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# ENHANCEMENT OF CRITICAL THINKING SKILLS ACQUISITION IN CHEMICAL KINETICS USING HIGHER ORDER THINKING LABORATORY AND INQUIRY STRATEGIES

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**Abstract**
*This study assessed the enhancement of critical thinking skills acquisition using Higher Order Thinking Laboratory Strategy (HOTLS) and Inquiry Strategy in Senior Secondary School Students in Chemical Kinetics in Makurdi metropolis of Benue State, Nigeria. Three research questions guided the study while three hypotheses were tested at 0.05 level of significance. Non-randomized pre-test post-test quasi-experimental design was employed. The population comprised 2,145 Senior Secondary Two students (1,222 males and 923 females) across the 16 public co-educational schools out of which 136 (65 male and 71 female) SS two students offering Chemistry in four intact classes were sampled using multistage sampling procedure. The instrument for data collection was Test of Critical Thinking Skills Acquisition (TCTSA). Face validation was done by three experts, two in Science Education, one in measurement and evaluation, all from Rev. Fr Moses Orshio Adasu University Makurdi. The instrument was trial tested and the reliability coefficient of TCTSA yielded 0.77 using Kuder-Richardson formula 20. Research questions were answered using mean and standard deviation while the null hypotheses were tested using Analysis of Covariance (ANCOVA). The findings revealed that students taught Chemical Kinetics with HOTLS differed significantly in their mean critical thinking skills scores, there is no significant difference in the mean critical thinking skills scores of male and female students taught with HOTLS, there is no significant difference in the mean critical thinking skills scores of male and female students taught with Inquiry strategy. It was recommended among others that Chemistry teachers should use HOTLS to teach Chemistry to improve critical thinking skills of students.*

**Keywords**: Higher Order Thinking Laboratory Strategy, Inquiry Strategy, Chemical Kinetics, Critical Thinking.

## Introduction

Science education is very crucial and occupies a vital position in the development and technological advancement of a nation. The importance of science cannot be over emphasized as the National policy on Education stated that incentives be made for study of sciences at each level of education (FRN 2014). Chemistry is the branch of science that studies the properties and

behaviour of matter. It is a natural science that deals with the element that make up matter which can be in form of compounds composed of atoms, molecules and ions. Thus, the composition, structure, properties, behaviour and the changes that every matter undergo during a reaction with other substances is the hub of studying chemistry (Onuegbu, 2023). One of the challenges students offering Chemistry face is the abstractness and complexities that is associated with learning of the subject. This makes it imperative for learners to think critically engaging the executive functions of the brain to make meaning out of a learning material in a systematic manner as to make sound judgement free from error and also arrive at a logical conclusion. Critical thinking skill is an important variable in education.

In the 21st century, fostering critical thinking skills has become a central goal of science education especially in Chemistry where reasoning, problem solving, evidence-based judgement is crucial for learners to succeed academically and all also apply their knowledge content to solve real word problems. Critical thinking skills are cognitive skills that enables individuals to analyze complex problem, evaluate evidence and makes informed decisions. These skills are skills of employability that can make an individual self- reliant, useful to himself and the society at large. Critical thinking skills refer to the ability to apply knowledge, skills and values in reasoning, reflection, problem solving, decision making, innovating and creating something new (Sulaiman, et al., 2017). When learners engage the top three of Bloom's taxonomy, they are said to be critical thinkers (Rahayu & Sutrino, 2019).

Research has underscored the importance of innovative teaching strategies in fostering critical thinking skills. Van Brederode et al (2020) submitted that development of critical thinking skills is scuttled by memorization of facts (rote learning) and teacher-centred strategy which denies the learners the opportunity to engage in deeper, self- regulated cognitive work. This results in poor mastery of subject content which in turn inhibits self-reliance.

One of the goals of education in Nigeria is to lay a sound basis for scientific, critical and reflective thinking FRN (2014). Our present-day economy is no longer driven by certificated but by knowledge. Ayua (2019) recommended that the drive for paper certificates/ grades by students and school system should be shifted to acquisition of sound knowledge and competencies that the learners can apply to solve problems. For this to be achieved, there must be a pedagogical shift from passive, maintenance classroom to active anticipatory and participatory learning. This paradigm shift demands that innovative strategies that engages learners thinking skills maximally be employed to elicit logical thinking from learners thereby helping them take ownership and responsibility for their learning. Innovative instructional strategies that engage learners maximally with systematically organized learning activities has been implicated to enhance critical thinking skills of learners. Research report of Ananda et al. (2023) accentuated the fact that students taught chemistry with laboratory – based approach acquired advanced level of reasoning.

Higher Order Thinking Laboratory Strategy (HOTLS) is a method of teaching students in a Chemistry laboratory with context-rich learning experiences which enhances conceptual understanding, designed to stimulate students' critical thinking skills of analysis, synthesis, evaluating and creating. HOTLS involves five stages which includes; understanding the challenges, producing ideas, preparing for practical activities, conducting practical activities and communicating and evaluating

the results of activities (Malik et al 2019). Research has underscored the development of critical thinking skills through science learning process in classrooms or practical in laboratories. Malik et al. (2017) observed that practical activity properly developed stimulates students' critical thinking skills. The authors argued that practical activities enhance motivation for learning of chemistry as well as equip students with basic skills of experiment. Students' engagement in practical activities helps them explore scientific approach to issues and consequently facilitates the mastery of learning materials helping them at the end to be responsible for their learning.

Instructional strategies like Inquiry strategy have been used in teaching and learning of Chemistry (Odukwe & Nwafor 2022). Inquiry learning strategy provides the opportunity for students to construct their own knowledge, using concepts that have been held to solve the problems encountered in other situations. Meaningful learning demands that students link new information with existing one in an active manner. Andrini (2016) noted that inquiry strategy provides students with the opportunity to link new information with existing cognitive structure resulting in meaningful learning. Students' activeness to observe, guess, and infer through group activities helps them communicate the results of the investigation with more emphasis on learning. In addition to cognitive abilities, psychomotor and affective abilities of students can be developed by using inquiry strategy. Inquiry learning is built on the assumption that humans have an innate urge to find their own knowledge. The main objective of inquiry learning is helping students to develop intellectually disciplined and thinking skills by providing questions and get answers on the basis of curiosity and this can be viewed in relation to gender since Chemistry lessons are attended by both males and females.

Gender is the characteristics of being a male or a female According to Ayua et al (2024), gender is a natural way by which humans are grouped into male or female. The authors submitted that the role of gender in science learning has continued to be in the Centre of research. The research report of Ramdani et al. (2021) accentuated the fact that males think more critically than girls in Chemistry when exposed to5E learning strategy. The study of Perdana et al. (2019) revealed that females think more critically than males in Chemistry. Okafor and Nwonu (2021) in their study observed that male students taught with 7E Learning Cycle Model had the highest mean scores than the females in promoting critical thinking skills in chemistry. Sugiharti et al. (2024) in their study revealed that there was no significant difference in critical thinking between males and females. This implied no superiority in critical thinking ability of male and female subjects as both improved equally well. From the foregoing, it is obvious that there is inconsistency in empirical report on the issue of gender and critical thinking skills. This study is set to find out the effect of higher order thinking laboratory and Inquiry strategies on critical thinking skills acquisition of male and female students in chemical kinetics.

**Statement of the problem**

One of the realities of the 21st century is its competitiveness in the labour market which demands that individuals be trained, developed and equipped with critical thinking skills which are skills needed to make them ready for work. The need for critical thinking for self-reliance is also one of the goals of the National policy on Education, (FRN, 2014) which emphasized the training and production of individuals

with sound basis for scientific, critical and reflective thinking that will enable them develop life manipulative skills for self-reliance being useful to themselves and also contribute to the development of the nation. Regrettably, the innovative instructional strategies needed in stimulating, fostering and enhancing critical thinking skills of learners are lacking in the Chemistry classroom. This engenders passive learners who only memorize facts rather than reason deeply and think critically to gain conceptual understanding of chemistry concepts. The implication of this is that students have superficial knowledge void of deep understanding of Chemistry which results in poor performance and inability to apply chemistry content taught in the classroom in a real-world situation to solve problem. Student who lacks understanding of content will definitely find it difficult to generate ideas that can make them employable, useful to themselves and the society thus having graduates with certificate that lacks sound knowledge or content in their subject area (Ayua, 2019)

It is against this backdrop that the enhancement of critical thinking skills acquisition in chemical kinetics using higher order thinking laboratory and inquiry strategies was studied in which the objectives of the study are to:

1. Determine the effect of higher order thinking laboratory and Inquiry strategies on the critical thinking skills of students taught chemical kinetics.
2. Determine the effect of higher order thinking laboratory strategy on the critical thinking of male and female students taught chemical kinetics.
3. Determine the effect of inquiry strategy on the critical thinking of male and female students taught chemical kinetics.

**Research Questions**:

1. What is the difference in the mean critical thinking skill scores between students taught chemical kinetics using higher order thinking laboratory strategy and those taught using inquiry strategy?
2. What is the difference in the mean critical thinking skill of male and female students taught chemical kinetics using higher order thinking laboratory strategy?
3. What is the difference in the mean critical thinking skills of male and female students taught chemical kinetics using inquiry strategy?

**Hypotheses:** These hypotheses guided the study

$Ho_1$: There is no significant difference in the mean critical thinking skills scores of students taught chemical kinetics using higher order thinking laboratory strategy and those taught using Inquiry Strategy.

$Ho_2$ There is no significant difference in the mean critical thinking skills scores of male and female students taught chemical kinetics using higher order thinking laboratory strategy

$H_{O3}$ There is no significant difference in the mean critical thinking skills scores of male and female students taught chemical kinetics with inquiry strategy

**Methods**

The study employed Quasi-experimental non-randomized design employing Pre-test and Post-test. The population of the study comprised 2,145 Senior Secondary Two students made up of 1,222 males and 923 females from 23 public secondary schools in Makurdi Metropolis. The sample consisted of 136 (65 male and 71 female) Senior Secondary two students (SS2) offering Chemistry drawn from four intact classes from 16 co-educational schools.

Test of Critical Thinking Skill Acquisition (TCTSA) which was developed by the researchers to measure critical thinking skills acquisition in chemical kinetics was used for data collection The test is short answer essay questions. It was structured with ten thought provoking questions that did not require a yes or no answer but engaged critical thinking skills of students as the questions were answered. However, the ten thought provoking questions stimulated students' thought process maximally. The test had a scoring sheet that contained what the students referred to in order to be able to score 2 marks for each correct answer. TCTSA was validated and trial-tested on 87 students that were not part of the sample. The scores generated from the trial test was used to calculate the reliability coefficient of TCTSA which yielded 0.77 using Kuder Richardson formular 20. The two experimental groups (EG1 and EG2) were pre-tested before the treatment which lasted for six weeks. Both groups were thought concept of chemical kinetics before administration of post-test using HOTLS (EG1) and IS (EG2). The data collected were analysed using mean and standard deviation to answer research questions and ANCOVA for hypothesis testing at 0.05 level of significance.

**Results**

The results were presented in order of the research questions and hypotheses as follows:

**Research Question One**

What is the difference in the mean critical thinking skill scores between students taught chemical kinetics using higher order thinking laboratory strategy and those taught using inquiry strategy?

**Table 1: Mean Critical Thinking Skill Scores between Students taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy and Inquiry Strategy**

| | Strategies | Pre-critical thinking skill | Post critical thinking skill | Mean gain |
|---|---|---|---|---|
| Higher Order Thinking Laboratory strategy | Mean | 10.86 | 21.12 | 10.26 |
| | N | 69 | 69 | |
| | Std. Deviation | 1.54 | 1.64 | |
| Inquiry Strategy | Mean | 10.46 | 15.66 | 5.20 |
| | N | 67 | 67 | |
| | Std. Deviation | 3.17 | 2.88 | |
| Mean difference | | | | 5.06 |

Table one shows disparity in the critical thinking skill scores among students taught chemical kinetics HOTLS and those taught with inquiry strategy (mean gain of 10.26 and 5.20 respectively) with a mean gain difference of 5.06 in favor of HOTLS.

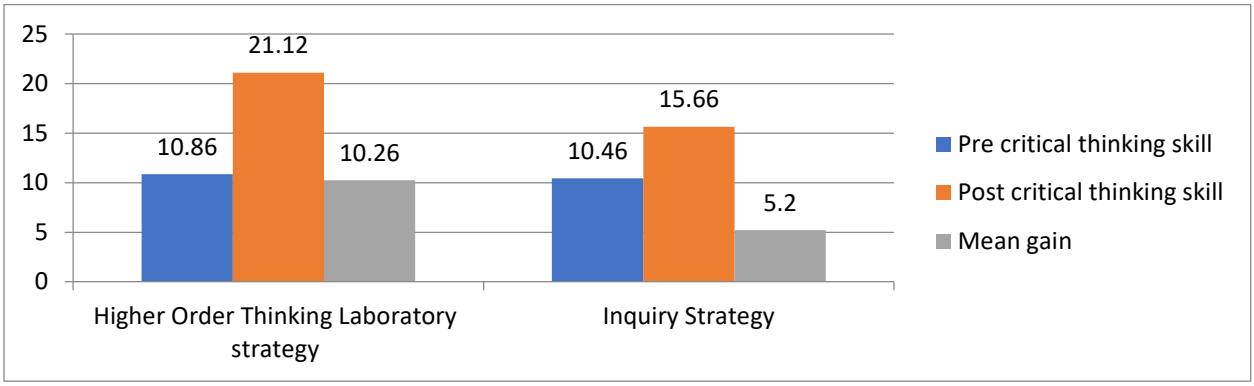


**Figure 1:** Pretest, Post-test and Mean Gain in Critical Thinking Skill Scores between Students taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy and Inquiry Strategy

**Research Question Two**
What is the difference in the mean critical thinking skills of male and female students in Chemistry taught chemical kinetics using higher order thinking laboratory strategy?

**Table 2: Mean Critical Thinking Skill of Male and Female Chemistry Students taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy**

| Gender | | Pre-critical thinking skill | Post critical thinking skill | Mean gain |
|---|---|---|---|---|
| Male | Mean | 10.79 | 21.12 | 10.33 |
| | N | 33 | 33 | |
| | Std. Deviation | 1.38 | 1.61 | |
| Female | Mean | 10.92 | 21.11 | 10.19 |
| | N | 36 | 36 | |
| | Std. Deviation | 1.69 | 1.70 | |
| Mean difference | | | | 0.14 |

Table two shows homogeneity in the critical thinking skill scores of male and female students taught chemical kinetics with HOTLS (mean gain of 10.33 and 10.19 respectively) with a mean gain difference of 0.14 in favor of male students in HOTLS group.

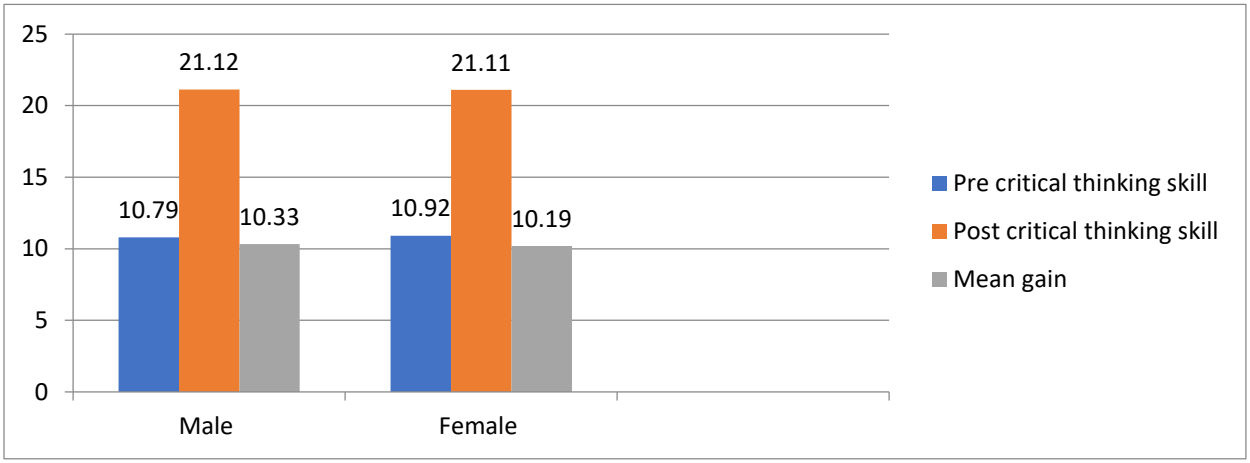


**Figure 2:** Pretest, Post-test and Mean Gain in Critical Thinking Skill of Male and Female Students in Chemistry taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy

**Research Question Three**

What is the difference in the mean critical thinking skills of male and female students in Chemistry taught chemical kinetics using inquiry strategy?

**Table 3: Mean Critical Thinking Skills of Male and Female Students in Chemistry taught Chemical Kinetics using Inquiry Strategy**

| Gender | | Pre-critical thinking skill | Post critical thinking skill | Mean gain |
|---|---|---|---|---|
| Male | Mean | 11.09 | 16.21 | 5.12 |
| | N | 32 | 32 | |
| | Std. Deviation | 2.72 | 2.80 | |
| Female | Mean | 9.89 | 15.14 | 5.25 |
| | N | 35 | 35 | |
| | Std. Deviation | 3.47 | 2.91 | |
| Mean difference | | | | 0.13 |

Table three shows homogeneity in the critical thinking skill scores of male and female students taught chemical kinetics with inquiry strategy (mean gain of 5.12 and 5.25 respectively) with a mean gain difference of 0.13 in favor of female students in inquiry strategy group.

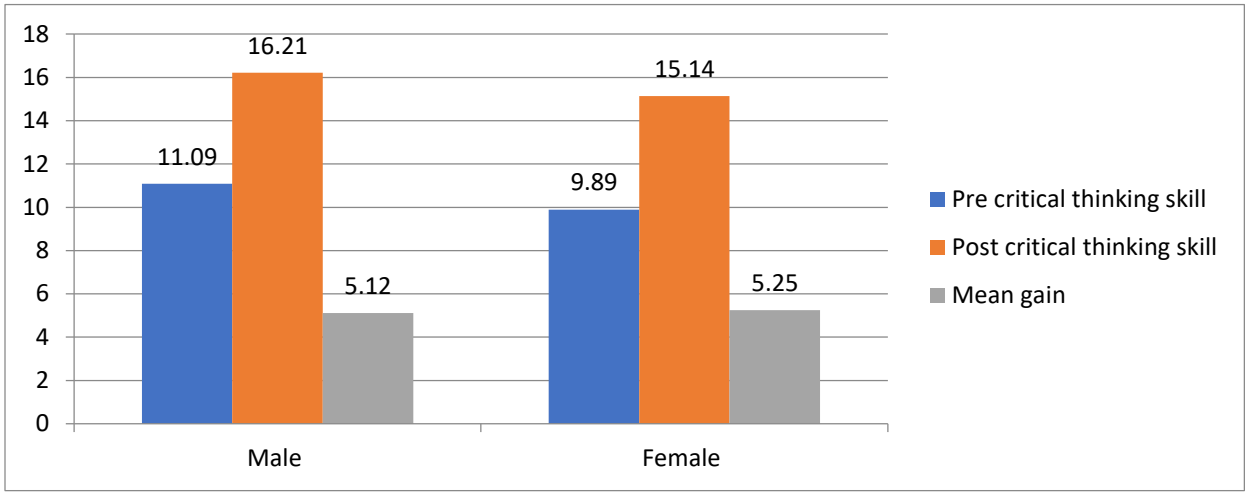


**Figure 3:** Pretest, Post-test and Mean Gain in Critical Thinking Skills of Male and Female Students taught Chemical Kinetics using Inquiry Strategy

**Hypothesis One**
There is no significant difference in the mean critical thinking skills scores of students in Chemistry taught chemical kinetics using higher order thinking laboratory strategy and those taught using Inquiry Strategy.

**Table 4: ANCOVA of Critical Thinking Skills Scores of Students in Chemistry taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy and Inquiry Strategy**

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. | Partial Eta Squared | Decision |
|---|---|---|---|---|---|---|---|
| Corrected Model | 1240.580[a] | 2 | 620.290 | 162.180 | .000 | .709 | Sig. |
| Intercept | 1131.693 | 1 | 1131.693 | 295.891 | .000 | .690 | |
| Pre Critical | 227.493 | 1 | 227.493 | 59.480 | .000 | .309 | |
| **Strategies** | **932.256** | **1** | **932.256** | **243.747** | **.000** | **.647** | |
| Error | 508.684 | 133 | 3.825 | | | | |
| Total | 47926.000 | 136 | | | | | |
| Corrected Total | 1749.265 | 135 | | | | | |

Table 4 showed that $F(1,133) = 243.747$; $p = 0.000 < 0.05$. Since p is less than 0.05, the null hypothesis is therefore rejected. This implies that there is significant difference in the mean critical thinking skills scores of students taught chemical kinetics using HOTLS and those taught using Inquiry Strategy.

**Hypothesis Two**
There is no significant difference in the mean critical thinking skills scores of male and female students taught chemical kinetics using higher order thinking laboratory strategy.

**Table 5: ANCOVA of Critical Thinking Skills Scores of Male and Female Students taught Chemical Kinetics using Higher Order Thinking Laboratory Strategy**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Decision |
|---|---|---|---|---|---|---|---|
| Corrected Model | 1.615[a] | 2 | .808 | .291 | .749 | .009 | Not Sig. |
| Intercept | 542.142 | 1 | 542.142 | 195.040 | .000 | .747 | |
| Pre Critical HOT | 1.614 | 1 | 1.614 | .581 | .449 | .009 | |
| **Gender HOT** | **.009** | **1** | **.009** | **.003** | **.955** | **.000** | |
| Error | 183.457 | 66 | 2.780 | | | | |
| Total | 30951.000 | 69 | | | | | |
| Corrected Total | 185.072 | 68 | | | | | |

a. R Squared = .009 (Adjusted R Squared = -.021)

Table 5 showed that F(1,66) = 0.003; p = 0.955 > 0.05. Since p is greater than 0.05 the null hypothesis is therefore not rejected. This implies that there is no significant difference in the mean critical thinking skills scores of male and female students taught chemical kinetics using higher order thinking laboratory strategy.

**Hypothesis Three**

There is no significant difference in the mean critical thinking skills scores of male and female students taught chemical kinetics with inquiry strategy.

**Table 6: ANCOVA of Critical Thinking Skills Scores of Male and Female Students taught Chemical Kinetics with Inquiry Strategy**

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. | Partial Eta Squared | Decision |
|---|---|---|---|---|---|---|---|
| Corrected Model | 264.170[a] | 2 | 132.085 | 29.461 | .000 | .479 | Not Sig. |
| Intercept | 452.512 | 1 | 452.512 | 100.932 | .000 | .612 | |
| Pre Critical IS | 244.820 | 1 | 244.820 | 54.606 | .000 | .460 | |
| **Gender IS** | **1.742** | **1** | **1.742** | **.389** | **.535** | **.006** | |
| Error | 286.934 | 64 | 4.483 | | | | |
| Total | 16975.000 | 67 | | | | | |
| Corrected Total | 551.104 | 66 | | | | | |

a. R Squared = .479 (Adjusted R Squared = .463)

Table 6 shows that F(1,64) = 0.389; p = 0.535 > 0.05. Since p is greater than 0.05, the null hypothesis is therefore not rejected. This implies that there is no significant difference in the mean critical thinking skills scores of male and female students taught chemical

kinetics with inquiry strategy.

**Discussion**

The finding revealed that the students taught with higher order thinking laboratory strategy had higher critical thinking skills scores than their counterparts taught the same concepts with inquiry strategy. This suggests that HOTLS is more effective in enhancing critical thinking skills than inquiry strategy. This could because HOTLS had more organized activities that offers students the opportunity of taking ownership and responsibility for their learning. These activities engaged students' thinking faculty much more as they sought for answers to the problem by the teacher hence increased their critical thinking skills. This finding aligned with Ananda et al. (2023) who revealed in their study that students when exposed to more organized activities where they have maximum participation engages their critical thinking skills more effectively. This finding is also in consonance with Brederode et al. (2020) who submitted that development of critical thinking skills is scuttled by memorization of facts (rote learning) and teacher-centred strategy which denies the learners the opportunity to engage in deeper, self-regulated cognitive work.

Also, the result revealed no significant difference in critical thinking skills level of male and female students taught using HOTLS. This implies that HOTLS is gender insensitive as it enhanced the critical thinking skills of both male and female students offering Chemistry. This could be because male and female have the same innate ability to learn and both participated meaningfully in Chemistry activities during the teaching and learning process. This finding is in agreement with Sugiharti et al. (2024) who in their study revealed that there was no significant difference in critical thinking between males and females. This implied no superiority in critical thinking ability of male and female subjects as both improved equally well. However, the study disagrees with Okafor and Nwonu (2021) who observed that male students had higher critical thinking scores than their female counterparts when taught with 7ELearning cycle in Chemistry.

Lastly, the result revealed no significant difference in the critical thinking levels of male and female students taught chemical kinetics using inquiry strategy. This is in agreement with Odukwe and Nwafor (2022) who observed that inquiry strategy increased critical thinking scores of male and female students equally. The study contradicts the finding of Ramdani et al. (2021) accentuated the fact that males think more critically than girls in Chemistry when exposed to 5E learning strategy.

**Conclusion**

The findings of this study provided empirical evidence on the effectiveness of innovative teaching strategies in improving students' critical thinking skills. By comparing Higher Order Thinking Laboratory Strategy (HOTLS) with Inquiry Strategy, the study offers insights into how pedagogical approaches can enhance critical thinking and problem-solving. The findings also contributed to gender-related discussions in science learning, highlighting the differential effects of these strategies on male and female critical thinking skills of students.

**Recommendation**

Based on the findings, it was recommended that:

1. Government through the Ministry of Education should organize teacher training workshop for in-service and pre-service chemistry teachers on

innovative strategies like higher order thinking laboratory and inquiry instructional strategies in schools.

2. Science Teachers Association of Nigeria (STAN) should popularize HOTLS in its workshops, seminars and symposium for pre-service and in-service teachers as pedagogical tool in enhancing critical thinking skills.
3. Teacher training institutions such as Faculties of Education, Colleges of Education, and National Teachers' Institute (NTI) should include HOTLS as instructional strategy to be taught in teacher training institutions.

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