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BRIDGING THE GENDER GAP THROUGH THINK-PAIR-SHARE AND CONCEPT MAPPING AMONG SSS IN CHEMICAL BONDING IN TARABA STATE

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ABSTRACT
This study investigated the effects of Think-Pair-Share (TPS) and Concept Mapping (CM) instructional strategies in narrowing the gender gap in academic achievement in chemical bonding among senior secondary school students in Taraba State. A quasi-experimental, pre-test–post-test, non-equivalent control group design was employed, involving 300 SS1 chemistry students (150 males, 150 females) from six public secondary schools in Taraba State, Nigeria. Students were assigned to TPS, CM, or Guided Discovery Method (GDM) groups. Data were collected using the Chemical Bonding Achievement Test (CBAT), and analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at a 0.05 significance level. Results revealed that TPS and CM significantly improved students' academic achievement compared to GDM. Gender differences were negligible in TPS and CM groups, but pronounced in GDM. The interaction effect between instructional method and gender was statistically significant, suggesting that strategy choice can influence gender-related performance patterns. These findings support Ausubel's meaningful learning theory and Gagné's learning hierarchy, emphasizing the role of interactive, student-centered strategies in promoting both achievement and equity in STEM classrooms. It is recommended that TPS and CM be integrated into the Nigerian secondary school chemistry curriculum to enhance learning outcomes and bridge gender disparities.

Keywords: Gender gap, chemical bonding, concept mapping, think-pair-share, academic achievement, Nigeria

INTRODUCTION
The underrepresentation and underachievement of female students in science, technology, engineering, and mathematics (STEM) fields remain persistent issues globally. This imbalance is not only a matter of equity but also a lost opportunity to harness the full potential of half the population in scientific and technological advancement. Among STEM subjects, chemistry is considered a core science discipline due to its centrality in various scientific applications and fields. However, gender disparities in students' performance and engagement continue to hinder educational outcomes in chemistry, particularly at the secondary school level (Santamaría et al., 2021).
In Nigeria, the issue is especially pronounced. Data from the West African Senior School Certificate Examination (WASSCE) and internal assessments reveal that male students consistently outperform female students in chemistry (Taraba State Ministry of Education, 2022). Several reasons have been advanced for this disparity, including societal stereotypes that perceive science as a male domain, lack of female role models in STEM fields, gender-insensitive instructional practices, and low self-efficacy among female students (Sharma & Bhatia, 2023; Ogbonna, 2021).

Conventional teaching approaches such as the lecture method often reinforce passive learning, which disproportionately affects female students who may benefit more from collaborative and supportive environments (Primo et al., 2020). Research suggests that instructional strategies that promote interaction, visualization, and active participation can improve learning outcomes for all students and especially help close gender gaps (Millán & Cappella, 2021).
Two promising pedagogical strategies Think-Pair-Share (TPS) and Concept Mapping (CM) have gained attention for their ability to foster deep conceptual understanding and inclusive classroom participation. TPS is a cooperative learning method that encourages students to individually process information, collaborate with peers, and share their insights with the class. It is rooted in

constructivist learning theory and emphasizes student engagement through dialogue and reflection (Kitaoka, 2020). CM, on the other hand, involves the use of graphical tools to represent relationships among concepts. It supports the development of meaningful learning by helping students visualize and organize abstract concepts like chemical bonding (Zhao et al., 2023).

The concept of meaningful learning, as outlined by Ausubel et al. (1978), stresses the importance of connecting new information to existing knowledge structures. This is particularly relevant in chemistry, where understanding topics like chemical bonding requires integrating multiple abstract concepts. Gagne's theory of learning hierarchies further supports this view by emphasizing the sequential acquisition of knowledge another principle leveraged in CM design (Nwanekezi & Arokoyu, 2014).

Given the persistent gender gaps in academic achievement and the promising results of TPS and CM, this study aims to evaluate the effectiveness of these strategies in improving students' understanding of chemical bonding and in minimizing gender-based performance differences.

Purpose of the Study

The primary purpose of this study is to investigate the effect of Think-Pair-Share and Concept Mapping instructional strategies on senior secondary school students' academic achievement in chemical bonding, with a particular focus on gender differences. The study seeks to determine whether these innovative teaching methods can create a more inclusive and equitable learning environment in chemistry education.

Research Questions

To guide the study, the following research questions were formulated:

1. What is the effect of Concept Mapping, Think-Pair-Share Guided Discovery Method on students' academic achievement in chemical bonding?
2. What is the interaction effect of instructional strategies and gender on students' academic achievement in chemical bonding?

Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

H_{01}: There is no significant difference in the mean achievement scores of students taught chemical bonding using CM, and TPS.

H_{02}: There is no significant interaction effect between instructional method and gender on students' academic achievement in chemical bonding.

Literature Review

This section explores relevant research on gender disparities in chemical bonding and the potential of innovative instructional strategies specifically Think-Pair-Share (TPS) and Concept Mapping (CM) to address these disparities. The review is organized into four subsections: gender disparities in chemistry education, the TPS strategy, the CM strategy, and the theoretical framework underpinning the study.

Gender Disparities in Chemistry Education

Despite growing global awareness of gender equity in education, gender disparities persist in STEM, especially in developing countries. Chemistry, as one of the foundational sciences, frequently reflects these disparities through lower female participation, engagement, and performance compared to males. Several studies attribute this performance gap to social and cultural biases, lack of encouragement, and gender-insensitive pedagogy (Primo et al., 2020; Ogbonna, 2021).

In Nigeria, research shows that boys outperform girls in science subjects, including chemistry, partly due to greater access to science resources, higher teacher expectations, and more supportive classroom interactions (Taraba State Ministry of Education, 2022). Female students often report lower confidence, anxiety toward science topics, and perceptions that chemistry is too abstract and difficult a sentiment amplified by rote learning and lecture-based methods (Santamaría et al., 2021). However, when innovative, student-centered methods are employed, this performance gap tends to narrow. For instance, Millán and Cappella (2021) demonstrated that instructional methods emphasizing collaboration and peer support help mitigate gender-based performance differences in science classes.

Think-Pair-Share Strategy

Think-Pair-Share (TPS) is a cooperative learning strategy developed by Lyman (1981), which fosters deeper cognitive engagement through structured peer discussion. The strategy consists of three steps: (1) Think; - students contemplate a question or problem independently, (2) Pair; - students pair with a peer to discuss their ideas, and (3) Share; - pairs share their insights with the larger group.

Research has shown that TPS enhances academic performance, especially in science subjects, by promoting active learning and increasing student participation (Ahmad, 2020). TPS reduces classroom anxiety and gives all students, including those who may be shy or marginalized (e.g., girls in STEM contexts), the opportunity to process and express their ideas in a low-stakes environment (Ali & Aleen, 2020). Huang and Wu (2021) further observed that TPS promotes reflective thinking and strengthens communication skills, both of which are essential for scientific reasoning.

In gender-focused studies, TPS has been linked to improved female engagement. Gongden and Delmang (2020) noted that the method allows female students to gain confidence through peer dialogue before addressing the whole class, reducing feelings of intimidation or marginalization.

Concept Mapping Strategy

Concept Mapping (CM), introduced by Novak and Gowin in the 1970s, is a visual representation tool that helps learners organize and relate concepts in a hierarchical structure. CM supports Ausubel's theory of meaningful learning by enabling students to connect new information with existing knowledge (Novak & Cañas, 2022).

In chemistry, which involves abstract and interrelated ideas (e.g., atomic structure, electron sharing, covalent and ionic bonds), CM has proven highly effective in enhancing understanding. Students who use CM tend to retain information longer, correct misconceptions, and develop a more integrated understanding of complex topics (Zhao et al., 2023).

Empirical studies have shown that CM can significantly improve academic achievement in science subjects. For example, Etokeren and Abosede (2022) found that students taught chemical bonding through CM scored significantly higher on achievement tests and demonstrated fewer misconceptions. Moreover, CM has been particularly beneficial for female students who may prefer visual and structured learning formats (Kilic & Cakmak, 2019).

Theoretical Framework

This study is grounded in two foundational theories of learning:

Ausubel's Theory of Meaningful Learning: Ausubel et al. (1978) emphasized the importance of prior knowledge in learning new concepts. Meaningful learning occurs when new information is connected to relevant existing cognitive structures. CM aligns with this theory by visually displaying these connections, making abstract chemistry concepts more accessible and understandable.

Gagné's Hierarchy of Learning: Gagné proposed that complex learning builds upon simpler tasks arranged in a hierarchy from signal learning to problem-solving (Nwanekezi & Arokoyu, 2014). TPS supports this theory by guiding students from individual reflection to paired discussion and finally group sharing, reinforcing knowledge through structured stages of learning.

These theoretical foundations justify the use of TPS and CM in the current study, especially in facilitating equitable and meaningful learning experiences for both male and female students.

METHODOLOGY

This section describes the design, population, sample, instrumentation, procedure, and data analysis methods employed in this study. The goal is to determine the effectiveness of Think-Pair-Share and Concept Mapping strategies in improving students' academic achievement in chemistry and in reducing gender disparities.

Research Design: The study employed a quasi-experimental design using a pre-test, post-test, non-equivalent control group design. This design was suitable because random assignment of students to intact classes was not possible, yet comparison among groups was necessary to determine treatment effects. Three experimental conditions were used: The Think-Pair-Share (TPS) group, the Concept Mapping (CM) group, and the Guided Discovery Method (GDM) group (control).

This design allowed for: Measurement of baseline knowledge (pre-test), Exposure to different instructional interventions, and Assessment of learning gains (post-test), while controlling for initial group differences using covariate analysis.

Population and Sample: The target population was all Senior Secondary School One (SS1) chemistry students in the northern zone of Taraba State, Nigeria. The region was chosen for its demographic diversity and representation of common educational challenges in the country.
Using multi-stage sampling technique, six public secondary schools were selected. Within each school, students were assigned to one of the three instructional methods based on existing classroom arrangements. In total, 300 students participated in the study:
150 male and 150 female students, Divided equally across the three groups: TPS (n = 100), CM (n = 100), and TLM (n = 100), With each group comprising 50 male and 50 female students.

Research Instrument: The main instrument used was the Chemical Bonding Achievement Test (CBAT), designed by the researchers in alignment with SS1 chemistry curriculum standards. The test contained: 30 multiple-choice items, each with four options, Covered key subtopics: atomic structure, ionic and covalent bonding, electron configurations, and valency, Validated by chemistry education experts for content and construct validity.
A pilot test was conducted with 50 students from schools not involved in the study. The reliability index was calculated using Kuder-Richardson Formula 20 (KR-20), yielding a coefficient of 0.84, indicating high internal consistency.

Procedure: The intervention lasted for six weeks, with three 40-minute chemistry lessons per week. All groups were taught the same topic: chemical bonding, using the three different strategies:

TPS Group: Teachers introduced questions or problems, asked students to think individually, pair up for discussion, and then share responses with the class. Emphasis was placed on dialogue, reflection, and inclusive participation.

CM Group: Students were guided in creating concept maps at the start and end of each lesson. Maps helped them visualize relationships between bonding concepts. Teachers facilitated discussion based on student-generated maps.

GDM Group: Students received instruction through conventional lecture methods with minimal student interaction or collaborative learning.

Pre-tests were administered before the intervention and post-tests immediately after the final lesson.

Data Analysis:
Descriptive and inferential statistics were used: Mean and Standard Deviation to summarize student performance by group and gender, Analysis of Covariance (ANCOVA) to determine the effect of instructional strategy and gender on students' post-test scores while controlling for pre-test differences, Significance level set at $p < 0.05$ for all hypothesis tests.

Results
This section presents the findings of the study in relation to the research questions and hypotheses. It includes descriptive statistics and inferential analysis of the students' academic achievement in chemical bonding, based on instructional strategies and gender.
Descriptive Statistics of Post-Test Scores
The mean and standard deviation scores of students taught using Think-Pair-Share (TPS), Concept Mapping (CM), and Guided Discover Method (GDM) are presented in Table 1.
Table 1:

Table 1: Mean and Standard Deviation of Students' Post-Test Scores by Instructional Strategy and Gender.

Group	Gender	N	Mean Score	Standard Deviation (SD)
Concept-mapping:	Male	50	78.4	5.2
	Female	50	77.8	5.6
Think-pair strategy:	Male	50	81.2	4.8
	Female	50	80.6	4.5
Guided-inquiry:	Male	50	69.1	6.3
	Female	50	65.4	6.7

From Table 1, students taught using Concept Mapping achieved the highest mean scores, followed closely by those in the Think-Pair-Share group. Students in the Traditional Lecture Method group had the lowest mean scores. Gender differences within TPS and CM groups were minimal, while a wider gender gap was evident in the TLM group.

Inferential Analysis
To determine whether the observed differences were statistically significant, Analysis of Covariance (ANCOVA) was conducted using the pre-test scores as a covariate.

Table 2: Summary of ANCOVA on Post-Test Scores by Instructional Strategy and Gender

Sources of Variation	Sum of Squares	df	Mean Square	F	p-value
Instructional Method	1243.23	2	621.61	25.76	0.000*
Gender	18.67	1	18.67	0.78	0.379
Method * Gender	225.14	2	112.57	4.67	0.011*
Error	7092.35	294	24.12		
Total	8579.39	299			

Significant at $p < 0.05$

Main Effect of Instructional Strategy: The result shows a significant main effect of instructional strategy on students' academic achievement in chemical bonding ($F(2, 294) = 25.76$, $p = 0.000$). This indicates that the method of instruction significantly influenced students' performance. Thus, hypothesis 1 is rejected.
Main Effect of Gender: No significant main effect of gender was found ($F(1, 294) = 0.78$, $p = 0.379$). This suggests that gender alone did not significantly affect achievement scores, supporting gender equity under effective instruction.
Interaction Effect of Instructional Strategy and Gender: A significant interaction effect was observed ($F(2, 294) = 4.67$, $p = 0.011$), indicating that the effect of instructional method on achievement varied by gender. This result leads to the rejection of hypothesis 2.

DISCUSSION

The purpose of this study was to determine the effect of Think-Pair-Share (TPS) and Concept Mapping (CM) strategies on students' academic achievement in chemical bonding and to examine whether these strategies could help bridge the gender gap in chemistry education. The findings are discussed in light of the research questions, hypotheses, and literature reviewed.

Effect of Instructional Strategy on Academic Achievement

The results showed that students taught using TPS and CM significantly outperformed those taught through the Guided Discovery Method (GDM). This aligns with the findings of Ahmad (2020) and Zhao et al. (2023), who reported that student-centered instructional strategies foster deeper understanding, engagement, and retention of concepts. In particular, CM provided a visual and structured means for students to organize chemical bonding concepts, which reduced cognitive load and improved comprehension (Kilic & Cakmak, 2019). TPS, on the other hand, promoted active peer interaction and collaborative problem-solving, which have been shown to enhance performance in science subjects (Huang & Wu, 2021). The improved performance in TPS and CM groups confirms the assertion by Novak and Cañas (2022) that meaningful learning is achieved when learners actively relate new concepts to existing cognitive frameworks. Similarly, Gagné's hierarchy of learning supports the step-by-step progression in TPS and the scaffolded connections in CM.

Gender Equity in Learning Outcomes

While gender had no significant main effect on students' achievement, the significant interaction between instructional strategy and gender indicates that the effectiveness of an instructional method depends partly on gender. In TPS and CM groups, gender differences in mean scores were minimal, suggesting that these methods create more equitable learning environments. This supports Gongden and Delmang's (2020) conclusion that gender-responsive teaching strategies, which allow for collaboration, discussion, and visualization, help reduce the intimidation and exclusion often felt by female students in STEM classrooms.
In contrast, the GDM group showed a pronounced gender gap, with males outperforming females. This pattern reflects earlier findings in Nigeria that lecture-based instruction tends to favor more confident, outspoken students often male thereby widening the performance gap (Ogbonna, 2021; Santamaría et al., 2021).

Implications of the Findings

The results have important implications for teaching chemistry in Nigerian secondary schools:
1. Instructional Reform: Moving away from teacher-centered approaches towards interactive, student-centered strategies can improve learning outcomes for all students.
2. Gender Inclusivity: Strategies like TPS and CM reduce performance disparities, providing both male and female students with equal opportunities to succeed.
3. Curriculum Integration: Embedding TPS and CM in chemistry curricula could institutionalize practices that promote equity and deep learning.

Connection to Theoretical Framework

The study's findings strongly support Ausubel's meaningful learning theory. Both TPS and CM encourage learners to actively integrate new knowledge with prior understanding, resulting in deeper conceptual mastery. Furthermore, Gagné's learning hierarchy is evident in the structured, incremental skill development facilitated by these strategies students' progress from simple idea formulation to complex problem-solving through guided stages.

The use of TPS and CM in teaching chemical bonding not only enhances academic achievement but also narrows the gender performance gap. These findings confirm that instructional strategies play a pivotal role in shaping equitable learning environments, and they reinforce calls for widespread adoption of interactive pedagogies in Nigerian science classrooms.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study examined the effects of Think-Pair-Share (TPS) and Concept Mapping (CM) instructional strategies on senior secondary school students' academic achievement in chemical bonding, with a focus on gender equity. The findings revealed that both TPS and CM significantly improved students' academic performance compared to the Guided Discovery Method (GDM). Additionally, the gender gap observed in the GDM group was notably reduced in the TPS and CM groups, indicating that these interactive, student-centered strategies promote a more equitable learning environment.

The results confirm the theoretical positions of Ausubel's meaningful learning theory and Gagné's learning hierarchy, demonstrating that instructional approaches which foster active engagement, collaboration, and visualization can support deeper understanding of abstract chemistry concepts. Moreover, the study underscores that effective pedagogy can diminish long-standing gender disparities in STEM education.

In summary, TPS and CM are effective not only for improving academic achievement in chemical bonding but also for promoting gender inclusivity in the classroom.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Teacher Professional Development: Chemistry teachers should be trained and encouraged to adopt TPS and CM as part of their regular instructional repertoire. Workshops and in-service training can be organized by educational authorities.
2. Curriculum Integration: The Nigerian secondary school chemistry curriculum should formally incorporate TPS and CM approaches, ensuring their consistent application in teaching abstract topics like chemical bonding.
3. School Support: Administrators should provide resources such as concept mapping tools, visual aids, and flexible seating arrangements to facilitate group work and peer interaction.
4. Gender-Responsive Teaching Policies: Education policymakers should develop guidelines that promote gender equity in STEM classrooms, emphasizing the role of inclusive strategies like TPS and CM.
5. Further Research: Longitudinal studies should be conducted to assess the sustained impact of TPS and CM on student achievement and interest in STEM careers, as well as their adaptability to other challenging science topics.

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