Effects of Cyclic-Inquiry and Interactive Modeling Techniques on Students' Academic Achievement in Chemical Equilibrium in Senior Secondary Schools in Uyo, Akwa Ibom State.

Akpan, Utibe C.
miracleobada98@gmail.com

Umanah, Felicia I.
feliciaumanah@aksu.edu.ng

Udofia, Sabbath E.
seudofia2015@gmail.com

Akpan, Iniobong F.
iniobongakpan@aksu.edu.ng
Department of Science Education
Faculty of Education
Akwa Ibom State University
Ikot Akpaden, Mkpat Enin
Akwa Ibom State, Nigeria

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Abstract
The study was carried out to examine the effect of modeling instructional techniques on students' academic achievement in chemical equilibrium in senior secondary schools in Uyo, Akwa Ibom State. Three (3) research questions and three (3) hypotheses were raised for this study. This study made use of a quasi-experimental research design of a pretest-posttest control group. The population for this study consisted of 2,760 Senior Secondary Two (SS2) Chemistry students in all the co-educational public secondary schools in the study area during the 2024/2025 academic session. The sample for the study comprised 152 senior secondary two students and a simple random sampling technique was used for the selection. A researcher-made instruments, "Achievement Test on Chemical Equilibrium (ATCE)" was used for data collection. Face and content validations were used for validating the instruments. Reliability coefficients of 0.86 was obtained for the "Achievement Test on Chemical Equilibrium (ATCE)" using the Kuder-Richardson 20 formula. Mean and standard deviation were used to answer the research questions raised while Analysis of Covariance (ANCOVA) was used to test the hypotheses formulated in the study at .05 level of significance. The major findings of the study showed that there is significant main effect of Interactive modelling, Cyclic-inquiry modelling and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium. It was concluded that Interactive modelling and Cyclic-inquiry modelling enhance students' academic achievement in chemical equilibrium in senior secondary schools in Uyo, Akwa Ibom State. The

modellings are friendly to both male and female students as gender had no effect on students' academic achievement. It was recommended among others that teachers should adopt modeling techniques as a primary instructional approach when teaching concepts like chemical equilibrium, since this modeling technique actively engages and enhances students' academic achievement.

Introduction

Science education is the cornerstone of modern society and forms the basis of recent technological advancements. It plays a fundamental role in shaping students' understanding of the natural world, fostering critical thinking and preparing them for careers in science, technology, engineering and mathematics (STEM). Science education encompasses the teaching and learning of scientific concepts, processes and reasoning across various disciplines. Science education aims to cultivate scientific literacy-enabling individuals to make informed decisions, engage in problem-solving and appreciate the world of science. It extends beyond the classroom, influencing industries, enhancing public policies and solving global challenges (Negedu, Alafiatayo & Dauda, 2024). A well-educated population in science contributes to innovation leading to economic growth, developing scientific literacy, critical thinking and problem-solving skills necessary for informed decision-making in personal, societal and global contexts (Agboola, 2025). Science education is believed to be a determinant of the progress and prosperity of any nation, its development has resulted in the explosion of knowledge and innovations in every sector of the society. All such innovations are directly or indirectly related to human ingenuity and creative potentialities which are vital for the progress of any society and plays a major role in making life more meaningful. One of the major aims of science education is to produce students who are successful social beings, therefore efforts should be made to provide adequate social practices alongside with formal education. The emphasis of science education is on enhancing students' scientific literacy through investigative activities that involves planning, measuring, observing, analyzing data, scientific evidences, designing and evaluating procedures. This fact is enriched in the National Policy on Education (Federal Republic Nigeria, 2014) which states that science education should among other things; equip students to live effectively in the modern age of science and technology. The policy also emphasizes science teaching and learning as an instrument for inculcating the necessary scientific knowledge, skills and competencies. The major goal of science education is to develop scientifically literate individuals that are concerned with high competence for rational thoughts and actions. Science education is needed to expel ignorance, poor cultural practices and beliefs in the society which calls for effective science education that is relevant for the economic improvement of the society. The objectives of science education in Nigeria according to Madueke (2016) includes the need to prepare students to:

i. Observe and explore the environment.
ii. Explain some natural phenomena.
iii. Develop scientific attitudes towards curiosity.
iv. Apply the skills and knowledge gained through science to solve everyday problem in the environment.
v. Critical reflection and objectivity.
vi. Develop self-confidence and self-reliance.

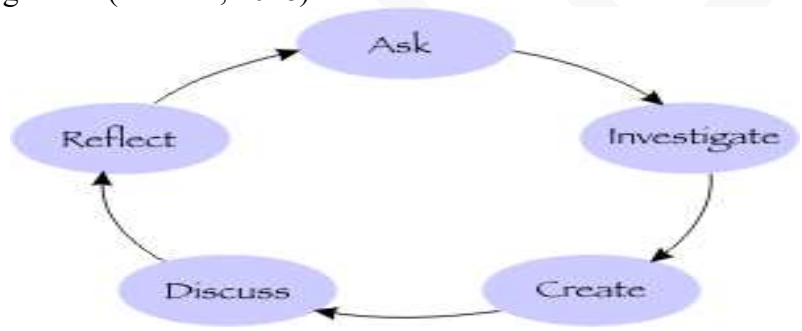
These objectives are necessary to enhance proper learning outcomes of science students (Hart, 2015). The importance of science education especially at the secondary school level cannot be overemphasized. It is in view of this that the Federal Government of Nigeria focuses their attention on how to improve science teaching and learning (Federal Republic of Nigeria, 2014). To this end,

some state Governments like Akwa Ibom State, Rivers State and Imo State have established special science schools at the secondary school level, in order to elevate the knowledge of science teaching among students in Nigeria. The Science Teachers' Association of Nigeria (STAN) and other educational agencies have also mounted several long vacation programs, conferences, workshops, seminars, science fairs and quizzes in order to improve science teaching and learning. For instance, the Science Teachers Association of Nigeria (STAN) conference held from Friday, 5th to Saturday 6th of December, 2025 at the federal Science Technical College, Awka; with the theme "Innovations and National Development in STEM Education". The purpose of the conference was to improve the welfare of teachers as well as equipping the teaching and learning environment in schools with better understanding and knowledge of science education. This was made necessary in order to give science teachers the adequate support needed to acquire better teaching experiences. In spite of these actions taken by the Government, students' achievements in chemistry have remained low (Ibe, 2016). In this regard, chemistry has posed a major challenge to students' academic achievement and is to be addressed accordingly. There is therefore need for chemistry teachers to rely on effective teaching methods which are easy to implement in the classroom for better understanding of chemistry by the students. The teaching of chemistry which is mostly applicable to virtually all other areas of science disciplines has become very necessary in passing science instructions to students. Chemistry education as one of the most vital units of science forms the major bedrock of science education. It's a more practical field as it helps to build most scientific frameworks in basic educational settings.

Chemistry as a natural science deal principally with the properties of substances, the changes they undergo, and the natural laws that describe these changes (Umanah & Sunday, 2022). Advancements in the field of Chemistry have brought about major improvements in our today's world. These improvements range from new medications that cure diseases, to new materials that make us safer and stronger, new sources of energy which gives rise to new and improved activities. In chemistry, students constantly analyze complex concepts, understand chemical processes, and draw logical conclusions from evidence. This process of critical analysis begins with the exploration of fundamental principles and extends to the application of these principles in various experiments and scenarios. By engaging in hands-on laboratory experiments, students not only reinforce theoretical concepts but also develop the ability to apply these concepts to real-world situations. Practical experiments like conducting titrations or observing chemical reactions help students think critically, hypothesize, and draw conclusions. It encourages students to think creatively when faced with scientific challenges. Students explore multiple avenues of inquiry and develop innovative solutions by predicting reaction products and devising experimental procedures. Despite the importance of Chemistry as the central science which forms the basic foundation for many science disciplines and improves the quality of life, the achievement of students in Chemistry in senior secondary schools have been poor in external examinations. Unfortunately, the teaching and learning of chemistry has been fraught with challenges which prevent many students from performing well in external examinations such as West African Senior School Certificate Examination (WASSCE) and National Examination Council (NECO). For instance, in Nigeria, about 45% of students failed chemistry in the just concluded West African Senior School Certificate Examination (2025), which indicates a sharp back-drop from last year's performance. The teaching of basic chemistry concepts can be properly enhanced through the adoption of effective teaching techniques in teaching science as it leads to better academic achievement of students (Udofia, 2022). There are several modern teaching techniques which could be preferably applied in the teaching and learning of science concepts in the 21st century as

compared to the conventional methods. Nowadays, classrooms are modified and equipped with modern teaching aids such as speakers, online streaming videos, virtual software, interactive whiteboards, visualizer, response system, compact disks, projectors and diverse educational software. These techniques are designed to provide basic frameworks for educators to organize their instructional strategies and improve the learning experiences of their learners.

There exist several forms of modeling techniques often used in teaching, each serving a different purpose and catering to various learning styles. These include Synectic modeling, insight modeling, cyclic-inquiry modeling, practical modeling, verbal modeling, physical modeling, visual modeling, cognitive modeling, metacognitive modeling, 5E-instructional modeling, conceptual system modeling, symbolic modeling, mental modeling and interactive-engagement modeling techniques. This study sought to focus on cyclic inquiry modeling and interactive-engagement modeling techniques. Cyclic-inquiry modeling technique is a structured process of learning and improvement that involves repeatedly cycling through several phases to address a specific question and problem. It is a cycle of inquiry learning or action-research that involves reflecting on practice and improves students' academic performance. It helps to engage students in asking and answering questions based on collected information gathered, which often leads to the creation of new ideas and concepts (Akpan & Umanah 2024). Abdi (2024) found that students instructed through inquiry-based learning achieved higher than the ones instructed through the traditional method. Cyclic-inquiry modeling technique embraces an exploratory approach that motivates learners' problems to be solved, giving answers to their questions, engages learners through motivation, hands-on activities, collaboration, dialogues and stimulates learners' construction of meaning through the process of solving problems and then posing emergent questions. It basically consists of five stages: ask, investigate, create, discuss and reflect. Each stage in this cycle is seen as a process that provides learners with context-situated and content-specified learning experiences that helps them explore the world out of curiosity and interest in a connected fashion which can be embedded, interrelated or independent depending on the situated learning needs (Ibrahim, 2018).



These five dimensions (as shown in figure 1.0 above) involved in the process which is Ask, Investigate, Create, Discuss and Reflect overlaps each other and not every step or category is present in any given inquiry. Each step can be embedded in any of the others.

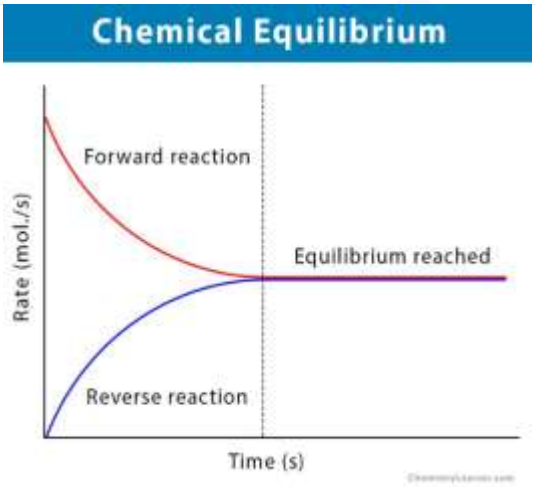
Ask is an inquiry step that develops from a question or problem arising out of experience. Meaningful questions are inspired by genuine curiosity about real world experiences and challenges. It is not something that can be delivered from "outside" this participation. This is why there is "an enormous pedagogical difference between answering someone else's question and formulating ones' own". (Odds et al, 2018.) It is very important to caution that inquiry does not

always start with a well-articulated question. In fact, questions themselves arise from reflections and actions in the world, including dialogue with others. Eastman (2019) stated this well that: "the best way to find out things is not to ask questions at all, if you fire off a question, it is like firing off a gun, bang it goes and everything takes flight and run for shelter. But if you sit, quietly and pretend not to be looking, all the little facts will come and peck around your feet, situations will venture forth thickets, and intentions will creep out and sun themselves on a stone", and if you are very patient, you will see and understand a great deal more than a man with a gun does.

Investigate relates to the varieties of experiences possible and those several ways which will become part of an indeterminate situation. It suggests that opportunities for learning requires diverse authentic and challenging materials and even becomes problems because experience includes interactions with others. This is also a moral dimension to inquiry. Similarly, physical, emotional, aesthetic and practical dimensions are inherent in inquiry and are not merely enhancement. Through investigations, curiosity is turned into actions as learners gather information, study, craft an experiment, observe or do interview. They may recast questions, refine a line of query or plunge down a new path that the original question did not, or could not anticipate. Investigating encourages students to examine their topics using various sources of information and then plan out their creation and offers them an opportunity to navigate their inquiry (Bruce & Lin, 2009) The student begins to make connections, as the in-formation gathered in the investigation stage begins to coalesce. The ability to synthesize meaning at this stage is the creative spark that forms all new knowledge. The student now undertakes the creative task of shaping significant new thoughts, ideas, and theories outside of his/her prior experience (Bruce, Jakobson & Thakkar, 2023). On this step each group of students Writes a report includes all the knowledge, ideas, and in-formation that have been discovered, and new conclusions reached that might be contribute to answering the main questions (Albaaly 2022) Collected information begins to merge as students start making links. Here, ability to synthesize meanings becomes the spark which creates new knowledge. Students generate new thoughts, ideas and theories that are not directly inspired by their own experiences and write them down in some kind of report. Students report that equilibrium can only be established when the rate of the forward reaction and the rate of the backward reaction are equal, and this can only be achieved under a closed system, it is otherwise referred to as "dynamic equilibrium". The discuss aspect in the inquiry cycle involves listening to others and articulating understanding. Through discussion and dialogue, construction of knowledge becomes a social enterprise. Learners share their ideas and ask others about their own experiences (Bruce & Lin, 2009). Shared knowledge is a community-building process, and the meaning of their investigation is to take up reactor relevance in the context of the learners' society. Learners compare notes, share experiences and discuss conclusions through multiple media like now, online social networks. For example, students often and occasionally sit around each other to discuss and share their newly inquired knowledge with the purpose to understand the concept taught and the principles surrounding them. They are invited to share their findings with the rest of the class, while the teacher takes notes on the background. In reflect, only the inquirer can recognize the intermediate situation, and further tells whether it has been transformed into a unified whole. Reflection may also mean recognizing further indeterminable leading to continual inquiry. Reflection means taking time to look back at initial questions, the research path and the conclusions made. The learners step back, takes inventory, makes observations and new discussions. Has a solution been found? Do new questions come into light? What might those questions be? And so, it begins. For instance, teachers and students takes time to look back at the concepts encountered during the earlier steps of the activity.

Interactive-engagement modeling technique (IE) refers to a teaching technique which engages students in active learning by demonstrating skills, procedures or behaviours providing opportunities for practice and feedback (Kalolo, 2024). It is a learning technique that enables direct interaction between students and teachers. Students interact with each other and with the instructors using guided materials created by the instructors (Jamil & Bhuju, 2023). Ebuoh, (2019) foumd that the use of models in teaching English Language in secondary schools in Enugu Education Zone was found to be better than teaching without models. Techniques such as cyclic-inquiry and interactive modeling might be applied in the teaching of some basic chemistry subjects like chemical equilibrium, in order to achieve higher achievements in chemistry.

Chemical equilibrium is the condition of a system where the concentrations of the reactants and products do not change with time. Also, the system does not show any change in its properties. During a reversible reaction, when the forward and reverse reaction rates become equal, the system achieves the state of chemical equilibrium. There is no further change in the concentrations of the reactants and the products.



Chemical Equilibrium

During equilibrium, the forward reaction rate becomes equal to the backward reaction rate. At this time, the number of reactant molecules transforming into products and the number of product molecules converting into reactants are the same. This equilibrium state can be carried out with the same reactants anywhere with similar conditions. Hence, chemical equilibrium is called dynamic equilibrium; as both the forward and reverse reactions do not cease, they continue to occur at equal rates. So, the ratio between reactants and products remains unchanged over time. A better understanding of chemical equilibrium concepts would lead a greater academic achievement in chemistry examination. The teaching of basic underlying principles of chemistry requires the full participation of both male and female students in the understanding of these concepts.

Gender refers to the socially constructed differences between males and females including their roles, responsibilities, behaviours and attributes as defined by culture and society. 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 (Umanah & Sunday, 2022). Okeke & Onuchukwe (2024) referred to gender as the social or cultural construct characteristics behaviors 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, no disparity (Akpan & Umanah, 2024, Shaibu & Mari, 2019). Adegwe (2022) maintained that gender has no significant influence on students' achievement in Chemistry. Olanrewaju (2020) reported insignificant differences between males and females' academic achievement in chemical equilibrium. Simon (2019) also reported no significant interaction effect of teaching methods and gender on students' academic achievement in Basic Science. The findings of Rufus (2022) affirms that there was no significant interaction effect of gender and instructional strategies on students' academic achievement in Physics. These researches are inconclusive in their report as to whether females and males differ in the ways they solve chemistry problems. As there is controversy on gender differences on their academic achievements, it is imperative to find out if gender differences exist on the academic achievement of students in the concept of equilibrium.

Statement of the Problem

In recent times, the problem of poor academic achievement in chemistry among senior secondary school students has been a major challenge in our nation's educational system, as students still find it difficult to understand some concepts being taught and reproduce same during examinations. Some of these challenges which includes lack of instructional and laboratory materials, lack of adequately trained teachers, poor classroom management, small class size, ineffective teachers' trainings and workshops, poor and outdated laboratory facilities, students' lack of understanding of difficult concepts, improper handling of science apparatus and equipment, poor teaching strategies adopted by teachers during classroom instruction have resulted in students' poor achievement in science examinations. Concepts such as chemical equilibrium which is sometimes seen by some teachers as complex and challenging to teach can easily be understood by students if taught with a more refined modeling technique. It has also been observed that most teaching strategies adopted by some science teachers seem to be outdated and faced-out, thus not able to make way for proper understanding of concepts by students in science subjects especially chemistry. It is in the light of the above, that this study attempts to make use of these modeling techniques to see if students' academic achievement in chemistry could be improved.

Purpose of the Study

The purpose of this study was to examine the effect of cyclic-inquiry and Synectic modeling techniques on students' interest and academic achievement in chemical equilibrium in senior secondary schools in Uyo, Akwa Ibom State. Specifically, the study aimed at investigating the:

1. Main effect of modeling techniques and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium
2. Main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium
3. Interaction effect of modeling techniques, expository and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

Research Questions

1 What is the main effect of modeling techniques and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

2 What is the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

3 What is the interaction effect of modeling techniques, expository method and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

Hypotheses

1. There is no difference in the main effect of modeling techniques on students' academic achievement in chemistry when taught the concept of chemical equilibrium.
2. There is no difference in the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium.
3. There is no difference in the interaction effect of modeling techniques and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium.

Methodology

The design adopted for this study was the quasi-experimental design of the pretest, posttest experimental research designs consisting of two (2) experimental groups (cyclic-inquiry and interactive-engagement modeling techniques) and expository method, being pre-tested and post-tested before and after being taught chemical equilibrium using these two (2) modeling techniques and expository method. The study was conducted in all the 14 public secondary schools in Uyo, Akwa Ibom State. The population size for this study consisted of 2,760 Senior Secondary Two (SS2) Chemistry students in all the selected co-educational public secondary schools in the study area during the 2024/2025 academic session (Source: Uyo Local Education Committee, 2024). with a sample size of 152 senior secondary two students drawn from this population using random sampling technique. A researcher-made instrument known as Achievement Test on Chemical Equilibrium (ATCE) consisting of 50 multiple choice items with four (4) options, A, B, C, D and one correct answer, all drawn from the concept of chemical equilibrium in chemistry were used to determine the achievement level of students in the chemistry. The instrument was both face and content validated and data analysis of the results obtained using descriptive statistics of mean and standard deviation and analysis of co-variance (ANCOVA) was used to test the research hypotheses at a 0.05 level of significance.

Results

The results are presented according to the research questions and hypotheses

Research Question One

What is the main effect of modeling techniques and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

Table 1: Descriptive Analysis of the Main Effects of the Treatments on the Students' Achievement in Chemistry (N =152).

Method	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
Interactive modeling	55	8.20	3.63	33.95	7.31	25.75
Cyclic-inquiry modeling	52	9.48	3.78	28.96	7.27	19.48
Expository method	45	8.58	3.31	15.87	3.29	7.29

The Table also showed the mean gain scores of students when taught the concept of chemical equilibrium using interactive modeling, cyclic-inquiry modeling and expository method were 25.75, 19.48 and 7.29, respectively. This means that students taught concept of chemical equilibrium using interactive modeling had the highest achievement mean scores, followed by those taught using cyclic-inquiry modeling while those taught using the expository method had the least achievement mean scores. This result implies that modeling-based instructional strategies are more effective than the expository method in enhancing students' academic achievement in chemistry, particularly in teaching an abstract topic such as chemical equilibrium.

Research Question Two

What is the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

Table 2: Descriptive statistics of the main effect of gender on students' academic achievement in chemistry (N =152)

Method	Gender	N	Pretest		Posttest		Mean Gain
			Mean	SD	Mean	SD	
Interactive modeling	Female	36	8.22	3.86	35.78	7.02	27.56
	Male	19	8.16	3.25	30.47	6.70	22.31
Cyclic-inquiry modeling	Female	40	9.78	3.78	28.98	7.15	19.20
	Male	12	8.50	3.75	28.92	7.97	20.42
Expository	Female	29	8.97	3.52	16.52	3.12	7.55
	Male	16	7.88	2.87	14.69	3.34	6.81

Results in Table 2 shows that the female students secured a slightly higher mean gain in the concept of chemical equilibrium in chemistry than their male counterparts (27.56 versus 22.31), when cyclic-inquiry modeling was adopted, the male students secured a slightly higher mean gain in the concept of chemical equilibrium in chemistry than their male counterparts (20.42 versus 19.20). For the expository method, the female students secured a slightly higher gain in the concept of chemical equilibrium in chemistry than their male counterparts (7.55 versus 6.81).

Research Question Three

What is the interaction effect of modeling techniques, expository method and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium?

Estimated Marginal (Adjusted Mean) and Standard Deviation Scores of the interaction effects of treatment and gender on students' academic achievement in chemistry (N =152)

Method	Gender	N	Estimated Marginal Mean (Adjusted Mean)	SD
Interactive modeling	Male	36	35.77[a]	7.02
	Female	19	30.49[a]	6.70
Cyclic-inquiry modeling	Male	40	28.71[b]	7.15

	Female	12	29.79[b]	7.97
Expository	Male	29	16.36[c]	3.12
	Female	16	14.97[c]	3.34

[a]Covariates appearing in the model are evaluated at the following values: Pretest = 8.20
[b]Covariates appearing in the model are evaluated at the following values: Pretest = 9.48
[c]Covariates appearing in the model are evaluated at the following values: Pretest = 8.58

Results in Table 3 shows the means of male students taught the concept of chemical equilibrium using Interactive modelling, Cyclic-inquiry modelling and Expository method as 35.77, 28.71 and 16.36 respectively while the female students taught the concept of chemical equilibrium using Interactive modelling, Cyclic-inquiry modelling and Expository method are 30.49, 29.79 and 14.97 respectively. This result indicates that interaction exist between male and female students taught Interactive modelling and Cyclic-inquiry modelling. This is because the mean of male students taught using Interactive modelling, is higher than that of their female counterparts taught using Interactive modelling and the mean of male students taught using Cyclic-inquiry modelling is lower than that of their female students taught using Cyclic-inquiry modelling.
Interaction also exists between male and female students taught Cyclic-inquiry modelling and Expository method. This is because the mean of male students taught using Cyclic-inquiry modelling is lower than that of their female counterparts taught using Cyclic-inquiry modelling and the mean of male students taught using Expository is higher than that of their female students taught using Expository.
as shown in fig 1.

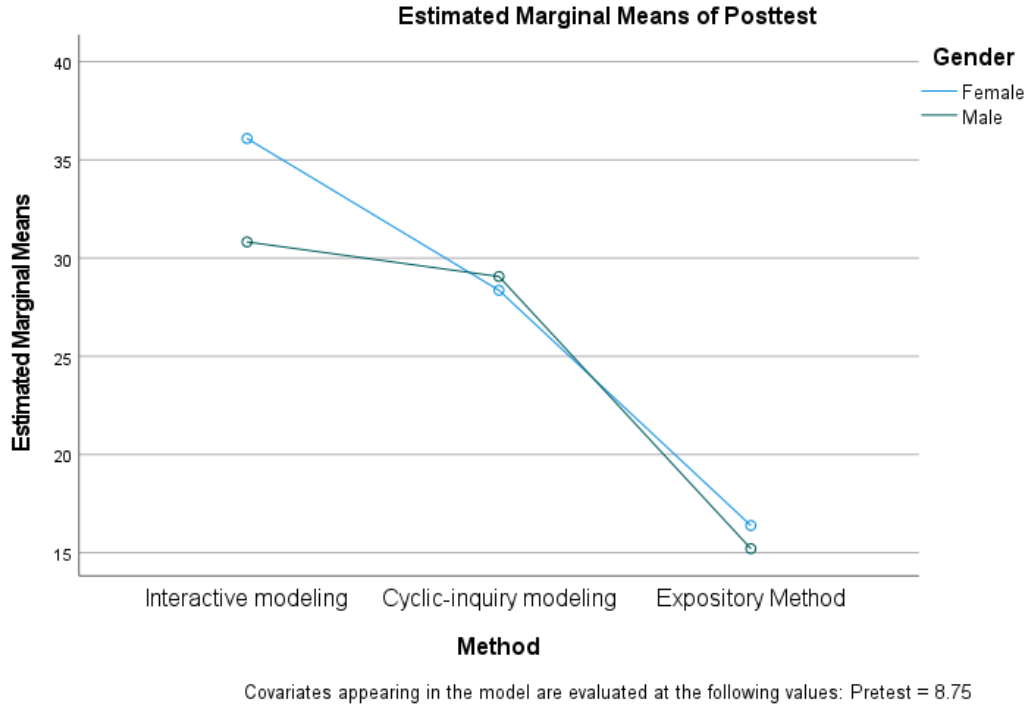


Fig 1

Hypothesis One

There is no difference in the main effect of modeling techniques on students' academic achievement in chemistry when taught the concept of chemical equilibrium.

Table 4: Result of ANCOVA analysis of chemistry students' academic achievement taught the concept of chemical equilibrium (N = 200) by treatment, gender and their interaction.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9487.86[a]	6	1581.31	45.96	.00
Intercept	9219.98	1	9219.98	267.96	.00
Pretest	674.30	1	674.30	19.60	.00
Method	7311.98	2	3655.99	106.25	.00
Gender	114.18	1	114.18	3.32	.07
Method * Gender	204.35	2	102.17	2.97	.05
Error	4989.24	145	34.41		
Total	124369.00	152			
Corrected Total	14477.10	151			

* Significant at p<0.05

The result in Table 4 shows the F-ratio of 106.25 of method and the corresponding probability level of significance of .00 alpha at 2 and 145 degrees of freedom. This level of significance is less than .05 in which the decision is based. With this result, the null hypothesis was rejected. This implies that there is no difference in the main effect of modeling techniques on students' academic achievement in chemistry when taught the concept of chemical equilibrium. In order to determine the direction of significance, the Least Square Difference (LSD) posthoc pairwise comparison test was done and the results are summarized in Table 5.

Table 5: LSD Posthoc Pairwise Comparison Test of Students' Posttest Scores Classified by Instructional Strategies with Pretest Scores as Covariate

(I) Strategies	(J) Strategies	Mean Difference (I-J)	Std. Error	Sign at P < .05
Interactive modeling	Cyclic-inquiry modeling	5.75*	1.18	.00
	Expository	18.31*	1.21	.00
Cyclic-inquiry modeling	Interactive modeling	-5.75*	1.18	.00
	Expository	12.55*	1.23	.00
Expository	Interactive modeling	-18.31*	1.21	.00
	Cyclic-inquiry modeling	-12.55*	1.23	.00

Table 5 shows a mean difference (5.75) between students taught the concept of chemical equilibrium using Interactive modelling and Cyclic-inquiry modelling, 18.31 between students taught the concept of chemical equilibrium using Interactive modelling and Expository method and 12.55 between students taught the concept of chemical equilibrium using Cyclic-inquiry modelling and Expository method. The levels of significance displayed in Table 5 indicated that students taught the concept of chemical equilibrium using Interactive modelling achieved significantly better than those taught the concept of chemical equilibrium using Cyclic-inquiry

modelling and Expository method. Students taught the concept of chemical equilibrium using Cyclic-inquiry modelling achieved significantly better than those taught chemical equilibrium using Expository method. It can be inferred from the result that Interactive modelling is the most facilitating, followed by Cyclic-inquiry modelling and Expository method is the least.

Hypothesis Two

There is no. significant difference in the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium

The result in Table 4 shows the F-ratio of 3.32 of gender and the corresponding probability level of significance of .07 alpha at 1 and 145 degrees of freedom. This level of significance is greater than .05 in which the decision is based. With this result, the null hypothesis was retained. This implies that there is no significant difference in the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium.

Hypothesis Three

There is no difference in the interaction effect of modeling techniques and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium.

The result in Table 4 shows the F-ratio of 2.97 of method and gender, and the corresponding probability level of significance of .05 alpha at 1 and 145 degrees of freedom. This level of significance is equal to .05 in which the decision is based. With this result, the null hypothesis was retained. This implies that there is no significant difference in interaction effect of modeling techniques and gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium.

Discussion

The finding of the main effect of Interactive modelling, Cyclic-inquiry modelling and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium revealed that there is significant main effect of Interactive modelling, Cyclic-inquiry modelling and expository method on students' academic achievement in chemistry when taught the concept of chemical equilibrium. This could be attributed to the fact that interactive-engagement modeling actively engages students in hands-on activities, demonstrations, and real-time feedback, which helps learners better visualize abstract concepts like chemical equilibrium. When students manipulate variables and observe changes, their conceptual understanding deepens, improving academic achievement. Cyclic-inquiry modeling also promotes students' exploration, questioning, and problem solving, which supports understanding but may require more time to master. The finding lends credence to that of Ebuoh, (2019) whose finding showed that the use of models in teaching English Language in secondary schools in Enugu Education Zone was found to be better than teaching without models. The finding further lends credence to that of Abdi (2024) who found that students instructed through inquiry-based learning achieved higher than the ones instructed through the traditional method. The finding of the main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium using Interactive modelling, Cyclic-inquiry modelling and expository method revealed that there is no significant main effect of gender on students' academic achievement in chemistry when taught the concept of chemical equilibrium using modeling techniques and expository method. This may be attributed to the fact that modeling-based instructional approaches provide equal learning opportunities and allow both male and female students to actively engage in the learning process.

Since the strategies emphasize participation, collaboration, and hands-on experiences, achievement is influenced more by instructional technique than by gender differences. The finding agrees with that of Sopuruchi (2022) who found that gender does not have a significant influence on achievement of Integrated Science students. The finding aligns with that of Rufus (2022) who found that there was no significant difference in the achievement of male and female students between those taught with modeling techniques and expository teaching methods. The finding also agrees with that of Akpan (2024) whose finding showed no significant difference between the achievement mean scores of male and female students taught gas laws using the three inquiry models. The finding of the interaction effect of modeling techniques, expository method and gender on students' academic achievement on the concept of chemical equilibrium in chemistry revealed that there is no significant interaction effect of modeling techniques, expository method and gender on students' academic achievement on the concept of chemical equilibrium in chemistry. This suggests that the effectiveness of instructional strategies was consistent for both male and female students, meaning that students' responses to the teaching methods were not dependent on gender. The instructional strategies, especially modeling approaches, benefited all learners equally. Therefore, achievement was influenced primarily by the teaching techniques rather than by gender differences. The finding aligns with that of Simon (2019) whose finding showed no significant interaction effect of teaching methods and gender on students' academic achievement in Basic Science. The finding also aligns with that of Rufus (2022) who found that there was no significant interaction effect of gender and instructional strategies on students' academic achievement in Physics.

Conclusion

Based on the findings of the study, it was concluded that Interactive modelling and Cyclic-inquiry modelling enhance students' academic achievement in chemical equilibrium in senior secondary schools in Uyo, Akwa Ibom State. The modellings are friendly to both male and female students as gender had no effect on students' academic achievement.

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