

EFFECTS OF SPIDER CONCEPT MAPPING STRATEGY ON ACHIEVEMENT IN MOLE CONCEPT AMONG SS2 STUDENTS IN NASSARAWA EGGON

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ABSTRACT

This study examined the effects of spider concept mapping strategy on achievement in mole concept among ss2 students in Nassarawa Eggon. The study was motivated by the persistent poor achievement of students in Chemistry, particularly in abstract and calculation-based topics such as the mole concept, which many students find difficult to understand and apply. A quasi-experimental research design involving a non-randomized pre-test and post-test control group was adopted. The population comprised all Senior Secondary Two Chemistry students in public secondary schools in the study area. A sample of 160 students was selected and assigned into experimental and control groups. The Mole Concept Achievement Test (MCAT) was used for data collection, with a reliability coefficient of 0.85. Two research questions and two null hypotheses guided the study and were tested at a 0.05 level of significance. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses. Findings revealed that students taught using the spider concept mapping strategy performed significantly better than those taught using the conventional method. The results also showed that there was no significant difference between male and female students' achievement when taught using the strategy. It was concluded that the Spider Concept Mapping Strategy is effective in improving students' achievement in the mole concept regardless of gender. It was recommended that Chemistry teachers adopt this strategy in teaching abstract concepts.

Keywords: Spider Concept Mapping Strategy, Mole Concept, Chemistry Achievement

Introduction

Science is one of the most powerful tools humans use to understand and make sense of the world around them. It is not just a collection of facts, but a way of thinking and investigating natural phenomena through observation, experimentation, and explanation of findings (Gordon, 2022). Through science, people are able to solve real-life problems related to health, agriculture, environment, and technology. Because of this, science has become an important part of national development and modern education systems across the world, including Nigeria, where it is taught in secondary schools as Biology, Chemistry, and Physics (Federal Ministry of Education, 2013).

Among the science subjects, Chemistry plays a particularly important role because it connects other sciences and explains the composition and behaviour of matter (Ababio, 2024). It is central to many areas of human development such as medicine, industry, food production, transportation, and environmental management. At the senior secondary school level, Chemistry exposes students to both theoretical and practical knowledge, helping them develop skills in observation, measurement, calculation, and problem-solving. Some of the major topics in Chemistry include atomic structure, chemical bonding, gas laws, electrolysis, quantitative analysis, and the mole concept. The mole concept is one of the most important but also one of the most difficult topics for students to understand. It deals with the idea of counting particles in substances, where one mole is defined as the amount of substance containing 6.022×10^{23} particles, known as Avogadro's number. This concept is very important because it forms the foundation for stoichiometry and helps students solve chemical calculations involving mass, volume, and number of particles. However, many studies, including Yakubu, Samuel, and Abdulkadir (2019), have shown that students struggle with this topic, especially when it involves calculations and problem-solving.

In terms of performance, academic achievement refers to how well students are able to meet learning objectives, usually measured through examinations. Unfortunately, achievement in Chemistry has not been encouraging over the years, especially in areas like the mole concept. Evidence from external examination bodies in Nasarawa-Eggon Local Government Area between 2015 and 2024 shows that the percentage of students who obtained credit passes in Chemistry remains low, ranging from 37.3% to 49.7% in WASSCE, 41.6% to 57.6% in NECO, and 49.8% to 62.6% in NABTEB. These figures suggest that a significant number of students are still not achieving at the expected level in Chemistry. Further evidence from the West African Examinations Council (2024) Chief Examiner's Report also supports this concern. The report highlights students' weaknesses in stoichiometric calculations, balancing equations, and applying chemical concepts correctly. These difficulties are often traced to poor foundational understanding, lack of mathematical skills, and ineffective teaching methods. In many classrooms, the lecture method is still widely used. While it allows teachers to cover content quickly, it often makes students passive learners who simply listen without truly understanding. This approach does not help much when dealing with abstract topics like the mole concept, which require careful explanation and strong conceptual linking. Because of these challenges, attention has shifted to more student-centered teaching methods that can improve understanding and engagement. One of such methods is the spider concept mapping strategy. This is a visual teaching approach where a main idea is placed at the center, and related ideas are arranged around it in a branching, web-like structure. This helps students see how concepts are connected, making it easier for them to understand and remember complex information. In Chemistry, especially in the mole concept, it can help students' link ideas such as mass, molar volume, and number of particles in a more meaningful way.

Another factor that often influences students' achievement in science is gender. Gender refers to the roles and expectations society assigns to males and females (Abuh, 2021). Although more

girls are now participating in science education than before, differences in achievement between male and female students are still observed in some cases. This makes it important to consider teaching strategies that support both genders equally and improve learning outcomes for all students. Overall, the continued poor achievement in Chemistry, particularly in the mole concept, suggests that something needs to change in the way the subject is taught. Students need teaching approaches that help them actively understand rather than memorize. The spider concept mapping strategy offers this possibility by making learning more visual, connected, and meaningful.

However, over ten years, there has been growing concern about students' poor achievement in science subjects, especially Chemistry. This concern has led researchers and educators to explore more effective ways of teaching concepts that students often find difficult. One such concept is the mole concept, which many students struggle to understand because it involves abstract thinking, mathematical relationships, and the ability to connect multiple ideas at once. Traditional teaching methods, particularly the lecture method, have been widely criticized for not adequately supporting students in developing a deep understanding of such complex topics (Hu, 2024). In response to these challenges, attention has shifted toward more learner-centered instructional approaches. One of these is concept mapping, a strategy introduced by Novak and Cañas (2010), which focuses on helping students organize knowledge in a meaningful way. Spider concept mapping allows learners to visually represent ideas and show how different concepts are related. This process not only helps students understand individual concepts but also enables them to see the “big picture.” According to Izci and Acikgoz (2024), spider concept mapping encourages deeper thinking and helps students retain information for a longer period. In the same vein, Teachers Institute (2025) explained that spider concept maps can be used to assess how well students understand relationships between scientific ideas.

A number of empirical studies have shown that concept mapping can significantly improve students' academic achievement. For example, Cheema and Mirza (2013) found that students who were taught using spider concept mapping performed better than those who were taught using conventional methods. Similarly, Otor (2013) reported improved achievement among Chemistry students who were exposed to spider concept mapping strategies. More recently, Emmanuel and Achor (2022) also observed that spider concept mapping helped students to better organize their thoughts and actively engage in the learning process, leading to improved achievement. When it comes to specific Chemistry topics such as the mole concept, the effectiveness of concept mapping becomes even more evident. Yakubu, Samuel, and Abdulkadir (2019) revealed that students taught using spider concept mapping strategies had a better understanding of the mole concept and achieved higher scores compared to their counterparts taught using conventional methods. This supports earlier findings by Shadreck and Ochonogor (2018) who emphasized that students' ability to solve stoichiometric problems depends largely on how well they understand the underlying concepts. Strategies that promote connections between ideas, such as spider concept mapping, therefore play a crucial role in improving learning outcomes. The spider concept mapping strategy, which is a specific form of concept mapping, presents information in a way that starts from a central idea and expands outward like a web. This approach is particularly suitable for teaching the mole concept because it allows students to connect related ideas such as molar mass, Avogadro's number, and gas relationships in a clear and organized manner. Achor and Bileya (2022) found that visual learning strategies, including spider concept mapping, can enhance students' achievement by making learning more meaningful. In a related study, Tella and Ogundiya (2022) reported that students who were taught using spider concept mapping strategies showed better understanding of Chemistry concepts compared to those taught using more conventional approaches.

Another important factor often considered in science education is gender. Gender differences in academic achievement have been widely discussed, with some studies suggesting that male and female students may perform differently due to social, cultural, or psychological factors (Abuh, 2021). However, findings in this area are not consistent, because some researchers have found little or no difference in performance between male and female students when effective teaching strategies are used. For instance, Wushishi, Danjuma, and Usman (2013) reported that spider concept mapping strategies helped to reduce gender differences in science achievement, as both male and female students benefited equally from the method. This suggests that student-centred approaches like spider concept mapping may create a more inclusive learning environment. Comparative studies on teaching methods have also shown that approaches which actively involve students tend to produce better results than conventional methods. Oloyede and Adetunji (2009) found that students taught using concept mapping better than those taught using the conventional method. Likewise, Ajayi and Angura (2017) observed that integrating technology with spider concept mapping further improved students' retention and understanding of Chemistry concepts.

In summary, the literature reviewed indicates that spider concept mapping is a highly effective instructional strategy for improving students' achievement in Chemistry, particularly in challenging topics like the mole concept. It supports meaningful learning, enhances understanding, and encourages active participation. In addition, it appears to minimize gender differences in achievement. However, despite these benefits, there is limited research focusing specifically on the use of the spider concept mapping strategy in Nigerian secondary schools, especially in Nasarawa-Eggon Local Government Area. This study, therefore, seeks to address this gap by examining how this strategy affects students' achievement in the mole concept and whether it influences performance based on gender.

Research Questions

1. What difference exists in the mean achievement scores of students taught the mole concept using the spider concept mapping strategy and those taught using the conventional method?
2. What difference exists in the mean achievement scores of male and female students taught the mole concept using the spider concept mapping strategy?

Hypotheses

1. There is no significant difference in the mean achievement scores of students taught the mole concept using the spider concept mapping strategy and those taught using the conventional method.
2. There is no significant difference in the mean achievement scores of male and female students taught the mole concept using the spider concept mapping strategy.

Methodology

This study adopted a quasi-experimental research design involving a non-randomized pre-test and post-test control group approach. The design was considered appropriate because intact school classes were used without disrupting normal school organization, while still allowing for meaningful comparison between an experimental and a control group. The targeted population of this study included all Senior Secondary Two Chemistry students in Nasarawa Eggon Local Government Area of Nasarawa State, with a total population of 1,843 students across 32 public senior secondary schools for the 2023/2024 academic session. The choice of Nasarawa Eggon Local Government Area was based on the observed persistent underperformance of students in Chemistry in WAEC examinations over the years. The Local Government Area has two Area Education Quality Evaluation Offices (AEQEO), namely Nasarawa Eggon and Mada Station, which oversee academic activities in the schools within the area. The selection of Senior Secondary Two students was

considered appropriate because they are still one year away from external examinations such as WAEC, NECO, and NABTEB, and therefore have adequate time to benefit from instructional intervention.

From the population, a sample of 160 students was selected using a simple random sampling technique. The sampled students were drawn from two intact classes, labeled Class A and Class B. Class A served as the experimental group and consisted of 80 students made up of 40 boys and 40 girls, while Class B served as the control group and consisted of 80 students made up of 38 boys and 42 girls. The focus of the study was the mole concept in Chemistry, particularly the aspects involving stoichiometric calculations and quantitative relationships between substances. In teaching the experimental group (Class A), the Spider Concept Mapping Strategy was used. This involved organizing the mole concept around a central idea and guiding students to build meaningful connections among related concepts such as molar mass, Avogadro's number, and gas volume relationships. The intention was to help students see Chemistry as an interconnected system rather than isolated formulas. The control group (Class B) was taught using the conventional method. In this approach, the teacher mainly explained the concepts, wrote notes on the board, and engaged students through listening and occasional questioning, with little emphasis on visual or conceptual linking of ideas.

The instrument used for data collection was the Mole Concept Achievement Test (MCAT). The test consisted of structured items designed to measure students' understanding and ability to apply the mole concept in solving Chemistry problems. The instrument was validated by experts in Chemistry Education to ensure its appropriateness and relevance. A reliability coefficient of 0.85 was obtained, indicating that the instrument was consistent and dependable. Before the treatment began, both Class A and Class B were given a pre-test to determine their initial understanding of the mole concept. The instructional treatment lasted for four weeks, with two class periods per week. After the teaching period, a post-test was administered to both groups to determine the effect of the instructional strategies used. The data collected were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at a 0.05 level of significance. All analyses were carried out using the Statistical Package for Social Sciences (SPSS) version 26.0.

Results

Research Question 1:

What is the difference in the mean achievement scores of students taught mole concept using spider concept mapping strategy and those taught using conventional method?

Table 1: Mean Achievement Scores of Students Taught Mole Concept Using Spider Concept Mapping Strategy and Conventional Method

Groups	N	Pre-test Mean	S.D	Post-test Mean	S.D	Mean Gain
Experimental	80	3.66	2.08	20.82	2.08	17.16
Control	80	5.00	2.02	14.25	2.08	9.25

The data presented in Table 1 show that students in the experimental group had a pre-test mean score of 3.66 (S.D = 2.08) and a post-test mean score of 20.82 (S.D = 2.08), with a mean gain of 17.16, while students in the control group had a pre-test mean score of 5.00 (S.D = 2.02) and a post-test mean score of 14.25 (S.D = 2.08), with a mean gain of 9.25. However, the mean gain of the experimental group (17.16) is higher than that of the control group (9.25). This shows that there is a clear difference between the mean achievement scores of students taught mole concept using spider concept mapping strategy and those taught using the conventional method, in favour of the

experimental group. This implies that students who were exposed to the spider concept mapping strategy demonstrated better improvement in their understanding of the mole concept compared to those taught using the conventional method. The result suggests that the strategy enhances students' ability to organise concepts meaningfully and improve their academic achievement in Chemistry. In order to determine whether the observed difference between the post-test mean achievement scores of the experimental and control groups was statistically significant, an ANCOVA statistic was used to test the hypothesis.

Hypothesis 1:

There is no significant difference in the mean achievement scores of students taught mole concept using spider concept mapping strategy and those taught using conventional method.

Table 2: ANCOVA Summary of Achievement Scores by Group

Source	Type III SS	Df	Mean Square	F	Sig.
Corrected Model	1058.306	2	529.153	98.450	.000
Intercept	5569.757	1	5569.757	1035.210	.000
Pre-test	1.207	1	1.207	0.224	.637
Groups	931.999	1	931.999	173.360	.000
Error	844.500	157	5.380		
Total	—	160			
Corrected Total	—	159			

$$F(1,157) = 173.360, p = 0.000 < 0.05$$

Since the p-value is less than 0.05, the null hypothesis is rejected. This indicates that there is a statistically significant difference in the mean achievement scores of students taught using spider concept mapping strategy and those taught using the conventional method, in favour of the experimental group.

Research Question 2:

What is the difference in the mean achievement scores of male and female students taught mole concept using spider concept mapping strategy?

Table 3: Mean Achievement Scores of Male and Female Students

Gender	N	Pre-test Mean	S.D	Post-test Mean	S.D	Mean Gain
Male	40	2.10	1.30	21.43	1.96	19.33
Female	40	4.79	1.78	20.38	2.08	15.59

The data presented in Table 3 show that the male students had a mean score of 2.10 (S.D = 1.30) at the pre-test and 21.43 (S.D = 1.96) at the post-test, with a mean gain of 19.33, while the female students had a mean score of 4.79 (S.D = 1.78) at the pre-test and 20.38 (S.D = 2.08) at the post-test, with a mean gain of 15.59. However, the mean gain of the male students (19.33) is slightly higher than that of the female students (15.59). This indicates that there is a difference between the mean achievement scores of male and female students taught using the guided discovery approach, although the difference is not very large. However, both male and female students showed substantial improvement in their post-test scores compared to their pre-test scores, suggesting that the guided discovery approach was effective in enhancing the achievement of students regardless of gender. This implies that the strategy supports learning for both male and female students in a similar manner, even though male students recorded a slightly higher mean gain. In order to determine

whether the observed difference between the post-test mean achievement scores of male and female students was statistically significant, an ANCOVA statistic was used to test the hypothesis.

Hypothesis 2:

There is no significant difference in the mean achievement scores of male and female students taught mole concept using spider concept mapping strategy.

Table 4: ANCOVA Summary of Achievement Scores by Gender

Source	Type III SS	df	Mean Square	F	Sig.
Corrected Model	42.372	2	21.186	5.210	.008
Intercept	4345.648	1	4345.648	1068.330	.000
Pre-test	28.963	1	28.963	7.120	.009
Gender	0.486	1	0.486	0.119	.731
Error	314.160	77	4.081		
Total	—	80			
Corrected Total	—	79			

$$F(1,77) = 0.119, p = 0.731 > 0.05$$

Since the p-value is greater than 0.05, the null hypothesis is accepted. This indicates that there is no statistically significant difference in the mean achievement scores of male and female students taught using spider concept mapping strategy.

Discussion

The results of this study with respect to Research Question 1 showed a clear difference in the academic performance of students taught the mole concept using the spider concept mapping strategy and those taught using the conventional teaching method. From the data presented in Table 1, students in the experimental group had a higher mean gain score (17.16) compared to their counterparts in the control group (9.25). This suggests that the spider concept mapping strategy helped students understand the mole concept better than the traditional method. To further confirm this difference, Hypothesis 1 was tested, and the result shown in Table 2 indicated that the difference in performance was statistically significant ($F(1,157) = 173.360, p < 0.05$). Based on this outcome, the null hypothesis was rejected. This means that the teaching method used had a real effect on students' achievement, with the spider concept mapping strategy proving to be more effective. This finding is consistent with earlier studies. For instance, Yakubu, Samuel, and Abdulkadir (2019) reported that students perform better when concept mapping is used in teaching difficult topics like the mole concept. In the same way, Otor (2013) and Jack (2013) found that concept mapping improves students' understanding and overall achievement in Chemistry. Emmanuel and Achor (2022) also noted that this approach encourages students to participate actively in lessons, which helps them grasp concepts more easily. In addition, Novak and Cañas (2010) explained that concept mapping supports meaningful learning by helping students connect new ideas with what they already know. One possible reason for the improved performance observed in this study is that the spider concept mapping strategy makes it easier for students to see how different ideas are connected. Concepts such as molar mass, Avogadro's number, and mole relationships become less abstract when they are visually organized. This agrees with the view of Izi and Acikgoz (2024), who pointed out that concept mapping promotes deeper understanding and helps students retain information for a longer time. However, not all studies agree with this finding. For example, Cheema and Mirza (2013) found no significant difference between students taught with concept mapping and those taught using conventional methods. This difference in results may be due to factors such as how the teaching strategy was applied, the duration of the study, or the background of the students involved. It is

possible that concept mapping works best when it is properly implemented and when students are guided effectively.

With regard to Research Question 2, the study examined whether there was any difference in performance between male and female students taught using the spider concept mapping strategy. As shown in Table 3, male students had a slightly higher mean gain score (19.33) than female students (15.59). To further confirm this difference, Hypothesis 2 was tested, and the result presented in Table 4 showed that the difference was not statistically significant ($F(1,77) = 0.119$, $p > 0.05$). This means that gender did not have a significant influence on students' achievement when the spider concept mapping strategy was used. Therefore, the null hypothesis was accepted. This finding agrees with the work of Wushishi, Danjuma, and Usman (2013), who found that concept mapping helps reduce gender differences in learning outcomes. Similarly, Emmanuel and Achor (2022) concluded that concept mapping is effective for both male and female students. These findings suggest that the strategy creates a learning environment where all students, regardless of gender, can benefit equally. The result also supports the view of Abuh (2021), who noted that although gender differences can sometimes exist due to social or cultural factors, the use of effective teaching methods can reduce or even eliminate such differences. In other words, when students are taught using appropriate strategies, both male and female learners have equal opportunities to succeed.

Conclusion

The study concludes that spider concept mapping strategy significantly improves students' achievement in the mole concept compared to the conventional method. It also establishes that the strategy is effective for both male and female students, as no significant gender difference was observed.

Recommendations

1. Chemistry teachers should adopt spider concept mapping strategy as an effective method for teaching abstract concepts such as the mole concept.
2. Students should be encouraged to actively participate in concept mapping activities to enhance understanding and retention.
3. Teacher training institutions should include concept mapping strategies in their curriculum to equip teachers with innovative teaching skills.
4. Educational stakeholders should organize workshops and seminars to train teachers on modern instructional strategies such as spider concept mapping.

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