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Effects of Two Inquiry Learning Models on Students' Academic Achievement and Retention on Gas Laws in Secondary School Chemistry in Uyo Metropolis, Nigeria

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Abstract
This study investigated "Effects of Two Inquiry Learning Models on Students' Academic Achievement and Retention on Gas Laws in Secondary School Chemistry in Uyo Metropolis, Nigeria". It adopted pretest, posttest non-randomized quasi-experimental research design. Instrument for data collection was Gas Laws Achievement Test (GLAT), with reliability value of 0.79 using Kuder-Richardson Coefficient of reliability. The same test was reshuffled and used as retention test. The target population of the study was all the SS2 Chemistry students in the study area. The sample was 100 students comprising boys and girls drawn from two schools out of 14 schools in Uyo metropolis. The three hypotheses for the study were tested at .05 level of significance using analysis of covariance (ANCOVA). The moderating influence of gender was also observed. The findings indicated, among others, that students taught gas laws using cyclic inquiry model had significantly higher achievement and retention mean scores than those taught using practical inquiry model, and the least facilitative in achievement was practical inquiry model. Based on the findings, it was recommended, amongst others, that Chemistry teachers should be trained on the impact and use of these inquiry models of learning, and implemented same during classroom instructions.
Keywords: model, inquiry, academic, achievement, retention.

Introduction

Chemistry is the science that deals with the study of matter, its properties, composition, structure, how and why substances combine or separate to form other substances, their transformations and the energy being released or absorbed during chemical processes. Every substance either naturally occurring or artificially produced consists of one or more of the hundred-odd species of atoms that have been identified as elements. Although these atoms in turn are composed of more elementary particles, they are the basic building blocks of matter. The chemistry curriculum for secondary schools is designed to prepare students to acquire adequate laboratory and field skills in chemistry, meaningful and relevant knowledge on chemistry as a science subject, ability to apply scientific knowledge to everyday life in matters of personal and community health, agriculture and reasonable functional scientific attitude (FRN, 2014).

Chemistry is recognized as one of the core science subjects offered at the senior secondary school level in Nigeria and is a requirement for further learning in many areas of living like medicine, pharmacy, astronomy, agriculture, engineering and production industries. The knowledge of chemistry has found various applications in the production of dyes, electricity, refining, metals, and mining and in technical industries like tanning, dyeing of fabrics, water treatment and purification, production of glass wares and fuel for driving engines including providing their parts. Understanding basic chemistry concepts is important for everyday living and every material in existence is made up of matter, including human bones. Chemistry is part of everything in human lives and is involved in everything humans do, from growing and cooking food, to cleaning homes and human bodies, and in launching space shuttles, thus helping in the description and explanation of the world, among others.

Evidently, poor academic achievement of secondary school students in chemistry seems to have risen in recent history. The problem of inconsistency in chemistry achievement has adverse effects on students and the society at large if not properly addressed. In order to address this problem, appropriate measures need to be taken to ensure that chemistry teachers adopt the right approach in teaching chemistry so as to minimize students' failure rate and limit poor achievement by students in chemistry.

The desire to know and understand the cause of students' poor achievement in chemistry has attracted the attention of researchers in recent times (Eyo & Bassey, 2018; Shihusa & Keraro, 2015). Some of the problems identified include: poor teaching strategies, inadequate number of qualified teachers, poor infrastructure, inadequate laboratory facilities, abstract nature of some concepts, teacher-centred instructions, and use of poor teaching models (Ezeoba, 2016). In order to improve academic achievements at external examinations by chemistry students, several teaching strategies have been adopted by teachers and students in the teaching and learning of chemistry. These strategies include: discovery, discussion, demonstration, field trips, blended learning, problem-solving, problem-based learning, lecture and inquiry strategies, among others. Inquiry strategy is adopted in teaching and learning chemistry because it is simple to apply and practically useful for students' understanding and grasp of concepts taught by teachers (Etiubon, 2019).

Inquiry is any process aimed at augmenting knowledge, resolving doubt, or solving a problem. It is often referred to as enquiry. It is a strategy where learners ask questions or investigate about a known concept with the aim of obtaining information about the concept. Inquiry strategy is defined as an approach to teaching, the art scientists use in teaching science and a highly effective method that helps students to understand concepts and use of process skills (Yagger & Akeary, 2016). Inquiry strategy consists of some learning modules known as "inquiry learning models". These inquiry models of learning form the basis of this study.

Inquiry learning models are models of teaching where learners seek to discover and create meaningful answers to recognized questions and problems by making diligent search, sometimes with minimum guidance from the teacher. Inquiry learning models also constitutes ways of questioning, seeking knowledge and information on finding out about phenomena. Inquiry learning model is a student-centred and a student-lead process whose purpose is to engage students in active learning, based on their own experiences. Inquiry learning model is not about memorizing facts, rather it is about formulation of questions and finding appropriate resolutions to these questions. It could be a complex task that requires dedicated support by the teachers in providing the necessary guidelines for the students during lessons to facilitate the fact that students experience the excitement of solving a task or problem on their own (Bishop, 2014). In inquiry learning model, students learn not only concepts, but self-direction, responsibility and social communication that permit them to assimilate and accommodate information (Suchman, 2017). The study reports that when inquiry models of learning are implemented, they become very effective in enhancing students' achievement, attitudes and skills development. With inquiry learning model, students learn science by doing it their own way.

Inquiry learning model is a socio-constructivist design (Carlson, 2013) of collaborative work. The students find resources, use tools and make progress by work-sharing, talking and building on everyone's work. Inquiry learning model directs the learners to identify problems and better ways of solving them scientifically. For instance, teachers' lack of knowledge in the application of inquiry learning models in the teaching of gas laws which is exploratory in nature, can be addressed by acquiring and integrating the appropriate teaching model like inquiry learning model. Saeed (2011) investigated the effect of inquiry-based instruction on senior secondary school students' academic achievement in chemistry, using quasi-experimental design. The findings indicated a positive outcome, and the researcher recommended among others that inquiry learning model should be integrated into classroom teaching and learning.

Various forms of inquiry learning models exist. They include the cyclic inquiry model, practical inquiry model, learning by design inquiry model, the scaffold knowledge integration (SKI), Discovery learning, knowledge-building community model as well as computer simulation. But this study will focus on cyclic inquiry model as well as practical inquiry model.

Cyclic inquiry model engages students to ask and answer questions on the basis of collated information that leads to the creation of new ideas and concepts. Learning activities are organized in a cyclic way, independently of the subject which leads to the creation of new ideas and other questions. The activity often finishes by the creation of a new document which tries to answer the initial questions. The cyclic inquiry model creates new ideas and concepts and their use in the classroom. It is also to engage the students in active learning based on their own questions. The cycle of inquiry has 5 steps, including (a) Ask (b) Investigate (c) Create (d) Discuss and (e) Reflect. This involves a spiral path of inquiry of asking questions, investigating solutions, creating answers, discussing discoveries and experiences, as well as reflecting on newly-found knowledge and asking new questions (Bruce & Bishop, 2012).

The ASK step focuses on a problem or a question that students begin to define, which are redefined again and again during the cycle. Here, students ask meaningful questions arising from genuine curiosity about real-life experiences and challenges. In the INVESTIGATION step, learners gather information, study, craft an experiment, observe or do an interview. The information gathering stage is a self-motivated exercise that is owned by the engaged learners. In the CREATE step, students, through group interactions, generate new thoughts, ideas and theories that are not directly inspired by their own experience and write them down as report. In the DISCUSS step, learners share their ideas and ask others about their own experiences. They also compare notes, share experiences and discuss conclusions through multiple media like online social networks. While in the REFLECT step, learners step back, take inventory, make observations and bring new discussions. They reflect to recognize further indeterminable experiences leading to continual inquiry.

Another inquiry model of interest for this study is the practical inquiry model. Practical inquiry model is a theoretical framework that defines the outcomes of collaboration learning in an academic environment through four phases of critical thinking and cognitive presence. Practical inquiry model, according to Garrison and Archer (2019), is based on John Dewey's foundational ideas of practical inquiry. In the practical inquiry model, the process of critical thinking is defined as a cognitive activity geared towards four consecutive phases which are:

i. Triggering events: This is where issues or problems are identified for inquiry through questions.

ii. Exploration: Students explore the issues, both individually and corporately, through critical reflection and discourse.

iii. Integration: Learners construct meanings from the ideas developed and apply newly gained knowledge to education during exploration.

iv. Application/Resolution: Learners apply the newly gained knowledge to educational context and workplace settings. The inquiry learning model considered in this study also includes learning by design model.

Gender is one of the factors affecting different concepts in life (Bassey & Eyo, 2015), including the academic achievement of students in chemistry. Studies on gender have been unresolved on their conclusions (Nussbaum, 2018). Gender is used to indicate the distinction between human beings on the basis of masculinity and femininity in relation to their expected role and how each perceive science learning. Okeke (2018) referred to gender as the social or cultural construct, characteristics, behaviours and roles which society ascribes to males and females. Studies abound on gender differences and students' achievement in science. While some studies observed gender disparity in science in favour of males, others report females' superiority and others still, zero disparity (Shaibu & Mari, 2017). Diana (2014) examined the effect of inquiry models on male and female students' academic achievement in science course. He pointed out that there is no significant difference in either male or female students' academic achievement.

Retention is the ability to store things experienced or learned. It is described as a form of reaction which has been presented in the past. In other words, it is a result of orientation or attitude which marks an on-going perception (Bawa, 2018). Olanrewaju (2017) posited that retention is the ability to store learned concepts which can be easily recalled from the short- and long-term memory. Inquiry models help in the retention of learned concepts by providing anchorage between what the students experienced and the intending gas law concepts to be presented to the learner.

Gas laws deal with how gases behave with respect to pressure, volume, temperature and amount. One of the most amazing things about gases is that despite its wide differences in chemical properties, all the gases more or less obey the gas laws. Gases are the only state of matter that can be compressed very tightly or expanded to fill a very large space. Gases can likewise be compressed into cylinders for cooking, bulbs for lightings, balloons for games, balls for sports and tubes for driving vehicles. This can further be explained through the better understanding of gas laws concept, which are sometimes perceived by most students as difficult.

Statement of the problem

Inquiry-based learning is suggested in the curriculum to be integrated into students' learning process to enable them explore their own learning for effective understanding of science concepts. Sadly, this is hardly employed during instructions by teachers and this affects the understanding and learning outcomes of science concepts like gas laws by students. Many students and teachers see gas laws as abstract and difficult to understand when encountered in Chemistry. Most teachers shy away from teaching the concept of gas laws as they appear complex and quite challenging to teach. These may result in students' poor achievement in both internal and external examinations. These difficulties may be due to chemistry teachers' ineffectiveness and non-utilization of the suggested inquiry learning model in the application of inquiry learning in the classrooms. This is also applicable to the way gas laws are being taught.

This study therefore attempted to use inquiry learning models to see if students' academic achievement and retention on gas laws could be improved. It is on this basis that this study seeks to investigate the effect of inquiry learning models on students' academic achievement and retention on gas laws in senior secondary school chemistry in Uyo, Nigeria.

Research questions

1. What is the achievement mean scores of students taught the concept of gas laws using cyclic inquiry model and practical inquiry model?

2. What is the academic achievement mean scores of male and female students in the concepts of gas laws when taught using cyclic inquiry model and practical inquiry model?
3. What differences exist in students' retention scores on gas laws when taught using cyclic inquiry model and practical inquiry model?

Hypotheses

Ho1: There is no significant difference in the academic achievement mean scores of students in the concept of gas laws in chemistry when taught using cyclic inquiry model and practical inquiry model.

Ho2: There is no significant difference in the academic achievement mean scores of male and female students on the concept of gas laws when taught using cyclic inquiry model and practical inquiry model.

Ho3: There is no significant difference in students' retention mean scores on gas laws when taught using cyclic inquiry model and practical inquiry model.

Methodology

The study was conducted in public secondary schools in Uyo Local Government Area of Akwa Ibom State, with 14 public secondary schools (Source: State Secondary Education Board, Uyo). The population size for this study consisted of 2,760 Senior Secondary Two (SS2) Chemistry students in all 14 public secondary schools in the study area.

The sample for the study comprised of 100 senior secondary two (2) students. These students were drawn from two intact classes in two co-educational public secondary schools. Purposive sampling technique was adopted in selecting the schools from the existing 14 public secondary schools in Uyo metropolis for the study. The selected schools were assigned as experimental groups.

A researchers-made instrument, Gas Laws Achievement Test (GLAT), was used for data collection. It is researchers-made instrument consisting of 30 multiple choice items with four (4) options, A, B, C, D and one correct answer. The items were drawn from the Boyles' Law, Charles' Law and Ideal gas law which were used to determine the achievement and retention level of students in the concept of gas laws. The achievement test was later reshuffled and used as retention test. The validation of the instrument of the study was measured simultaneously with both face and content validity by two experienced chemistry teachers and one expert each in science education and test and measurement, all from the University of Uyo, Uyo. The reliability of the instrument was measured by administering it to a trial-test group of thirty (30) students in another school in Uyo local government which was not part of the study. The same instrument was readministered to the same group of students after 2 weeks. The set of scores obtained were correlated using Pearson Product Moment Correlation (PPMC), which yielded a reliability coefficient of 0.79. On the basis of the high reliability index obtained, the instrument was deemed suitable for measuring the students' academic achievement with consistency.

Data analysis of the results obtained was carried out using descriptive statistics of mean, standard deviation and analysis of co-variance (ANCOVA). Mean and standard deviation was used to answer the research questions while Analysis of Covariance was used to test the research hypotheses at a 0.05 level of significance. The researchers accept/retain the hypotheses if the calculated P-value is greater than 0.05 level of significance, but reject the hypotheses if the calculated P-value is less than 0.05 level of significance.

In the procedure for the experiment, the researchers obtained a letter of introduction from the Department of Science Education, University of Uyo which was presented to the principals of the schools sampled to obtain appropriate permission to carry out the studies. The lesson package prepared by the researchers was scrutinized by two experienced chemistry education experts from the Department of Science Education, University of Uyo.

Pretest was administered to the two experimental groups; the cyclic inquiry model and practical inquiry model groups. The lesson packages were used to standardize the presentation of gas law concepts by the research assistants. The teaching was done for four weeks of three periods of chemistry lesson per week. The students in treatment group one was taught gas laws concepts using cyclic inquiry model while those in treatment group two were taught gas laws concepts using practical inquiry. One week later after the teaching of the concepts of gas laws, post-test was administered to the treatment groups. Three weeks after the post-test, the reshuffled test questions were used as retention test. The teaching of the concepts and administration of the test was strictly supervised by the researchers and the investigation lasted for eight weeks.

Presentation of results

Research question 1: What is the academic achievement mean scores of students taught the concept of gas laws using cyclic inquiry model and practical inquiry model?

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Table 1: Mean and standard deviation scores of students' pretest and posttest scores taught gas laws using Cyclic Inquiry Model and Practical Inquiry Model

Group	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
Cyclic inquiry model	50	15.02	5.52	15.88	5.62	0.86
Practical inquiry Model	50	12.90	3.56	13.64	3.64	0.74

Results in Table 1 show the mean gain score of the treatment groups as 0.86 and 0.74 for cyclic inquiry model and practical inquiry model respectively. This result indicates that students taught gas laws using Cyclic inquiry model had the highest mean gain score, followed by Practical inquiry model

Ho1: There is no significant difference in the academic achievement mean scores of students taught the concept of gas laws using cyclic inquiry model and practical inquiry model.

Table 2: Analysis of Covariance (ANCOVA) of Students' Posttest Scores Classified by Cyclic Inquiry Model and Practical Inquiry Model with Pretest scores as Covariate

Source of Variation		Sum of Squares	df	Mean Square	F	Sig. at P<.05
Covariates	Pretest	3058.70	1	3058.70	575.61	0.00
Main Effects	Model	3.36	2	1.68	0.32	0.73
Residual		775.82	146	5.31		
Total		3837.87	149	25.76		

In Table 2, the calculated Probability value (P-value) .73 of the main effects (models) is greater than the significance level (.05). Therefore, the null hypothesis is retained. This implies that at P < .05, there is no significant difference in the mean scores of students taught the concept of gas laws in chemistry using cyclic inquiry and practical inquiry model.

Research question 2: What is the academic achievement mean scores of male and female students taught the concept of gas laws using cyclic inquiry model and practical inquiry model?

Table 3: Mean and standard deviation scores of male and female students' pretest and posttest taught gas laws using cyclic inquiry model and practical inquiry model?

Model	Gender	N	Pretest		Posttest		Mean Gain
			Mean	SD	Mean	SD	
Cyclic inquiry model	Male	23	16.13	4.39	16.87	4.87	0.74
	Female	27	14.07	6.25	15.04	6.16	0.97
Practical inquiry model	Male	23	12.43	3.15	13.52	3.26	1.09
	Female	27	13.30	3.90	13.74	3.99	0.44

Results in Table 3 show the mean gain of male students taught the concept of gas laws using cyclic inquiry model and practical inquiry model as 0.74 and 1.09 respectively, while those of their female counterparts are 0.97 and 0.44 respectively. This result indicates that female students' mean gain score taught the concept of gas laws using cyclic inquiry model is higher than that of their male counterparts; while mean gain score is higher for male than female for those taught with practical inquiry model.

Ho2: There is no significant difference in the academic achievement mean scores of male and female students taught the concept of gas laws using cyclic inquiry model and practical inquiry model.

Table 4: Analysis of Covariance (ANCOVA) of male and female students' posttest scores taught using models with pretest scores as covariate

Source of Variation		Sum of Squares	Df	Mean Square	F	Sig. at P<.05
Covariates	Pretest	3058.70	1	3058.70	567.03	.00
Main Effects	Model	3.36	2	1.68	0.31	.73
	Gender	2.64	1	2.64	0.49	.49
2-Way Interactions	Model * Gender	1.80	2	0.90	0.17	.85
Residual		771.376	143	5.394		
Total		3837.873	149	25.758		

In Table 4, the calculated Probability value (P-value) .49 of the main effects of Gender is greater than the significance level (.05). Therefore, the null hypothesis is retained. This implies that at P < .05, there is no significant difference in the academic achievement of male and female students taught the concept of gas laws using cyclic inquiry model and practical inquiry model.

Research question 3: What differences exist in students' retention scores on gas laws when taught using cyclic inquiry model and practical inquiry model?

Table 5: Mean and standard deviation scores of students' posttest and retention scores taught gas laws using cyclic inquiry model and practical inquiry model

Group	N	Posttest		Retention		Mean Gain
		Mean	SD	Mean	SD	
Cyclic inquiry model	50	15.88	5.62	17.22	5.87	1.34
Practical inquiry Model	50	13.64	3.64	14.54	3.70	0.90

Results in Table 5 shows the mean gain score of the treatment groups as 1.34 and 0.90 for cyclic inquiry model and practical inquiry model respectively. This result indicates that students taught gas laws using Cyclic inquiry model had the highest mean gain score, followed by Practical inquiry model.

Ho3: There is no significant difference in students' retention mean scores on gas laws in chemistry when taught using cyclic inquiry model and Practical inquiry model.

Table 6: Analysis of Covariance (ANCOVA) of students' retention scores classified by cyclic inquiry model and practical inquiry model with posttest as covariate

Source of Variation	Sum of Squares	df	Mean Square	F	Sig. at P<.05
Covariates Posttest	3517.35	1	3517.35	702.08	.00
Main Effects Model	14.56	2	7.28	1.45	.24
Residual	731.44	146	5.01		
Total	4263.36	149	28.61		

In Table 6, the calculated Probability value (P-value) .24 of the main effects (models) is greater than the significant level (.05). Therefore, the null hypothesis is retained. This implies that at P < .05, there is no significant difference in the students' retention scores on gas laws in chemistry when taught using cyclic inquiry model and practical inquiry model.

Discussion of findings

The research findings are discussed to show the implication for teaching and learning the concept of gas laws.

The findings on the difference in the academic achievement scores of students taught the concept of gas laws using the cyclic inquiry model and practical inquiry model indicated a non- significant difference. This result indicates that all models were at the same level of academic performance in teaching the concept of gas laws. According to Saeed (2011), the study on the effects of cyclic inquiry model on achievement of students in chemistry indicated a non-significant difference.

The findings on the difference in the academic achievement scores of male and female students on gas laws when taught using cyclic inquiry model and practical inquiry model indicated a non-significant difference. The inquiry models provided an efficient learning environment, giving the learners the opportunity to explore the underlying principles of gas. The finding is in line with Diana (2014) who examined the effect of inquiry models on male and female students' academic achievement in science course. He pointed out that there is no significant difference in either male or female students' academic achievement.

The findings from the difference in students' retention mean scores in chemistry when taught gas laws using cyclic inquiry model and practical inquiry model indicated a non-significant difference. The finding is in line with the findings of Adegwe (2012) who maintained that retention has no significant influence on students' achievement in chemistry, particularly when investigations are done with inquiry.

Conclusion

The study investigated the effects of two inquiry learning models on students' academic achievement and retention in senior secondary school chemistry in Uyo Metropolis, Nigeria. The study was guided by three research questions and three null hypotheses. The research design adopted for the study was quasi-experimental design using a non-randomized pre-test post-test experimental group design. A purposive sampling technique was adopted for the study and the population consisted of all senior secondary II (SS2) students in the fourteen (14) public secondary schools in Uyo Metropolis with a sample of hundred (100) students. The instruments used for data collection data was the Gas Law Achievement Test (GLAT), which was later reshuffled and used as retention test. The instrument was face and content validated. Descriptive statistics was used to answer the research questions while the hypotheses were tested using the Analysis of Covariance (ANCOVA). The results showed that the hypotheses indicated no significant difference among the models in the academic achievement and retention scores in the concept of gas laws. It can therefore be concluded from this study that cyclic inquiry model and practical inquiry model, amongst others, can serve as a unique method for the teaching and learning of difficult topics in chemistry and other science subjects, because of their practical nature which creates room for students to learn through inquiry and from previously existing scenarios, therefore helping to eradicate and minimize the failure rates among science students.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Students of chemistry should apply inquiry models to their learning structure and try to look out for other new and effective models of learning in order to enhance their academic achievement in gas laws and other concepts in chemistry.
2. Teachers of chemistry should make effective use of inquiry models in the teaching of gas laws and other concepts in chemistry in order to improve learning.
3. Seminars, conferences and workshops should be organized for science teachers, especially those in chemistry, for more enlightenment and effective utilization of inquiry models as strategies for teaching and learning.

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