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Academic Performance and Retention of Male and Female Secondary School Students Taught the Mole Concept Using the Just-In-Time Instructional Strategy in Zaria, Kaduna State, Nigeria

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Abstract

The Mole Concept is a fundamental but challenging area of secondary-school chemistry because it requires students to integrate conceptual understanding, mathematical reasoning, and problem-solving. This study examined differences in the academic performance and retention of male and female Senior Secondary II chemistry students taught the Mole Concept using the Just-In-Time Instructional Strategy (JiTT) in Zaria Education Zone, Kaduna State, Nigeria. A quantitative, one-group pretest–posttest–post-posttest design was adopted. The sample comprised 231 SS II chemistry students (128 males and 103 females) selected from a public co-educational secondary school after baseline comparison of five randomly selected schools. Data were collected using the 40-item Mole Concept Performance Test, which had a test–retest reliability coefficient of 0.70. Mean, standard deviation, and independent-samples t-test were used at the 0.05 significance level. No significant gender difference was found in academic performance, $t(229) = 0.78$, $p = .439$, $d = 0.10$. However, male students recorded significantly higher retention scores than female students, $t(229) = 2.51$, $p = .013$, $d = 0.33$. The findings suggest that JiTT can support comparable immediate performance across gender, while additional reinforcement and retrieval opportunities may be needed to strengthen long-term retention.

Keywords: just-in-time instruction, academic performance, retention, mole concept, gender, secondary school chemistry

1 Introduction

Science and technology are essential to national development, with chemistry serving a pivotal role because of its relevance to fields such as medicine, pharmacy, engineering, and agriculture (Mustapha & Dahiru, 2026). Chemistry education is crucial for preparing students to contribute to scientific and technological advancement (Babalola & Hafsatu, 2015). Nevertheless, student performance in chemistry remains a concern, particularly in areas requiring mathematical reasoning, conceptual understanding, and abstract thinking (Bamidele et al., 2013). These difficulties are often attributed to ineffective instructional methods, insufficient practical resources, and the inherently abstract and mathematical nature of topics such as redox reactions, electrochemistry, and the Mole Concept (Umahaba, 2016; Yakubu, 2017; Lawal et al., 2026). Mastery of the Mole Concept is particularly challenging because it requires students to integrate conceptual understanding, mathematical reasoning, and problem-solving skills. Documented difficulties with the Mole Concept and stoichiometry among secondary school chemistry students highlight the need for instructional strategies that actively engage learners in constructing and applying knowledge (Bamidele et al., 2013). Approaches that emphasise problem-solving, active participation, and meaningful engagement are likely to foster deeper understanding of complex chemistry concepts (Abdulkadir & Ibrahim, 2025).

Just-In-Time Teaching (JiTT) is an instructional approach in which students complete preparatory activities, commonly called warm-ups, before classroom instruction. Teachers review students’ responses to identify misconceptions, areas of difficulty, and learning needs and then use this information to inform classroom activities (Novak et al., 2010). This approach enables instruction to target students’ specific learning challenges and provides opportunities for questioning, discussion, clarification, feedback, and active engagement (Marrs & Novak, 2004). Gender has been investigated as a factor influencing students’ academic outcomes in science and related disciplines. Historically, social and cultural factors restricted girls’ participation in science; however, recent studies indicate increased female participation and improved performance (Akintoye & Oluwaferanmi, 2026; Salma & Umami, 2024). Some research suggests that female students benefit from learner-centred teaching strategies, whereas other studies report better outcomes for male students or no significant gender differences (Orji & Ibe, 2025; Jack & Bitrus, 2024). These mixed findings imply that gender and instructional methods may interact to influence students' learning outcomes. While previous research has examined gender differences in learning outcomes and the use of active or Just-In-Time instructional approaches, limited evidence exists on whether male and female students differ in performance and retention when the Mole Concept is taught using the Just-In-Time Instructional Strategy in Nigerian secondary schools. Evidence from Zaria, Kaduna State, is particularly limited. This gap is significant because the Mole Concept poses unique conceptual and mathematical challenges, and instructional strategies may have varying effects depending on context (Landas, 2024). The present study therefore investigated the academic performance and retention of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy in Zaria Education Zone, Kaduna State, Nigeria.

The study addressed the following research questions:

1. What is the difference between the academic performance of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy?
2. What is the difference between the retention scores of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy?

The findings are intended to inform chemistry teachers and teacher educators about the applicability of JiTT for teaching challenging and abstract chemistry concepts and about the extent to which male and female students achieve comparable learning outcomes using this strategy.

2 Literature Review/Theoretical Framework

2.1 Constructivist Learning Theory

The present study is anchored in Constructivist Learning Theory, associated particularly with Piaget (1954), which views learning as an active process through which learners construct and reorganise knowledge through interaction with their environment. Rather than passively receiving information from the teacher, learners actively interpret new experiences in relation to their existing cognitive structures. The theory emphasises assimilation, accommodation, and equilibration. Assimilation occurs when learners incorporate new experiences into existing cognitive structures, whereas accommodation involves modifying existing structures when new experiences cannot be adequately explained by previous understanding. Equilibration refers to the process through which learners develop more stable understanding as they reconcile new experiences with existing knowledge. The theory is particularly relevant to science education because scientific concepts often require learners to establish relationships among observable phenomena, symbolic representations, mathematical procedures, and abstract explanations. This is especially true of the Mole Concept, which requires students to understand relationships involving particles, mass, volume, concentration, molar mass, and amount of substance (Furió-Más et al., 2002; Gobang et al., 2023). Consequently, effective learning of the Mole Concept requires more than memorisation of formulas; it requires students to construct meaningful conceptual understanding and apply mathematical reasoning to different problem situations.

Constructivist Learning Theory provides a theoretical basis for understanding how Just-In-Time Teaching may support learning of the Mole Concept. JiTT requires students to engage with instructional materials and complete preparatory activities before classroom instruction. Teachers review students' responses to identify misconceptions, areas of difficulty, and learning needs and use this information to guide subsequent classroom activities (Novak et al., 2010). Classroom instruction can then involve clarification, questioning, discussion, feedback, and problem-solving based on students' demonstrated understanding (Gavrin, 2010; Novak, 2011). The relationship between JiTT and constructivism is evident in the active role assigned to students and the responsive role of the teacher. Preparatory activities enable students to activate prior knowledge and identify areas of understanding and difficulty. Subsequent classroom interactions provide opportunities to address misconceptions, modify cognitive structures, and develop more coherent understandings. In the context of Mole Concept, this process may help students connect abstract chemical quantities with mathematical relationships and practical problem-solving. Constructivism also provides a framework for considering retention as an outcome of learning. Active engagement, meaningful processing, application, and feedback can support the integration of new knowledge with existing cognitive structures. However, initial understanding does not ensure long-term retention. Continued practice, reinforcement, retrieval, application, and feedback are necessary for knowledge to remain accessible over time. Thus, the constructivist perspective supports examination of both immediate academic performance and retention following JiTT-based instruction.

2.2 Empirical Literature and Research Gap

The Mole Concept is a fundamental component of chemistry because it provides a quantitative link between microscopic entities and measurable quantities. It supports learning in areas such as stoichiometry, chemical equations, concentration, and other quantitative aspects of chemistry. However, the topic is often difficult for secondary school students because it requires integrating abstract conceptual understanding with mathematical reasoning and problem-solving (Kyado et al., 2021). Bamidele et al. (2013) examined Nigerian secondary school chemistry students' attitudes towards concept mapping in learning the Mole Concept, while Yakubu (2017) investigated concept mapping as a strategy for improving students' academic performance in the topic. Just-In-Time Teaching provides one possible response to these difficulties. The strategy connects students' preparation before class with classroom instruction by requiring students to complete preparatory activities and enabling teachers to use their responses to identify areas requiring attention (Novak et al., 1999, 2010). Gavrin (2010) similarly described JiTT as an approach that can promote active learning and provide teachers with information for adapting instruction to students' learning needs.

Gender is another variable that has received considerable attention in science education. Gender refers to socially and culturally constructed roles, behaviours, responsibilities, and expectations associated with males and females within a particular society. Educational outcomes may be influenced by social, cultural, environmental, and instructional factors that shape students' engagement with learning (Dan'inna, 2016). Historically, science and technology have been perceived in some contexts as male-dominated fields, raising concerns about unequal participation and achievement (Salma & Umami, 2024). More recent studies indicate increasing female participation and improved performance in science education. However, empirical findings concerning gender differences in science learning remain inconsistent. Some studies suggest that female students may benefit from learner-centred approaches, whereas others report outcomes favouring male students or no significant gender differences (Jack & Bitrus, 2024; Orji & Ibe, 2025). Earlier studies have also produced mixed results. Dahiru (2013) reported findings concerning gender and achievement under collaborative learning in chemistry, whereas Khairulanuar et al. (2010) found gender-related differences under particular learning conditions. In contrast, Ajaja and Eravwoke (2010) reported no significant gender difference following cooperative learning in integrated science, and Adesoji et al. (2015) examined gender-pair cooperative learning in chemistry without establishing a universal advantage for either gender.

The mixed findings suggest that gender should not be regarded as a universal predictor of students' academic outcomes. Rather, differences may depend on instructional strategy, subject matter, classroom environment, learner characteristics, and the outcome being measured. This is particularly important when distinguishing academic performance from retention. Although previous research has examined gender and achievement under various instructional approaches, relatively limited attention has been given to gender differences in retention following JiTT-based instruction, particularly in chemistry. The reviewed literature reveals a significant gap. While the Mole Concept remains a challenging area in chemistry education and active-learning approaches are recommended to address students' difficulties, there is limited empirical evidence on the use of JiTT to teach the Mole Concept among Nigerian secondary school students. Existing studies have primarily focused on academic achievement rather than retention, and there is insufficient evidence on whether male and female students differ in both performance and retention when taught the Mole Concept using JiTT. This study addresses this gap by examining the academic performance and retention of male and female SS II chemistry students taught the Mole Concept using the Just-In-Time Instructional Strategy in Zaria Education Zone, Kaduna State, Nigeria.

3 Materials and Methods

3.1 Research Design

The study employed a one-group pretest–posttest–post-posttest design to examine students' performance and retention in the Mole Concept following instruction using a modified Just-In-Time Teaching (JiTT) strategy. The study was conducted with an intact Senior Secondary II (SS II) Chemistry class because random assignment of individual students was not practicable within the existing school structure. The Mole Concept Performance Test (MCPT) was administered before the intervention (pretest), immediately after six weeks of instruction (post-test), and two weeks after the post-test (post-post-test) to assess retention.

3.2 Population and Sample

The population comprised 3,441 SS II students offering Chemistry in 18 public co-educational secondary schools in the Zaria Education Zone, Kaduna State, consisting of 1,883 males and 1,558 females. Five schools were selected from the 18 schools using simple random sampling: Government Science Secondary School (GSST) Jukun, Government Secondary School (GSS) Aminu, GSS Muchia, GSS Karaukara B, and GSS Likoro, all within Zaria Metropolis. The MCPT was administered as a baseline measure, and pretest scores were analysed to determine whether statistically significant differences existed in students' initial performance across the selected schools. GSS Aminu and GSS Likoro were identified as having comparable baseline performance. A subsequent random selection between the two schools resulted in the selection of GSS Aminu. The final sample consisted of 231 SS II Chemistry students from GSS Aminu, comprising 128 males and 103 females.

3.3 Instructional Procedure

Instruction was implemented using a modified JiTT strategy over six weeks. Before each lesson, students received warm-ups consisting of notes, questions, or assignments related to the forthcoming topic. The materials were prepared using relevant library resources and manually distributed to students several days before the corresponding classroom session. Students studied the materials, completed the assigned tasks individually, and submitted their responses to the researcher before the lesson. The researcher reviewed the responses to identify areas of difficulty, misconceptions, and gaps in understanding. The findings were used to guide classroom instruction. Classroom sessions therefore focused on clarifying identified misconceptions, discussing the warm-up materials, questioning, problem-solving, and feedback. At the end of each session, the next warm-up was assigned. Because of limited access to electronic resources in the study setting, the conventional JiTT procedure was adapted by replacing web-based resources with library resources, electronic distribution and submission with manual procedures, and digital projection with chalkboard presentation. The instructional cycle was structured as: Warm-up → Student response → Teacher review → Identification of misconceptions → Classroom adaptation → Feedback and problem-solving → Subsequent warm-up.

3.4 Instrument for Data Collection

Data were collected using the researcher-developed Mole Concept Performance Test (MCPT). The instrument consisted of 40 multiple-choice items covering the major content areas of the Mole Concept. Each item had one correct answer and four distractors, and each correct response attracted one mark, giving a maximum score of 40. The test comprised 27 numerical problem-solving items and 13 conceptual items. The researcher developed the MCPT from relevant Senior School Certificate Examination (SSCE) questions and chemistry practice materials and designed it to assess students' understanding and application of the Mole Concept. The content validity of the MCPT was established through expert review by three senior lecturers in Science Education and experienced Chemistry assessment personnel. The experts evaluated the items for clarity, relevance, appropriateness to the students' level, and adequacy of content coverage. Their recommendations, particularly concerning the clarity and presentation of chemical equations, were incorporated into the final version of the instrument. The MCPT was pilot-tested with 50 SS II Chemistry students from a school outside the study area. Test–retest reliability was determined using the Pearson product–moment correlation coefficient, which yielded a reliability coefficient of 0.70, indicating acceptable stability of the instrument.

3.5 Administration of Treatment and Data Collection

The researcher administered the modified JiTT treatment to the 231 participants over six weeks. Before the intervention, the MCPT was administered as a pretest. Following the six-week instructional period, the same instrument was administered as a post-test to determine changes in students' performance. Two weeks later, the test items were reshuffled and re-administered as a post-post-test to assess retention. The scores obtained from the pretest, post-test, and post-post-test were used to examine changes in students' performance and retention and to address the research questions and hypotheses.

3.6 Data Analysis

Data obtained from the study were analysed using mean and standard deviation to summarise students' academic performance and retention scores. Independent-samples t-tests were used to determine whether statistically significant differences existed between the mean performance scores of male and female students and between their mean retention scores at the 0.05 level of significance.

4 Results

The results are presented according to the two research questions. Academic performance results are based on post-test scores, whereas retention results are based on post-post-test scores.

4.1 Research Question 1

What is the difference between the academic performance of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy?

Table **1**

Mean and Standard Deviation of Male and Female Students' Academic Performance in the Mole Concept

Gender	N	Mean	SD	Mean Difference
Male	128	24.51	5.82	0.61
Female	103	23.90	6.00	

The results in Table 1 show that male students obtained a higher mean academic performance score (M = 24.51, SD = 5.82) than female students (M = 23.90, SD = 6.00). The mean difference was 0.61 points, indicating only a small observed difference.

4.2 Hypothesis 1

H_{01}: There is no significant difference between the mean academic performance scores of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy.

Table **2**

Independent-Samples t-Test Comparing Male and Female Students' Academic Performance

Outcome	Male M (SD)	Female M (SD)	t	df	p-value	Mean Difference	95% CI	Cohen's d
Academic performance	24.51 (5.82)	23.90 (6.00)	0.78	229	.439	0.61	[-0.93, 2.14]	0.10

Note. CI = confidence interval. Cohen's d was calculated from the reported t statistic and group sizes.

The independent-samples t-test showed that the difference in academic performance between male and female students was not statistically significant, $t(229) = 0.78$, $p = .439$, 95% CI [-0.93, 2.14], $d = 0.10$. Therefore, H_{01} was not rejected. Although male students had a slightly higher mean score than female students, the observed difference was small and not statistically significant.

4.3 Research Question 2

What is the difference between the retention scores of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy?

Table **3**

Mean and Standard Deviation of Male and Female Students' Retention Scores

Gender	N	Mean	SD	Mean Difference
Male	128	23.84	5.86	1.94

Female	103	21.90	5.82

The results in Table 3 show that male students obtained a higher mean retention score (M = 23.84, SD = 5.86) than female students (M = 21.90, SD = 5.82). The mean difference was 1.94 points in favour of male students.

4.4 Hypothesis 2

H_{02}: There is no significant difference between the mean retention scores of male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy.

Table **4**

Independent-Samples t-Test Comparing Male and Female Students' Retention Scores

Outcome	Male M (SD)	Female M (SD)	t	df	P	Mean Difference	95% CI	Cohen's d
Retention	23.84 (5.86)	21.90 (5.82)	2.51	229	.013	1.94	[0.42, 3.47]	0.33

Note. CI = confidence interval. Cohen's d was calculated from the reported t statistic and group sizes.

The independent-samples t-test showed a statistically significant difference in retention scores between male and female students, t(229) = 2.51, p = .013, 95% CI [0.42, 3.47], d = 0.33. Male students had significantly higher retention scores than female students. Therefore, H_{02} was rejected.

5 Discussion

The findings of this study showed that male and female students taught the Mole Concept using the Just-In-Time Instructional Strategy (JiTT) did not differ significantly in academic performance. Although male students recorded a slightly higher mean performance score (M = 24.51, SD = 5.82) than female students (M = 23.90, SD = 6.00), the difference was not statistically significant, t(229) = 0.78, p = .439. This indicates that male and female students achieved broadly comparable immediate learning outcomes following instruction with JiTT. This finding is supported by Omopekunola et al. (2023), who reported that gender did not significantly influence achievement among secondary-school physics students taught using Just-In-Time Teaching, F(1, 95) = 0.38, p = .539. The treatment-by-gender interaction was also not significant, F(1, 95) = 0.13, p = .716. These findings provide direct empirical support for the present result that male and female students can achieve comparable academic performance when exposed to JiTT. Jack and Bitrus (2024) similarly reported no significant gender difference in academic performance among students taught the Mole Concept using Krall's five-step problem-based learning model, F(1, 69) = 0.40, p = .528, partial η^2 = .003. The similarity is noteworthy because both studies involved secondary-school students learning the Mole Concept through student-centred instructional approaches.

Further evidence is provided by Yakubu et al. (2019), who investigated concept-mapping instruction on achievement and retention in the Mole Concept among secondary-school chemistry students in Kaduna State, Nigeria. They reported no significant gender difference in achievement among students exposed to concept mapping. Although concept mapping differs from JiTT, both strategies require learners to process and construct knowledge actively. However, a different pattern emerged with respect to retention. Male students obtained a higher mean retention score (M = 23.84, SD = 5.86) than female students (M = 21.90, SD = 5.82), and the difference was statistically significant, t(229) = 2.51, p = .013, 95% CI [0.42, 3.47], d = 0.33. The effect size indicates that the magnitude of the difference was small. The retention finding receives empirical support from Jack and Bitrus (2024), whose ANCOVA revealed a significant gender effect on retention following instruction through Krall's five-step problem-based learning model, F(1, 69) = 5.069, p = .013, partial η^2 = .023. The agreement suggests that gender differences may become more apparent at the retention stage than at the immediate post-instruction performance stage when students learn the Mole Concept through an active instructional strategy. Nevertheless, the present retention finding should be interpreted cautiously because empirical evidence is not uniform. Yakubu et al. (2019) reported no significant gender difference in retention among students taught the Mole Concept through concept mapping. Similarly, Ibe (2026) found no significant gender difference in chemistry retention among students taught using Think-Pair-Share, $F(1, 187) = 0.664$, $p = .416$.

The contrasting findings indicate that gender differences in chemistry retention should not be regarded as universal. Rather, such differences may depend on instructional strategy, subject matter, learner characteristics, classroom environment, assessment procedures, and the interval between instruction and retention assessment. The significant gender difference observed in the present study should therefore be interpreted as a finding specific to the conditions under which JiTT was implemented, rather than evidence of an inherent or general male advantage in chemistry retention. The distinction between immediate academic performance and retention is important. The present study found no significant gender difference immediately after instruction but found a significant difference at the later retention assessment. This suggests that similar levels of immediate learning do not necessarily guarantee identical maintenance of knowledge over time. Ibe (2026) and Yakubu et al. (2019) further demonstrate that instructional strategy can influence retention while gender effects may remain nonsignificant within particular instructional conditions. Taken together, the evidence supports the conclusion that JiTT was associated with comparable immediate academic performance among male and female students in the present study. In contrast, a relatively small gender difference emerged in retention. Because the study used a one-group design without a control group, the retention difference should not be interpreted as evidence that JiTT caused the gender difference. Rather, under the particular conditions of the present study, male and female students differed in the extent to which their learning was maintained over time.

6 Conclusion

The study examined the academic performance and retention of male and female SS II chemistry students taught the Mole Concept using the Just-In-Time Instructional Strategy in Zaria Education Zone, Kaduna State, Nigeria. The findings showed no statistically significant difference in academic performance between male and female students. However, a statistically significant difference was found in retention, with male students recording higher retention scores than female students. The findings suggest that the Just-In-Time Instructional Strategy can support comparable immediate academic performance among male and female students. However, comparable performance does not necessarily result in comparable retention. Chemistry teachers should therefore complement JiTT with follow-up revision, retrieval practice, problem-solving activities, reinforcement, and feedback to enhance retention among all learners. Future studies should employ larger samples and controlled or quasi-experimental designs to determine whether the observed retention difference is replicated across schools and instructional contexts.

7 Declaration

Ethical Statements: Ethical principles were observed throughout the study. Approval to conduct the research was obtained from the Department of Science Education, Ahmadu Bello University, Zaria, under the guidance and supervision of the research supervisory team. Informed consent was obtained from all participants before data collection. Participants were informed about the purpose and procedures of the study, the voluntary nature of their participation, their right to withdraw at any stage without penalty, and the measures taken to maintain the confidentiality of the information provided. Permission to conduct the study was also obtained from the Kaduna State Quality Assurance Authority and the principals of the participating schools. The data collected were used strictly for research purposes. Participants' identities and individual responses were kept confidential and handled in accordance with relevant ethical and institutional requirements.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: K. Habib conceived and designed the study, developed the research instruments, conducted the data collection, performed the data analysis, and drafted the manuscript. C. Dalla contributed to the study design, supervision of the research process, interpretation of the findings, and critical revision of the manuscript. A. A. Adeiza contributed to the literature review, interpretation of the results, and critical review and revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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Data Availability Statement: The dataset generated and analysed during the study is not publicly available because it contains information relating to individual student participants. However, the data may be made available by the corresponding author upon reasonable request, subject to appropriate ethical and institutional restrictions.

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