Investigating the Effectiveness of Merrill's Principle of Instruction on Secondary School Chemistry Students Achievement in Delta State

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Abstract

The main purpose of the study was to determine the effectiveness of Merrill's first principles of instruction on secondary school chemistry students' achievement in Delta State. In order to achieve the purpose of the study, three research questions were raised and their corresponding hypotheses were formulated; they were tested at 0.05 alpha level of significance. The design adopted for the study was the non-randomized pre-test post-test control group quasi–experimental design. The instrument for data collection was the Chemistry Achievement Test. The instrument was properly validated and its reliability was determined before it was used. The instrument yields a reliability coefficient of 0.79 using Kuder-Richardson Formula 21 statistics after a pilot test. Data collected were analyzed using statistics of the mean, standard deviation, student's independent sample t-test, and Analysis of Covariance ANCOVA. The findings of the study included: (i) a significant difference in the achievement of students taught with Merrill's first principles of instruction and those taught with lecture method in favour of those taught with Merrill's first principles of instruction; (ii) no significant difference in the achievement of male and female students taught with Merrill's first principles of instruction, and (iii) there was a significant effect of interaction of methods and sex on achievement. Based on the findings of the study, it was concluded that Merrill's principle of instruction is more effective in the teaching of chemistry and recommended that teachers should be trained through workshop and seminar to acquire the skills needed for its usage.

Keywords: Principle, Instruction, Chemistry, Achievement

1. Introduction

The purpose of education in any nation is to promote national development in both technological and economic spheres. One of the fields of study that contributes to this development is Science Education. Science Education involves the teaching and learning of scientific concepts. A branch of Science Education is Chemistry Education, which focuses on

imparting knowledge of chemistry concepts. Achumugu and Obaka (2019) described chemistry as the scientific study of the composition, properties, and reactions of matter, serving as a foundation for progress in various disciplines. Chemistry is considered the central science because it connects other natural sciences, making a good understanding of chemistry essential for students pursuing careers in science, technology, engineering, and mathematics (STEM). The relevance of chemistry is evident across scientific fields. For example, in medicine, chemistry contributes greatly to the development of new drugs, the understanding of biochemical and metabolic processes, the creation of diagnostic tools, biomaterials, and regenerative medicine (Adu-Gyamfi, Ampiah, and Agyei, 2020).

A crucial aspect of Chemistry Education is determining how students learn chemistry and identifying the most effective teaching methods. The method of instruction plays a vital role in lesson delivery. Osakwe and Idoko (2020) noted that students' poor performance could be linked to how teachers present concepts. The twenty-first-century classroom has introduced several changes in instructional practices at different educational levels (Onah, Ugwuanyi, Okeke, Nworgu, Agwagah, Ugwuanyi, Obes, Nwoye, and Okeke, 2020). To keep pace with these changes, chemistry teaching must continually improve due to its role in national development. This improvement requires the adoption of suitable instructional methods. Methods aligned with the ideas of social constructivist theorists, such as encouraging social interaction and activating prior knowledge should be employed to achieve the goals of Chemistry Education. These approaches enhance effective learning of chemistry, allowing students to understand scientific methods and develop critical thinking skills essential for technological and economic progress. One teaching approach capable of achieving this, is Merrill's First Principles of Instruction.

According to the University of Iowa (2024), Merrill's First Principles provide a sound basis for developing effective instructional materials, activities, and assessments that promote meaningful learning. Kurt (2022) identified Merrill's principles as problem-based strategies proven to enhance learning outcomes. Merrill (2013) explained that for learning to be effective, students must participate actively in lessons, find relevance in the activities, and recognize the need for learning. He emphasized that lessons should be designed to motivate learners to master and enjoy the learning process. Burton (2022) added that applying Merrill's principles helps teachers design structured, engaging, and effective learning experiences.

Merrill's First Principles of Instruction emphasize active engagement of learners through authentic problem-solving, use of prior knowledge, demonstration of new concepts, application of knowledge, and integration into real-life experiences. Merrill asserted that effective learning stems from problem-solving. The five principles include: problem/task-centered, activation, demonstration, application, and integration. The problem/task-centered principle involves engaging learners with real-world problems and encouraging discussions among peers. The activation principle focuses on drawing on learners' existing knowledge and connecting it with new ideas to enhance retention. Merrill advised that learning should challenge learners, keeping them motivated and engaged in constructing new knowledge. The demonstration principle stresses showing learners how to apply concepts, either through information or portrayal demonstrations—the latter being more specific and effective. Teachers can use videos, real-life demonstrations, and role-plays to illustrate ideas.

The application principle promotes learning through practical application of acquired knowledge to solve real-world problems, making learning meaningful and improving retention. Assessment strategies should support this process (www.microteach.co.uk). The integration principle encourages learners to connect new knowledge with everyday life, fostering long-term retention and relevance. This principle aligns with the first, as both stress meaningful engagement and application of learning to real-life contexts. Alias and Razak (2024) highlighted the importance of engaging learners in authentic problem-solving to promote

meaningful learning. Similarly, Cai and Moallem (2021) emphasized the link between Merrill's principles, theory, and practice. Truong, Elen, and Clarebout (2019) and Salehi and Ghanbari (2019) recommended that Merrill's principles be used in designing instructional content. In agreement, Pappas (2017) stated that Merrill's five core principles are centered on learning through problem-solving. Hence, there should be a shift from the traditional lecture method which is teacher-centered to approaches that focus on guiding and monitoring students, as advocated by Odo, Agwagah, Ugwuanyi, Onesimus, Nwoye, Emeji, Okeke, Osakwe, Okeke, and Ugwuanyi (2021). Several studies have demonstrated the effectiveness of Merrill's First Principles in enhancing creativity and achievement in areas outside chemistry (Badali, Derakhshi, Bagheri, and Ansari, 2016; Keshti, Ghasemi, and Badali, 2016; Badalia, Hatami, Farrokhnia, and Omid, 2020). Therefore, it becomes essential to investigate its effectiveness in teaching chemistry. On this basis, the present study sought to determine its effectiveness.

This study originated from the persistent challenges faced by chemistry education students as reported in the West African Senior School Certificate Examination (WASSCE) Chief Examiners' annual reports. The recurring issues identified in the West African Examinations Council (WAEC) Chief Examiners' reports from 2018 to 2023 revealed that many candidates were unable to: write balanced equations for overall cell reactions in electrochemical cells constructed with copper and silver electrodes; state correct observations for reactions involving NaCl and $AgNO_3$ upon the addition of ammonia solution and dilute HNO_3; draw accurate diagrams for the preparation of dry oxygen gas and correctly identify the sources of N_2 and H_2 in the Haber's process, as well as the impurities present in the raw materials; draw and label the diagram for the laboratory preparation of a dry sample of chlorine; explain why metals are good conductors of electricity; differentiate between molar mass and relative atomic mass; apply appropriate units in calculations; determine the mass concentration of solutions; identify correct colours in reactions; and apply theoretical knowledge effectively in practical questions. Furthermore, the reports indicated that a majority of candidates encountered difficulties while performing qualitative analysis on solid samples, among other lapses. Considering these recurring weaknesses as documented in the Chief Examiners' reports, there arises a compelling need to explore alternative teaching methods that can enhance students' active engagement and participation in the teaching–learning process. Consequently, the statement of the problem is: "What effect will the application of Merrill's First Principles of Instruction have on chemistry students' academic achievement?"

2. Literature Review

Merrill's First Principles of Instruction (MPI) is an instructional design framework developed by David Merrill in 2002. The principle provides guidelines and principles for creating effective learner-centered instructional experiences. It aims to promote meaningful and engaging learning and is recognized for focusing on maximizing knowledge from learning experience. MPI consist of five learning principles which are Task-centered, Activation, Demonstration, Application, and Integration.

At the task-centered stage, emphasis is placed on designing authentic real world problems that learners are likely to encounter. This stage promotes the active engagement of learners in problem-solving activities and this fosters their critical thinking and problem-solving skills. At this activation stage the principle is focused on engaging learners' prior knowledge and their experiences creating a foundation for new learning. To achieve this, learners' curiosity is stimulated by presenting real-world examples, and connecting new information to their existing knowledge. The demonstration stage lays emphasis on providing clear models or examples which illustrate the desired learning outcomes. Learners observe demonstrations to develop an understanding of how to perform the desired tasks. After the demonstration principles comes the application principle. This principle put emphasis on

providing opportunities for learners to practice and apply their knowledge and skills in authentic contexts. This involves designing activities that require learners to actively apply what they have learnt in solving problems, making decisions and engaging in realistic tasks.

The last is the integration principle which focuses on promoting the transfer of knowledge and skills to new situations. With this principle, opportunities are provided for learners to enable them connect their learning to real-world contexts and apply it in meaningful ways. Integration can be achieved by presenting complex and authentic problems or scenarios that require learners to apply their learning in novel ways. These five key principles form the foundation of Merrill's instructional design approach and are designed to create meaningful, engaging, and transferable learning experiences for learners. Merrill's principle of instruction is focused on maximizing knowledge from learning experience. Merrill believed that effective learning experiences are rooted in problem-solving. These principles deliver value because learners who are exposed to it know how to apply what they have learnt.

Research studies have been carried out to determine the efficacy of Merrils first principle of instruction. For example, Badali, Hatami, Farrokhnia and Noroozi (2020) investigated the effects of using Merrill's first principles of instruction on learning and satisfaction in MOOC. The findings of the study were in favor of participants in the experimental condition both in terms of learning and satisfaction compared to the participants in the control group condition, Jalilehvand (2016) did a study to determine the Impact of Merrill's First Principles of Instruction on Students' Creativity. The results showed that there was a meaningful difference between the creativity level of experimental group and control group. Banihashem, Kheshti, Ghasemi and Mehraji (2018) sorted to determine the effect of integration of Merrill's first principles of instruction with team based learning on the achievement of recall and application of nursing students. The findings of the study revealed that before interventions, there were no meaningful difference between score mean of recall and application of both groups. The results after treatment showed a significant increase in the rate of experimental group score in both recall and application level significantly in comparison with control, Odo, et al (2021) did a study to determine the effect of first principle of Merrill's instruction in promoting students' achievement in mathematics, The result of the study showed that Merrill's First Principles of Instruction improves the mean achievement scores of students in Number and Numeration more than the traditional lecture method. In addition, Cai and Moallem (2021) did a study on the application of Merrill's First Principles of Instruction redesign on Online Graduate Course through the rapid prototyping approach. The study showed that, student confirmed that the redesign course has connections with theory and practice. Most existing research reports on the effect of the use of Merrill's first principles of instruction are in mathematics, creativity and course redesign. None of which is in chemistry. This suggested the need for undertaking a similar study, using chemistry. This is the gap this study investigated and filled.

Research Questions

The following research questions were raised to guide the study.

- Is there any difference between the mean achievement scores of chemistry students taught with the Merrill's First Principle of Instruction and those taught with lecture method?
- Is there any difference between the mean achievement scores of male and female chemistry students with Merrill's First Principle of Instruction and those taught with lecture method?
- Is there any effect of interaction between method and sex on achievement?

Research Hypotheses

H_{01}: There is no significant difference between the mean achievement scores of chemistry students taught with Merrill's First Principles of Instruction and those taught with lecture method.

H_{02}: There is no significant difference between the mean achievement of scores of male and female chemistry students taught with Merrill's First Principles of Instruction and those taught with lecture method.

H_{03}: There is no significant effect of the interaction between method and sex on educational achievement.

3. Research Objectives

The main objective of the study was to determine the effectiveness of Merrill's First Principle of Instruction on Secondary School Chemistry Students' Achievement in Delta State. Specifically the study

3.1 To determine the difference between the mean achievement scores of chemistry students taught with Merrill's First Principle of Instruction and those taught with the lecture method.

3.2 To ascertain the difference between the mean achievement scores of male and female chemistry students with Merrill's First Principle of Instruction and those taught with the lecture method.

3.3 To establish the effect of the interaction between method and sex on achievement.

4. Research Methodology

4.1 Research Design

The design employed for the study was pre-test post-test non-equivalent control group quasi-experimental design. It consisted of two instructional methods (Merrill's First Principles of Instruction and the lecture method), sex (male and female) and repeated testing (Pre-test, post-test). In this design, subjects were not randomized into groups. Rather, intact classes were used. The variables for the study include: Instructional strategies: Merrill's First Principle of instruction and lecture method (independent variables), achievement (dependent variable), and sex (intervening variable). This design was considered appropriate because it was not possible to randomly assign subjects into groups and as such, intact classes were used. According to Johnson and Christensen (2000), any design where randomization which is a condition for true experimental design is omitted, the design is described as quasi-experimental design.

4.2 Population and Sampling

The population for the study consisted of fifty thousand five hundred and twenty five (50,525) Chemistry class 11 students in all mixed public Senior Secondary Schools in Delta State. There are four hundred and seventy one (471) schools in Delta State, one hundred and eighty-seven (187) in Delta Central, one hundred and sixty-eight (168) in Delta North and one hundred and sixteen (116) in Delta South (Delta State Ministry of Education, 2022).

The sample for the study consisted of one hundred and forty students from four mixed secondary schools randomly selected from two Senatorial Districts. Two schools each were selected from each of the Senatorial Districts. Four Senior Secondary Schools, four chemistry teachers and four intact classes made up the sample for the study. The sampling technique used in the selection of the schools and classes was the simple random sampling technique (balloting), using the withdrawal with replacement strategy. In doing this, all the mixed secondary schools in the two Senatorial districts were listed. The names of the schools were written on pieces of paper, folded and put into a blind bag. Using withdrawal with replacement method of balloting, the required number of schools was selected. Only public schools were

used because they all have almost the same learning environment, and they are governed by a central body which is the Post Primary Education Board.

4.3 Research Instrument

The instrument for data collection was the Chemistry Achievement Test (CAT). It is made up of two sections. Section A contained questions asked on students' bio-data, while Section B contained 25 items drawn from the West African Examination council (WAEC) School Certificate past questions. They were multiple choices with one correct answer and four distractors. Each question in Section B requires one answer to be chosen by the respondents. Each correct answer given by the students in section B was scored two marks (2) while wrong answers were scored zero (0). The maximum mark for this section was 50. In answering the research questions and testing the hypotheses, only the summation of the scores of the correct answers in Section B of the CAT was used.

4.3.1 Validity of Research Instrument

The face validity of the research instrument was determined by three experts: one Science Educator, one expert in Chemistry and one expert in Measurement and Evaluation. They specifically looked at the Chemistry Achievement Test (CAT), the research questions and the hypotheses with the intention of establishing if the instrument could generate the needed data to answer the research questions and test the hypotheses. They suggested that two items should be reframed, and this was effected after which it was approved for data collection, and its content validity was done using a table of specifications based on Bloom's taxonomy of educational objectives, which showed that the content areas were rightly represented, as shown in Table 1.

Table 1 Specifications on 25-item Chemistry Achievement Test

Content	**Knowledge 15%**	**Comprehension 25%**	**Application 60%**	**Total**
Periodic				
Table and				
Chemical equation 30%				
	1	2	4	7
Nomenclature of				
Compounds 50%	2	3	8	13
Chemical Reaction 20%				
	1	1	3	5
Total	**04**	**06**	**15**	**25**

In determining the construct validity of the Chemistry Achievement test, a trial test of the instrument was carried out on forty (40) SS II students in two schools in Ika South Local Government Area of Delta State, who were not part of the study. However, the characteristics of the trial students were similar to the characteristics of the sample used for the study. Specific among the characteristics was that all the students were exposed to the same contents of the SS II Chemistry Curriculum and have a similar learning environment. The following are the findings generated from the process.

(1) Factor Analysis: The extraction method involving Principle Component Analysis and Rotation Method of Quatrimax with Kaiser Normalization for the determination of construct validity was used. The analysis of the responses of the 40 respondents to the twenty five items resulted in the non-reduction of number by selecting only items with an initial Eigen value of at least 1.

(2) Item difficulty: The difficulty of each item in the Chemistry Achievement Test instrument was determined using item difficulty index formula. This was achieved by dividing the number of subjects who answered the item correctly by the number of subjects who made attempts. The answer ranged from 0.00-1.00. The item difficulty index is often called p-value because it is a measure of proportion. Wiseman (1999) and Ajaja (2013) stated that test items with difficulty indices of 0.00-0.20 are too difficult, while those items with 0.8-1 are too easy. Based on these specifications, only items with difficulty indices of 0.3-0.7 were selected for the test instrument. All the test items selected from the past WASSCE question papers met this specification.

4.3.2 Reliability of the Instrument

In order to determine the reliability of the instrument (CAT), the instrument was given to forty chemistry students who were not part of the students used for the study. The data collected were analyzed using the Kuder Richardson Formula (k21), and the analysis yielded an R-value of 0.79. With this value, which is above 0.70, the instrument was considered reliable for data collection.

4.4 Treatment Procedure

Step I: Training of the teachers used for Merrill's First Principles of Instruction and Lecture Method groups

4.4.1 Merrill's First Principle of Instruction Group

The Merrill's principles of instruction group teachers were trained teachers for three days. On day one, the teachers were trained on the concepts of Merrill's First Principles of instruction, the advantages of the usage of Merrill's First Principles of Instruction, and their theory underlying its usage and steps to be followed**.** On day 2, the teachers were trained on how to teach, using the strategy for 2hours. Then they were asked to practice under the supervision of the researcher. On day 3, the teachers were made to continue the practice on how to use the strategy in the classroom, following the steps. The session came to an end when the researcher was convinced that the teachers could effectively apply the methodology after evaluating their practices.

4.4.2 The Lecture group teachers

On day one, the lecture group teachers were trained briefly on how to use the lecture method. In training the lecture group teachers, the teachers were exposed to basic steps for using the lecture method in the classroom.

Step II: Pre-testing of the groups

A week before the commencement of the treatment, which lasted for six weeks, the students who were used for both Merrill's First Principles of instruction and the lecture groups were pre-tested, using the Chemistry Achievement Test. The completed chemistry achievement test question papers were collected from the students after forty-five minutes. They were scored and recorded as a pre-test. The pre-test scores were used to determine the equivalence of the groups. Immediately after the pretest, the investigator distributed the plans on the usage of Merrill's First Principles of Instruction and the Lecture method to the teachers (research assistants). They were instructed to follow the guide strictly in the application of the recommended instructional methods in their respective classes.

Step III: Application of the Strategies in Teaching Steps followed using Merrill's First Principles of Instruction

- Problem/Task centered: In order to gain the students attention, the students were engaged in class discussion. This gave the learners the opportunity to share their previous knowledge before the topic was introduced.

- Activation stage: The teacher created a scenario where learners were engaged with the lessons through the provision of task-centered learning activities that activated learners' prior knowledge.
- Demonstration of concepts: The teacher modeled the concept to be studied by solving practical problems and giving students the opportunity to work together in groups.
- Evaluation: Students asked questions and teacher posed questions that engage students with learning that has real-world application. Students were given opportunity to critique their answers. After this, clear strategies and visual cues were given to aid accurate understanding by the teacher.
- Application stage: To further promote learning through application of the newly acquired knowledge and skills to other situations, students were given more assignment that enable them to make use of the acquired knowledge.

Post testing

In order to collect data to enable inferences to be drawn from the study, at the end of the treatment, which lasted for six weeks, a post-test was administered after the treatment using the Chemistry Achievement Test (CAT). This instrument was administered to the two groups of students, and the appropriate data were generated and collated.

5. Research Results and Discussion

5.1 Research Results

Research Question One: Is there any difference in the mean achievement scores between chemistry students taught with Merrill's First Principle of instruction and those taught with the lecture method?

To answer this research question, descriptive statistics of the mean and standard deviation were used to compare the post-test scores of both groups of students, as shown in Table 2.

Table 2 Descriptive statistics of mean and standard deviation comparing the mean scores of chemistry students taught with Merrill's Principle of Instruction strategy and lecture method

Groups	N	Mean	Mean Diff.	S.D.
Merrill's First principles	60	33.883	4.663	9.433
Lecture Method Group	82	29.220		8.527

Table 2 shows that the Merrill's group students had a mean score of 33.883 and a standard deviation of 9.433 and a mean score of 29.220 and a standard deviation of 8.527 for the lecture group. The mean difference between the two sets of scores was 4.663, with the Merrill's group having the higher mean score. This shows that there is a difference in the mean scores between the students taught with Merrill's principle and lecture method. To determine if the difference is significant, $H_{01}$was tested using an independent sample t-test and result is shown in Table 4.

To identify the appropriate statistics to be used to test hypothesis one, the collected data were analyzed using independent sample t-test at pre-test and the result is tabulated in Table 3.

Table3 Independent sample t- test statistics comparing the difference in mean scores between students taught with Merrill's instructional strategy and lecture method at pre-test

Groups	N	Mean	Mean Diff.	S.D.	df	t	Sig (2-tail)
Merrill's principle	60	16.650	1.435	5.210	140	1.614	0.93
Lecture Method Group	82	18.0854	4.821				

Table 3 shows that Merrill's first principle of instruction group students had a mean score of 16.650 and a standard deviation of 5.210, and a mean score of 29.220 and a standard deviation of 18.0854 for the lecture group at pre-test. The mean difference between the two sets of scores was 1.435, with the lecture group having the higher mean score. This shows that there is a difference in the pre–test mean scores. The table also shows that the observed difference is not significant since the calculated sig value of 0.93 is higher than the critical sig value of 0.05. With this, the independent sample t-test becomes the appropriate statistic used to test $H0_1$.

H_{01}: There is no significant difference in the mean achievement scores between chemistry students taught with Merrill's First Principles of instruction and with the lecture method.

In order to determine if the difference is significant independent sample t-test was used to analyze the data collected and the result is shown in Table 4.

Table 4 Independent sample t-test statistics comparing the difference in mean scores of Chemistry students taught with Merrill's' First Principles of instruction strategy and Lecture method at the post-test

Groups	N	Mean	Mean Diff.	S.D.	df	tcal	Sig (2-tail)
Merrill's principle	60	33.883	9.433	4.663	140	3.077	0.003
Lecture Method Group	82	29.220		8.527			

Table 4 shows that the observed difference is significant since the calculated sig value of 0.003 is less than the critical sig value of 0.05. With this, $H0_1$, which states that there is no significant difference in the mean achievement scores between chemistry students taught with Merrill's' First Principle of instruction strategy and lecture method, was rejected.

Research question 2: Is there any difference in the mean achievement scores between male and female chemistry students taught with Merrill's First Principles of instruction strategy?

In answering research question 2, mean and standard deviation statistics were employed to analyze the data and the result is shown in Table 5.

Table 5 Descriptive statistics comparing mean achievement scores of male and female students taught with Merrill's principle of instruction

Sex	N	Mean	Mean Diff.	S.D.
Male	28	31.460		9.084
			4.967	

Female	32	36.367	9.281

Table 5 shows that the male students in Merrill's group had a mean score of 31.460 and a standard deviation of 9.084 and females had a mean score of 36.367 and a standard deviation of 9.281. The mean difference between the two sets of scores was 4.967, with the females having the higher mean score. This shows that there is a difference in the post–test mean scores between the male and female students taught with Merrill's First Principles. To determine if the difference is significant, an independent sample t-test was used to test $H0_{2,}$ and the results are shown in Table 5.

H_{02}: There is no significant difference in the mean achievement scores between male and female chemistry students taught with Merrill's First Principle of instruction strategy

In determining if the observed difference is significant, independent sample t-test was used to test hypothesis 2 and the result is shown in Table 6, since there was no significant difference in the pre-test scores as shown in Table 6.

Table 6 Independent sample t-test statistics comparing the mean achievement scores of male and female students in Merrill's principle of instruction strategy at the post-test

Sex	N	Mean	Mean Diff.	S.D.	df	tcal	Sig (2-tail)
Male	28	31.460		9.084			
			4.967		58	2.097	0.40
Female	32	36.367		9.281			

Table 6 shows that the observed difference was not significant since the calculated sig value of 0.40 is higher than the critical sig value of 0.05. With this, $H_{02,}$ which states that there is no significant difference in the mean achievement scores between male and female chemistry students with Merrill's First Principles of Instruction, was not rejected.

Research Question 3: Is there any effect of the interaction between method and sex on achievement?

To answer this research question, mean and standard deviation statistics were used to analyze the data collected, and the result is shown in Table 7.

Table 7 Descriptive statistics comparing the interaction mean achievement scores of male and female students taught with Merrill's principle of instruction and lecture method

Methods	Sex	N	Mean	Mean Diff.	S.D.
Merrill's First principles	60	33.883			9.433
				4.663	
Lecture Method Group	82	29.220			8.527
	Male	28	31.460		9.084
Merrill's First principles				4.967	
	Female	32	36.367		9.281
Lecture Method Group	**Male**	44	30.477		8.631
				3.714	
	Female	38	27.763		8.280

Table 7 shows that the Merrill's group students had a mean score of 33.883 and a standard deviation of 9.433 and a mean score of 29.220 and a standard deviation of 8.527 for the lecture group. The mean difference between the two sets of scores was 4.663, with the Merrill's group having the higher mean score. This shows that there is a difference existing in the mean scores between the students taught with Merrill's principle and lecture method. In addition, the table also shows that, the male students in Merrill's First Principle group had a mean score of 31.460 and a standard deviation of 9.084 while the female students had a mean score of 36.367 and a standard deviation of 9.281. The mean difference between the two sets of scores was 4.967, with the female students having the higher mean score. The Table also shows that the male students in the lecture group had a mean score of 30.477and a standard deviation of 8.631, and female students had a mean score of 27.763 and a standard deviation of 8.280. The mean difference between the two sets of scores is 3.714, with the male students having the higher mean score. This shows that there is a difference in the post–test mean scores between the male and female students taught with both methods and this connotes an interaction effect.

To determine if the effect of interaction is significant, Analysis of Variance Statistics (ANOVA) was used to test $H0_{3,}$ and the results are shown in Table 8.

H_{03}: There is no significant effect of the interaction between methods and sex on achievement

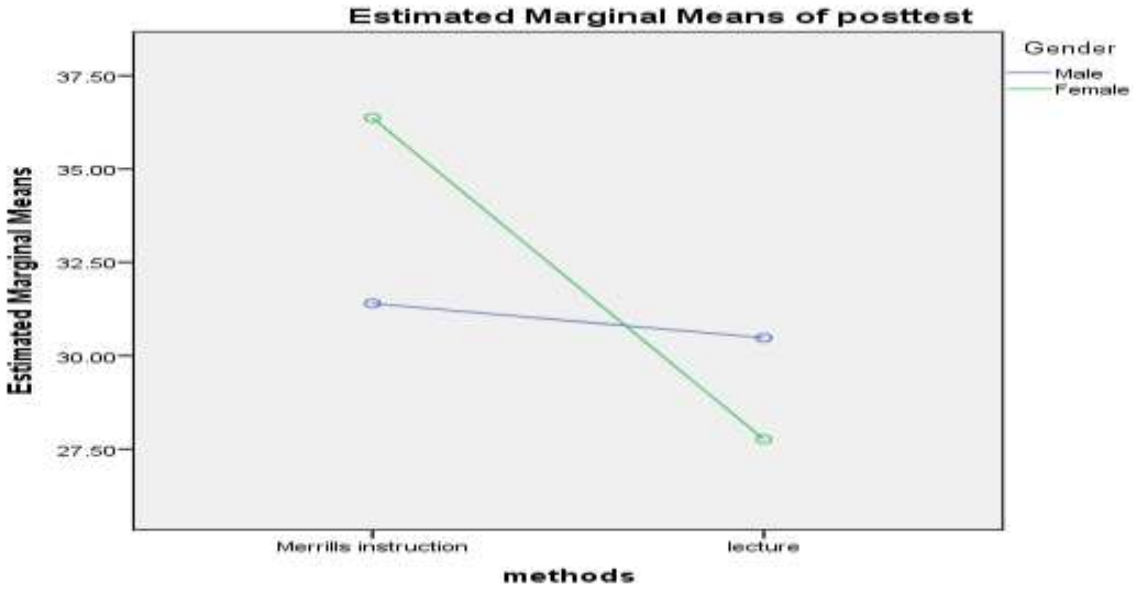
To answer hypothesis 3, ANOVA statistics were used to test the data collected, and the result is shown in Table 8.

Table 8 ANOVA Statistics showing the interaction effects between Methods and Sex on Achievement

Source	Type III sum of Square	df	Mean square	F	Sig
Corrected Model	1273.854	3	424.619	5,518	0.001
Intercept	137220	1	137220.861	1783.094	0.000
Methods	784.283	1	784.283	10.191	0.002
Sex	43.851	1	43.851	0.570	6.452
Method*Sex	509.848	1	509.842	6.625	0.011
Error	10620.012	138			
Total	150035-000	142			
Corrected Total	11893.866	141			

Table 8 shows that the effect of interaction is significant because the calculated sig of 0.011 is less than the calculated sig value of 0.05.

Fig. 1 showed that there exist a disordinal interaction effect.



With this, $H0_3$ which states that there is no significant effect of interaction between method and sex is rejected.

5.2 Discussion

This study investigated the effect of Merrill's' First Principles of Instruction on chemistry students achievement at the secondary school levels in Delta State. The study is significantly timely, considering the problems encountered by chemistry teachers and students in the teaching and learning of chemistry. The problems encountered are made evident in the yearly West African Examination Council Chief Examiner's report from 2018 -2023 .Based on the weaknesses contained in the Chief examiners report, it becomes necessary to search for an alternative method that will help stimulate learners' interest and foster their active participation in the teaching-learning process. The use of Merrill's First Principle of instruction has given an indication that it is a strategy that could address the weakness of the lecture method, that is predominately used in the teaching of Chemistry and can help in reversing the trend (Omoifo, 2012) and also assist in the creation of the schools we deserve (Urevbu, 1997).

The first finding of the study showed that there is a significant difference in achievement of students taught with Merrill's First Principles of instruction strategy and those taught with lecture method. This is shown in Table 2 where the mean of the Merrill's First Principles group instruction strategy is higher than that of the lecture method group of students. And this was found to be significant in Table 4. This finding may be due to the fact that, the students in the Merrill's First principles instruction group of students were made to carry out series of activities individually and in collaboration with themselves and their teachers during the teaching - learning process. These individual and collaborative activities would have made them have a better understanding of the concept taught and this is reflected in their achievement unlike those in the lecture method groups who got little or no assistance from their fellow peers and limited assistance from their teachers. This finding is buttressed with the social constructivist theory of Vygosky's (1978) who advocated the efficacy of social interaction in promoting effective learning. This findings is in line with the findings of Jalilehvand (2016), Badali, Derakhshi,and Ansari (2016),Ghasemi and Badali (2016),Banihashem, Kheshti, Ghasemi and Mehraji (2018), Badalia, Hatami , Farrokhnia and Omid (2020) whose findings showed the efficacy of the usage of Merrill's principles of instruction on creativity and achievement.

The second findings of the study showed a no significant difference in the achievement of male and female students taught with Merrill's First Principles of instruction in Table 5. This notable difference was not significant as shown in Table 6. This result may be due to the fact that all the students irrespective of their sex benefitted equally during the teaching and learning process. This shows that the method is not sex-biased. This is because the use of the Merrill's First Principle of instruction provided an environment that enabled both male and female students participate in the teaching - learning process irrespective of their sex. The interactive environment enabled them to share ideas and this may have made them benefit from the concept learnt at almost equal measure. This finding is also buttressed by Vygosky's (1978) social constructivism theory. This finding is in agreement with Omovie, and Eravwoke-Agboro (2023) Agboro-Eravwoke (2021), Agboro-Eravwoke (2022) and Agboro (2019), whose findings showed no significant relationship between chemistry students' conceptual understanding as regards sex and that of Davis and Brown(2019) whose results indicated that gender does not influence academic achievement among biology students, Odo, Agwagah, Ugwuanyi, Shiaki, Nwoye, Emeji, Okeke, Osakwe,Okeke, Ugwuanyi (2021), found no statistically significant difference in the mean achievement scores of male and female students in Number and Numeration after being exposed to Merrill's First Principle of Instruction.

The last findings of the study showed that there was a significant effect of the interaction of method and sex on achievement as shown in Table 8. This is an indication that the combined effects of method and sex influence students' achievement. This means that the Merrill's First Principles of instruction do not solely influence the students' achievement. This finding disagrees with that of Ajaja (2013) and Chukwuka and Ajaja (2023) who found a non-significant interaction effect between method and sex on achievement in Biology, and also that of Obodo, andIfunanya (2023) who found no significant interaction effect of teaching method and sex on students interest scores in basic science.

6. Conclusions

In line with the findings of the study, the following conclusion were drawn;

6.1 Merrill's principle of instruction is more effective in the teaching of chemistry when compared with lecture Method.

6.2 Merrill's principle of instruction of instruction is not sex biased.

7. Recommendations

Base on the findings of the study, the following recommendation emerged

7.1 In-service teachers should be trained through workshop and seminar and pre-service teachers' curriculum should be reviewed to include the strategy so that both teachers will be equipped with the knowledge of its usage and be encouraged to use it.

7.2 Policy-makers should make policies to enforce continuous training of teachers by government and also make policy that will enable teachers effectively implement the use of Merrill's principle of instruction with little or no supervision.

7.3 Curriculum planners should emphasizes that the method should be used for teaching each concept in the curriculum and also review the curriculum to include the Merrill's principle of instruction so that pre-service teachers can acquire the necessary skills needed for its implementation while still on the teacher training programme.

7.4 Teacher educators should ensure that pre-service chemistry teachers apply Merrill's first principle of instruction during their teaching practice exercise.

8. Limitation and Future Research

The limitations of the study is the use of only two Senatorial Districts to represent the whole population and also the use of multiple choice test, as result of this, further research should be carried out using a larger sample and essay questions.

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