EFFECT OF GUIDED-INQUIRY ON MECHANISTIC REASONING IN MECHANISMS OF ORGANIC CHEMISTRY REACTIONS AMONG COLLEGES OF EDUCATION CHEMISTRY STUDENTS, NORTH-WEST GEO-POLITICAL ZONE, NIGERIA.

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Abstract

The research was effect of Guided-Inquiry on Mechanistic Reasoning in Mechanisms of Organic Chemistry Reaction Mechanisms among State Colleges of Education Chemistry Students, North-west Geo-political Zone, Nigeria. A quasi-experimental design was employed to generate data. The population of the study comprised of 3615 NCE II Chemistry students of seven state colleges of education. The sample of the population consist of fifty (50) male and forty nine (49) female students which were selected through random sampling techniques. The study had two objectives and in line with them two research questions were raised and two null hypotheses were formulated and tested. The instruments used for data collections was Test of Mechanistic Reasoning Ability in Organic Reaction Mechanism (TMRAORM). Inferential statistics of t-Test analysis and mean were used to analyze the data collected. There was significant difference in the mean score in mechanistic reasoning between experimental and control groups with t-cal value and p-value of .6257 and .0391 respectively at .05 level of significance. There was also significant difference in the mean score in mechanistic reasoning of male and female students in organic chemistry reaction mechanisms with (t – cal = 1.452, P = 0.043).Therefore, it was recommended that the government of sub-saharan Africa should design programmes and policies that will incorporate the use of guided-inquiry instructional strategy in teaching and learning of chemistry in tertiary institutions.

Keywords: *Guided-Inquiry, Mechanistic Reasoning, Mechanism, Organic Reaction, SubSaharan Africa*

Introduction

Sub-Saharan Africa is a geographical area of the continent of Africa that lies south of the Sahara which is faced with an unprecedented challenge of educational development, the basic foundation of all sectors of human development verspoor (2008). Human resource in sub-saharan Africa can be well explore when education becomes the front burner in this part of the continent because it has the potentiality of creating avenues for taping other physical resources. Science as it is well known is life and life is science, without which there will be no meaningful development. Karamustafaoglu (2010) pointed out that being educated in science and technology plays a key role for the future of societies and the effects of science and technology are seen overtly in every aspect of living. The growth of any nation, in this case, Sub-Saharan Africa is a measure of its level of science education. Babajide (2015) defined science education as a field of study that exposes learners to the content of science as well as the methodology (processes) of acquiring scientific knowledge for practical science applications. The British Science Council (2009) defined science as the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence. While Olorukooba (2007) is of the view that science is a way of knowing, a systematic method of learning about nature based on observation and testing leading to the formulation of hypothesis, laws, facts and theories. From the above definitions one can assert that science is the study of nature through systematic processes leading to discoveries.

Chemistry as a branch of science has become one of the most important disciplines in the school curriculum. Ejidike and Oyelana (2013) found out that its importance in general education has gained world-wide recognition. This is why the National Science curriculum has three basic science subjects (Biology, Chemistry, Physics) of which a student is expected to choose chemistry at the Secondary School level in Nigerian (Ihuarulam, 2008). Among these basic science subjects, chemistry occupies a unique position because it is a pre–requisite for the study of many science courses, such as medicine, biochemistry, pharmacy, agricultural science, laboratory technology, geology (Ihuarulam, 2008). Nnoli (2011) defined chemistry as the science that systematically studies composition, properties of organic and inorganic substances and various elementary forms of matter. Therefore, chemistry is characterized by the study of science that deals with the composition, structure and properties of substances and the transformations that they undergo.Jegstad, Kirsti, Sinnes& Astrid (2015) opined that the branch of science education known as "chemistry" must be taught in a relevant context in order to promote full

understanding of current sustainability issues. This could be archieved when sub-sahara African students are taught chemistry using guided-inquiry approach of teaching and learning.

Guided-Inquiry Approach has been described by Onwirhiren and LawaL (2016) as problem solving, critical thinking, reflective inquiry, deductive thinking and not mere personal assumptions. Kulthau, Moniotes and Caspari (2007) defined guided-inquiry as careful planning, close supervision, ongoing assessment and targeted intervention by teacher(s) through the inquiry process that gradually leads students towards independent learning. According to Bransford, Brown and Cocking (2000), inquiry-based teaching approach is supported on knowledge about the learning process that has emerged from research. In guided-inquiry, children become involved in many of the activities and thinking processes that scientists use to present new knowledge. Science educators inspire teachers to replace traditional teachercentered instructional practices, with inquiry-oriented methods that (a) engage student interest in science, (b) provide chances for students to use suitable laboratory skills to collect evidence, (c) require students to solve problems using reasoning and proofs, (d) encourage students to carry out further study to develop more rich explanations, and (e) stress the importance of writing scientific descriptions on the basis of evidence (secker, 2002). When guided inquiry is properly utilized, it facilitates mechanistic reasoning and invariably enhance the understanding of mechanisms of organic reactions by both male and female students in an academic environment, in particular, the Sub-Sahara African environment.

Bhattacharyya, (2013) stated that the skill of proposing mechanisms of reactions using the electron-pushing formalism (EPF) or merely, electron-pushing is not only of value to organic chemists but also is important for students enrolled in organic chemistry courses at all levels. This enhances their mechanistic reasoning as they become able to understand why and how reactions can occur. According to Russ, Scherr, Hammer, & Mikeska (2008), Educational research indicates that students have resources for productive mechanistic thinking but often struggle to explain phenomena using mechanistic accounts. Additionally, (Coffey 2011) discovered that teachers frequently fail to pay attention to the substance of students' thinking and to recognize both productive and constraining forms of reasoning, thereby missing valuable opportunities to support and guide the development of meaningful understandings. Mechanistic reasoning is one of those reasoning abilities that needs attention.

Mechanistic reasoning as a cognitive process, is used by scientists in all natural sciences and is an important component of organic chemistry. Researches of Goodwin (2003), Bhattacharyya (2013) and Caspari, Kranz and Graulich (2018) from chemical education literatures have shown that mechanistic reasoning could be define tentatively in different ways. Based on philosophy of organic chemistry, Goodwin (2003) sees mechanistic reasoning to include an approach to change, composing of both entities and activities. Caspari, Kranz and Graulich (2018) looked at mechanistic reasoning as comparative reasoning about cause–effect relations between explicit structural differences and energetic changes occurring in a mechanistic step. The contributions of

Machamer, Darden, and Craver, (2000) stemmed out from the word "mechanism", which defines "Entities and activities organized in such a way that they are products of regular changes from start or set-up to finish or termination conditions".

In mechanistic representations in organic chemistry, entities are usually presented by Lewis structures (Caspari, et al, 2018), while 'Activities' illustrate the dynamic part of a mechanism as can be seen in nucleophilic addition. They are transformations of entities and of their sets of properties (for example, change in bonding, change in potential energy). In mechanistic representations, activities are mostly presented by curved arrows. Organic chemists also occasionally include other representations of activities alongside electron pushing, for example a proton transfer, H^+. Caspari, et al, (2018) posited that the electron-pushing formalism is the most important tool that organic chemists use to represent activities in a reaction mechanism. Constructing mechanistic explanations is an essential feature of doing science, inquiry-based science instruction that gives students opportunities to develop mechanistic reasoning skills which of course inquiry in science may be describe as the pursuit of coherent mechanistic account of phenomena. For a coherent flow of this knowledge, students have to be taught, no matter the gender setting of a given learning environment.

The heterogenous gender settings of colleges of education is a factor to be reckon with in terms of performance in chemistry as they are not gender bias. Nwagbo & Chukelu, (2011) looked at gender as socially ascribed attribute, differentiating feminine from masculine. It has been reported as one of the factors that may interact with cognitive extent and sources of the recorded differences in the achievement of males and females in chemistry. Some researches carried out in the process of learning science-based subjects, show preference of males over females students while others females over males. Ifeako, (2005); Obeka (2007); Nwagbo

and Okoro (2012); reported that males achieved significantly higher than females, Ekwueme and Umoinyang (2006), Longjohn (2009) reported in favour of females. No matter the differences, the aim of this research work is to see the effect of guided inquiry on mechanistic reasoning in mechanism of organic reaction among NCE students in state colleges of education, North-west Geo-political, Zone, Nigeria.

The theoretical frameworks that guides the study are based on Constructivist, and Mechanistic

System Approaches. One of the theories championing the course of this study is the work of John Dewey (1982), an educational theorist, who is one of the pioneers of constructivism. He rejected the idea that schools should focus on rote memorization and instead suggested that students should be engaged in real-world, practical tasks. Dewey's theory of "Reflex Arc" states that human experience is not a disjointed sequence of fits and starts, but a developing circuit of activities. Learning is framed as a cumulative, progressive process where inquirers move from dissatisfying phase of doubt toward a satisfying resolution of a problem. Dewey (1998) advocated for inquiry learning and called for education to be grounded in authentic experiences. He argues that in order for education to be most effective, content most be presented in a way that allows students to relate information to prior experiences, thus deepening the connection with new knowledge. It is in the light of this that students were guided on mechanistic step by step breaking and formation of bonds involved in organic reaction mechanisms. In the same vent, Jean Piaget (1977), another pioneer of constructivism, developed the theory of cognitive development. The theory states that learning occur by an active construction of meaning by learners rather than learners being passive recipients of information. The theory of cognitive development suggested that children deepen their understanding of the world by acting on and reflecting on the effects of their prior knowledge. He stated that children are capable of organizing their knowledge in an increasingly complex networks. Piaget wrote, "To understand is to discover, or reconstruct by rediscovery, and such conditions must be compiled with if in future individuals are to be formed who are capable of production and creativity and not simply repetition". Piaget believes that learning is seriously influenced by learners' developmental stages, therefore the study used guided inquiry approach in which the teacher played a role in planning and facilitating learning processes, by providing diagrammatic representations of step by step organic reaction mechanisms, at their own pace, where breaking and formation of bonds were looked at in stages.

This study is also designed based on mechanistic theory by Rene Descartes and Galileo in 17th century. They developed a theory of the mind as an immaterial, non-extended substance that engages in various activities such as rational thought, imagining, feeling and willingness to carry out a task. The theory state that; human behaviours can be explained in the exact same way that mechanical and physiological processes are explained and understood, (Machamer et al., 2000). Based on the work of Hammer, Russ and Scherr, in Conlin, Gupta, Scherr, and Hammer (2008), constructing mechanistic explanations is an essential feature of doing science, in which inquirybased science instruction gives students opportunities to develop mechanistic reasoning skills.

Indeed, inquiry in science may be described as "the pursuit of coherent mechanistic accounts of phenomena". According to Bhattacharyya (2013), the following tasks can be performed using mechanistic reasoning: Explaining the products of a reaction, especially unexpected ones or sideproducts, Predicting the products of a reaction given the starting materials, Explaining stereo- and regiochemical outcomes of reactions, Choosing the appropriate experimental conditions including stoichiometry, solvent, and temperature for a reaction.

It has been observed that most students wrongly perceived organic chemistry as a difficult course to understand. From the research of Ngozi-Olehi, Duru, Uchegbu&Amanze (2018), the performance of chemistry students in AlvanIkoku College of Education in Organic chemistry III (CHEM 323 for degree programme) and Natural Products and Amines (CHE 323 for NCE programme) from 2010-2012 leaves a lot to be desired in the learning of this area of chemistry. Observations were made of a progressive increase in the percentage of students failing the courses by the years; 7 %, 55 % and 61 % for CHEM 323 for degree programme and 40 %, 47 % and 52 % for CHE 323 for NCE programme in 2010, 2011 and 2012 respectively. Mechanism of organic reactions happens to take the center stage in learning and understanding of CHEM 323 courses both at the NCE level and at the degree level. Before those years, (Njoku 2004) and (Lakpini, 2006) had observed that many factors such as poor teaching methods, mathematical nature of chemistry, and abstract nature of chemistry concepts account for such students' poor performance. This study therefore, sought to determine the effect of guided-inquiry on mechanistic reasoning in organic reaction mechanisms among NCE students in order to have an improved teaching methodology that will enable development of mechanistic reasoning among
learners.

Objectives of the Study

The study seeks to investigate the Effect of Guided-Inquiry on Mechanistic Reasoning in Mechanism of Organic Chemistry reactions. The specific objectives of this study are to;

i. determine the effect of guided-inquiry on mechanistic reasoning of students in mechanism of organic chemistry reaction concepts.
ii. determine the effect of guided-inquiry on mechanistic reasoning in mechanism of organic chemistry reaction concepts among male and female chemistry students.

Research Questions

Mechanistically, the study sought to address the following questions:

1. What is the difference between mean scores in Mechanistic Reasoning of chemistry students taught Mechanism of Organic Chemistry Reactions using Guided-Inquiry and those taught using Lecture Method?
2. What is the difference between the Mechanistic Reasoning Ability scores of male and female Chemistry Students taught Mechanism of Organic Chemistry Reactions using Guided- Inquiry?

Null Hypotheses

To guide the study the following null hypotheses were tested at < 0.05 level of significance:

HO_1: There is no significant difference between the mean scores in Mechanistic Reasoning of students taught Mechanism of Organic Chemistry Reactions using Guided-Inquiry and those taught using Lecture Method.

HO_2: There is no significant difference between the mean of Mechanistic Reasoning Ability scores of male and female Chemistry Students taught Mechanism of Organic Chemistry Reactions using Guided-Inquiry?

Methodology

A quasi-experimental design by randomization was used to explore the effect of Guided-Inquiry on Mechanistic Reasoning in Mechanisms of Organic Chemistry Reactions among Colleges of Education Chemistry Students. Two groups were constituted, experimental and control groups of mixed gender. The students in the experimental group (EG) were taught organic chemistry reaction mechanisms using guided-inquiry while those of the control group (CG) were taught the same concept using lecture method. The population of the study comprised of 3615 NCE

II Chemistry students of seven state colleges of education in the Northwest Zone, Nigeria. The number of male students were 2457 while the female students were1158; Statistics gotten from National Commission for Colleges of Education, Nigeria. The population is presented in Table1.

Table1: Population of the Study

S/N	SCHOOL	State	Location	M	F	Total
1.	Kaduna State College of Education	Kaduna	Gidan-Waya	562	460	1022
2.	Zamfara State College of Education	Zamfara	Maru	65	13	78
3.	Shehu Shagari College of Education	Sokoto	Sokoto	73	14	87
4.	Isah Kaita College of Education	Katsina	Dutse-Nma	129	14	143
5.	Kebbi State College of Education	Kebbi	Argungu	480	147	627
6.	Jigawa State College of Education	Jigawa	Gume	1161	85	246
7.	SaadatuRimi College of Education	Kano	Kumbotso	987	425	1412
TOTAL				**2457**	**1158**	**3615**

Source: *NCCE Record of State Colleges of Education in Northwest Zone Nigeria.*

The choice of the colleges was paramount because of the homogeneity in the used of same minimum standard, Settings and facilities. The sample of the population consist of twenty-five (25) male and twenty-five (25) female students for the experimental group while the control group consist of twenty-five (25) male and twenty-four (24) female students. The sample size is in line with Sambo (2008a), that central limit theorem recommended sample size minimum of 30 subjects in a variable for a study of this kind. For purpose of this study, two research instruments were used to generate data. The instruments were: Test of Mechanistic Reasoning Ability in

Organic Reaction Mechanism (TMRAORM) and Test of Performance in Organic Reaction Mechanism (TPORM). The reliability coefficients for the instruments were determined using test, retest method. The scores were subjected to Pearson Product Moment Correlation Coefficient (PPMC). The reliability coefficients of the instruments obtained were 0.82 and 0.70 respectively. According to Sambo (2008) and Pallant (2011) asserted that estimated reliability coefficient values above 0.70 are considered acceptable for an instrument to be used in this kind of study. Inferential statistics were used to test the null hypotheses at $P \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

This section deals with analysis of demographic data, testing of hypothesis and discussion of findings as follows:

Table: 1Demographic Characteristic of participants

Gender	*N*	*Percentage*
Male	**49**	**49.5%**
Female	**50**	**50.5%**
Total	**99**	**100%**

The table above reveals that 49 (49.5%) male students and 50 (50.5%) female students summing up to 99. This means there is no significant different between the number of participants on the basis of gender.

HO_1: There is no significant different between the mean score in mechanistic reasoning of students taught mechanism of organic chemistry reactions using guided-inquiry and those taught using lecture method.

Table: 2t-Test Result of Mechanistic Reasoning of Students taught Organic Reaction Mechanism using Guided-inquiry and Students taught using Lecture method

Variables	*N*	*X*	*SD*	*Df*	*t-cal*	*p-val*
Experimental	**50**	**15.1**	**10.258**	**45**	**.6257**	**.0391**
Control	**47**	**11.94**	**7.452**			

p-value< .05 at 45 df 2 tailed

The above tables reveals t-cal value and p-value of .6257 and .0391 respectively at .05 level of significance. The p-value is less than .05 level of significance to justify that there is significance difference in mean score of mechanistic reasoning of students taught mechanism of organic chemistry reactions using Guided-inquiry method as against those taught using Lecture method to the favour of guided-inquiry method. Thus, the null hypothesis is rejected.

HO_2: There is no significant different between the mean score of mechanistic reasoning ability of male and female chemistry students taught mechanism of organic chemistry reactions using guided-inquiry method.

Table:3 t-Test Different between Male and Female Students taught Organic Chemistry

Reaction Mechanisms using Guided-Inquiry Method

Gender	N	X	SD	df	t-cal	R-val
Male	**25**	**17.16**	**10.42**	**48**	**1.452**	**0.043**
Female	**25**	**12.04**	**7.13**			

P-value < .05 at 48 df 2-tailed

Table 1 above reveals t-value of 1.452 and p-value of .043 at .05 level of significance. This result shows a significant difference in the mean score of mechanic Reasoning ability between male and female students with the p-value less than .05 level of confidence. The difference however favour male students. Thus the null hypothesis is rejected.

SUMMARY OF FINDINGS

Based on the result of the data analysis, the findings of the study are summarized as follows:

(1) There is significant difference in the mean score in mechanistic reasoning between experimental and control groups with t-cal value and p-value of .6257 and .0391 respectively at .05 level of significance.

(2) There is significant difference in the mean score in mechanistic reasoning of male and female students in organic chemistry reaction mechanisms with (t – cal = 1.452, P = 0.043).

Discussion of Findings

The study shows significant influence of Guided-Inquiry on Mechanistic Reasoning in Organic Chemistry Reaction Mechanisms. This is in agreement with the study of Ugwuandu (2010) who found out that there was a significant difference between the achievements of students taught biology with guided-inquiry and those taught with lecture method in favour of guided-inquiry. This means that when guided inquiry is properly used, it has the capacity of boosting the mechanistic reasoning of students in organic chemistry reaction mechanisms. The present study also reveals that there is significant difference in the mean score of mechanistic reasoning ability between male and female students. This shows that the mechanistic reasoning abilities of female students were not up to the reasoning abilities of the male students in the sub-saharan Africa, considering the geographical area of the study.

Conclusion

In line with the findings of this study, the researchers concludes that there was significant influence in mechanistic reasoning of students taught mechanism of organic chemistry reactions using guided-inquiry and those taught using lecture method. This shows that teaching method is a factor if at all human resources is to be harness in sub-saharan Africa. It is also concluded that there is significant different between the mean score of mechanistic reasoning ability of male and female chemistry students taught mechanism of organic chemistry reactions using guided-inquiry method. Signifying an educational gab between male and female students in this part of the world.

Recommendations

In line with conclusions of this study, the following recommendations were made:

1. The use of guided-inquiry was found to enhance students' mechanistic reasoning and so teachers should be encourage to adopt the instructional strategy in order to improve the performance of students in the sub-saharan Africa.
2. Workshops should be organized to improve the skills of teachers in using the guidedinquiry method of teaching organic chemistry reaction mechanisms.
3. The government of sub-saharan Africa should design programmes and policies that will incorporate the use of guided-inquiry instructional strategy in teaching and learning of chemistry in tertiary institutions.
4. As guided-inquiry is gender friendly, chemistry teachers should use it to minimize gender disparity among chemistry students in the sub-saharan Africa in order to ensure sustainable development.

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