impact of the JCLGS on procedural knowledge (PK) development was a modest one as compared to conceptual knowledge (CK) and content knowledge (COK) development in this study.

However, compared to other related studies, the effect size values on conceptual knowledge (CK) and content knowledge (COK) of this study were too big. The effect size value on procedural knowledge (PK) was not that much different from other related studies. Keep in mind that learners' conceptual knowledge (CK) development had favored their content knowledge (COK) success. Learners' use of the JCLGS in this study had largely improved their conceptual knowledge (CK) and content knowledge (COK) development of various lessons of calculus. It had affected their interest and attitude positively towards intermediate calculus. The JCLGS had motivated them to visualize those abstract mathematical objects that might not be possible by conventional method which are mostly carried out using a black/whiteboard. These are by numerically, symbolically, geometrically, algebraically/formula and calculus means representations of various abstract calculus concepts. This is because as one of mathematics software packages GeoGebra has potential environments capable of representing abstract concepts in a variety of ways. Students were highly initiated to know all about other software packages used for teaching/learning mathematics. Thus, the significance of JCLGS on learners' conceptual knowledge (CK) and content knowledge (COK) development and their attitudinal change could be taken as the main finding.

5.5 Recommendations

The observed solutions to learners' learning the challenge of knowledge of concepts (CK), procedures (PK), and content (COK) and their attitude problem towards calculus were not viewed by the researcher as completely addressed. However, the researcher believes that as he did his best in devising and implementing the innovative technology assisted strategy. Experimental group learners had learned the learning activities of calculus by exhibiting high interest through the technology assisted learning strategy. In the course of this, the researcher had used his maximum energy to reduce any sort of flaws. Here, the researcher is not meant that the study was conducted without limitations. Rather, even one can take the research design itself was a limitation of the study. Keeping all these in mind, concerned bodies in the world who engaged in the mathematics education sphere of life and scientific research community could consider the outcomes as input for their career. The researcher would like to recommend the findings to be applied by them as appropriately as possible in their day to day activities by selecting suitable better active learning method, try integrating it with appropriate software package if there is and then apply it forming a group consisting of 4 or 5 learners. Specifically, university/college instructors and school teachers could take this intervention as a model and are advised to use it while presenting their lessons. Generally, the current study contributes to the scientific research community understanding and awareness how mathematics software package can be blended with active learning strategy for stimulating learners in their learning of mathematics.

5.6 Suggestion for Further Studies

As a mathematics educational research, it might be recalled this study employed post-positivist philosophical perspective, deductive approach, mixed methods approach in a non-equivalent pre-test and post-test comparison group quasi-experimental design, longitudinal research (pre- and post-intervention over a semester), two stages random sampling and achievement test and attitude questionnaire (instruments of data collection) and; descriptive analysis, independent-samples t-test, and Two-Way ANOVA for repeated measures (data analysis procedures). The subject area used was the basics of intermediate calculus and the study area were two public universities in the Ethiopia context. All these things were dealt with in the umbrella of the socio-cultural context learning theory with some limitations of the study mentioned. As to the researcher's stance, the findings of this study remarkably addressed learners' conceptual knowledge (CK)/concepts and content knowledge (COK) learning challenge of calculus and their attitude problem through the intervention. The procedural knowledge challenge was not appropriately addressed as anticipated. The methods used for a particular research study do have merits and demerits. Bearing this in mind, the researcher would like to suggest researchers to look for new/additional contribution to the solution of this problem approaching it differently. They would tackle this same research problem on calculus or other mathematics/science courses through say quantitative approach with very large sample size and/or qualitative approach like focus group discussion by considering the appropriate theory that helps guide their study.

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Appendix A: Calculus Classroom Achievement Test used in the Pilot, Pre and Post Study

General Direction

This classroom achievement test has been prepared aiming at collecting data for the research to be conducted for the PhD thesis from voluntarily participants. It was intended to ensure its validity and reliability, and diagnose learners' conceptual, procedural and content knowledge on the basics of intermediate calculus and thereby taking remedial action on their learning problem. It has got three parts namely true-false items (closed-ended), multiple-choice items (closed-ended) and work-out type (open-ended). The first part consists of twenty questions, the second part thirty questions and the third part five questions. Kindly answer each question in accordance with the specific instruction provided in each part. In doing this, the researcher would like to thank you in advance for genuinely and co-operatively answering the questions. In addition, you are kindly requested to specify your:

Sex: _______________

Age: _______________.

Part-I (True/False items)

Underline **"T"** if the statement is correct and **"F"** for the one which is incorrect.

1. Both functional and limiting values of any function f at any real number $x = a$ are always equal. **(T, F)**
2. If $\lim_{x\to a} f(x) = 5$, then both $\lim_{x\to a^-} f(x)$ and $\lim_{x\to a^+} f(x)$ exist, and $\lim_{x\to a^+} f(x) = 5$. **(T, F)**
3. Both functional and limiting values of a function $f(x) = \frac{1}{x}$ at $x = 0$ are equal. **(T, F)**
4. The limit of a function $f(x) = \frac{x^3 - 1}{|x-1|}$ at $x = 2$ exists. **(T, F)**

5. Both functional and limiting values of a polynomial function p at any real number $x = a$ are not always equal. **(T, F)**.

6. $\lim_{x \to 9} \frac{x-9}{\sqrt{x}-3} = 6$. **(T,F)**

7. Both functional and limiting values of any rational function at any real number $x = a$ are always equal. **(T, F)**

8. The maximum and minimum values of a function $f(x) = x$ on $(0,1)$ are, respectively, 1 and 0. **(T, F)**

9. A function f is continuous on $[a,b]$ only if it is continuous on (a,b). **(T, F)**

10. The absolute value function, $f(x) = |x|$, is continuous but not differentiable $x = 0$. **(T, F)**.

11. Absolute extreme values of a continuous function f on $[a,b]$ occur only at the end points. **(T, F)**

12. The Mean-value Theorem holds true for the function $f(x) = x^3 + 4x$ on the interval $[-2,1]$. **(T, F)**

13. A relative extreme of any function f occurs at each of its critical numbers. **(T, F)**

14. The critical numbers of the function $f(x) = \sqrt{4-x^2}$ are $x = -2,\ 0,\ 2$. **(T, F)**

15. A function f that is continuous on $[a,b]$ and differentiable on (a,b), is said to be increasing on $[a,b]$ if $f'(x) < 0 \, \forall x \in (a,b)$. **(T, F)**

16. $\lim_{x \to \infty} \sqrt[3]{\frac{2+3x-5x^2}{1+8x^2}} = \frac{\sqrt[3]{-5}}{2}$. **(T, F)**

17. The function $f(x) = x^2$ is an example of a monotonic function. **(T, F)**

18. The function $F(x) = \frac{1}{3}x^3 + 5$ is one of the antiderivatives of the function $f(x) = x^2$. **(T, F)**

19. Inflection point of the graph of a twice differentiable function f occurs only on those x values for which $f''(x) = 0$. **(T, F)**

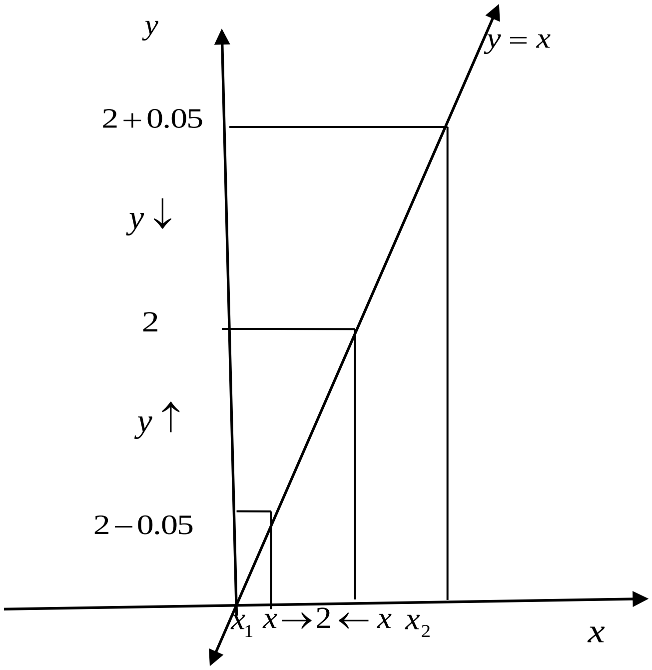
20. The point $(0,0)$ is an inflection point of the graph of $f(x) = x^4$. **(T, F)**

Part-II- (Multiple-choice Items)

Choose the one that best answers from the alternatives given and encircle the letter of your choice.

1. Which one of the following statements is true about the concept of limit of a function?
   A. The limit of a function at a point is always equal to the value of the function at that point.
   B. If the limit of a function at a point exists, then the function is defined at that point.
   C. If the limit of a function at a point exists, then it is unique.
   D. If the limit of a function exists at a point, then both right and left-hand limits of a function are not equal at that point.
   E. A function can have two different limits at a point.

2. Suppose you are given the figure shown below.



Based on the information given above, the values of x_1 and x_2 are, respectively,

A. $3.8025 \, and \, 4.2025$

B. $\sqrt{1.95} \, and \, \sqrt{2.05}$

C. $1.90125 \, and \, 2.10125$

D. $1.95 \, and \, 2.05$

E. $0.975 \, and \, 1.025$

3. Which one of the following statements is **NOT** true about the properties of combination of limits of functions?

A. If the limit of a function exists at a point, then the limit of a constant times that function exists at that point.

B. If the limit of the sum of two functions exists at a point, then the limit of each function exists at that point.

C. If the limits of two functions exist at a point, then the limit of the difference of these functions exist at that point.

D. If the limits of two functions exist at a point, then the limit of the product of these functions exist at that point.

E. If the limits of two functions exist at a point, then the limit of the quotient of two functions exist at that point provided the limit of the denominator is not zero.

4. If $\lim_{x\to a} f(x) = 2$, $\lim_{x\to a} g(x) = -4$ and $\lim_{x\to a} h(x) = 19$, then what is the value of $\lim_{x\to a} \frac{3f(x)-8g(x)}{h(x)}$?

A. 2 B. 0 C. -32 D. 38 E. 6

5. Which one of the following statements is **<u>NOT</u>** true?

A. The limit of a constant function exists at every real number.

B. The limit of a polynomial function exists at every real number.

C. The limit of a square root function, $f(x) = \sqrt{x}$, exists at every positive real number.

D. The limit of an absolute value function, $f(x) = |x|$, exists at every real number.

E. The limit of a rational function exists at every real number.

6. Given: $0 < |x-2| < \delta \Rightarrow |(4x+1)-9| < 0.01 = \varepsilon$. Then, the largest possible δ is

A. 0.0025 B. 0.01 C. 0.0125 D. 0.005 E. 0.05

7. Which one of the following statements is true?

A. $\lim_{x\to a^{\pm}} f(x) = \pm\infty \Rightarrow y = a$ is a vertical asymptote of the graph of f.

B. $\lim_{x\to \pm\infty} f(x) = L \Rightarrow y = L$ is a vertical asymptote of the graph of $f(x)$.

C. $\lim_{x\to a^{\pm}} f(x) = \pm\infty \Rightarrow x = a$ is a vertical asymptote of the graph of f.

D. $\lim_{x\to \pm\infty} \frac{1}{x} = 0 \Rightarrow x = 0$ is a horizontal asymptote of the graph of $f(x) = \frac{1}{x}$.

E. $\lim_{x\to 0^{\pm}} \frac{1}{x^2} = \pm\infty \Rightarrow y = 0$ is a vertical asymptote of the graph of $f(x) = \frac{1}{x^2}$.

8. Which one of the following statements is **NOT** true about the concept of a continuous function?

   A. Both functional and limiting values of a continuous function at a point are equal.

   B. If the limit of a function exists at a point, then the function is continuous at that point.

   C. If a function is continuous at a point, then the function is defined at that point.

   D. If a function is continuous at a point, then the limit of the function exists at that point.

   E. A function f is continuous at a point $x = a$ if $\forall \varepsilon > 0\ \exists \delta > 0$ such that $0 < |x - a| < \delta \Rightarrow |f(x) - f(a)| < \varepsilon$.

9. What would be the value of the smallest positive number N for which the statement $x > N \Rightarrow \left|\frac{x}{x+1} - 1\right| < 0.01 = \varepsilon$ is to hold true?

   A. 101 B. 100 C. $\frac{1}{99}$ D. 99 E. $\frac{1}{100}$

10. Which one of the following statements is **NOT** true about properties of combination of continuous function?

    A. If a function is continuous at a point, then a constant times of that function is continuous at that point.

    B. If two functions are continuous at a point, then their difference is continuous at that point.

    C. If two functions are continuous at a point, then their quotient is continuous at that point provided that the denominator is not zero.

D. If two functions are continuous at a point, then their product is alsocontinuous at that point.

E. If the sum of two functions is continuous at a point, then each individual function is continuous at that point.

11. Suppose that f and g are continuous functions such that $\lim_{x\to 3} g(x) = 5$ and $f(3) = -2$. Then, $\lim_{x\to 3} \frac{f(x)}{g(x)}$ is equal to

A. $\frac{5}{2}$ B. $-\frac{2}{5}$ C. 5 D. -2 E. It does not exist.

12. Which one of the following statements is true?

A. If $\lim_{x\to a} f(x) = f(a)$, then f is differentiable at $x = a$.

B. If $\lim_{x\to a} f(x)$ exists, then f is continuous at $x = a$.

C. If $\lim_{x\to a} f(x)$ exists, then $\lim_{x\to a} f(x) = f(a)$.

D. If a function f is differentiable at $x = a$, then $\lim_{x\to a} f(x) = f(a)$.

E. If a function f is defined at a number $x = a$, then f is differentiable at $x = a$.

13. $\lim_{x\to 0} \frac{\sqrt{2+x} - \sqrt{2}}{x} =$ ___________

A. $\sqrt{2}$ B. $\frac{1}{\sqrt{2}}$ C. $\frac{\sqrt{2}}{4}$ D. $\frac{\sqrt{2}}{2}$ E. It does not exist.

14. Which one of the following statements is **NOT** true about the concept ofderivative at a point $x = a$?

A. Both functional and limiting values of a differentiable function at a point are equal.

B. If a function is differentiable at a point, then the function is defined at that point.

C. A function f defined at a number $x=a$ has a derivative at $x=a$ if $\lim_{h\to 0}\frac{f(h+a)-f(a)}{h}$ exists.

D. The derivative $f'(a)$ of a function f represents the slope of the tangent line to its graph at the point $(a, f(a))$.

E. If the limit of a function exists at a point, then the function is differentiable at that point.

15. If $f(x)=x^3-4x+3$, then $\lim_{h\to 0}\frac{f(1+h)-f(1)}{h}$ is

A. -1 B. 1 C. 0 D. 3 E. -4

16. Which one of the following statements is **<u>NOT</u>** true about properties of combination of differentiable functions?

A. If a function is differentiable at a point, then a constant times a function is differentiable at that point.

B. If two functions are differentiable at a point, then their difference is differentiable at that point.

C. If two functions are differentiable at a point, then their quotient is differentiable at that point provided that the denominator is not zero.

D. If the sum of two functions is differentiable at a point, then each individual function is differentiable at that point.

E. If two functions are differentiable at a point, then their product is also differentiable at that point.

17. What is the largest possible product of two non-negative numbers whose sum is 1?

A. $\frac{1}{4}$ B. $\frac{1}{2}$ C. $\frac{1}{8}$ D. 1 E. 0

18. Which one of the following is **NOT** a technique for the derivative of combination of differentiable functions?

A. The derivative of constant times a function is the constant times the derivative of the function.

B. The derivative of a quotient of two functions is the quotient of the derivative of the numerator and the derivative of the denominator.

C. The derivative of a sum of two functions is the sum of their derivatives.

D. The derivative of a difference of two functions is the difference of their derivatives.

E. The derivative of a product of two functions is the first function times the derivative of the second function plus the second function times the derivative of the first function.

19. If $F(x)=4\left(\frac{f(x)+g(x)}{g(x)}\right)$, $f(2)=-3$, $f^{'}(2)=-4$, $g(2)=1$ and $g^{'}(2)=-5$, then which one of the following is equal to $F'(2)$?

A. -28 B. 4 C. -36 D. -16 E. -76

20. Which one of the following statements is **Not** true?

A. A number $x=a$ in the domain of f is a critical number of f if $f^{'}(a)=0$ an $f^{'}(a)$ does not exist.

B. A relative minimum point of a function is a point at which its graph changes from decreasing to increasing.

C. Every continuous function on a closed and bounded interval has both maximum and minimum values.

D. Maximum and minimum values of a continuous function on $[a,b]$ only occur at the end points $x=a$ and $x=b$.

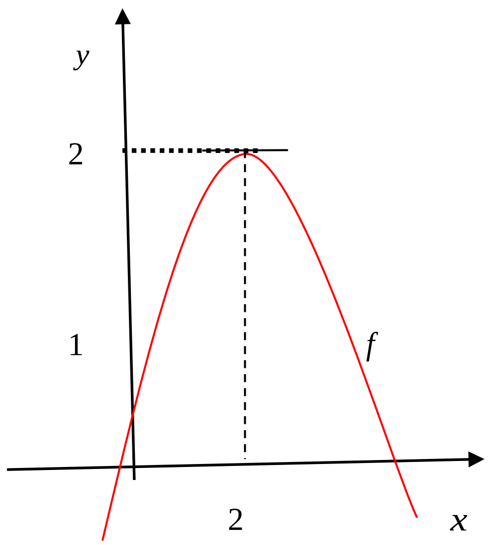
E. Every strictly decreasing function is decreasing.

21. A function f is defined on $\left[\frac{1}{2}, \frac{7}{2}\right]$ by $f(x) = \begin{cases} 4x-2, & x<1 \\ (x-2)(x-3), & x \geq 1 \end{cases}$. The absolute maximum and minimum values of f are, respectively

A. 0 *and* 2 B. $-\frac{1}{4}$ *and* $\frac{3}{4}$ C. $\frac{3}{4}$ *and* $-\frac{1}{4}$

D. 2 *and* 0 E. 2 *and* $-\frac{1}{4}$

22. The figure shown below depicts the graph of a certain function f. Identify-out the wrong statement based on the situation provided.



A. $(1,2)$ is an absolute maximum point of f.

B. $f''(1) < 0$.

C. $f'(x) > 0$ for $x < 1$ and $f'(x) < 0$ for $x > 1$.

D. $f'(x) = 0$

E. f is decreasing on $(1, \infty)$.

23. Given the function $f: f(x)=\begin{cases} 2x-1 \text{ if } x<-1 \\ x^2+1 \text{ if } -1\le x\le 1 \\ x+1 \text{ if } x>1 \end{cases}$. Identify a true statement about thecontinuity of f.

A. f is continuous everywhere except at $x=0$.

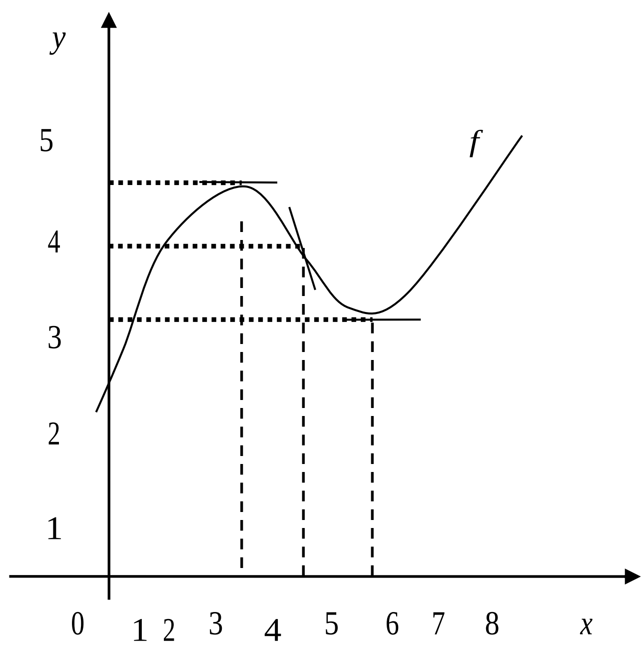
B. f is continuous everywhere except at $x=-1$ and $x=1$.

C. f is continuous everywhere except at $x=1$.

D. f is continuous everywhere except at $x=-1$.

E. f is continuous everywhere.

24. The figure shown below depicts the graph of a certain function f. Identify a true statement that correctly describes the situation.



A. $(5,3)$ is a relative minimum point of f.

B. For $x<3$, $f(x)$ is concave upward.

C. $(4,4)$ is an inflection point of f.

D. 3 is a relative maximum value of f .

E. For $3<x<4$, $f(x)$ is concave upward.

25. If the function $f(x)=\begin{cases}\dfrac{x^2-6x+8}{x^3-2x^2+2x-4} & \text{if } x\neq 2\\ k & \text{if } x=2\end{cases}$ is continuous everywhere, what is the value of k?

A. 1 B. $\frac{1}{2}$ C. $-\frac{1}{3}$ D. $\frac{1}{8}$ E. -1

26. If $f(x)$ is continuous on $[\alpha,\beta]$ and differentiable in (α,β) where $\alpha\neq\beta$ such that $f(\alpha)=3$ and $f(\beta)=5$, then the Mean-Value theorem states that there is a point γ between α and β such that

A. $(\beta-\alpha)f'(\gamma)=2$ B. $f(\gamma)=0$ C. $f'(\gamma)=2$ D. $\beta-\alpha$ E. $f'(\gamma)=0$

27. Which one of the following is true about the function $f(x)=|x-2|$?

A. f is differentiable at $x=2$ and $x=3$.

B. f is differentiable at $x=3$ but not at $x=2$.

C. f is differentiable at $x=2$ but not at $x=3$.

D. f is not differentiable either at $x=2$ or $x=3$.

E. f is a differentiable function.

28. Let $G(x)=f\left(\dfrac{3x^2+1}{x-1}\right)$ where f is differentiable function on $\Re\setminus\{1\}$. If $f'(-2)=2$, then what is the value of $G'(-1)$?

A. -2 B. 2 C. 4 D. -6 E. 8

29. Let f be twice differentiable function on $\Re$. Which one of the following is necessarily true?

A. If $f''(c)=0$ for some $c\in\Re$, then $(c, f(c))$ is an inflection point of f.

B. If the number c is a critical number of f, then f has a relative extreme value at $x=c$.

C. If $f'(x)>0$ for all $x\in\Re$, then f is decreasing function on $\Re$.

D. If f has a relative extreme value at $x=c$, for some $c\in\Re$, then c is a critical number of f.

E. If $f'(c)=0$ *and* $f''(c)<0$ for some $c\in\Re$, then f is concave downward on for $(c-\delta, c+\delta)$ for some $\delta>0$.

30. If $f(x)=\begin{cases} -2(x+1) \text{ if } x\le 0 \\ k(1-x^2) \text{ if } x>0 \end{cases}$ then the value of k for which $\int_{-1}^{1} f(x)dx=1$

A. -1 B. 0 C. 1 D. 2 E. 3

Part-III- (Work-out Items/Open-ended)

Attempt each question by defining the term(s) as well as showing the necessary steps as clearly and precisely as possible.

1. (i) Define precisely: $\lim_{x\to 4} x=4$? [Use the formal $(\varepsilon-\delta)$ definition of limit]

   (ii) Using the definition in (i) prove that $\lim_{x\to 4} x=4$.

2. (i) State the Intermediate Value Theorem.

   (ii) Find the number which is guaranteed by the Intermediate Value Theorem for the function $f(x)=x^2-3x+2$ on the interval $\left[0, \frac{3}{2}\right]$.

3. (i) Define precisely the derivative of a function $f(x) = 3x^2$ at $x = 3$.

   (ii) Using the definition in (i), find the equation of the tangent line at the point $(3,27)$.

4. (i) State the Mean-Value Theorem for derivative of function.

   (ii) Find the number which guarantees the Mean-Value Theorem for the function $f(x) = x^3 + 4x$ on the interval $[-2,1]$.

5. Calculate the area of the region in the first quadrant bounded by the graphs of $y = 8x, y = x^3$ *and* $y = 8.$

Appendix B: Learners' Attitudes Questionnaire used in the Pilot, Pre and Post Study

General Direction

This study makes use of an adapted pre-existing questionnaire that was constructed based on five criteria as to how students view mathematics/calculus such as the normality of intermediate calculus/mathematics (N), attitudes towards intermediate calculus/mathematics inquiry (I), adoption of intermediate calculus/mathematics attitudes (A), enjoyment of intermediate calculus/mathematics lessons (E) and attitudes towards intermediate calculus/mathematics through learning the use of jigsaw co-operative learning strategy integrated with GeoGebra (JCLGS). It is aimed at pilot test voluntarily participants to collect data for the research to be conducted in the PhD thesis. It was intended to ensure the construction of the validity/reliability of the questionnaire encompassing statements on issues related to learners' attitudes towards intermediate calculus/mathematics. It contains fifty (50) questions. Kindly decide your most likely opinion by rating each statement in accordance with the instruction provided. In doing this, the researcher would like to thank you in advance for your cooperation. In addition, you are kindly requested to specify your:

Sex: _______________

Age: _______________.

Specific Instruction: Please indicate your most likely opinion from a five-point Likert response scale where scales 1, 2, 3, 4 and 5 represent Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A) and Strongly Agree (SA) respectively, by marking (√) in front of each question, regardless of whether the answer is right or wrong.

Table B1: Learners' Attitudes Questionnaire used in the Pilot Test (Fraser, 1982)

Labels	Statements about Mathematics/Intermediate Calculus Related Attitude	Scales				
		SA	A	N	D	SD
$Q_{1N\_}$	Mathematicians usually like to solve equations in non-working days (weekend or holiday).					
Q_{2I+}	I would prefer to find out why something is true by solving a mathematical problem than being told.					
Q_{3A+}	I enjoy reading about mathematical objects like terms, notions, concepts …, which disagree with my previous ideas.					
Q_{4E+}	Mathematics lessons are fun.					
Q_{5CIS+}	I enjoy working with mathematics/calculus problems through learning integrated with computer packages as tool.					

Q_{6N+}	Mathematicians are about as fit and healthy as other people.					
$Q_{7I\_}$	Solving mathematical/calculus problems on my own is not as good as finding out information from teachers.					
$Q_{8A\_}$	I do not like solving similar mathematical/calculus problems to make sure I understand the concept.					
$Q_{9E\_}$	I do not like mathematics/calculus lessons.					
$Q_{10CIS\_}$	Using computer packages as a tool in mathematics/calculus learning cannot benefit visualizing concepts and developing knowledge.					
$Q_{11N\_}$	Mathematicians do not have enough time to spend with their families.					
Q_{12I+}	I would prefer to solve mathematical/calculus problems rather than read about them.					
Q_{13A+}	I am interested to learn/know all about the mathematical/calculus issues.					
Q_{14E+}	Universities should have more mathematics/calculus lessons each week.					
Q_{15CIS+}	Representing mathematics/calculus concepts in multiple ways using computer packages as a tool enhances their learning.					
Q_{16N+}	Mathematicians like sports as much as other people do.					

$Q_{17I\_}$	I would rather agree with other peoples' solutions than investigating a mathematical/calculus problem to find out for myself.					
$Q_{18A\_}$	Finding out about new mathematical/calculus theories (corollary, lemma, theorem …), is unimportant.					
$Q_{19E\_}$	Mathematics/calculus lessons bore me.					
$Q_{20CIS\_}$	I do not like learning mathematics/calculus linked with real-life problems using computer packages as tool.					
$Q_{21N\_}$	Mathematicians are less friendly than other people.					
Q_{22I+}	I would prefer to solve mathematical/calculus problems on my own rather than have a teacher explain them.					
Q_{23A+}	I like to listen to people whose opinions about mathematics/calculus are different from mine.					
Q_{24E+}	Mathematics/calculus is one of the most interesting courses in the university.					
Q_{25CIS+}	Learning mathematics/calculus using computer packages as a tool makes the knowledge of concepts and procedures/steps to be easily understood.					
Q_{26N+}	Mathematicians can have a normal family life.					
$Q_{27I\_}$	I would rather find out about mathematical/calculus issues by asking an instructor, than working on my own.					

Q28A_	I find it boring to hear about new ideas about mathematics/calculus.					
Q29E_	Mathematics/calculus lessons are a waste of time.					
Q30CIS_	Computers packages are not good tools for the learning of mathematics/calculus.					
Q31N_	Mathematicians do not care about their working conditions.					
Q32I+	I would rather solve a mathematical/calculus problem by experimenting than by being told the answer.					
Q33A+	I like to use new methods of solving mathematical/calculus problems which I have not used before.					
Q34E+	I really enjoy going to classes where mathematics/calculus lessons are delivered.					
Q35CIS+	Learning calculus using computer packages as tool reduces my mental work (cognitive load).					
Q36N+	Mathematicians are just as interested in art and music as other people are.					
Q37I_	It is better to ask the teacher the answer of a mathematical/calculus problem than to find out by myself.					
Q38A_	I am unwilling to change my ideas on mathematics/calculus when evidence shows that the ideas are poor.					

Q39E_	The material (content) covered in mathematics/calculus lessons is uninteresting.					
Q40CIS_	Learning mathematics/calculus with the aid of computer packages as a tool does not economize time.					
Q41N_	Mathematicians are happily married.					
Q42I+	I would prefer to solve a mathematical/calculus problem on a topic than to read about it in a textbook.					
Q43A+	I identify in mathematics/calculus problems unexpected results, as well as expected ones.					
Q44E+	I look forward to mathematics/calculus lessons.					
Q45CIS+	Computer packages are valuable tools for learning mathematics/calculus.					
Q46N+	If you met a person who studies mathematics/calculus, he/she would probably look like anyone else you might meet.					
Q47I_	It is better to be told mathematical/calculus facts than to find them out from problem-solving.					
Q48A_	I do not like listening to other people's opinions about mathematics/calculus.					
Q49E_	I would enjoy university more if there were no mathematics/calculus lessons.					

Q50CIS_	Using computer packages as a tool cannot encourage a creative learning environment of mathematics/calculus.					

Appendix C: Student Research Consent Form

(To be completed by learner participant aged 18 years and above)

Research Proposal Topic: Computer Interactive Simulation, a Tool for Conceptual and Procedural Knowledge Development of Intermediate Calculus

Purpose of the Research: The purpose of this study is mainly to examine the influence that learning strategy integrated with computer interactive simulation (CIS) as a tool has on undergraduate learners' conceptual (CK) and procedural (PK) knowledge development of intermediate calculus.

Nature of the study: It is solely to develop research thesis on mathematics in accordance with the requirements for the degree of Doctor of Philosophy in Mathematics, Science and Technology Education in the subject Mathematics Education at the University of South Africa.

Researcher's Details

Name: Sirak Tsegaye Yimer (Yimer S T)

Address: Ambo University, P.O. Box 19, AMBO, Ethiopia

Telephone: +251911085149 (mobile)

Research Site: Ambo University and Wollega University

You are enrolled in one of the departments selected to participate in a research study. It is hoped that you have read and familiarized yourself with the purpose, nature, methods, scope and intent of the research study mentioned above. If you agree to participate, you will be required to sit for the classroom achievement/diagnostic test on basic calculus in the pre-test and post-test as well as for attitude questionnaire. The researcher kindly requests for you to bear in mind that the information you are providing is very essential to obtain the expected results. Your co-operation will contribute more for the completion of the study. The findings in turn may help improve future learners' learning of intermediate calculus. In so doing, you are advised not to hesitate if something should occur that may cause you harm. This is to say that confidentiality will be ensured at every step of the study. During and after data are collected, you will be identified by a code to guarantee anonymity. If you have any reservation, your decision to carry on or quit is respected at any time without a penalty.

I **Keriya Hawi** consent to participating in this research. I understand that the researcher will ensure confidentiality as is explained above. Furthermore, I understand that I may quit my participation in this study at any time, or refuse to respond to any questions to which I choose not to respond. I am a voluntary participant and have no liability or responsibility for the implementation, methodology, claims, substance, or outcomes resulting in any adverse consequences or disparate treatment due to that decision. I fully understand that this research is being conducted for constructive educational purposes. Finally, I would like to give my permission to the researcher to use the data collected for the sole purpose of this study, through my signature here under.

Participant's Name (Representative): **Keriya Hawi**

Participant's Signature: ____________

Date: **Nov 17, 2016**

Appendix D: Letter of Permission from Ambo and Wollega Universities

The Federal Democratic Republic of Ethiopia

Ref. No AU/T466/1/11/2016

Date 15 JAN 2016

To: Institute for Science & Technology Education, University of South Africa (UNISA)

Subject: Giving Letter of Consent

Mr. SIRAK TSEGAYE YIMER (YIMER S T) requested **AMBO UNIVERSITY** to get letter of consent from the participant in his research work. The researcher is looking for all those student participants who are taking basic calculus courses. The departments entertaining these courses are **Mathematics, Physics, Chemistry and Statistics.** He also points out in detail the research proposal topic, purpose, nature, methods, scope, and intent of the research study in the student consent form.

Therefore, we would like to inform your institution that Mr. SIRAK TSEGAYE YIMER (YIMER S T) is allowed to conduct his PHD project in our University to give all the necessary data and facilities he needs in the study.

With best regards!

Lakew Wondimu Abachiri (PhD)
Academic & Research Vice President

The Federal Democratic Republic of Ethiopia
Ambo University

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Wollega University
Research and Technology Transfer Vice President Office

ቁጥር /Ref. WU/85 980/90/01-26/08
ቀን/Date/ 15/06/2008

To: Institute for Science & Technology Education, Unversity of South Africa (UNISA)

Subject: Giving Letter of Consent

Mr. SIRAK TSEGAYE YIMER (YIMER S T) requested Wollega University to get letter of consent from the participant in his research work. The researcher is Looking for all those student participants who are taking basic calculus courses. The departments entertaining these courses are **Mathematics, Physics, Chemistry and Statistics**. He also points out in detail the research proposal topic, purpose, nature, method, scope, and intent of the research study in the student consent form.

Therefore, we would like to inform your institution that Mr. SIRAK TSEGAYE YIMER (YIMER S T) is allowed to conduct his PhD project in our University to give all the necessary data and facilities he needs in the study.

With best regards!

ዱንካና ንጉሣ ቀነኢ (ዶ/ር)
Dunkana Negussa kenie (PhD)
የምርምርና ቴክኖሎጂ ሽግግር ምክትል ፕሬዝዳንት ጽ/ቤት
Research and Technology Transfer Vice President Office

CC
- Mr. Sirak Tsegaye Yimer
  WU

ፖ.ሣ.ቁ 395 ነቀምት
ስልክ: +251578619223
ፋክስ:+251576617980

E-mail: WU@ethionet.et

P.O. Box 395 Nekemte
Tel: +251578619223
Fax: +251576617980

Appendix E: Letter of Permission for Attitudes Questionnaire (TOMRA/TOSRA)

-----Original Message-----

From: Sirak Tsegaye [mailto:belsirak@yahoo.com]

Sent: Saturday, 2 July 2016 4:22 AM

To: Barry Fraser

Subject: Kindly requesting your consent to license me to use TOMRA or TOSRA in my research project

Dear Professor Barry J. Fraser, first of all would like to say how are you doing well? I am happy and doing well. Having said this as to our well-being let me introduce myself as follows. I am now working at Ambo University, Ethiopia as instructor. And also I am studying for the degree of doctor of philosophy in Mathematics, Science and Technology Education at UNISA. As your information, I wrote a letter to Noorehan Awang to demonstrate his consent to license me to use TOMRA or TOSRA questionnaire in my research project. However, he replied as you are the one you given the permission to use it. So, as mentioned in the subject line, I kindly request your consent to license me to use it. For that, I thank you so much in advance.

Kind regards,

Sirak Tsegaye Yimer

RE: Kindly requesting your consent to license me to use TOMRA or TOSRA in my research project

Friday, July 1, 2016 4:44 PM Mark as Unread

From: "Barry Fraser" <B.Fraser@curtin.edu.au>

To: "Sirak Tsegaye" <belsirak@yahoo.com>

Full Headers Printable View

Sirak

You have my permission to modify and use TOSRA (and TOMRA, which is a modification of TOSRA).

Dr Barry J Fraser

FIAE FTSE FASSA FAAAS FAERA FACE

John Curtin Distinguished Professor

Science and Mathematics Education Centre

School of Education

Tel | +61 8 9266 7896

Fax | +61 8 9266 2503

Email | B.Fraser@curtin.edu.au

Web | http://smec.curtin.edu.au

Address | GPO Box U1987 Perth WA 6845

Appendix F: Ethical Clearance

UNISA | college of science, engineering and technology

Dear Mr Sirak Tsegaye Yimer (student number 57652740)

Date: 2016-06-06

Application number: 2016_CGS/ISTE_003

REQUEST FOR ETHICAL CLEARANCE: (Topic: Use of Computer Interactive Simulation on Conceptual and Procedural Knowledge of Calculus)

The College of Science, Engineering and Technology's (CSET) Research and Ethics Committee has considered the relevant parts of the studies relating to the abovementioned research project and research methodology and is pleased to inform you that ethical clearance is granted for your research study as set out in your proposal and application for ethical clearance.

Therefore, involved parties may also consider ethics approval as granted. However, the permission granted must not be misconstrued as constituting an instruction from the CSET Executive or the CSET CRIC that sampled interviewees (if applicable) are compelled to take part in the research project. All interviewees retain their individual right to decide whether to participate or not.

We trust that the research will be undertaken in a manner that is respectful of the rights and integrity of those who volunteer to participate, as stipulated in the UNISA Research Ethics policy. The policy can be found at the following URL:
http://cm.unisa.ac.za/contents/departments/res_policies/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf

Please note that the ethical clearance is granted for the duration of this project and if you subsequently do a follow-up study that requires the use of a different research instrument, you will have to submit an addendum to this application, explaining the purpose of the follow-up study and attach the new instrument along with a comprehensive information document and consent form.

Yours sincerely

Dr CE Odhonogor
Chair: Ethics Sub-Committee (STRI/ISTE) CSET

Prof NN Feza
Director/Head: ISTE

18 JULY 2016

Prof I Alderton
Executive Dean (Acting): College of Science, Engineering and Technology

University of South Africa
College of Science, Engineering and Technology
The Science Campus
C/o Christiaan de Wet Road and Pioneer Avenue, Florida Park, Roodepoort
Private Bag X6, Florida, 1710
www.unisa.ac.za/cset

UNISA | college of science, engineering and technology

Appendix G: Validity Evaluation of the Data Collection Instruments

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Ambo University
College of Natural & Computational Sciences
Department of Mathematics

Ref. No: **M/D/859/016**
Date: Jan. 29, 2016

To Mr. Fekadu Tolossa
Mr. Bayissa Degaga
Mr. Tsegaye Kebede
Ambo University, Department of Mathematics

Subject: Kindly requesting you to cooperate on validity evaluation of diagnostic test on the basics of calculus

We kindly request to play your role (on a research which is to be conducted by our staff member Mr. Sirak Tsegaye Yimer on the title: **Use of Computer Interactive Simulation on Conceptual and Procedural Knowledge of Calculus)** on validating content-related evidence of the validity of diagnostic test on the basics of calculus based on the following points:

- evaluating the adequacy of sample questions of basic calculus (or level of difficulty) in the diagnostic test whether it fulfills the proposed objectives of the research is based on the syllabus,
- evaluating researcher definition of the measurement is based on the syllabus and
- evaluating clarity of printing and size of type (format of the test), appropriateness of language and so on.

We thank you for your cooperation.
With best regards

Dadi Asefa

Head, Department of Mathematics

Please quote our Ref.No. in replying Fax 251-112-36-22-37 P.O.Box 19 AMBO, ETHIOPIA Tel.No. 0112365203
E-mail:maths@ambou.edu.et Mobile: +251911092501

Appendix H: Learning Activities

Table H2: Learners' Learning Activities Used in JCLGS

General Learning Objectives	Upon completion of each learning activity, learners

	should be able to:	
	Visualize the concepts of limit, one-sided limits, infinite limits, and limits at infinity, continuity, one-sided continuity, derivative and integral of any continuous function f(x) at a point with using the JCLGS.	
	Explore different ways of representations of mathematical objects like the concept of limit such as numerically or symbolically or algebraically or geometrically or graphically or calculus means.	
	Compute combinations (sum, difference, constant multiple, multiplication, quotient) of limits of two or more functions whenever they exist.	
	Develop imagination about certain mathematical objects like limit, continuity, derivative and integral.	
Learning Lessons/Topics	Limit	Formal $(\varepsilon - \delta)$ definition of limit of a function f(x) at a number (point) x_0
		Formal $(\varepsilon - \delta)$ definition of one-sided limits (right-left limits)
		Infinite limits and limits at infinity
	Continuity	Formal $(\varepsilon - \delta)$ definition of continuous

		function f(x) at a number (point) x_0
		One-sided continuity
	Derivative	
	Integral	
Learners' Learning Activities/Tasks	Does any function defined for any number in $\mathbb{R}$? Support your answer by familiar examples.	
	Discuss the behavior of any function at a number/point for which it is not defined in the subset of $\mathbb{R}$.	
	Explain the notion functional value and discuss it by considering familiar instances.	
	Why the need to study limit concept? Justify your answer with practical (Physics) and theoretical (Mathematics) examples.	
	Discuss over the formal $(\varepsilon - \delta)$ definition of limit of a function f(x) at a number (point) x_0 by considering some familiar functions from polynomial, rational, nth root, exponential, logarithmic, trigonometric functions, absolute value function, function like $f(x) = \frac{\sin(x)}{x}$ and so on.	
	Explain the notion limiting value and discuss it by	

	considering familiar instances.
	Elaborate the similarities and differences between functional and limiting values by taking familiar functions.
	Do limits of functions (if they exist) be numbers?
	Can we combine (add, subtract, multiply, constant multiple, divide) two or more functions whose limits exist at the same number x_0 as well as nth root and nth power of a function f(x) whose limit exists at a number x_0?
	Discuss over the formal $(\varepsilon - \delta)$ definition of one-sided (right-left hand) limits of a function f(x) at a number (point) x_0 by considering functions like $\sqrt{x}$, $\frac{\lvert x\rvert}{x}$, ... at $x = 0$.
	Discuss the relationship between limit (two-sided limit) and one-sided limit of a function f(x) at a number (point)x_0.
	Discuss over the definition of infinite limits of a function f(x) at a number (point) x_0 by considering functions like$\frac{1}{x}$, $\frac{1}{x^2}$, … at $x = 0$ and generally for any rational function at the number (point) for which it is

	not defined.
	Discuss whether the infinite limit of a function is a number or not. If it is not a number, can we conclude that this limit of a function exists?
	Explain the relationship between infinite limit and vertical asymptote of the graph of a function.
	Discuss the definition of limit at infinity of a function f(x) by considering functions like $\frac{1}{x}$, $\frac{1}{x^2}$, … at $\pm\infty$ and generally for any rational function at $\pm\infty$.
	Explain the relationship between limit at infinity and horizontal asymptote of the graph of a functionf(x).
	Discuss the formal $(\varepsilon - \delta)$ definition of a continuous function f(x) at a number (point) x_0 by considering some particular functions from polynomial, rational, nth root, exponential, logarithmic, trigonometric, absolute value function, $\frac{\sin(x)}{x}$and so on.
	Is any function f(x) defined at a number x_0 always continuous at that number? Support your answer by considering a piece-wise defined function.
	Is any function f(x) whose limit exists at a number x_0 always continuous at that number? Support your

	answer by considering a piece-wise defined function.
	Are functional and limiting values of any continuous function f(x) at a number x_0 always equal?
	Can we combine (add, subtract, multiply, constant multiple, divide) two or more functions which are continuous at a numberx_0?
	Discuss the formal $(\varepsilon - \delta)$ definition of one-sided continuity of a function f(x) at a number (point) x_0 by considering familiar examples.
	Discuss the relationship between continuity (two-sided continuity) and one-sided continuity of a function f(x) at a number (point)x_0. Support your understanding by providing familiar examples.
	Discuss the definition of derivative function f(x) at any number x and at a particular number (point) x_0 in its domain.
	Realize the differences between derived function f(x) at any number x and at a particular number (point) x_0 in its domain through interaction with your group.
	Elaborate the geometrical interpretation of a derived function f(x) at a particular number (point) x_0 in its

	domain.
	Is this derived function f(x) at a particular number (point) x_0 has something to do (related) with slope of the graph of the function (curve)?
	Discuss the definition of definite integral of a continuous and non-negative function f(x) over a closed and bounded interval$[a, b]$.
	Is this definite integral of a function f(x) has something to do (related) with the area of the region bounded by the graph of the function (curve), the vertical lines $x = a$ and $x = b$ and the x-axis?
	Discuss the definition of anti-derivative (indefinite integral) of a function f(x) over a given interval I.
	Discuss whether anti-derivative (indefinite integral) of a function f(x) over a given interval I is a pure number or a function.
	Discuss the relationship between derivative and indefinite integral (anti-derivative) of a continuous function f(x) over someinterval I.
	Discuss the similarities and differences between definite integral and anti-derivative (indefinite integral)

	of a continuous function f(x) over a given interval I.
Instructors' Activities/Tasks	Introducing concepts like limit (two-sided), one-sided limit (right-left limits), infinite limit, limit at infinity, continuity, one-sided continuity, derivative, definite and indefinite integrals that learners have learnt in the normal class using traditional lecture method.
	Explaining the guiding principles to learners about how to form Jigsaw co-operative learning groups consisting of 4 or 5.
	Telling the learning activities in the daily lesson.
	Supervising, mentoring, facilitating, assisting, helping, guiding and directing what learners are discussing together.
	Creating learning and thinking environment
	Praising learners' efforts and good answers
	Evaluation of learners' attempt
	Summarizing some important points that learners have felt challenging through their endeavors.
Learners' Learning Methodologies	Using jigsaw co-operative learning strategy integrated with Geogebraas a tool as appropriately as possible.
	Representing each mathematical object (notation,

	concept,..) geometrically, algebraically, graphically, numerically and computationally using GeoGebra Software Package in Mathematics Laboratory class to transform the topic (content) to be further understood.
Use for Pedagogy	Encourages learners to be actively engaged in the learning environment.
	Enhances learners' hands on experience.
	Learners can easily visualize the abstract mathematical objects.
	Learners develop the habit of working and solving problems together and sharing their experiences (team work).
	Increases learners' reasoning and thinking power as well as imagination about mathematical aspects.
	Learners could concept the use of various mathematics software packages in mathematics learning environment other than this.
Assessment of Learner's Learning	Posing questions upon the completion of learners' interaction, giving home activities, providing quizzes and tests.

Assessment of the Learning Activities	Allow facilitators and learners to forward their opinions as to the assessment about how each learning activity has constructed by creating conducive environment. The results of this assessment should be viewed as a useful means
	for developing and applying the learning activities very appropriately and adequately.

Table H3: Basic functions of one variable frequently used in the JCLGS

Constant function, $f(x)=k$
Identity function, $f(x)=x$
Power functions, $f(x)=ax^2 \, or \, ax^3 \, or ...$
Polynomial functions, $p_n(x)=a_nx^n+a_{n-1}x^{n-1}+...+a_1x+a_0, a_n \neq 0 \, and \, n \, is \, a \, non-negative \, integer.$
Rational functions, $r(x)=\frac{p(x)}{q(x)}$ where $p(x) \& q(x)$ are polynomial functions
Nth root function $\sqrt[n]{f(x)}$ where $f(x)$ can be polynomial function, rational function,…noticing such conditions when n is odd or even integer

General form of exponential function, $f(x)=a^x$ for $a>0 \& a \neq 0$, natural exponential function $f(x)=e^x$ where e is an irrational number greater than one whose decimal representations is approximately equal to 2.718288183
General form of logarthmic functions, $f(x)=\log_a^x, a>0 \& a \neq 1$, natural exponential function when $a=e$, i.e., $f(x)=\log_a^x=\ln x$, common logarithmic function when $a=10$, i.e., $f(x)=\log_{10}^x$
Trigonometric functions: $\sin x, \cos x, \tan x, \sec x, \csc x, \cot x$
Some other types (combination) of functions like $\frac{\sin(x)}{x}, x\sin x$

Appendix I: Item Analysis of the True-false (closed-ended) Items

Table I5: Learners' Total Response Scores on the True-false Test Items

Code	Item/Question 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Learner's score
S1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	19
S2	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	18
S3	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	17
S4	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
S5	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	18
S6	1	1	1	0	1	0	1	0	1	1	1	1	1	0	0	1	1	1	1	1	15
S7	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	1	1	1	15

S8	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	1	17
S9	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
S10	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	0	16
S11	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	19
S12	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	14
S13	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	17
S14	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	0	15
S15	0	0	1	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	1	1	13
S16	1	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	0	1	1	14
S17	1	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	16
S18	0	1	0	0	1	1	1	1	0	1	1	0	0	0	1	1	1	0	1	1	12
S19	1	1	1	0	0	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	15
S20	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	17
S21	0	1	1	0	1	0	1	0	1	1	1	0	1	1	0	0	0	1	1	1	12
S22	0	0	1	0	0	1	1	0	0	1	1	0	1	0	0	1	1	0	1	1	10
S23	0	0	1	0	1	0	0	1	1	1	0	0	0	0	1	0	0	1	0	1	8
S24	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0	1	1	0	0	12
S25	1	1	0	0	1	0	0	0	1	1	1	1	1	0	1	1	0	1	1	1	13
S26	0	1	0	0	1	0	0	0	1	0	1	1	0	1	0	0	0	1	1	0	8
S27	1	0	1	1	1	0	0	1	1	1	1	0	0	1	0	1	1	0	0	1	12
S28	1	0	1	0	0	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	10
S29	0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	1	1	0	1	10
S30	0	0	0	1	0	1	0	0	0	0	1	0	1	1	1	1	1	1	1	0	10

Table I6: Item Total Score on the True-false Items and Frequency Distribution of Scores

Item/Question	Number of Learners Correctly Answered the Item (Item Total Score)	Learner's Score Distribution	
		Test Score	Number of Learners
1	23	0	0
2	18	1	0
3	25	2	0
4	17	3	0
5	25	4	0
6	20	5	0
7	15	6	0
8	18	7	0
9	26	8	2
10	22	9	0
11	26	10	4
12	17	11	0
13	18	12	4
14	21	13	2
15	23	14	2
16	24	15	4
17	22	16	2
18	23	17	4
19	22	18	3
20	24	19	3

		20	0	

Table I8: Item Difficulty, Item Discrimination and Reliability Index of Item Score, and Reliability Co-efficient of the Total Score of the True-false Items

Item	Item Difficulty level Index, P	Item Discrimination Index, D	Reliability Index of Item Score, r_{pbi}	Reliability Index of the Total Test Score, KR-21 r_{test}
1	0.77	0.4	0.24	0.7
2	0.6	0.4	0.29	
3	0.83	0.4	0.18	
4	0.57	0.4	0.29	
5	0.83	0.13	0.12	
6	0.67	0.53	0.45	
7	0.5	0.27	0.08	
8	0.6	0.27	0.16	
9	0.87	0.27	0.37	
10	0.73	0.67	0.35	
11	0.87	0.53	0.43	
12	0.57	0.4	0.29	
13	0.6	0.27	0.16	
14	0.7	-0.13	0.12	

15	0.77	0.4	0.35
16	0.8	0.67	0.58
17	0.73	0.27	0.18
18	0.77	0.27	0.14
19	0.73	0.4	0.11
20	0.8	0.53	0.27
	Average=0.72	Average=0.38	Average=0.26

Appendix J: Item Analysis of the Multiple-choice (closed-ended) Items

Table J9: Learners' Item Response score and Total Scores on the Multiple-choice Items

Code	Item/Question																														Learner's Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
S1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	25
S2	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	26
S3	1	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	22
S4	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	0	0	1	1	1	0	1	0	22
S5	0	1	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	1	1	0	1	1	0	1	0	1	1	0	0	0	20
S6	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	23
S7	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	0	1	0	22
S8	1	1	1	1	0	1	1	0	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	20
S9	1	0	0	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	1	15

S10	0	1	1	1	0	1	0	0	1	1	1	0	1	0	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	18
S11	0	1	0	1	1	1	0	0	1	0	1	0	0	0	1	0	0	1	0	1	0	1	1	1	0	0	0	1	0	0	13
S12	1	0	0	1	1	1	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	16
S13	1	0	0	1	0	1	0	0	0	0	1	0	1	1	0	0	0	1	0	1	1	1	0	0	1	0	1	1	0	0	13
S14	1	0	0	1	1	1	0	1	0	1	1	0	0	1	0	1	0	1	1	1	1	0	1	0	0	1	0	1	0	0	16
S15	1	0	0	1	1	1	0	1	0	1	1	0	1	0	1	1	0	0	1	1	1	0	0	0	1	1	1	1	0	1	18
S16	1	0	0	1	1	1	1	0	0	0	1	0	0	0	1	0	1	0	1	1	1	1	0	0	1	0	0	0	0	1	14
S17	0	1	0	1	1	1	0	0	0	0	1	1	1	0	1	0	1	0	1	1	1	1	0	0	1	1	1	1	0	0	17
S18	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	8
S19	0	1	0	1	1	0	1	0	0	0	0	0	1	0	1	1	0	0	0	1	0	1	0	0	1	0	1	1	0	0	12
S20	0	1	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	1	0	1	0	1	1	0	0	0	1	0	1	0	11
S21	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5
S22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
S23	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
S24	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	5
S25	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	5
S26	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	6
S27	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	4
S28	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0	0	5
S29	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	8
S30	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	8

Table J10: Item Score of the Multiple-choice Items and Frequency Distribution Score

Item	Number of Learners Correctly Answered the Item (Item Total Score)	Learners' Score Distribution	
		Test Score	Number of Learners
1	17	0	0
2	15	1	0
3	8	2	2
4	20	3	0
5	13	4	1
6	18	5	4
7	14	6	1
8	8	7	0
9	8	8	3
10	15	9	0
11	24	10	0
12	8	11	1
13	11	12	1
14	9	13	2
15	15	14	1
16	15	15	1
17	8	16	2
18	15	17	1
19	13	18	2

20	22	19	0
21	16	20	2
22	20	21	0
23	10	22	3
24	10	23	1
25	14	24	0
26	20	25	1
27	14	26	1
28	9	27	0
29	7	28	0
30	5	29	0
		30	0

Table J12: Item Difficulty, Item Discrimination and Reliability Index of Item Score and Reliability Co-efficient of the Total Score of the Multiple-choice Items

Item	Item Difficulty level (Index), P	Item Discrimination Index, D	Reliability Index of Item Score, r_{pbi}	Reliability Index of the Total Test Score, KR-21, r_{test}
1	0.57	0.67	0.37	0.9
2	0.5	0.8	0.5	
3	0.27	0.8	0.45	

4	0.67	0.8	0.74
5	0.43	0.4	0.24
6	0.6	0.67	0.54
7	0.47	0.93	0.6
8	0.27	0.8	0.65
9	0.27	0.67	0.45
10	0.5	0.8	0.61
11	0.8	0.27	0.51
12	0.27	0.27	0.24
13	0.37	0.67	0.69
14	0.3	0.53	0.3
15	0.5	0.67	0.53
16	0.5	0.8	0.49
17	0.27	0.8	0.59
18	0.5	0.67	0.34
19	0.43	0.8	0.7
20	0.73	0.93	0.67
21	0.53	0.8	0.68
22	0.67	0.4	0.29
23	0.33	0.67	0.31
24	0.33	0.4	0.31
25	0.47	0.53	0.53
26	0.67	0.13	0.32
27	0.47	0.93	0.66

28	0.3	0	0.07
29	0.23	0.67	0.52
30	0.17	0	0.11
	Average=0.45	Average=0.61	Average=0.46

Appendix K: Item Analysis of the Work-out (Open-ended) Items

Table K13: Learners' Item Response Score by the Two Raters on the Work-out Items

	Item/Question									
	Q_1		Q_2		Q_3		Q_4		Q_5	
	Rater		Rater		Rater		Rater		Rater	
Code	1	2	1	2	1	2	1	2	1	2
S1	2.5	2.5	2.5	2	3	2	2.5	2.5	3	3
S2	2	2	2	2	2.5	2.5	2.5	2	4	3.5
S3	2.5	2.5	2.5	2.5	3	3	2.5	2.5	3	3
S4	1	0.5	0.5	0.5	2.5	2	1	1	3	3
S5	3	3	2	2	3	3	2	2	0	0
S6	3	3	1	1	3	3	2	2	1	0
S7	2.5	2	2	2	2.5	2.5	2	2	0	0
S8	2.5	2	1.5	1.5	2.5	2	1	1	0	0
S9	3	3	0.5	0	2	2	0.5	0.5	0	0
S10	1	1	1.5	1.5	2	2	2.5	2.5	0	0
S11	2	2	0	0	1.5	1.5	2	2	0	0
S12	2	2	1.5	1.5	3	3	0	0	0	0

S13	1	1	1.5	1.5	2.5	2	0.5	0	3	3
S14	3	3	1	1	3	3	1	1	0	0
S15	1.5	1.5	1.5	1.5	2	1.5	2	2	0	0
S16	1.5	1	1	1	2.5	2.5	1.5	1.5	0	0
S17	1	1	1.5	1	2.5	2.5	2	2	0	0
S18	0	0	0	0	0	0	0	0	0	0
S19	2.5	2	1	1	2.5	2.5	0.5	0.5	0	0
S20	0.5	0.5	1	1	1.5	1	2	2	0	0
S21	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	0	0
S26	0.5	0	0	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0
S28	0	0	0	0	0	0	0	0	0	0
S29	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	0	0	0	0	0	0	0

Appendix L: Factor loadings, Cronbach's alpha Coefficients, Eigen values and Variance

Table L20: Three Factors Influencing Learners' Attitudes

Labels	Statements of the Scale	Factors		
		Normality	Enjoyment	Attitude towards

		(F_1)	(F_2)	Calculus and GeoGebra (F_3)
Q_{6N+}	Mathematicians are about as fit and healthy as other people.	.604		
$Q_{11N\_}$	Mathematicians do not have enough time to spend with their families.	.418		
Q_{16N+}	Mathematicians like sports as much as other people do.	.413		
$Q_{21N\_}$	Mathematicians are less friendly than other people.		.766	
Q_{26N+}	Mathematicians can have a normal family life.	.489		
$Q_{31N\_}$	Mathematicians do not care about their working conditions.	.512	.488	
Q_{36N+}	Mathematicians are just as interested in art and music as other people are.	.634		
Q_{46N+}	If you met a mathematician, he/she would probably look like anyone else you might meet.	.678		
Q_{5CIS+}	I enjoy working with calculus problems through learning integrated with GeoGebra as a			.410

	tool.		
Q10CIS_	Using GeoGebra as a tool in calculus learning cannot benefit in visualizing concepts and developing knowledge.	.634	.568
Q15CIS+	Representing calculus concepts in multiple ways using GeoGebra as a tool enhances your learning.		.405
Q20CIS_	I do not like learning calculus linked with real-life problems using GeoGebraas a tool.	.601	.491
Q25CIS+	Learning calculus using GeoGebra as a tool makes knowledge of concepts and procedures/steps to be easily understood.		.591
Q30CIS_	GeoGebra is not good tools for mathematics/calculus learning.		.600
Q35CIS+	Learning calculus using GeoGebra as a tool reduces my mental work (cognitive load).		.540
Q40CIS_	Learning calculus with the aid of GeoGebra as a tool cannot		.519

	economize time.			
Q_{45CIS+}	GeoGebra is a valuable tool for calculus learning.			.543
Q_{50CIS}	Using GeoGebra as a tool cannot encourage creative learning environment of calculus.			.400
Q_{4E+}	Mathematics/calculus lessons are fun.	.415		
$Q_{9E\_}$	I do not like mathematics/calculus lessons.		.544	
Q_{14E+}	Universities should have more mathematics/calculus lessons each week.	.513		
$Q_{19E\_}$	Mathematics/calculus lessons bore me.	.472	.525	
Q_{24E+}	Mathematics/calculus is one of the most interesting courses in the university.	.513		
$Q_{29E\_}$	Mathematics/calculus lessons are a waste of time.		.690	
Q_{34E+}	I really enjoy going to classes where mathematics/calculus lessons are presented.	.624		
$Q_{39E\_}$	The material (content) covered		.579	

	in mathematics/calculus lessons is uninteresting.			
Q_{44E+}	I look forward to mathematics/calculus lessons.	.493		
$Q_{49E\_}$	I would enjoy university more if there were no mathematics/calculus lessons.		.552	
Eigen values		8.01	4.14	5.067
Percentage of Variance Explained		0.16 (16.03)	0.083 (8.3)	.101(10.1)
Cronbach's alpha (α) coefficient		.806	.813	.815
Total Cronbach's alpha (α) coefficient		.84		
Total Percentage of Variance Explained		34.43		

Appendix M: Data on Comparison Group and Experimental Group

Table M1: Comparison Group Conceptual Knowledge (CK) Achievement Scores

Code	Pre-test scores (45%)	Post-test scores (45%)	Difference in scores
LMCK1	18	8	-10
LMCK2	8	6	-2
LMCK3	21	7	-14
LMCK4	12	14	2
LMCK5	20	16	-4
LMCK6	12	19	7
LMCK7	13	16	3
LMCK8	12	11	-1
LMCK9	12	8	-4
LMCK10	14	6	-8
LMCK11	16	18	2
LMCK12	19	7	-12
LMCK13	15	10	-5
LMCK14	17	15	-2
LMCK15	11	12	1
LMCK16	24	25	1
LMCK17	15	13	-2
LMCK18	13	10	-3
LMCK19	16	17	1

LMCK20	15	15	0
LMCK21	10	9	-1
LMCK22	9	11	2
LMCK23	14	7	-7
LMCK24	18	17	-1
LMCK25	12	10	-2
LMCK26	8	14	6
LMCK27	13	13	0
LMCK28	11	16	5
LMCK29	11	22	11
LMCK30	11	17	6
LMCK31	21	23	2
LMCK32	13	20	7
LMCK33	9	11	2
LMCK34	7	15	8
LMCK35	19	24	5
LMCK36	10	13	3
LMCK37	19	27	8
LMCK38	13	18	5
LMCK39	15	11	-4
LMCK40	12	19.5	7.5
LMCK42	12	15	3
LMCK42	16	22	6
LMCK43	13	16	3

LMCK44	17	13	-4
LMCK45	10	14	4
LMCK46	15	16	1
LMCK47	21	23	2
LMCK48	14	13	-1
LMCK49	11	8	-3
LMCK50	10	16	6
LMCK51	14	18	4
LMCK52	13	16	3
LMCK53	10	12	2
LMCK54	17	15	-2
LMCK55	9	19	10
LMCK56	21	24.5	3.5
LMCK57	16	18	2
LMCK58	11	12	1
LMCK59	9	17	8
LMCK60	15	20	5
LMCK61	8	12	4
LMCK62	21	26	5
LMCK63	12	13	1
LMCK64	9	12	3
LMCK65	11	11	0
LMCK66	15	22	7
LMCK67	10	10	0

LMCK68	23	31.5	8.5
LMCK69	13	14	1
LMCK70	9	12	3
LMCK71	10	13	3
LMCK72	22	24	2
LMCK73	20	22	2
LMCK74	10	10	0
LMCK75	10	10	0

Table M2: Experimental Group Conceptual Knowledge (CK) Achievement Scores

Code	Pre-test scores (45%)	Post-test scores (45%)	Difference in scores
CMCK1	13	19.5	6.5
CMCK2	18	26.5	8.5
CMCK3	19	44	25
CMCK4	22	45	23
CMCK5	15	39.5	14.5
CMCK6	14	25.5	11.5
CMCK7	20	30.5	10.5
CMCK8	17	34	17
CMCK9	16	44	28
CMCK10	9	27.5	18.5
CMCK11	15	33.5	18.5

CMCK12	11	22.5	11.5
CMCK13	19	34.5	15.5
CMCK14	21	34	13
CMCK15	16	23	7
CMCK16	10	41.5	31.5
CMCK17	13	37	24
CMCK18	14	24	10
CMCK19	21	35	14
CMCK20	18	42	24
CMCK21	12	14	2
CMCK22	17	28	11
CMCK23	18	40	22
CMCK24	11	18	7
CMCK25	9	20	11
CMCK26	19	25.5	6.5
CMCK27	19	43	25
CMCK28	13	39.5	26.5
CMCK29	25	45	20
CMCK30	8	15.5	7.5
CMCK31	16	36	20
CMCK32	19	42.5	23.5
CMCK33	13	25.5	12.5
CMCK34	13	28	15
CMCK35	11	18	7

CMCK36	5	19.5	14.5
CMCK37	22	44	22
CMCK38	23	42	19
CMCK39	11	13	2
CMCK40	11	18	7
CMCK41	7	24	17
CMCK42	7	23	16
CMCK43	15	36.5	21.5
CMCK44	12	21	9
CMCK45	11	13	2
CMCK46	14	42	28
CMCK47	15	36.5	21.5
CMCK48	9	20	11
CMCK49	20	38	18
CMCK50	5	24.5	19.5
CMCK51	6	29	23
CMCK52	14	37.5	23.5
CMCK53	7	19	12
CMCK54	14	22	8
CMCK55	14	30	16
CMCK56	10	16	6
CMCK57	16	19.5	3.5
CMCK58	6	29	23
CMCK59	12	29.5	17.5

CMCK60	18	33.5	15.5
CMCK61	15	28.5	13.5
CMCK62	10	28	18
CMCK63	10	32	22
CMCK64	17	31.5	14.5
CMCK65	9	28	19
CMCK66	15	31	16
CMCK67	10	33.5	23.5
CMCK68	15	29	14
CMCK69	10	34	24
CMCK70	17	42.5	25.5
CMCK71	19	32.5	13.5
CMCK72	11	22	11
CMCK73	17	30	13
CMCK74	8	13	5
CMCK75	12	14	2

Table M3: Comparison Group Procedural Knowledge (PK) Achievement Scores

Code	Pre-test scores (28%)	Post-test scores (28%)	Difference in scores
LMPK1	10	5	-5
LMPK2	5	6	1
LMPK3	7	20	13

LMPK4	5	7	2
LMPK5	10	6	-4
LMPK6	9	18	9
LMPK7	9	10	1
LMPK8	9	25	16
LMPK9	12	17	5
LMPK10	4	13	9
LMPK11	10	11	1
LMPK12	8	27	19
LMPK13	8	19	11
LMPK14	8	21	13
LMPK15	5	9	4
LMPK16	15	20	5
LMPK17	7	11	4
LMPK18	9	11	2
LMPK19	12	28	16
LMPK20	9	8	-1
LMPK21	9	13	4
LMPK22	9	17	8
LMPK23	7	15	8
LMPK24	8	17	9
LMPK25	5	13	8
LMPK26	6	5	-1
LMPK27	8	8	0

LMPK28	6	10	4
LMPK29	5	5	0
LMPK30	7	11	4
LMPK31	8	8	0
LMPK32	6	14	8
LMPK33	6	6	0
LMPK34	9	5	-4
LMPK35	6	10	4
LMPK36	5	7	2
LMPK37	5	10	5
LMPK38	5	5	0
LMPK39	6	8	2
LMPK40	9	14	5
LMPK41	7	10	3
LMPK42	11	17	6
LMPK43	9	7	-2
LMPK44	12	8	-4
LMPK45	5	7	2
LMPK46	7	5	-2
LMPK47	8	9	1
LMPK48	4	9	5
LMPK49	4	6	2
LMPK50	8	12	4
LMPK51	6	8	2

LMPK52	9	11	2
LMPK53	5	5	0
LMPK54	9	8	-1
LMPK55	10	7	-3
LMPK56	4	2	-2
LMPK57	8	10	2
LMPK58	9	10	1
LMPK59	5	5	0
LMPK60	16	11	-5
LMPK61	8	6	-2
LMPK62	10	10	0
LMPK63	1	3	2
LMPK64	6	2	-4
LMPK65	7	10	3
LMPK66	13	7	-6
LMPK67	8	9	1
LMPK68	9	16	7
LMPK69	7	8	1
LMPK70	5	6	1
LMPK71	10	5	-5
LMPK72	8	10	2
LMPK73	4	9	5
LMPK74	4	6	2
LMPK75	6	7	1

Table M4: Experimental Group Procedural Knowledge (PK) Achievement Scores

Code	Pre-test scores (28%)	Post-test scores (28%)	Difference in Scores
CMPK1	4	9	5
CMPK2	8	12	4
CMPK3	6	21	15
CMPK4	7	21	14
CMPK5	6	4	-2
CMPK6	8	17.5	9.5
CMPK7	7	18	11
CMPK8	9	10	1
CMPK9	11	20	9
CMPK10	6	15	9
CMPK11	8	17	9
CMPK12	6	8	2
CMPK13	6	22	16
CMPK14	10	24	14
CMPK15	9	4	-5
CMPK16	11	25	14
CMPK17	6	13	7
CMPK18	8	8	0

CMPK19	13	24	11
CMPK20	8	16	8
CMPK21	5	2	-3
CMPK22	10	6	-4
CMPK23	12	21	9
CMPK24	6	10	4
CMPK25	8	14	6
CMPK26	4	6	2
CMPK27	9	22	13
CMPK28	5	20	15
CMPK29	8	16	8
CMPK30	10	3	-7
CMPK31	8	24	16
CMPK32	10	20	10
CMPK33	4	21.5	17.5
CMPK34	8	13.5	5.5
CMPK35	7	6	-1
CMPK36	4	7	3
CMPK37	13	23	10
CMPK38	6	21	15
CMPK39	4	5	1
CMPK40	10	1	-9
CMPK41	7	6	-1
CMPK42	6	13	7

CMPK43	10	24	14
CMPK44	7	10	3
CMPK45	6	10	4
CMPK46	14	23	9
CMPPK47	14	17	3
CMPK48	7	7	0
CMPK49	10	18	8
CMPK50	8	6	-2
CMPK51	6	6	0
CMPK52	8	23	15
CMPK53	7	4	-3
CMPK54	7	11	4
CMPK55	4	10	6
CMPK56	10	9	-1
CMPK57	10	17	7
CMPK58	6	6	0
CMPK59	10	17	7
CMPK60	14	19	5
CMPK61	5	9	4
CMPK62	7	9	2
CMPK63	10	10	0
CMPK64	7	15	8
CMPK65	7	11	4
CMPK66	9	8	-1

CMPK67	6	18	12
CMPK68	7	8	1
CMPK69	5	15	10
CMPK70	10	23	13
CMPK71	7	4	-3
CMPK72	4	10	6
CMPK73	5	10	5
CMPK74	8	4	-4
CMPK75	3	6	3

Table M5: Comparison Group Content Knowledge (COK) Achievement Scores

Code	Pre-test scores (100%)	Post-test scores (100%)	Difference in Scores
LMCOK1	31	17	-14
LMCOK2	14	15	1
LMCOK3	34.5	31	-3.5
LMCOK4	21.5	25	4.5
LMCOK5	32	26	-6
LMCOK6	34.5	42	7.5
LMCOK7	23	30	7
LMCOK8	33	40	7
LMCOK9	27	27	0

CMCOK10	18	22	4
LMCOK11	26.5	33	6.5
LMCOK12	35.5	36	0.5
LMCOK13	27	32	5
LMCOK14	33	38	5
LMCOK15	17	22	5
LMCOK16	46.5	50	3.5
LMCOK17	29	27	-2
LMCOK18	25	30	5
LMCOK19	41	49	8
LMCOK20	27.5	27	-.5
LMCOK21	22	26	4
LMCOK22	24	29	5
LMCOK23	27	27	0
LMCOK24	32	36	4
LMCOK25	20	26	6
LMCOK26	15	21	6
LMCOK27	28	28	0
LMCOK28	29	36	7
LMCOK29	21	37	16
LMCOK30	30	35	5
LMCOK31	40	43	2
LMCOK32	21	52	31
LMCOK33	20	22	2

LMCOK34	24	24	0
LMCOK35	37	41	4
LMCOK36	26	28	2
LMCOK37	32	49	17
LMCOK38	26	31	5
LMCOK39	25	30	5
LMCOK40	34	46	12
LMCOK41	31	36	5
LMCOK42	38	56	18
LMCOK43	32	32	0
LMCOK44	36	33	-3
LMCOK45	27	30	3
LMCOK46	29	31	2
LMCOK47	36	36	0
LMCOK48	27	29	2
LMCOK49	21	24	3
LMCOK50	23	36	13
LMCOK51	29	31	2
LMCOK52	29	30	1
LMCOK53	31	36	5
LMCOK54	36	33.5	-2.5
LMCOK55	36	32	-4
LMCOK56	31	37.5	6.5
LMCOK57	36	48	12

LMCOK58	32	35	3
LMCOK59	22	28	6
LMCOK60	41	51	10
LMCOK61	29	32.5	3.5
LMCOK62	39	43	4
LMCOK63	21	21	0
LMCOK64	17	27	10
LMCOK65	29	29.5	.5
LMCOK66	35	34.5	-.5
LMCOK67	24	31	7
LMCOK68	41	64.5	23.5
LMCOK69	27	28	1
LMCOK70	21	23.5	2.5
LMCOK71	32	39	7
LMCOK72	32	40	8
LMCOK73	36.5	37	.5
LMCOK74	23	23	0
LMCOK75	20	23	3

Table M6: Experimental Group Content Knowledge (COK) Achievement Scores

Code	Pre-test scores (100%)	Post-test scores (100%)	Difference in Scores
CMCOK1	19	38.5	19.5

CMCOK2	38	50.5	12.5
CMCOK3	34.3	87	52.7
CMCOK4	46.3	91.5	57.2
CMCOK5	25	65.5	40.5
CMCOK6	26	63	37
CMCOK7	38.5	67.5	29
CMCOK8	36	60	24
CMCOK9	37	87.5	50.5
CMCOK10	23.3	55.5	32.2
CMCOK11	27	69	42
CMCOK12	28	43	15
CMCOK13	28.3	71.5	43.2
CMCOK14	32.6	83.8	51.2
CMCOK15	31.3	39	7.7
CMCOK16	36.9	92.5	55.6
CMCOK17	32.8	75	42.2
CMCOK18	25	39	14
CMCOK19	41	65	24
CMCOK20	35.5	77	41.5
CMCOK21	19	24	5
CMCOK22	32.4	41	8.6
CMCOK23	41	76	35
CMCOK24	24	42	18
CMCOK25	24	46	22

CMCOK26	24.5	32.5	8
CMCOK27	30.3	86.5	56.2
CMCOK28	23.5	79	55.5
CMCOK29	38.5	85.5	47
CMCOK30	22	26	4
CMCOK31	27.6	79	51.4
CMCOK32	41.5	84	42.5
CMCOK33	32.4	64.5	32.1
CMCOK34	27.5	59.5	32
CMCOK35	23.3	33	9.7
CMCOK36	13.3	36.5	23.2
CMCOK37	46.4	91	44.6
CMCOK38	32	85	53
CMCOK39	16	22	6
CMCOK40	28	30	2
CMCOK41	17.3	36	18.7
CMCOK42	15.9	51	35.1
CMCOK43	28	79	51
CMCOK44	23.3	41.8	18.5
CMCOK45	24	31	7
CMCOK46	37.9	85	47.1
CMCOK47	34	75.5	41.5
CMCOK48	21	39.8	18.8
CMCOK49	31.4	69.8	38.4

CMCOK50	21.3	36	14.7
CMCOK51	22	43	21
CMCOK52	27	81.5	54.5
CMCOK53	14	35	21
CMCOK54	23	48	25
CMCOK55	25.1	43	17.9
CMCOK56	27.3	40.3	13
CMCOK57	38.1	67.3	29.2
CMCOK58	14	45	31
CMCOK59	24.3	56.3	32
CMCOK60	34	69	35
CMCOK61	24	47.8	23.8
CMCOK62	23.5	53.5	30
CMCOK63	24	54	30
CMCOK64	32.6	62.5	29.9
CMCOK65	20.3	49.8	29.5
CMCOK66	31	43.3	12.3
CMCOK67	19	65.3	46.3
CMCOK68	28	46	18
CMCOK69	22.8	64.5	41.7
CMCOK70	40	86.5	46.5
CMCOK71	32.3	40.3	8
CMCOK72	18	34	16
CMCOK73	30	53	23

CMCOK74	19	24	5
CMCOK75	21.5	31	9.5

Appendix N: Turnitin Originality Report

Document Viewer

Turnitin Originality Report

Processed on: 06-Nov-2018 15:10 SAST

ID: 1033916533

Word Count: 63497

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TF1 By Sirak Yimer

Similarity Index	Similarity by Source	
16%	Internet Sources:	13%
	Publications:	8%
	Student Papers:	8%

Appendix O: Language Editor's Certificate

TO WHOM IT MAY CONCERN

This is to confirm that John James Barton has edited the thesis:

Jigsaw Co-operative Learning Strategy Integrated with GeoGebra, A Tool for Content Knowledge Development of Intermediate Calculus: First Year Undergraduate Learners of Two Public Universities of Ethiopia

by

Sirak Tsegaye Yimer

The onus is, however, on the author to make the changes suggested and to attend to the language editor's queries.

Please direct any enquiries regarding the editing of this article to me.

Kind regards,

J J Barton Ph.D.

John James Barton

2019-01-10

From: Dawit Negeri Urgessa (M.A in Teaching English as Foreign Language)

Sent: 26 November 2019

To: Sirak Tsegaye Yimer

Subject: Certificate for Language Editing and Proof Reading

This is to certify that Dawit Negeri Urgessa edited and proof read the thesis entitled: Jigsaw Co-operative Learning Strategy Integrated with GeoGebra: A Tool for Content Knowledge Development of Intermediate Calculus for First Year Undergraduate Learners of Two Public Universities in Ethiopia. I found the grammar and sentence structure look good and meet the standard required for PhD thesis.

I observed an interesting finding in the thesis that, the use of jigsaw co-operative learning strategy integrated with GeoGebra improved first year undergraduate learners' conceptual and content knowledge development of calculus. This learning strategy also positively changed learners' attitude towards calculus. The work will contribute a lot to academic and scientific research work if it is published in peer-reviewed journals.

Best regards,

Dawit Negeri Urgessa (M.A in Teaching English as Foreign Language)

Appendix P: Curriculum Vitae

Curriculum Vitae: Sirak Tsegaye Yimer
P. O. BOX: 19, Ambo University E-Mail: sirakbeliyu@gmail.com or AU/A/00427@wie.et
Personal Data
Surname: Yimer **First Names:** Sirak Tsegaye **Date of Birth:** 20 January 1972 **Nationality:** Ethiopian **Languages:** English, Amharic, Afan Oromo **Home/Work Address:** Ambo University, Ambo, Ethiopia **Mobile Phone Number**: +251-911085149

Educational Background

Name of Institution	Degree	Date of Completion
Addis Ababa University	MSc in Mathematics	24 July 2009
Kotebe College of Teacher Education	B.E.D in Mathematics	25 September 1993
Arsi Negelle Senior Secondary High School	Certificate (Grade 11 and 12)	8 July 1989
Shashemene Comprehensive Secondary High School	Certificate (Grade 9 and 10)	8 July 1987
Kerara Edu Junior Secondary School	Certificate (Grade 7 and 8)	8 July 1985
Tigil Fire Elementary School	Certificate (Grade 1, 2, 3, 4, 5, and 6)	8 July 1983

Work Experience

Job Title	Employer	Town	Region	Month/Year
Instructor	Ambo University	Ambo	Oromia	February 2010 to date
Instructor	Hawassa College of Teachers Education	Hawassa	SNNP	February 2009-January 2010
Senior Instructor	Alage T.V.E.T College	Alage	Oromia and SNNP	October 2004-January 2009
Teacher	Hirna Senior Secondary School	Hirna	Oromia	September 1994-June 2003

Community Involvement

Title	Provider	Date of Issues
Community Service, Practice Based Tutorial Program given for high school students	Ambo University	December-May 21, 2017 22 November 2014-11January 2015 8 March-4 May 2014 16 February -21 April 2013

Training

Title	Providers	Date of Issue

Higher Diploma Program	Dilla University	6 July 2010
MatLab and C++ Program Research Methods in Natural Science and Data Analysis using STATA software application	Ambo University	21 November 2011 March, 2019
Ms-Win, MS-Word, MS-Excel and Access	COMPTEC VISION	9 December 2005
Publication		
Yimer, S. T., & Feza, N. N. (2019). Learners' Conceptual Knowledge Development and Attitudinal Change towards Calculus Using Jigsaw Co-operative Learning Strategy Integrated with GeoGebra. *International Electronic Journal of Mathematics Education*, *15*(1), 1-26. https://doi.org/10.29333/iejme/5936		