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Instructional Model and the Application of Biotechnology Knowledge (Critical Thinking in Biotechnology) by High School Students in the Anglophone Subsection of Education in Cameroon

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ABSTRACT

This study was a pretest and posttest experimental research design which set out to investigate the impact of an Instructional model (Ekwale Ada's Instructional Model) on the application of biotechnology knowledge by high school students in the Anglophone Subsection of Education in Cameroon. That is to investigate whether students taught with the Ekwale Ada's Instructional Model for Biotechnology Knowledge Application exhibit a higher level of critical thinking in biotechnology than students who were taught without the model (traditional methods of teaching). The Ekwale Ada's Instructional Model for Biotechnology Knowledge Application was an instructional package which integrated Inquiry based learning (Hands on), collaborative learning (Cooperative learning), Demonstrations, increase in the length of time learners are engaged in activities, Scaffolding and Remediation. The target population was upper sixth science students in the Anglophone Subsection of Education in the North West Region, South West Region, and some displaced upper sixth science students from North West and South West Regions into the Littoral Region for the 2018/2019 academic year.

The researcher constructed a Biotechnology Application Test (BAT) in the form of a pretest and a post test. These tests contained three sections: An MCQ section, a short answer section and a section in which practical activities were carried out.

KEYWORDS: *Instructional Model, Biotechnology Application, Biotechnology Knowledge, Critical thinking in Biotechnology, Science High School, Students Anglophone Subsection, Education, Cameroon*

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The indicator of biotechnology knowledge application was critical thinking in biotechnology. For critical thinking, the researcher created an inventory for the respondent to go through which covered problem identification (knowledge); understanding the situation of the problem (comprehension); gathering of facts to solve the problem (application); discussions of the causes of the problem (analysis); a decision on how to solve the problem (synthesis) and resolution of the problem (take action). The researcher then created a five point inventory scale to grade the critical thinking activities which ranged from excellent (5 marks); Good (4 marks); average (3 marks); below average (2 marks); and poor (1mark).

The students who were taught with the Ekwale Ada's Instructional Model for biotechnology knowledge Application (experimental group) scored higher in critical thinking than those who were taught with traditional methods (control group) with a calculated independent t test value of 67.02 for the experimental group and 1.05 for the control group with a critical t-value of 1.96 at 0.05 level of significance with 70 degrees of freedom.

The sample of the study was 72 upper sixth science students who offer biology (36 students for the experimental group and 36 students for the control group). Out of the 36 students from both the experimental and control groups, 18 were males and 18 were females making a total of 36 males and 36 females for the whole experiment. The sample was obtained from one government school, one mission school and one lay private school in each region. In the North West Region, 24 students were sampled 12 males and 12 females (08 from GBHS Bayelle, 08 from St Paul High School Nkwen and 08 from St Michael's High School). 24 students were sampled in the South West Region 12 males and 12 females (08 from GHS Buea, 08 from Baptist High School Buea and 08 from Frankfils Comprehensive High School Buea). In the Littoral Region, 24 displaced students 12 from the North West Region and 12 from the South West Region were sampled 12 males and 12 females (08 from GBHS Bonaberi, 08 from PHS Douala and 08 from Mother Theresa College Bonaberi Douala). Therefore the sample was 72 individuals (36 for the experimental group and 36 for the control group).

The study was an experimental study in which a teacher made pretest was administered to both the experimental and control groups; the students of the experimental group were taught with the Ekwale Ada's Instructional Model for biotechnology knowledge application (treatment) while those of the control group were taught without the model (traditional methods of teaching). After the treatment, a teacher made post test was administered both to the experimental and the control groups. The experimental group was located in GHS Mamfe while the control group was located in Progressive Comprehensive High School Bamenda.

One non-directional hypothesis was stated in both the null and alternate forms. The null hypothesis was:

1. There was no significant difference in critical thinking skills in biotechnology between students taught with the Ekwale Ada's model and those who were taught without the model.

The data for the pre-test and the post-test for the experimental group and control group were collected in the form of scores. The independent t test was used to find out the difference in means of the scores of the pretest of the experimental group and the control group and the difference in mean of the scores of the posttest of the experimental group and the control group. The null hypothesis was rejected and the alternate hypothesis was retained. The hypothesis indicated that there was a significant difference in the means of the post-test of the experimental group and the control group.

The result of the study was:

1. There was a significant difference in critical thinking skills in biotechnology between students taught with the Ekwale Ada's model and those who were taught without the model. The experimental group on whom the treatment was administered performed significantly better (67.02) than the control group (1.05) on whom the treatment was not administered.

INRODUCTION

In a world that is increasingly becoming complex, success does not only depend on knowledge acquisition but on knowledge application. If knowledge is only gained and is not used for the good of humans, then all the resources used for the acquisition of that knowledge are wasted. Knowledge can only be applied when higher order skills such as critical thinking, problem solving and creativity are exhibited by learners. Most developing Countries including Cameroon have students and graduates who are turgid with head knowledge but almost impossible to apply the knowledge acquired to solve problems which would contribute to the advancement of their societies. Application of knowledge gained from schools is very important if societal problems must be solved. Drucker, (1994) stated that, "how well an individual, an organization, an industry, a Country, does in acquiring and applying knowledge will become the key competitive factor. There will be no "poor" Countries but there will be ignorant Countries". To Drucker, rich Countries are those who apply knowledge to solve societal problems while Countries which do not apply knowledge to solve societal problems are designated ignorant countries.

According to Endeley and Kintati (2017), the high unemployment among secondary school leavers in Cameroon poses fundamental questions about the skills students are impacted with in secondary schools through instruction and their relevance to the job market. This is to say that, higher order skills such as critical thinking, problem solving and creativity can only be acquired by students through quality instruction. Higher order skills such as critical thinking can also be acquired by students through well-structured school curriculum. Agborbechem (2006) was in line with this when he postulated that, the curriculum of Cameroon schools should be structured in such a way that, school leavers would acquire all the skills that will make them fit into the Cameroon labour and industrial market. It is only when learner centred methods of teaching are used that higher order skills such as critical thinking, problem solving and creativity are evoked in learners and it is only with the endowment of these skills that learners are able to apply acquired knowledge to solve societal problems. The absence of these higher order skills has a negative impact on knowledge application and makes the school leavers unfit for the job market. Tanyi (2016) created a student adjustment inventory manual which could be used to conquer the barriers of inclusive classrooms. When inclusion is practised in classrooms, and the barriers of these classrooms are eradicated, the individual differences among the learners would be taken care of and the learners would be able to exhibit higher order skills such critical thinking and problem solving and creativity which will help them to compete in the national and international labour market.

In recent years, a key concern for policy makers had been how to ensure that, the wealth of knowledge generated within schools can be transferred to industry. This would enable society in general and local businesses in particular to benefit from the scientific and technological expertise of schools. As Justman and Teubal (1991) and Bell and Pavitt (1993) explain, technology is central to the development process and long term structural change is driven by technology. Any Country that wishes to be developed must first make sure her learners apply science and technology knowledge to solve societal problems because that is what development entails. Freeman (1987), Camison and Fores (2010), Etzkowitz; Ranga; Benner; Guaranys; Maculan and Kneller; (2008), focus broadly on facilitating the transfer of knowledge from the university to industry. According to Mwamadzingo (1995), the science-push theory recognizes science and technology as independent determinants of industrial innovations leading to economic growth. These innovations cannot take place in the absence of higher order skills. According to (Vijayaratnam, 2012), we need "thinking" students who can incessantly respond to real-world demands by the use of higher order skills. Thinking students would be students who have acquired higher order skills such as critical thinking, problem solving and creativity and put these skills to use inorder to develop their countries. According to Mosk (2001), Countries like Japan and Korea, have become industrialized due to a high level of applicability of science and technology knowledge by their students and graduates.

Education is meant to develop the individual intellectually (cognitive domain), morally (affective domain) and psychomotorly inorder to equip him or her to function effectively in the society. Each time all the domains of learning are exploited, individuals will develop critical thinking, problem solving and creativity skills and therefore participate with increased capacity in the development of their Country. Ahidjo (1967) was in line with this when he posited that, the end of education is not to instruct people for the pleasure of instructing them; it is to enable them to participate with increased output capacity in the development of their country. Similarly, Ukeje (1966) stated that it is the role of education is to promote participation in social improvement; to influence people's ways of doing things; to be in accord with the changing times; to improve standards of living; show ways of preventing sickness and practicing sound habits of health, sanitation and nutrition. Standards of living cannot be improved if knowledge gained in schools is not applied. How can the products of schools participate with increased output capacity in the development of their Country when they lack higher order skills such as critical thinking, problem solving and creativity? There are many factors that affect knowledge application and quality instruction which impacts the learners with higher order thinking skills might be one of the factors. Without collaborative learning, inquiry based learning, engagement of students in group learning activities, increase in the length of time learners are engaged in the activities, scaffolding and remediation, higher order skills such as critical thinking, problem solving and creativity cannot be developed in students.

BACK GROUND OF THE STUDY

Higher order skills such as critical thinking, problem solving and creativity are essential ingredients of technological advancement in any society since they lead to innovation. Quality instruction elicits higher order skills. According to Eggen and Kauchak (2001), an instructional model incorporates a variety of teaching strategies and therefore causes instruction to be effective. Instructional models always enhance students' higher order skills such as critical thinking, problem solving and creativity. Vong & Kaewurai (2016); Yusuf & Nuradeen (2012); Munyaradzi (2013); Vong & Kaewurai (2017); Garrison (1992); Henri (1991); Alazzi (2008); Collins, Brown & Holum (1991); Tiruneh, Verburgh & Elen (2014); Reed (1998); Goyak (2009); Foster & Lemus (2015); Ford (2014); Gokhalo (1995); Adams (2001); Baylor (2002); Walker (2003); Barel (2006); Walker (2000); Zion & Sadeh (2007); Endeley & Kintati (2017); Duckworth (1990); Creemers & Kyriakides (2006); Kreizberg Kreizberg (2009); Guleker (2015); Marzano (2001); Glaser (2012); Marzano (2012) and Friedel, Irani, Rudd, Gallo, Eckhardt & Ricketts (2008) were in line with the fact that instructional models enhance critical thinking in learners.

Inquiry based learning (Hands on learning) enhances critical thinking in learners. Kazempour (2013); Gokhalo (1995); Kara (2012); Spektor-Levy (2004); Grasha (1996); Tambo (2012); Schwartz (2012); Marx, Blumer Field, Krajcik, Fishman, Soloway, Geier and Tal (2004) and Marx, Blumerfield, Krajeik, Fishmann, Geier & Tal (2004) are in congruence with the idea that Inquiry based learning (Hands on learning) enhances critical thinking in learners.

Cooperative Learning (Collaborative Learning) enhances critical thinking in learners. Cooper (1995); Gupta (2005); Goyak (2009); Fennell (1992); Sofroniou & Poutos (2016); Dee Castle (2014); Adenle (2005); Okoro (1993); Marx, Blumerfield, Krajcik, Fishman & Tal (2004); Rodriguez, Florez & Barreto (2014); Grasha (1996); Ashwin (2009); Wenger (1998); Hemlo-Silver, Duncan and Chinn (2007); Freeman et al (2004); Hake (1998); Springer, Stanne & Donovan (1999); Lyman (1981); Michaelsen, Knight; & Fink (2004); Astin (1993); Berger & Milem (1999); Chickering & Gamso (1987); Goodsell & Mayer (1992); Kuh (1995); Kuh et al (2005); Kuh & Vesper (1997); Pace (1995); Pascarella & Terenzini (1991); Loeser (2008); Brophy (1987); Rowntree (1981); Habeshaw (1997); Michaelsen, Knight & Fink (2004); Pascarella & Terenzini (2005); Marzano (2001); Lin (2006) and Loeser (2008) postulated that, Cooperative Learning (Collaborative Learning) enhances critical thinking in learners.

Demonstrations enhance critical thinking. Eley & Norton (2004); Doise (1975); Valiant & Euler (1982); Adenle & Uwameiye (2012) and Hodson (1990) were in line with the fact that demonstrations enhance critical thinking.

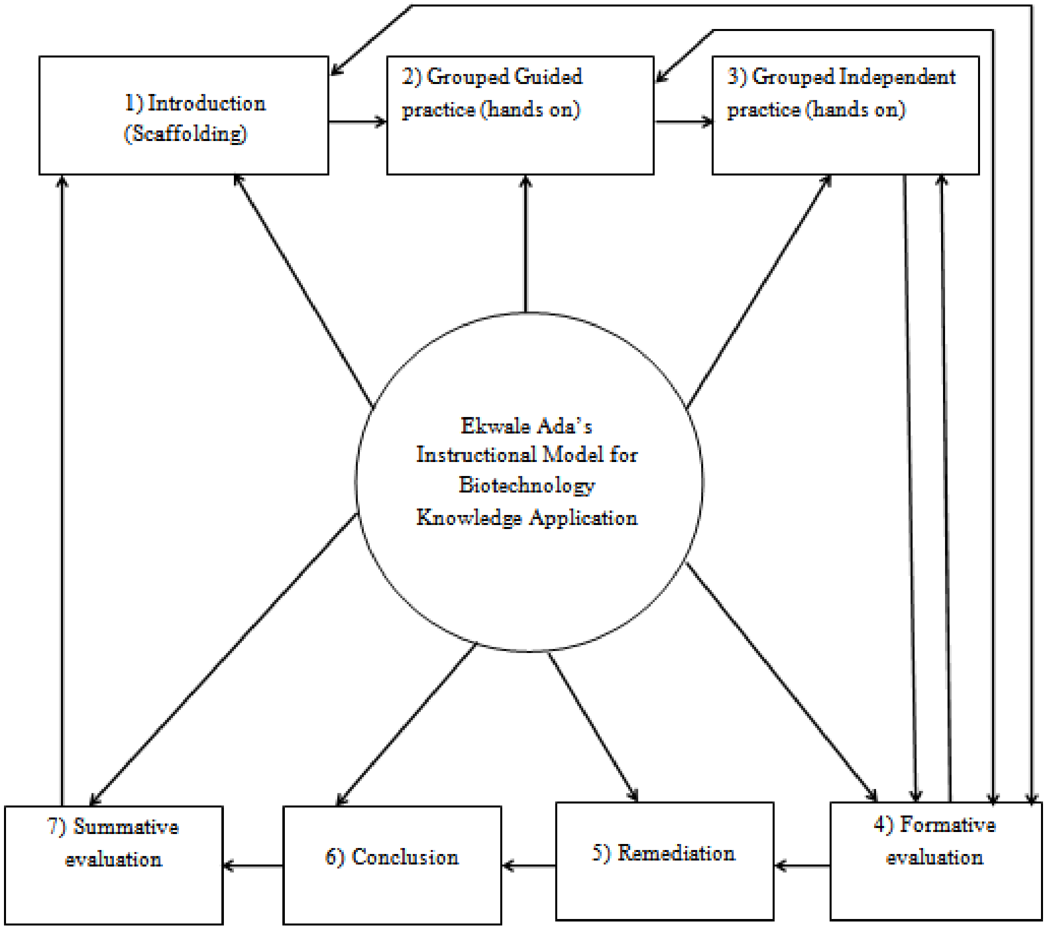
The length of time learners are engaged in activities enhances critical thinking. Frederick et al (2004); Klem & Connel (2004); Putman et al (2013) and Kozloff (2002); John Carroll (1963); Bloom (1976); Ellis & Worthington (1994); Olufumilaya (2014); Slavin (1994); Connel (2004); Hake (1998); Frederick & Walberg (1980); Karweit (1989); Stephenson & Stigler (1992); Springer et al (1999); Klen, Stevenson & Stigler (1992) and Knight & Wood (2005); Adenle (2005) and Okoro (1993) postulated that, the length of time that learners are engaged in activities promotes critical thinking, problem solving and creativity.

Scaffolding fosters critical thinking as postulated by Wass, Harland & Mercer (2011); Braun (2004); Cheong and Cheung (2008); Gelder (2001); Sharma and Hannafin (2004); Kim, Sharma, Land & Furlong (2013); Wilson (2016); Browne (2009); Emerson (2013); Wass & Golding (2014); Wilson (2014); Ram, Meijier & Rrekelmans (2015); Whiley, Witt & Colvin (2017) and Utrianen, Marttunen & Kallio (2017).

Remediation fosters critical thinking as postulated by Abrami, Bernard, Borokhovski and Waddington (2015) in a meta-analysis of 341 research works; Boylan (2012); Darling-Hammond (2019); Abrami (2015); Chikwature (2016); Chikwature & Oyedele (2016).

In 1986, President Ahidjo (Former President of the Republic of Cameroon) created the Institute of Rural Applied Pedagogy (IRAP) in all Regional headquarters in Cameroon which adapted programs that integrated training which combined general knowledge with practical work in agriculture, animal husbandry, poultry, bricklaying, carpentry, etc. This was an endeavour to make sure the knowledge gained in school was applied. Today, these institutes are not functioning well and some are almost abandoned. How then can the products of schools participate with increased output capacity in the development of their Country when students are turgid with head knowledge but cannot apply the knowledge? This lack of knowledge application is due to the absence of higher order skills such as critical thinking, problem solving and Creativity.

Figure 1.0: The Ekwale Ada's Instructional Model for Biotechnology Knowledge Application



The Ekwale Ada's Instructional Model for Biotechnology Knowledge Application

The stages (steps) of the model and their explanations were outlined below:

1. Introduction:

Introduction involves the following: Review of theory work (Test prior knowledge; importance of the unit to the life of the learners; goal(s) of the unit; statement of specific objectives in the cognitive, psychomotor and the affective domains from the goals). Review the content under subheadings each subheading covering a particular objective by scaffolding. This was to help the students to have a mastery of what they learnt in biotechnology during the theory classes.

2. Guided practice (hands on with the teacher scaffolding):

The learners in their groups selected a biotechnology problem they wish to solve, thought of a product they wish to produce inorder to solve the problem, stated the recipes/ procedures for the production of the products, designed equipment they feel will help them to produce the product. The teacher provided materials and the equipment which the learners would use for their activities. That is the learners perform the activities with the teacher guiding them (hands on). The learners develop their own step by step procedure for the activities (the learners constructed recipes and procedural guidelines for the production of the products). They manipulate the materials and the locally made equipment to create and thus produce the biotechnology product that would solve the pertinent problem in the society which they anticipated with the guidance of the teacher. They design the labelling containers/packages and state a particular name of the product. The learners worked in groups. The learners made used of inquiry learning, collaboration and demonstrations. The teacher observed the students and gave them guidance by scaffolding where the task seemed difficult and answered the questions posed by the students.

3. Independent practice (hands on without the teacher scaffolding):

The learners in their groups selected another biotechnology problem different from the one above, produced the recipes/ procedures for the production of the products, designed equipment they felt would help them to produce the product. The teacher provided materials and the equipment which the learners would use for their activities. The learners performed the activities without the guidance of the teacher. The learners developed their own step by step procedure for the activities (the learners constructed recipes and procedural guidelines for the production of the products). They manipulated the materials and the locally made equipment to create and thus produce the biotechnology product that will solve the pertinent problem in the society which they had anticipated without the guidance of the teacher. They designed the labelling containers/packages and stated a particular name of the product. The learners worked in groups. The learners made use of inquiry learning, collaboration and demonstrations.

4. Formative Evaluation:

The teacher conducted formative evaluation by asking the students questions. The responses were graded and the data was used as feedback for some corrective mechanisms.

5. **Remediation:**
The teacher used the information from the formative evaluation to scaffold the groups of learners who could not go through their activities and those who were deficient in some of the steps they created.

6. **Conclusion:**
The module was brought to a 'conclusion' and the teacher allowed the learners to recap what they covered in the activities. It was meant to remind the learners about the goal for the instruction.

7. **Summative Evaluation:**
In this evaluation, the teacher administered (BAT) the biotechnology knowledge application test (posttest); scored and graded it. A certificate or attestation of attendance in a biotechnology experiment was issued to each of the participants.

Time frame for the use of the Model:
The time frame for the whole experiment was six weeks. The time frame for administration of the pretest for both the test and questionnaire was one week. The time frame for the model (treatment) was four weeks. The first week of the treatment was used to accomplish step one (introduction which involved scaffolding the students on biotechnology content). The second week of the treatment was used on step two (guided practice hands on). The third week of the treatment was used for step three (Independent practice hands on) and step four (Formative evaluation). The fourth week was used for step five (Remediation) and step six (conclusion). The post test for both the test and the questionnaire was administered for one week. The posttest was the summative evaluation. The pretest covered a time span of one week. The treatment covered a time span of four weeks. The posttest covered a time span of one week. Therefore the whole experiment covered a time span of six weeks.

During the first week of the treatment, the teacher did a review of the theory part of biotechnology by scaffolding students on biotechnology content and assigned the students to groups by random sampling. During the second week of the treatment, the students identify a biotechnology problem in the society and constructed a recipe/procedural guideline for the production of the products and design the equipment to be used on paper. The teacher provided materials and equipment to the students and the students then engaged in the activities by manipulating the materials and the equipment to produce the biotechnology product that will solve the biotechnology problem identified. As this was going on, the teacher gave guidance and scaffolded the students. During the third week of the treatment, the students identified another biotechnology problem in the society and constructed a recipe/procedural guideline for the production of that product and designed the equipment to be used on paper. The teacher provided materials and equipment to the students and the students then engaged in the activities by manipulating the materials and the equipment to produce the biotechnology product that would solve the biotechnology problem identified. As this was going on, the teacher did not give guidance and did not scaffold the students but allowed them to undergo their group activities. As the activities were going on the teacher conducted formative evaluation. During the fourth week of the treatment, the teacher did remediation to groups of students who were in difficulty and concluded the module. The treatment covered a time span of four weeks. The pretest covered a time span of one week and the posttest covered a time span of one week. The posttest was the summative evaluation questions. The pretest and the posttest were marked by the researcher with the help of three research assistants. The participants were given certificates designed by the researcher.

PROBLEM STATEMENT
Critical thinking skills and other higher orders skills which are very important in knowledge application are absent in science high school students in Cameroon due to lack of quality instruction. Since the Cameroon GCE BOARD included biotechnology as part of the advanced level biology syllabus in 2003, the number of students who answer questions on biotechnology and score a pass mark had been low as compared to the numbers who answer questions and score a pass in other parts of biology. The advanced level subject report for GCE general subjects from 2004 to 2019 reveal that, the parts of advanced level biology questions which deal with application of biotechnology knowledge were poorly handled as evidence of the very low scores by students. In the biotechnology questions, the students measured up a bit in parts that do not deal with application of biotechnology knowledge while 95% of the candidates scored 0 in parts of questions that deal with application of biotechnology knowledge. In the 2017 GCE, the score for the biotechnology question slightly improved but the same problem came up in that, the candidates still performed extremely poor in the section of the question that dealt with application of biotechnology which is a pertinent problem that has been occurring. As a teacher of advanced level Biology since 1999 and a marker of advanced level biology since 2001, I had observed that students perform poorly in the section of biotechnology that dealt with knowledge application. This might be due to the absence of higher order skills such as critical thinking, problem solving and creativity. Critical thinking, problem solving and creativity skills can only be acquired by learners when the instruction is of quality and when good teaching strategies are used.

The programme for advanced level biology in Anglophone Cameroon includes short term projects in which students are supposed to carry out production of yoghurt, afofop, corn beer, baking etc. but they only write small essays about the products without practically producing them which rules out critical thinking, problem solving and creativity. After school, they would not be able to invent/create new biotechnology products. Therefore, biotechnology knowledge would be accumulated at this level of Education so that application would be done in the University. With this schedule, application of biotechnology knowledge cannot occur as one big magic step at the tertiary level of education. It should first start in the secondary level so that it can take place with increasing sophistication at the university and other tertiary institutions which is the essence of spiral education. The learners had never used their own critical thinking, problem solving and creativity to invent new products which do not exist, design local equipment for the production of the products, develop procedures for the production of the products, use the equipment and materials in the learners context of existence to produce the products and preserve, parcel and label the products using their knowledge in biotechnology. The teachers had never used learner centred methods of teaching biotechnology syllabus, nor had they integrated learner centred methods of teaching therefore, there had been no promotion of deep learning. This showed that, the level of biotechnology application was low and if nothing was done about it, Cameroon will lag behind the other African Countries in biotechnology knowledge application.

The Competence Based Approach instituted in Secondary Schools by the Cameroon Government to encourage learner centred approach to teaching was slow in gaining grounds as most teachers do not wish to teach using the new syllabus and they do not wish to face the challenges of teaching large numbers of students with learner centred methods of teaching. How then can our learners apply the knowledge acquired from schools? There was therefore a gap between knowledge acquisition in biotechnology on one hand and applicability of this knowledge on the other hand.

THEORIES

Bloom's Theory of Mastery Learning

Benjamin Bloom stated that, the basic task in education is to find strategies which will take individual differences into consideration but which will do so in such a way as to promote the fullest development of the individual. The two main ideas of mastery learning are time and quality instruction which enables learning for all kinds of learners. Benjamin Bloom coined the term "Learning for Mastery" and then later "Mastery Learning" in 1968 and 1971 to describe an educational method in which each student stays with a certain unit of learning material in a process of assessing and correcting until the objectives of that unit are mastered before moving on to the next unit.

This theory is related to this work in that, learners have to be scaffolded by the teacher above their natural aptitudes and attitudes in order for them to gain mastery in the learning and therefore be able to exhibit higher order skills such as creativity, critical thinking and problem solving and thus high levels of knowledge application.

Gagne's Theory on conditions of learning

This theory stipulates that, there are several different types or levels of learning. The significance of these classifications is that, each different type requires different types of instruction. Gagne identifies five major categories of learning: Verbal information (Declarative knowledge); Intellectual skills (concept learning, procedural learning, principle learning and problem solving); Cognitive strategies (Organizing strategies, elaborating strategies, rehearsing strategies and metacognitive strategies); Motor skills (Psychomotor skill learning) and Attitudes (Cognitive, behavioural and affective component). He identified different internal and external conditions which are necessary for each type of learning.

Gagne (1965) identified the mental conditions for learning. These were based on the information processing model of the mental events that occur when adults are presented with various stimuli. Gagne created a nine-step process called the events of instruction, which correlate to and address the conditions of learning. These events of learning are Gain attention (Reception); Inform learners of the objectives (Expectancy); Stimulate recall of prior learning (Retrieval); Present the content (Selective perception); Provide learning guidance (Semantic encoding); Elicit performance (Responding or providing practice); Provide feedback (Reinforcement); Assess performance (Retrieval); Enhance retention and transfer to the job (Generalization).

This theory is related to this work in that, instruction in biotechnology involves: Intellectual skills (concept learning, procedural learning, principle learning and problem solving); Cognitive strategies (Organizing strategies, elaborating strategies, rehearsing strategies and metacognitive strategies) and motor skills (Psychomotor skill learning). The events of learning satisfy or provide the necessary conditions for learning (Gagne, Briggs and Wager, 1992). When the events of learning are followed chronologically, during instruction, learning takes place easily and the knowledge gained can also be applied easily. The ninth event of learning specifically is on how to enhance learning in such a way that will lead to knowledge application or transfer of knowledge to jobs which is highly related to this topic.

Social Constructivist Theory by Vygotsky

Vygotsky was a social constructivist. He theorised that, the most important tool that shapes cognitive functioning is language (Robbins, 2001). His theory also emphasize that knowledge is situated and collaborative (Bearison and Dorval, 2002) and Maynard (2001). That is knowledge is distributed among people and environments which include objects, artefacts, tools, books and the communities in which people live. This shows that knowledge can best be advanced or students understand better through interaction with others in cooperative activities. One of Vygotsky's ideas was the concept of the Zone of Proximal Development (ZPD) which is the range of tasks that are too difficult for children to master alone but can be adequately learnt with the guidance and assistance of a teacher, adults or more skilled children. The lower limit of the ZPD is the level of problem solving reached by the child when he/she is working independently while the upper limit is the level of additional responsibility the child can accept with the assistance of a good instructor and probably quality instruction. Hasse (2001) found out that, social interactions during instruction between the learners and the instructor and between the learners and other learners helps in developing children's cognition. According to this researcher, social interactions might go further to develop the child's affective domain as the child sees his/her instructor and peers behave and the psychomotor domain as he/she sees the instructor and the peers manipulate objects such as materials and equipment.

This theory is relevant to this work in that, as students learn in groups during class activities and during practical activities; they easily learn psychomotor skills, language skills and social skills and can later apply the knowledge gained effectively. This theory is also related to this work in that, instruction has to be of quality inorder to target the upper limit of the ZPD and produce profound learning in the cognitive, affective and psychomotor domains without which learners cannot apply the knowledge acquired.

Bloom et al (1956) Taxonomy of Educational Objectives

Work on the cognitive domain was completed in the 1950s and is commonly referred to as Bloom's Taxonomy of the Cognitive Domain (Bloom, Englehart, Furst, Hill, &

Krathwohl, 1956). Others have developed taxonomies for the affective and the psychomotor domains. The major idea of the taxonomy is that what educators want students to know (encompassed in statements of educational objectives) can be arranged in a hierarchy from less to more complex. The levels are understood to be successive, so that one level must be mastered before the next level can be reached. The original levels by Bloom et al. (1956) were ordered as follows: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation.

Anderson and Krathwohl (2001) and Krathwohl (2002) revised Bloom's taxonomy to fit the more outcome-focused modern education objectives, including switching the names of the levels from nouns to active verbs, and reversing the order of the highest two levels. The lowest-order level (Knowledge) became **remembering**, in which the student is asked to recall or remember information. Comprehension became **Understanding**, in which the student would explain or describe concepts. Application became **Applying**, or using the information in some new way, such as choosing, writing, or interpreting. Analysis was revised to become **Analyzing**, requiring the student to differentiate between different components or relationships, demonstrating the ability to compare and contrast.

This theory is related to this research in that, biotechnology knowledge can be learnt cognitively by the learners being able to store large amounts of knowledge in their long term memory. The learners learn psychomotorly by being involved in class and practical activities in which they manipulate materials and equipment. The learners learn affectively by developing interest in the subject especially during collaborative activities. In this case, the learners are holistically trained and can therefore apply the knowledge appropriately. The levels of Bloom's taxonomy involved in this study are two of the simple cognitive levels which are knowledge and comprehension and three of the complex levels which are application, synthesis and evaluation.

Theory of Critical thinking & problem solving:
Garrison (1992) developed a theory of critical thinking as a problem solving process in five stages: Problem identification; problem definition; Problem exploration; Problem applicability and Problem integration. These five steps are explained by Henri (1991) as critical reasoning skills shown in the table below:

Table 1.0: The five Staged theory of Critical thinking & problem solving

Garrison's CT stages	Henri's critical reasoning skills
1. Problem identification a triggering event arouses interest in a problem	Elementary clarification observing or studying a problem, identifying its elements, observing their linkages
2. Problem definition define problem boundaries, ends and means	In-depth clarification analysing a problem to understand its underlying values, beliefs and assumptions
3. Problem exploration ability to see to the heart of problem based on deep understanding of situation	Inference admitting or proposing an idea based on links to admittedly true propositions
4. Problem applicability evaluation of alternative solutions and new ideas	Judgement making decisions, evaluations and criticisms
5. Problem integration acting upon understanding to validate knowledge	Strategies for application of solution following on choice or decision

Robert J Sternberg's (1998) Triarchic Theory of Human Intelligence
According to this theory, creativity is a balance among three forms of thinking which are:
1. **Analytical thinking:** It involves critique, judge; compare/contrast; evaluate and assess.
2. **Creative thinking:** It involves assess, discover, imagine, suppose and predict.
3. **Practical thinking:** It involves every day problem solving.

Howard Gardner's (1983) 8 intelligences
According to Howard Gardner, intelligence can be seen in the following specific areas: Linguistic intelligence; Logic/mathematical intelligence; Musical intelligence; Spatial intelligence; Bodily/Kinaesthetic intelligence; Interpersonal intelligence; Intrapersonal intelligence; Naturalistic intelligence and Existential intelligence (ability to use intuition to understand one's environment).

The theories of critical thinking, problem solving and creativity have an impact on this research work since the indicators of biotechnology knowledge application are critical thinking, problem solving and creativity.

METHODOLOGY
Research Design
The research design that was adopted for this study was the Pretest-Posttest experimental research design. Padidar (2013) defined experimental research design as observation under controlled conditions which is concerned with examination of the effect of the independent variable on the dependent variable where the independent variable is manipulated through treatment or intervention(s), and the effect of those interventions is observed on the dependent variable.

Padidar (2013) defined the pretest-post-test design as the design in which subjects are randomly assigned to either the experimental group or the control group and the effect of the dependent variable on both groups is seen before the treatment (pretest) and later, the treatment is carried out on the experimental group only, and after treatment, observation of the dependant variable is made on both the groups to examine the effect of the manipulation of the independent variable on the dependant variable.

Target Population
The target population of the study consisted of Upper Sixth Science high school students in the North West and South West Regions of Cameroon and the Upper Sixth Science displaced North West and South West students in the Littoral Region in the 2018/2019 academic year.

Sample of the Study
The sample size was 72 upper sixth science students. This was because sample sizes for experimental studies are usually small to enable proper handling of the experiment. The sample of the study was 72 Upper Sixth Science students who offer biology (36 students for the experimental group and 36 students for the control group). Out of the 36 students from both the experimental and control groups, 18 were males and 18 were females making a total of 36 males and 36 females for the whole experiment. The sample was obtained from one government school, one mission school and one lay private school in each region.

Sampling Technique
The sampling method or sampling technique of this study was both the probability sampling and the non-probability sampling. The difference between nonprobability and probability sampling is that nonprobability sampling does not involve random selection and probability sampling does. Probability sampling ensures that all individuals have equal chance of being selected. The nonprobability sampling does not give individuals equal chance of being selected.

For the nonprobability sampling, the purposive sampling was used to select the Government, Mission and Lay Private schools where there were Biology-Chemistry and Food Science Laboratories. This was done so that the food products should be produced in the Food Science Laboratory while the drugs and other products should be produced in the Biology and Chemistry Laboratories.

For the probability sampling, the stratified random sampling was used inorder to select male and female students from Government, Mission and Lay private schools. The sample was made up of 72 students.

Instrumentation
Test
Since the study was experimental and therefore a quantitative study, a pretest was administered to both the experimental group made up of 36 students and the control group was also made up of 36 students. The treatment was given to the experimental group. The post test was administered to both the experimental group and the control group.

The pretest and the posttest were parallel tests which contained three sections each. Section one covered 20 MCQ questions for a time frame of 40 minutes scored for 20 marks. Section two covered short answer essay questions for a time frame of one hour 30 minutes scored for 50 marks. Section three covered application of biotechnology knowledge (practical work) in which the students produced valuable products using the materials and equipment provided for a time frame of four hours scored for 30 marks.

The Ekwale Ada's Inventory for the grading of biotechnology practical activities was developed by the researcher and used to grade the practical part of the test in the laboratory.

Questionnaire
The researcher also developed another inventory which was a questionnaire containing 04 questions two negative and two positive and created its grading system which was used to investigate biotechnology instruction and biotechnology knowledge application.

Method of Data Collection
Tests were administered and data collected through, pretest-posttest. On the first day, section one and two of the pretest were administered on both the experimental group and the control group made up of 36 students each. On the second, third, fourth, fifth and sixth days, section three, was administered. The treatment was given to the experimental group for four school weeks. Then the posttest was administered on the experimental group and the control group for one week after the treatment. A total of six weeks were used for the experiment. Upon arrival at each school, the researcher presented herself to the head of the institution and she was granted access into the school which facilitated the administration of the treatment and the instruments. The experimental group was taught in GHS Mamfe (South West Region). The control group was taught in Progressive Comprehensive High School in Bamenda (North West Region).

Method of Data Analysis
Both descriptive and inferential statistics were used for data analyses. For descriptive statistics, means, standard deviations, bar charts and pie charts were used. For inferential statistics, the Independent t test was used to analyse the data. Before the data were collected through tests, participants were informed of the nature of the study, and reassured of anonymity and confidentiality as such, their names were not mentioned on the test papers.

FINDINGS
Hypothesis Ho: There is no significant difference in critical thinking skills in biotechnology between students taught with the Ekwale Ada's Model and those who were taught without the model.
Ha: There is a significant difference in critical thinking skills between students taught with the Ekwale Ada's model and those who were taught without the model.

DESCRIPTIVE STATISTICS
The descriptive statistics were the means, standard deviations, bar charts and pie charts for the test and the questionnaire administered.

Table2.0: Means and Standard deviations of critical thinking, considering the test administered before the treatment

Test Administered	No. of respondents	No of sections	Mean	Std. Deviation
Critical thinking				
Experimental Group	36	3	77.11	2.92
Control Group	36	3	25.42	3.59

Table 3.0: Means and Standard deviations of critical thinking, considering the test administered after the treatment.

Test Administered	No. of respondents	No of sections	Mean	Std. Deviation
Critical thinking				
Experimental Group	36	3	77.11	2.92
Control Group	36	3	25.42	3.59

Table 4.0: Means and Standard deviations of critical thinking, considering the Questionnaire administered before treatment

Questionnaire Administered	No. of respondents	No of Items	Mean	Std. Deviation
Critical thinking				
Experimental Group	36	4	7.81	2.44
Control Group	36	4	7.36	2.26

Table 5.0: Means and Standard deviations of critical thinking, considering the Questionnaire administered after treatment

Questionnaire Administered	No. of respondents	No of Items	Mean	Std. Deviation
Critical thinking				
Experimental Group	36	4	7.14	2.90
Control Group	36	4	8.83	2.47

Table 6.0 Description of sample according to schools attended in the experimental group

School Attended	Sample	Percentage (%)
Government schools	12	33.333
Mission schools	12	33.333
Lay private school	12	33.333
Total	**36**	**100.0**

Description of Sample Characteristics
Experimental Group

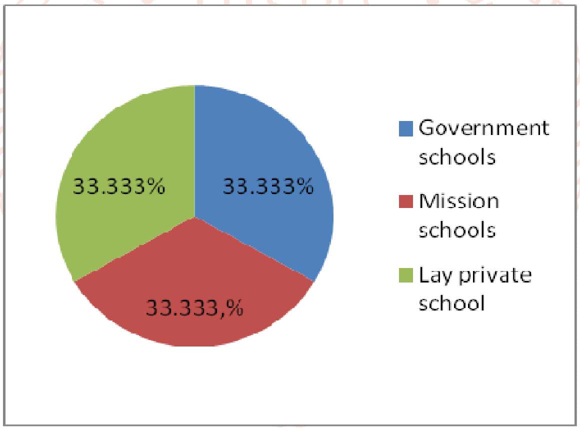


Fig. 2.0: Pie-chart illustrating information on table 6.0

Table 7.0: Description of Sample of Control Group According to School Attended

School Attended	Sample	Percentage (%)
Government schools	12	33.333
Mission schools	12	33.333
Lay private school	12	33.333
Total	**36**	**100.0**

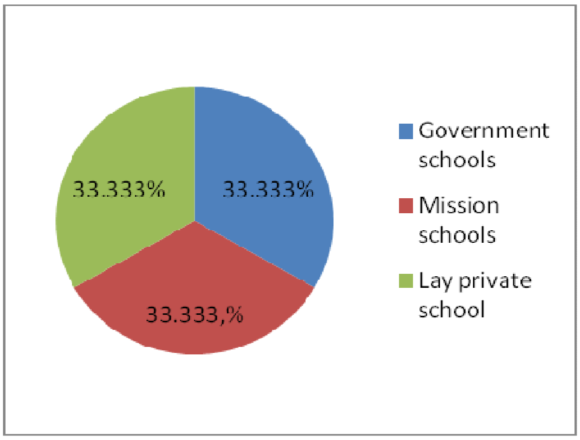


Fig. 3.0: Pie-chart illustrating information on table 7.0

Results on tables 6 and 7 including figure 2 and figure 3 show that the sample in the experimental and control groups each had equal representation from government, mission and lay private schools. That is 33.333% each for government, mission and lay private schools.

Experimental Group

Table 8.0: Description of sample according to gender in the experimental group

Gender	Sample	Percentage (%)
Females	18	50.0
Males	18	50.0
Total	**36**	**100.0**

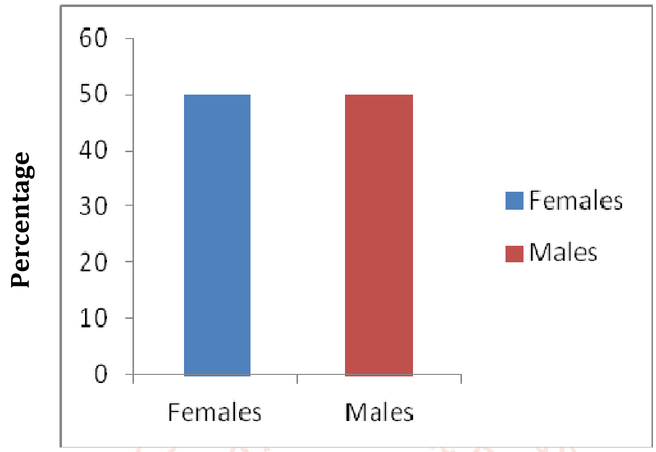


Fig. 4.0: Bar charts illustrating information on table 8.0

Control Group

Table 9.0: Description of sample according to gender in the control group

Gender	Sample	Percentage (%)
Females	18	50.0
Males	18	50.0
Total	**36**	**100.0**

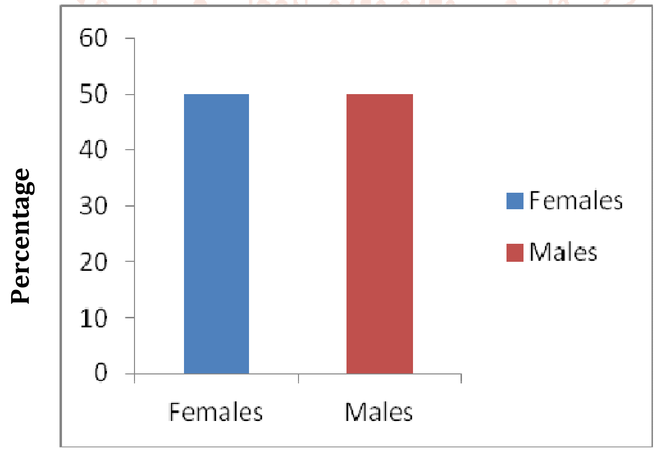


Fig. 5.0: Bar charts illustrating information on table 9.0

Results on table 8 and 9 including fig. 4 and 5 show that the sample in the experimental and control groups each had equal representation of females and males. That is 50.0% of their respective samples.

Experimental Group

Table 10.0: Description of sample according to region in the experimental group

Region	Sample	Percentage (%)
North West	12	33.333
South West	12	33.333
Internally displaced North West	06	16.666
Internally displaced South West	06	16.666
Total	**36**	**100.0**

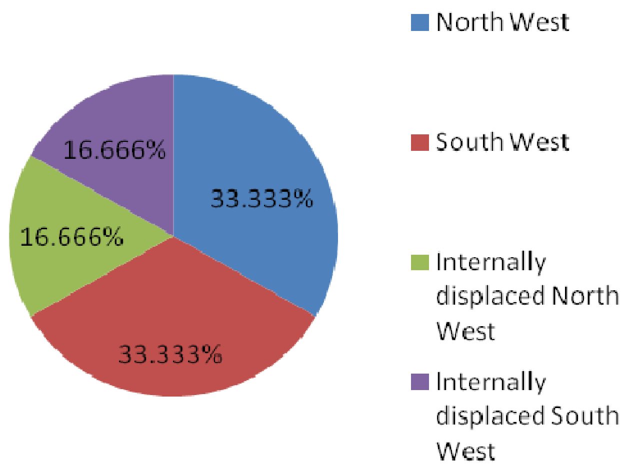


Fig. 6: Pie chart illustrating information on table 10

Control Group

Table 11.0: Description of sample according to Region in the control group

Region	Sample	Percentage (%)
North West	12	33.333
South West	12	33.333
Internally displaced North West	06	16.666
Internally displaced South West	06	16.666
Total	**36**	**100.0**

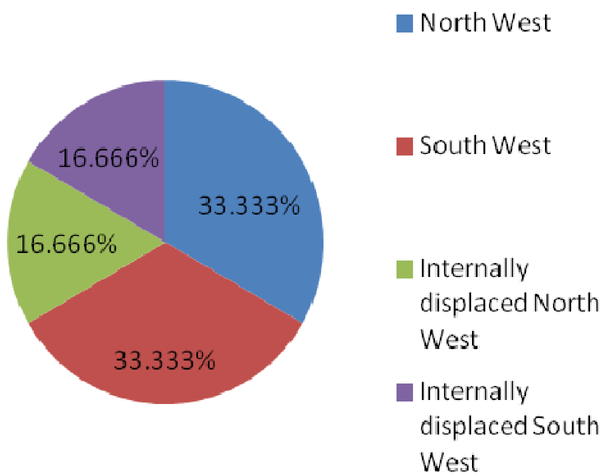


Fig. 7: Pie chart illustrating information on table 11

Results on table 10 and 11 including figures 6 and 7, show that, the sample in the experimental and control groups each had equal representation as far as regions are concerned. North West and South West each had a representation in each group of 33.333%. The internally displaced in each of the two regions was 16.666.

The sample characteristics therefore as analysed from tables 06 to 11 and represented on figures 2 to 7 show each group had identical representation for the stated characteristics of type of school attended, gender, and region in all respect.

INFERRENTIAL STATISTICS

Table 12: Nominal description of Pre-test Results for Critical Thinking

Treatment in view	Group	Performance	Sample
Critical thinking	Experimental group	Passed	----
		Failed	36
	Control Group	Passed	----
		Failed	36

The pre-test was scored on a maximum performance of 100. A pass was rated at 50/100. From this rate, the nominal results of the pre-test shows that for both the experimental and control groups, before the application of the treatment, no student passed when critical thinking was scored. All failed at the pre-test level.

Table 13: Nominal Description of Post-Test Results for Critical Thinking

Treatment applied	Group	Performance	Sample
Critical thinking	Experimental group	Passed	36
		Failed	-----
	Control Group	Passed	-----
		Failed	36

Results on Table 13 show that, when the treatments of critical thinking was applied, the post results proved that, the entire sample in the experimental group passed, while those in the control group all failed.

Table 14: Nominal Description of Pre-test Responses for the Questionnaire in relation to Critical Thinking

Before treatment of the following	Group	Performance	Sample
Critical thinking	Experimental group	Passed	02
		Failed	34
	Control Group	Passed	02
		Failed	34

Results on Table 14 show that scores emanating from the pre-test responses for the questionnaire indicated that, before treatments were applied, those who scored in their responses above 50% were as follows; two students for both the experimental and control groups in critical thinking. The scores for the responses were rated at a maximum of 24.

Table 15: Nominal Description of Post-Test Responses for the Questionnaire in Relation to Critical Thinking

After Treatment of the Following	Group	Performance	Sample
Critical thinking	Experimental group	Passed	35
		Failed	01
	Control Group	Passed	02
		Failed	34

Results on Table 15 show that the responses on the questionnaire for the experimental group registered a significantly overwhelming pass rate than for the control group. For critical thinking, 1 student scored below 50% marks for the experimental group and 34 students scored below 50% marks for the control group.

Hypothesis Analysis

The hypothesis was analysed in two sections:

The pretest and posttest results for critical thinking for the experimental group and the control group were compared using the independent t-test. This is to ensure that the two groups were at the same level before the experiment and after the treatment the post test results were also compared for the two groups, to establish whether the use of the Ekwale Ada's model had an impact on the students using the independent t-test.

The independent variable in this hypothesis was model of instruction, while the dependent variable was the students' performance in the test for critical thinking.

Group 1: Experimental Group

Group 2: Control Group

The scores of the dependent variable were got from the scores recorded from the critical thinking test which was administered to the students before and after the administration of the model. The statistical analysis technique used to test this hypothesis was the independent t-test. The result of the analysis was presented in Table 4.5

Table 4.5: Independent t-test analysis of difference between Control Group and Experimental Group in the pretest and posttest results of the critical thinking test which was administered. (N=72)

Groups in experiment on critical thinking	N	Mean	SD	t-value
Experimental Group before treatment	36	23.14	3.87	
				1.05
Control Group before treatment	36	21.22	3.57	
Experimental Group after treatment	36	77.11	2.92	
				67.02*
Control Group after treatment	36	25.42	3.59	

***p<0.05, df=70; critical t = 1.97**

The result of the analysis in table 4.4 reveals that the calculated t-value of 1.05 is lower than the critical t-value of 1.96 at 0.05 levels of significance with 70 degrees of freedom. With this result the null hypotheses was retained and alternative rejected for the critical thinking skills before treatment. This means that there is no significant difference in the students' critical thinking skills between the control group and the experimental group before the administration of the Ekwale Ada's Model.

After the treatment was administered the calculated t-value of 67.02 is higher than the critical t-value of 1.96 at 0.05 levels of significance with 70 degrees of freedom. With this result the null hypotheses was rejected and alternative retained for the critical thinking skills after treatment. This means that there is a significant difference in the students' critical thinking between the control group and the experimental group after the administration of the Ekwale Ada's Model. A further examination of the difference revealed that the experimental group on whom the treatment was administered performed better (mean=67.02) than the control group on whom the treatment was not administered.

Summary of Findings

There was a significant difference in critical thinking skills between students taught with the Ekwale Ada's Model and those who were taught without using the Model. The experimental group on whom the treatment was administered performed better (mean=67.02) than the control group (1.05) on whom the treatment was not administered.

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