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 problem solving 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, Problem Solving in Biotechnology, Science High School, Students Anglophone Subsection, Education, Cameroon


The indicator of biotechnology knowledge application was problem solving in biotechnology. For problem solving, the researcher created an inventory for the respondents to attend to which involved identification of a problem in the society which can be solved by a biotechnology product; Description of the problem clearly; Statement of multiple solutions to the problem; Selection of the best solution to the problem; Statement of the consequences of the best solution; and usage of the best solution to solve the problem. The researcher created a five point inventory scale which ranged from excellent (5 marks); Good (4 marks); average (3 marks); below average (2 marks); and poor (1 mark) used to grade the problem solving activities. The students who were taught with the Ekwale Ada’s Instructional Model for biotechnology knowledge Application (experimental group) scored higher in problem solving than those who were taught with traditional methods (control group) with a calculated independent t test value of 58.28 for the experimental group and 1.40 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 science high school 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 and 08 from Frankfils Comprehensive College 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 from 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 is no significant difference in problem solving in biotechnology between students taught with the Ekwaile 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 data was analysed using the SPSS Programme. The independent t test was used to find out the difference in means of the scores of the pretest of the experimental group and 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. They 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 problem solving in biotechnology between students taught with the Ekwaile Ada’s Model and those who were taught without the model. The experimental group on whom the treatment was administered performed significantly better (5828) than the control group (1.40) on whom the treatment was not administered.

INTRODUCTION

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 problem solving, critical thinking 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 Endaley 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 problem solving, critical thinking and creativity can only be acquired by students through quality instruction. Higher order skills such as problem solving, can also be acquired by students through well-structured school curriculum. Aghorbechem (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 problem solving, critical thinking 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 problem solving, critical thinking 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; Guarany; 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 use these skills 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. In developing countries like Cameroon, where science and technology are essential ingredients for economic growth, much attention is given to the acquisition of higher order skills (problem solving, critical thinking and creativity) which lead to achievements in science and technology courses in schools.

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 creativity skills and therefore participate with increased capacity in the development of their Country. Ahidejo (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 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 creativity cannot be developed in students.

**BACK GROUND OF THE STUDY**

Higher order skills such as creativity are essential ingredients of technological advancement in any society since it leads to innovation. Quality instruction elicits higher order skills such as creativity. According to Egggen 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 problem solving, creativity and critical thinking since they incorporate several teaching strategies.

Instructional Models for increase students’ level of problem solving. This is in congruence with Gupta (2005); Goyak (2009); Dewey (1930); Bloom (1970); Gage & Berliner (1992); Samson (2015); Nafees (2012); Munyaradzi (2014); Yi Lin (2017); Adebola (2011); Dudley (1971); Olsen (1973); Adedayo (1998); Lynn (2016); Yusuf & Nuradeen (2012); Gokhalo (1995); Adams (2001); Baylor (2002); Walker (2003); Barel (2006); Walker (2000); Zion & Sadeh (2007); Duckworth (1990); Greemers & Kyriakides (2006); Kreizberg Kreizberg (2009); Guleker (2015); Endele & Kintati (2017); Dettaan (2009); Samson (2015); Marzano (2001); Glaser (2012); Marzano (2012); Pushkin (2007) and Friedel, Irani, Ruddle, Gallo, Eckhardt & Ricketts (2008).


Cooperative Learning (Collaborative Learning) which is one of the indicators of the Ekwayne Ada’s Instructional Model for biotechnology knowledge application enhances problem solving in learners. Ajaja (2013); Rudina (2011); Smyansky, Hedges & Woodworth (1990); Goyak (2009); Loeser (2008); Brophy (1987); Rowntree (1981); Habeshaw (1997); Michaelson, Knight & Fink (2004); Freeman et al (2014); Hale (1998); Springer, Stanne & Donovan (1999) postulated that, Cooperative Learning (Collaborative Learning) enhances problem solving in learners.

Demonstration which is one of the indicators of the Ekwayne Ada’s Instructional Model for Biotechnology knowledge Application enhances problem solving. Eley & Norton (2004); Doise (1975); Valiant & Euler (1982); Adenle & Uwameije (2012) and Hodson (1990) are in congruence with the fact that, demonstrations enhance problem solving.

The length of time that students are engaged in activities promotes the development of higher order skills such as critical thinking, problem solving and creativity. Frederick et al (2004); Klem & Connel (2004); Putman et al (2013) and Kozoff (2002); John Carroll (1963); Bloom (1976); Ellis & Worthington (1994); Olufumilayo (2014); Slavin (1994); Connel (2004); Hale (1998); Springer et al (1999); Frederick & Walberg (1980); Karweit (1989); Stephenson & Stigler (1992) Klen Stevenson Stigler (1992) and Knight & Wood (2005) postulated that, the length of time that the learners are involved in activities promotes critical thinking, problem solving and creativity.

Scaffolding one of the indicators of the Ekwayne Ada’s Instructional Model for biotechnology knowledge application fosters problem solving in learners. Scaffolding within the zone of proximal development is an appropriate approach which helps learners to learn more skills and solve problems independently as posited by Asimow (2015); Research Gate (2015); Clark (2017); Kim (2011); Haataja (2019); Ringenberg (2006) and Frederick (2014).

Remediation one of the indicators of the Ekwayne Ada’s Instructional Model for biotechnology knowledge application fosters problem solving in learners as posited by Thomas (2000); Bishara (2016); Todd Higgs & Mumford (2019); Martin, Elliott & Mumford (2019); Dees (1991); Fuchs, Powell & Zumeta (2009) & Nozari & Siamian (2014).

The Competence Based Approach was instituted in 1996 by the Cameroon Government to Secondary Schools inorder to enable learners apply the knowledge acquired in each unit of study. It also encourages teachers to teach learners using learner centred methods of teaching and also by using material and examples which are found in the learners’ context of existence which could easily lead to the acquisition of higher order skills such as creativity, critical thinking and problem solving. This programme had been implemented in the junior secondary school since 1996 and in the senior secondary school September 1999. The Competence Based Approach has not been very successful because many teachers are neither willing to teach using the new syllabus nor are they ready to pass through the rigorous exercise of teaching large numbers of students using learner centred methods of teaching.
In 1986, President Ahmadj 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 Creativity, critical thinking and problem solving.

**Figure 1.0: 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 lesson to the life of the learners; goal(s) of the lesson; statement of specific objectives in the cognitive, psychomotor and the affective domains from the goal). Review the content under subheadings each subheading covering a particular objective by scaffolding. This is 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 select a biotechnology problem they wish to solve, think of a product they wish to produce, state the recipes/procedures for the production of the products, design equipment they feel will help them to produce the product. The teacher provides materials and the equipment which the learners will 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 students 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 will 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 make use of inquiry learning, collaboration and demonstrations. The teacher observes the students and gives them guidance by scaffolding where the task seems difficult and answers the questions posed by the students.

3. **Independent practice (hands on without the teacher scaffolding):**
   The learners in their groups select another biotechnology problem different from the one above, produce the recipes/procedures for the production of the products, design equipment they feel will help them to produce the product. The teacher provides materials and the equipment which the learners will use for their activities. That is the learners perform the activities without the teacher guiding them. The learners develop their own step by step procedure for the activities (the students construct 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 will
solve the pertinent problem in the society which they had anticipated without 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 make use of inquiry learning, collaboration and demonstrations.

4. Formative Evaluation:
The teacher conducts 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 uses the information from the formative evaluation to scaffold the groups of students 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 allows the students 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 (pretest and posttest); scored and graded it. A certificate or attestation of biotechnology knowledge application 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 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 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 that product and design the equipment to be used on paper. The teacher provides materials and equipment to the students and the students then engage 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 design the equipment to be used on paper. The teacher provides materials and equipment to the students and the students then engage 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 did not give guidance and did not scaffold the students but allowed them to undergo independent 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
Problem solving is a higher order skill which is lacking in learners due to the fact that learners are exposed to poor 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 measure up a bit in parts that do not deal with application of biotechnology knowledge while 95% of the candidates score 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 deals 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 students 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 is being 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 start first 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 students 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, therefore, there had been no promotion of deep learning This showed that, the level of biotechnology application is low and if nothing is done about it, Cameroon will lag behind the other African Countries in biotechnology knowledge application.

The Competence Based Approach instituted to Secondary Schools by the Cameroon Government to encourage learner centred approach to teaching, skill development and the self-reliant nature in learners is slow in gaining grounds as most teachers do not want 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 is 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 show 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 (Beirason 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.

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>
<thead>
<tr>
<th>Table 1.0: The five Staged theory of Critical thinking &amp; problem solving</th>
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<tbody>
<tr>
<td><strong>Garrison’s CT stages</strong></td>
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<tr>
<td>1. Problem identification</td>
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<tr>
<td>a triggering event arouses interest in a problem</td>
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<tr>
<td>2. Problem definition</td>
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<tr>
<td>define problem boundaries, ends and means</td>
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<tr>
<td>3. Problem exploration</td>
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<tr>
<td>ability to see to heart of problem based on deep understanding of situation</td>
</tr>
<tr>
<td>4. Problem applicability</td>
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<tr>
<td>evaluation of alternative solutions and new ideas</td>
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<tr>
<td>5. Problem integration</td>
</tr>
<tr>
<td>acting upon understanding to validate knowledge</td>
</tr>
</tbody>
</table>


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 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. 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. In the North West Region, 12 students were sampled
6 males and 6 females.

**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 in order to select male and female students from
Government, Mission and Lay private schools and from the
North West, South West and the Littoral Regions. The sample
was made up of 72 students (36 males and 36 females).

**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.

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

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, pie charts and bar 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 problem
solving in biotechnology between students taught with the
Ekwale Ada’s model and those who were taught without
using the model.

**Ha:** There is a significant difference in problem solving in
biotechnology between students taught with the Ekwale
Ada’s model and those who were taught without the model.
This hypothesis is analysed in two sections:
### Table 2.0: Means and Standard deviations of problem solving, considering the test administered before treatment

<table>
<thead>
<tr>
<th>Test Administered</th>
<th>No. of respondents</th>
<th>No of sections</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>3</td>
<td>6</td>
<td>21.86</td>
<td>4.01</td>
</tr>
<tr>
<td>Control Group</td>
<td>3</td>
<td>6</td>
<td>20.61</td>
<td>3.57</td>
</tr>
</tbody>
</table>

### Table 3.0: Means and Standard deviations of problem solving, considering the test administered after treatment

<table>
<thead>
<tr>
<th>Test Administered</th>
<th>No. of respondents</th>
<th>No of sections</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>3</td>
<td>6</td>
<td>75.97</td>
<td>3.31</td>
</tr>
<tr>
<td>Control Group</td>
<td>3</td>
<td>6</td>
<td>24.86</td>
<td>4.09</td>
</tr>
</tbody>
</table>

### Table 4.0: Means and Standard deviations of problem solving, considering the Questionnaire administered before treatment

<table>
<thead>
<tr>
<th>Questionnaire Administered</th>
<th>No. of respondents</th>
<th>No of Items</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>3</td>
<td>6</td>
<td>7.75</td>
<td>2.42</td>
</tr>
<tr>
<td>Control Group</td>
<td>3</td>
<td>6</td>
<td>7.36</td>
<td>2.18</td>
</tr>
</tbody>
</table>

### Table 5.0: Means and Standard deviations of problem solving, considering the Questionnaire administered after treatment

<table>
<thead>
<tr>
<th>Questionnaire Administered</th>
<th>No. of respondents</th>
<th>No of Items</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental Group</td>
<td>3</td>
<td>6</td>
<td>18.00</td>
<td>3.15</td>
</tr>
<tr>
<td>Control Group</td>
<td>3</td>
<td>6</td>
<td>9.94</td>
<td>2.19</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>School Attended</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government schools</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Mission schools</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Lay private school</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>School Attended</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government schools</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Mission schools</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Lay private school</td>
<td>12</td>
<td>33.333</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>100.0</td>
</tr>
</tbody>
</table>

---

**Description of Sample Characteristics**

**Experimental Group**

![Pie-chart illustrating information on table 6.0](image)

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

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

<table>
<thead>
<tr>
<th>Gender</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>18</td>
<td>50.0</td>
</tr>
<tr>
<td>Males</td>
<td>18</td>
<td>50.0</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Gender</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>18</td>
<td>50.0</td>
</tr>
<tr>
<td>Males</td>
<td>18</td>
<td>50.0</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>100.0</td>
</tr>
</tbody>
</table>

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 as far as regions are concerned. North West and South West Regions each had a representation in each group of 33.33%. The internally displaced in each of the two regions was 16.666.

Experimental Group

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North West</td>
<td>12</td>
<td>33.33%</td>
</tr>
<tr>
<td>South West</td>
<td>12</td>
<td>33.33%</td>
</tr>
<tr>
<td>Internally displaced North West</td>
<td>06</td>
<td>16.666%</td>
</tr>
<tr>
<td>Internally displaced South West</td>
<td>06</td>
<td>16.666%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Fig. 6: Pie chart illustrating information on table 10

Control Group

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

<table>
<thead>
<tr>
<th>Region</th>
<th>Sample</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North West</td>
<td>12</td>
<td>33.33%</td>
</tr>
<tr>
<td>South West</td>
<td>12</td>
<td>33.33%</td>
</tr>
<tr>
<td>Internally displaced North West</td>
<td>06</td>
<td>16.666%</td>
</tr>
<tr>
<td>Internally displaced South West</td>
<td>06</td>
<td>16.666%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

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 Regions each had a representation in each group of 33.33%. 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.
INFERENTIAL STATISTICS
Nominal Data

Table 12: Nominal description of Pre-test Results for Problem Solving

<table>
<thead>
<tr>
<th>Treatment in view</th>
<th>Group</th>
<th>Performance</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>Experimental group</td>
<td>Passed</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Control Group</td>
<td>Passed</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>36</td>
</tr>
</tbody>
</table>

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 problem solving was scored. All failed at the pre-test level.

Table 13: Nominal Description of Post-Test Results for Problem Solving

<table>
<thead>
<tr>
<th>Treatment applied</th>
<th>Group</th>
<th>Performance</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>Experimental group</td>
<td>Passed</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>Control Group</td>
<td>Passed</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>36</td>
</tr>
</tbody>
</table>

Results on Table 13 show that, when the treatments of problem solving was applied, the posttest 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 Problem Solving

<table>
<thead>
<tr>
<th>Before treatment of the following</th>
<th>Group</th>
<th>Performance</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>Experimental group</td>
<td>Passed</td>
<td>02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Control Group</td>
<td>Passed</td>
<td>01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>35</td>
</tr>
</tbody>
</table>

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 the experimental and one student for the control group in problem solving. 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 Problem Solving

<table>
<thead>
<tr>
<th>After Treatment of the Following</th>
<th>Group</th>
<th>Performance</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving</td>
<td>Experimental group</td>
<td>Passed</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>Control Group</td>
<td>Passed</td>
<td>02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed</td>
<td>34</td>
</tr>
</tbody>
</table>

Results on Table 15 show that the responses on the questionnaire for the experimental group registered a significantly overwhelming pass rate of (36 on 36) than for the control group (02 on 36). For problem solving, 2 students scored below 50% mark.

Hypothesis Analysis
The hypothesis was analysed in two sections:
The pretest and posttest results for problem solving 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 model had an impact on the students using the independent t-test.

The independent variable in this hypothesis was test groups, while the dependent variable was the students' performance in the test for problem solving.

Group 1: Experimental Group

Group 2: Control Group
The scores of the dependent variable were got from the scores recorded from the problem solving 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 4.6
The result of the analysis in table 4.6 reveals that the calculated t-value of 1.40 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 problem solving skills before treatment. This means that there is no significant difference in the students’ problem solving 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 58.28 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 problem solving skills after treatment. This means that there is a significant difference in the students’ problem solving 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=58.28) than the control group on whom the treatment was not administered.

Summary of Findings

There is a significant difference in problem solving 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 better (mean=58.28) than the control group (1.40) on whom the treatment was not administered.

REFERENCES


null


Kara, M.W. (2012).The Effects of an Instructional Model Utilizing Hands-on Learning and Manipulatives on Maths Achievement of Middle Schools Students in Georgia Digital Commons Liberty.edu/cgi/view content.cgi? Article, 1653 and Content, doctoral.17/10/2016 at 13:58 p.m.


