

DEPLOYING MASTERY AND ACTIVE LEARNING STRATEGIES FOR EFFECTIVE TEACHING OF DIFFICULT CONCEPTS IN CHEMISTRY EDUCATION

ASSOC. PROF. UGBE, AGIOLIWHU UGBE

Faculty of Science Education

University of Education & Entrepreneurship, Akamkpa

Email: ugbeugbe80@gmail.com Phone No: 08065102765

NTONI, NKINKWA IROM

Faculty of Science Education

University of Education & Entrepreneurship, Akamkpa

nkirkwantoni42@gmail.com 08166981415

&

UMORU, JAMES IGUI

Faculty of Science Education

University of Education & Entrepreneurship, Akamkpa

umorojames5@gmail.com 07037380443

ABSTRACT

This study aimed at investigating the effects of deploying mastery and active learning strategies in teaching difficult concepts and student's achievement and retention in Senior Secondary School Chemistry. A total of 235 Senior Secondary School Two chemistry students will be involved in the study. This number was made up of 123 males and 112 females drawn from ten secondary schools in Calabar Education Zone of Cross River State. Three research questions and three research hypotheses were formulated to guide the study and were tested at 0.05 level of significance. Quasi experimental design was used for the study, adopting a non-randomized pretest-posttest control group with 3x3x2 factorial arrangement. Three research instruments were used to gather data for the study namely Chemistry Achievement Test (CAT), Chemistry Retention Test (CRT) and Cognitive Ability Test (CAT). Also, Kuder-Richardson formula-21 was used to establish the reliability of Chemistry Achievement Test (CAT). Data collected was analyzed using Analysis of Covariance (ANCOVA) and Scheffe Post Hoc analysis was used to obtain the direction of significance. Based on the result of the findings indicating the efficacy of mastery and active learning strategies, it was concluded that Mastery learning strategy facilitate students performance and retention in the concept of quantum number follow by active learning strategy. It was therefore recommended that science teachers should adopt Mastery and Active learning strategies to teach various concepts in chemistry.

Keywords: Mastery Learning, Active Learning, Performance, Retention, Difficult Concept.

INTRODUCTION

Chemistry is an indispensable tool for the scientific and technological emancipation of any growing nation. It is a widely held view by (Freeman, 2024) that the scientific development of any nation is enhanced by the quality of chemistry education in its schools. This implies that chemistry education is the bedrock of technological development (Adeoye, 2010). High level of scientific and technological attainment is dependent on the chemistry education of the citizenry, hence the knowledge of chemistry concepts at all levels of education are indeed essential ingredients for developing strong foundations and sound academic achievement in the subject as well as its application in other science and technology fields. (Adeoye, 2010)

Consequently, in order to foster the development of science and technology in Nigeria the national content of chemistry education at the secondary school level as stated in the National Policy on Education FRN (2014) seek to expose the students to

1. Basic chemistry concepts.
2. Creativity and development of process skills and correct attitudes.
3. Individual experimentation questioning and problem- solving using simple inexpensive equipment.
4. The role and significance of chemistry in the study of other disciplines
5. The relevance of chemistry to the society and
6. Extra-curricular activities designed to inculcate a deeper appreciation of science and technology and their role in the development of human society

Researchers for over ten years are faced with finding relevant solutions to the problem of poor achievement recorded yearly in senior secondary school chemistry examinations conducted by west African Examinations Council (WAEC) and National Examination Council (NECO) in Nigeria (Okoronka, 2023). Researchers in chemistry instruction also acknowledge that the traditional lecture- style known as expository method in teaching chemistry concepts failed to impart deep seated conceptual understanding of chemistry contents in students (Clark & Elen, 2016).

It is therefore pertinent to look for methods and strategies that can be used in order to address the problems of teaching and learning of chemistry in senior secondary schools. Such variables that could be manipulated include: Mastery learning and active learning strategies which are all forms of constructivism. Constructivist learning is based on cognitive theory of learning which holds that learning takes place as a result of intuition.

Mastery learning is a strategy of teaching and learning that involves the student reaching a level of predetermine mastery on units of instruction before being allowed to progress to the next unit. It is a process whereby students achieve the same level of content mastery but at different time intervals (Davis & Sorrell, 2017). The mastery learning strategy divides subject matter into units that have predetermined objectives or units expectations. Students alone work through each unit in an organized fashion. Students must demonstrate mastery on a particular unit typically 70% before moving on to new material. A student who does not achieve mastery receive remediation through tutoring, peer monitoring or additional homework. Also, additional time for learning is prescribed for those requiring remediation.

Students continue the cycle of studying and testing until mastery is met. (Robonson, 2023).

Active learning is an instructional approach in which students engage in meaningful learning activities and think about what they are doing, rather than passively receiving information (Bonwell & Elson, 1991). It is deeply rooted in constructivist theory (Piaget, Vygotsky) where learners build knowledge actively. It is an educational approach where students engage in learning activities that involve doing and thinking rather than passively receiving information. It focuses on student centered experiences, encouraging them to actively participate in discussions, solve problems, conduct investigations, and reflect on the content they are learning. Key benefits include deeper understanding, increased knowledge, retention, improved critical thinking, higher motivation and engagement (Bonwell & Elson, 1991).

The key principles in active learning strategy are (1) Engagement: where students are actively involved in the learning material through interactive tasks (2) Reflection: Here learners think about the information, its relevance, and how it connects to their existing knowledge (3) Application: Students apply new concepts and skills in practical situations. Common activities inherent in active learning strategy include, discussion: students tackle complex question and finding solutions. Writing: articulating ideas and understanding in their own words. Answering polling questions: students participate in interactive questions and answer sessions as well as group activities that involve collaborating with peers on tasks and projects. (Prince, 2004).

The major characteristics of active learning include student-centered approach, collaborating and interaction, critical thinking and problem-solving as well as reflection and feedback. Strategies of active learning include think-pair-share, problem-based learning (PBL), case studies, peer teaching, role play and simulations, flipped classroom and concept mapping.

The benefits of active learning strategy include (1) improves critical thinking and retention (2) promotes remark and communication (3) enhances motivation and engagement as well as developing lifelong learning skills. (Freeman, 2014).

Difficult concepts in chemistry often include abstract topic with significant mathematical components. They combine abstract models, mathematical reasoning, and microscopic-macroscopic connections to master them, students benefit from visual aids (models, diagrams), practical experiment and consistent problems-solving practice (Chang, Barnfold, 2019).

These concepts often include thermodynamics, chemical kinetics, Stoichiometry and mole concept, quantum chemistry, electrochemistry and advanced organic concept like hybridization a NMR spectroscopy which require deep conceptual understanding and high-level reasoning. (Akpan, 2017). This study is based on constructivist theory advocated by (Piaget, Vygotsky) where learners build knowledge actively.

Statement of the problem

There is perception by students that chemistry is a difficult subject and this has led to declining rate of students achievement in chemistry in Senior Secondary School Certificate Examination (SSCE) conducted by West African Examination Council (WAEC) and National Examination Council (NECO) in Nigeria.

Table 1

WAEC and NECO: Chemistry performance report (2019-2023)

2019:	WAEC	45-55%	NECO	50-60%
2020:	WAEC	42-52%	NECO	50-62%
2021:	WAEC	48-58%	NECO	52-64%
2022:	WAEC	45-54%	NECO	50-60%
2023:	WAEC	46-56%	NECO	50-60%

Source: <http://www.waeconline.org.nge-learning/chemistry/chermain. internal>

This table indicates percentages range of candidates that obtained credit/C6 or better in chemistry.

A survey reveals that 45-55%, 50-60% 42-52%, 50-62%, 48-58%, 52-64%, 45-54%, 50-60%, 46-56% and 50-60%. Of those who enroll in chemistry at WAEC and NECO in 2019, 2020, 2021, 2022 and 2023, respectively passed at credit level.

This indicate that students achievement in chemistry is low. Also, in the senior secondary chemistry curriculum, there are some concept that are deemed difficult by both the teachers and students and quantum numbers is one of such concepts <https://www.scribd.com>

For over five years, students performed poorly in the concept of quantum, numbers in chemistry at the senior secondary school certificate examination (SSCE), (WAEC, 2019: 2023). It may imply that instructional strategies used in teaching of chemistry may not have helped in enhancing students academic performance and retention. Therefore, it becomes inevitable to try out other instructional strategies that could enhance effective teaching and learning of chemistry. The problem of the study is how can student's performance and retention in chemistry be enhanced? Which of the strategies: mastery learning, active learning or conventional learning would proof most effective in facilitating students achievement and retention in the concept of quantum numbers in chemistry? This study seeks to find answers to these questions.

Purpose of the study

The purpose of the study was to investigate the effects of mastery, active and conventional learning strategies on student performance and retention in senior secondary school chemistry.

The study was designed to achieve the following specific objectives.

1. To determine the effects of instructional strategies (mastery learning, active learning and conventional learning) on students achievement in the concept of quantum numbers in chemistry.
2. To examine the effects of instructional strategies (mastery learning, active learning and conventional learning) on students retention in the concept of quantum numbers in chemistry.
3. To assess the effects of cognitive ability levels (high, average and low) on students performance in the concept of quantum numbers in chemistry when taught with mastery, active and conventional learning strategies.

Research questions

In order to guide the study, the following research questions were posed.

1. What differences exist among the performance of students in the concept of quantum number in chemistry when taught using mastery, active and conventional learning strategies?
2. What differences exist among the retention of students in the concept of quantum number in chemistry when taught using mastery, active and conventional learning strategies?
3. What differences exist among the performance of students with different cognitive ability levels (high, average and low) in the concept of quantum numbers in chemistry when taught with mastery, active and conventional learning strategies?

Research hypotheses

The study specifically tested the following null hypotheses at .05 level of significance.

1. There is no significant difference in the mean performance scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies.
2. There is no significant difference in the mean retention scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies.
3. There is no significant difference in the mean achievement scores of chemistry students with high, average and low cognitive ability levels taught the concept of quantum numbers using mastery, active and conventional learning strategies.

Methodology

Research design

The research adopted a non-randomized pretest-posttest control group with a 3x3x2 factorial arrangement in quasi-experimental design. Intact classes were used for both experimental and control groups.

Area of Study

This study was conducted in schools in Calabar Educational Zone of Cross River State out of three Educational Zones.

Population

The population for the study was made up of all the 1,120 senior secondary two (Ss2) chemistry students for the 2024/2025 session in the 20 co-educational secondary schools in Calabar Educational zone of Cross River State.

Sampling technique and sample

A total of two hundred and thirty five (235) students took part in the study. This was made up of 123 males and 122 females in senior secondary two (SS2) chemistry students in the selected six schools for the study, purposive sampling technique was used to select schools from the target population.

Fourteen (14) schools met the criteria, the criteria were:

1. Schools that have equipped chemistry laboratory
2. Schools that have experience chemistry teachers
3. Schools that are currently presenting candidates for Senior Secondary Certificate Examinations (SSCE).
4. Schools in which the concept of quantum number have not been taught yet.

Six (6) schools among those that met the criteria were selected by balloting. This involves the use of thoroughly mixed ballot papers. The subjects' test scripts were numbered serially and balloting was carried out by the researcher to select the scripts of subjects that constituted the sample. One intact class was randomly selected in each school. The six schools were randomly assigned to treatment and control groups. Three schools were used for control groups, while the reminding 3 were used for treatment.

Instrumentation

The following instruments were used to collect data for the study.

- i. Chemistry Achievement Test (CAT)

This was used to determine the performance of students in the concept of quantum numbers.

- ii. Chemistry Retention Test (CRT)

This test was used to determine the retention of students in the concept of quantum number when taught with different instructional strategies. The pretest and posttest contained the same questions in the retention test but arranged in different order.

- iii. Cognitive Ability Test (CAT)

The test was used to determine the cognitive ability levels of the subjects used for the study and results obtained were used to classify students into high, average and low ability levels.

Each of the instrument contained fifty (50) multiple choice items constructed on the concept of quantum numbers, with items having four option with only one correct answer. All the instruments were face and content validated by the researcher. Reliability of the instruments was also determined using kuder-Richardson formula 21. Chemistry Achievement Test (CAT) had a reliability coefficient of 0.77, while cognitive Ability Test (CAT) had a reliability coefficient of 0.82 scoring.

The researcher scored the instruments immediately after its administration. Each correct answer was scored two (2) marks. The total (maximum mark) for all the fifty questions was one hundred (100) and the minimum was zero (0).

Research Procedure

Relevant permission was obtained from the school principals as well as the chemistry teachers in each of the school that were used for the study. Chemistry teachers in each school used were trained and serve as research assistants to teach each group. The research assistants were trained for one week on the use of the teacher's instructional guide for various strategies that were used for teaching the concept of quantum numbers. Training was done in three phases to ensure that the research assistants have the requisite knowledge of the strategies as well as adhere strictly to the instructional guide constructed for each strategy.

Pre-achievement test was administered prior to treatment to all groups and the results were used as covariate measures. After the administration of the pre-achievement test, cognitive ability test was also administered to all the groups with the help of research assistants. Results obtained were used to classify the students into three groups of ability levels using inter-quartile range.

Teaching of the concept, quantum numbers was done by the research assistants in each school using the teacher's instructional guide developed group 1 was taught using mastery learning, experimental group 2 was taught using active learning while the control group was taught using lecture learning strategy. The posttest was administered immediately after the treatment to all the groups.

Three weeks after the posttest had been given the retention test was administered. A reshuffled version of (CAT) Pretest was administered as posttest, also administered as retention test.

Method of data analysis

The data collected were analyzed using descriptive statistics (Mean, standard deviation and mean gain scores). Analysis of Covariates, (ANCOVA) using pre-achievement test as covariates, and scheffe multiple companion test were used for posthoc analysis. All hypotheses were tested at .05 level of significance.

Results

The three hypotheses were tested at .05 level of significance.

Hypothesis one (1)

There is no significant difference in the mean achievement scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies. The analysis is as shown in table 2.

Table 2: One way Analysis of covariance (ANCOVA) of posttest scores of chemistry students taught with mastery, Active and conventional learning strategies using pretest scores as covariates.

Sources of Variation	Sum of Squares	Df	Mean Square	F	Sig.	Decision at P <.05
Corrected Model	11562.09	3	3854.03	132.85	.000	*
Intercept	1148.23	1	11448.23	394.63	.00	*
Pretest	851.76	1	851.76	29.36	.00	*
Strategy	7407.99	2	3703.99	127.68	.00	*
Error	6701.33	231	27.01			
Total	912204.00	235				
Corrected Total	18263.42	234				

* = significant at P<.05 alpha level

a = R- square = .633 (Adjusted R. squared = .628)

The result in table 2. Shows that the main effect of treatment (strategies) on students academic achievement in the concept of quantum numbers in chemistry was significant ($F(2,232) = 127.68$, $p = .000$). Therefore, the null hypothesis stating a non-significant difference in the mean achievement scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies was rejected. This implies that the three types of instructional strategies (mastery, active and conventional) differ significantly in their enhancement of the achievement of chemistry students in the concept of quantum numbers.

Table 2 also shows a multiple regression squared index (R^2) of 63. This implies that 63% of the total variance in the achievement of students in the concept of quantum numbers in chemistry is attributable to the influence of instructional strategies.

In order to find out the effectiveness of instructional strategies and direction of significance under investigation, the posttest scores were subjected to Scheffe multiple comparison test for a posthoc analysis as shown in table 3.

Table 3: Results of Scheffe's Posthoc test for multiple comparison of instructional strategies on students achievement in chemistry.

Dependent Variable: Posttest Scores

(I) Instructional strategies	(J) Instructional strategies	Mean Difference (I-J)	Std Error	sig	95% confidence lower bound	Internal upper bound
MAS	ACT	6.67*	.86	.000	4.97	8.36
	CON	14.67*	.92	.000	12.84	16.45
ACT	MAS	-6.67*	.86	.000	-8.36	-4.97
	CON	7.98*	.92	.000	6.17	9.78
CON	MAS	-14.64*	.92	.000	-16.45	-12.84
	ACT	-7.98*	.92	.000	-9.78	-6.7

* = The mean difference is significant at the .05 level

Where: MAS = mastery

ACT = Active

CON = conventional

As shown table 3, the mean difference between MAS and ACT was 6.67, between MAS and CON was 14.67 and between ACT and CON was 7.98. This implies that mastery learning was the most effective in facilitating students achievement in the concept of quantum numbers in chemistry. This was follow by active learning strategy while conventional learning strategy was the least effective in facilitating students achievement in the concept of quantum numbers in chemistry.

Hypothesis two (2)

There is no significant difference in the mean retention scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies.

The analysis is as shown in table 4.

Table 4: one way analysis of covariance (ANCOVA) of retention scores of chemistry students taught with mastery, Active and conventional learning strategies using pretest scores as covariates.

Source of variation	Sum of squares	Df	Mean square	F	Sig	Decision at p <.05
Corrected model	15374.18	3	5124.94	165.17	.000	*
Intercept	13540.22	1	13540.22	436.39	.000	*
Pretest	783.48	1	783.48	25.25	.000	*
Strategy	10475.04	2	5237.52	168.80	.000	*
Error	7167.38	231	31.03			
Total	1027544.00					

* = significant at p <.05 alpha level

a = r squared= .682 (Adjusted R. squared = .678

The result in table 4 shows that the main effect of treatment (strategies) on students retention in the concept of quantum numbers in chemistry was significant ($F(2.232) = 168.80, p = .000$). Therefore, the null hypothesis stating a non-significant difference in the main retention scores of chemistry students taught the concept of quantum numbers using mastery, active and conventional learning strategies was rejected. This implies that the three types of instructional strategies differ significantly in their enhancement of the retention of chemistry students in the concept of quantum numbers. Table 4 also shows a multiple regression squared index (R^2) of .68. This implies that 68% of the total variance in the retention of students in the concept of quantum number in chemistry is attributed to the influence of instructional Strategies.

Hypothesis three (3)

There is no significant difference in the mean achievement scores of chemistry students with high, average and low cognitive ability levels taught the concept of quantum numbers using mastery active and conventional learning strategies.

The analysis is as shown in table 5

Table 5 one way analysis of covariance (ANCOVA) of posttests scores of chemistry students with different ability levels using pretest scores as covariates.

Source of Variation	Sum of squares	Df	Mean square	F	sig	Decision at p <.05
Corrected model	7183.09	3	2394.03	49.91	.000	*
Intercept	8703.80	1	87.3.80	181.44	.000	*
Pretest	1464.73	1	1464.73	30.53	.000	*
Ability	3027.99	2	1513.99	31.56	.000	*
Error	11081.34	231	47.97			
Total	912204.00	235				
Corrected Total	18263.42	234				

a = R. Square = .393 (Adjusted R. squared = .385)

* = significant at P<.05 alpha level.

The result of table 5 shows that the main effect of cognitive ability levels on students achievement in the concept of quantum numbers in chemistry was significant ($F(2.232) = 31.56$, $p = .000$). Therefore, the null hypothesis stating a non-significant difference in the mean achievement scores of chemistry students with high, average and low cognitive ability levels taught the concept of quantum numbers using mastery active and conventional learning strategies was rejected. The table shows a multiple regression squared index (R^2) of .385. This implies that 39% of the total variance in the achievement of chemistry students in the concept of quantum numbers is attributed to the influence of cognitive ability levels.

Discussion of Results

The primary aim of the study was to find out the effect of instructional strategies (mastery, active and conventional learning strategies) on students achievement and retention in the concept of quantum numbers in chemistry. The results of the investigation as shown in table 2 indicated a significant difference was found to exist in the achievement of students in the concept of quantum numbers in chemistry after being taught with mastery, active and conventional learning strategies. The table also reveals that 63% of the total variance in the achievement of students in the concept of quantum numbers in chemistry was attributable to the influence of instructional strategies. In order to find the order of effectiveness of instructional strategies and direction of significance under investigation, Scheffe multiple comparison test was employed for the posthoc and the results indicated that mastery learning strategy was the most effective in facilitating students achievement, followed by active learning strategy while conventional was the least.

The findings supports the earlier studies of Ngesa (2002), Wachanga and Gamba (2004) that mastery learning strategy yielded better achievement and retention in science subjects than non- mastery strategies. This study is also in agreement with the work of Kulik, et al (2021)

that mastery learning strategy stressed more of mastery of content through corrective skills, therefore superior to regular teaching method. This study is also in line with the findings of Freeman (2014) that active learning strategy is a viable strategy that enhances achievement, develop higher- order thinking skills like creativity, critical thinking and problem-solving. This is due to the fact that active learning involves hands-on activities.

Results in table 5 also indicated that a significant difference was found to exist in the mean achievement scores of chemistry students with high, average and low cognitive ability levels taught the concepts of quantum numbers using mastery, active and conventional learning strategies. The result is in line with the findings of Adeyemo (2010) that students ability levels have significant influence on problem- solving tasks. The result is also in agreement with the finding of Inyang and Ekpenyong (2000), and Orimogunje (2003) that students ability levels is a significant factor in their achievement in the chemistry units studied and a significant difference exists between the mean posttest and pretest scores among students of different ability levels in the learning and understanding of chemistry concepts.

Conclusion

Based on the results of the study, it can be concluded that mastery learning strategy facilitate students performance and retention in the concept of quantum numbers in chemistry followed by active learning strategy. The use of mastery and active learning strategies in this study have been found to close the gap between low and average cognitive ability levels. Hence the strategies improve students achievement and retention in the concept of quantum numbers in chemistry.

Recommendations

Based on the results of the findings the following recommendations are made:

1. Teachers should endeavor to use mastery and active learning strategies alongside the conventional method in teaching various concepts in chemistry.
2. Seminars, workshops and conferences should be organized by government for chemistry teachers to appraise them with the use of mastery and action learning strategies.

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