

EFFECT OF CONCEPT MAPPING TEACHING STRATEGY ON SECONDARY SCHOOL STUDENTS' ACADEMIC ACHIEVEMENT IN CHEMICAL BONDING IN ENUGU EDUCATION ZONE

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Abstract

The students' persistently low performance on external exams cast suspicion on their chemistry teachers' methods of instruction. Thus, the aim of the research is to find out how concept mapping, a teaching strategy, impact students' academic achievement in chemical bonding in the Enugu Education Zone. The study was guided by two research questions and three null hypotheses. It used a quasi-experimental design. 4,532 SS2 Chemistry students made up the study's population. A combination of random and purposive sampling procedure was utilized to choose 82 students'. While the control group received instruction via lectures, the experimental group was taught utilizing a concept mapping teaching strategy. The Chemistry Achievement Test (CAT) was the instrument used for data collection, and its reliability index was evaluated using Kuder-Richardson's formula-20 and certified by three experts which yielded coefficients 0.92. The mean, standard deviation, and analysis of covariance were used to analyze the data. The findings demonstrated that students exposed to the concept mapping teaching strategy outperformed their peers who received instruction via lectures. For improved student achievement, it was suggested that Chemistry teachers to use a concept mapping teaching approach when teaching chemistry.

Keywords: Effect, Concept mapping teaching strategy, Chemistry, Academic achievement, Chemical bonding.

Introduction

Science is a comprehensive and organized body of knowledge that employs a systematic approach to exploring the natural world in a testable and verifiable manner. Its roots can be traced back to various historical civilizations, long before the modern era. Unlike other forms of inquiry, science is dedicated exclusively to understanding the natural world, explicitly excluding supernatural explanations (Ezeudu, 2011). It serves as a method for learning about the myriad components of the physical universe—animals, plants, rivers, oceans, deserts, mountains, soils, air, people, societies, ecosystems, and more exploring how these elements function and how they came to be as they are. Wilson (2012) defines science as a system of acquiring knowledge grounded in the scientific method, which organizes a body of knowledge obtained through rigorous research. Ezeano (2013) further elaborates that science involves studying matter and the structure and behavior of the natural and physical world based on observation and experimentation. Ezeano emphasizes that science is a dependable process for learning, as it relies on testing ideas with evidence or data gathered from the natural environment. According to Idoko (2014), science is a dynamic and objective process that seeks to uncover new discoveries and insights about the unifying patterns and concepts

of the natural world. Ezeano (2013) also notes that science is composed of three core disciplines: Physics, Chemistry, and Biology.

Chemistry, one of these core disciplines, focuses on the composition, properties, and behavior of matter within various environments. It is concerned with the interactions of atoms and the properties of chemical bonds. Chemistry systematically studies the composition, properties, and activities of both organic and inorganic substances and various elementary forms of matter. This discipline is crucial in the school science curriculum, especially for students considering careers in science. Helmenstine (2012) describes chemistry as "the central science" because it bridges other natural sciences, such as physics, geology, and biology. Bagley (2017) defines chemistry as the branch of science that deals with identifying substances that make up matter. Okon (2012) underscores the importance of chemistry in the scientific and technological development of any nation, highlighting its significance as a pivotal science subject. The recognition of chemistry's crucial role in human and environmental development has led to its establishment as a core subject within the physical sciences. In Nigeria, chemistry is a prerequisite for various science-related courses, including medicine, pharmacy, biochemistry, nursing, engineering, industrial chemistry, and anatomy. This recognition underscores chemistry's importance in the school science curriculum and its pervasive influence on everyday life. Chemical reactions underpin activities as fundamental as breathing, eating, and even reading. Chemistry, as a scientific discipline, has catalyzed advancements across numerous sectors. In agriculture, chemistry has improved food production and streamlined farming practices. The textile industry relies on chemistry for clothing production, while the pharmaceutical industry uses it to develop medicines. Chemistry also plays a vital role in transportation, hygiene, pollution control, cement production, paints, pigments, plastics, petroleum, sugar, paper, and education. Studying chemistry equips students with skills in critical thinking, deductive reasoning, problem-solving, and communication (Durukan, 2011). Early and effective chemistry education can enhance student achievement and provide transferable skills applicable to numerous careers (Munroe, 2011). A significant area of chemistry is the study of chemical bonding. The process by which atoms combine to form molecules, ions, crystals, and other stable species that make up common compounds in daily life to produce chemicals that support life is known as chemical bonding. As the atoms get closer to one another, their nuclei and electrons interact and rearrange themselves in space to form a configuration that minimizes the total energy when compared to all other possible configurations. The component of the atoms creates a bond between the molecules when the total energy of a grouped atom is less than the sum of its separate energies. The bonding energy is the process by which the energy is reduced. Because it leads to the production of atoms, molecules, and valence, the study of chemical bonding is crucial to the study of science. This is essential for various industrial productions. These compounds are used in soap making, fertilizer production, and rust and stain removal, highlighting their importance in daily life and industrial applications.

Despite chemistry's importance to national development, academic achievement in the subject often falls short of the expectations. Academic achievement is defined as a student's scholastic standing at a given moment, reflected through grades and performance on educational tests, as well as cumulative indicators like degrees and certificates (Eze and Omeje, 2023). An examination conducted by West African Examinations Council (WAEC) for Senior Secondary School (SSS) Chemistry students revealed that students' performance in Nigeria specifically

Enugu State is consistently below the expectation in the subject. For instance, in the 2022 West African Examinations Council (WAEC) session, out of the total 71,452 candidates who registered and sat for the exam, only 16,077 students, representing 22.5%, passed Chemistry at the credit level. In the subsequent years, the trend persisted. In 2023, there was a further decline in the number of students passing, with only 20.7% achieving credit and above. This was made more evident in Joint Admission and Matriculation Board (JAMB), 2024 as it was credited that about 85.5% of the candidates that sat the examination scored below 50%. Despite some improvements, student achievement in chemistry remains generally unfavorable. The WAEC Chief Examiner noted that many students struggled with questions on chemical bonding due to their inability to apply concepts. The examiners attributed poor performance to the prevalent use of the lecture method, which lacks opportunities for practical application. According to Onah (2023), the teachers poor instructional approach has been accounted for students' poor achievement in physics in particular and science in general. This poor instructional approach has been engulfed with traditional lecture method.

Ineffective instructional strategies have been identified as a major factor contributing to poor student performance in chemistry (Akinsola and Igwe, 2009). These researchers have highlighted the predominance of the traditional lecture method, which does not promote cognitive and meta-cognitive development (Akinsola&Igwe, 2017). The traditional lecture method is a teacher-centered approach where the teacher delivers the lesson with minimal active participation from students. This method, characterized by a one-way form of communication, is often referred to as the didactic approach, as most of the talking is done by the teacher while students remain passive listeners. Unfortunately, this approach is widely used by teachers across various school subjects, contributing to suboptimal student engagement and learning outcomes. The conventional lecture method, characterized by excessive talking, note-taking, and rote learning, does not promote meaningful learning (Onah, 2022). This method relies heavily on textbooks and workbooks, often failing to engage students in hands-on activities that stimulate interest in science (Duran and Dokme, 2016). This study aims to compare the effects of cooperative learning and inquiry-based learning on students' academic achievement in the secondary school chemistry concept of chemical bonding. To address these weaknesses, the WAEC Chief Examiners (2022) recommended the following: Teachers should attend coordination exercises during marking to learn current teaching and learning trends. Classroom instruction should incorporate appropriate teaching strategies to foster positive student attitudes towards chemistry. Teachers should provide more classwork and assignments. Teachers should enhance their teaching skills with modern methodologies such as cooperative learning and inquiry-based learning. The government should recruit qualified chemistry graduates. Students should show greater dedication to their studies. Students should be encouraged to purchase chemistry textbooks. Again, researchers have recommended an innovative teaching strategy like concept mapping for its recurring decimal and ability to improve students' learning outcomes (Ezeugo and Agwagah, 2018).

The concept "mapping teaching strategy" is a method that utilizes schematic diagrams to represent concepts, words, tasks, ideas, or other items, all of which are linked and arranged radially around a central key concept or word. This technique can incorporate concept maps (cmap) and pictures to create visual linkages between ideas, aiding in the classification of concepts, solving quantitative problems, and decision-making. According to Buzan and

Buzan (2010), the concept mapping strategy is a powerful graphic organizer that unlocks the potential of the human brain by providing useful links between ideas. It is an effective way of transferring information in and out of the brain and serves as a creative and logical method for note-taking and note-making, visually mapping out ideas (Ezeugo and Agwagah, 2018). Concept mapping leverages the full range of cognitive skills, including the use of words, images, numbers, logic, rhythm, color, and spatial awareness, all integrated into a single, powerful tool. As a non-linear learning strategy, it encourages radical thinking, using only key words and images that link new information with prior knowledge in a non-linear fashion (Francis and Baba 2023). The approach simplifies complex information by focusing on essential words, clauses, and phrases, making it accessible even for novice learners. It also promotes self-expression and exploration of concepts, with no limits on associations and connections. Francis and Baba (2023) describe the concept mapping teaching strategy as one that enables students to build upon their existing knowledge when presented with new information, facilitating meaningful learning. Common elements of all concept maps include a natural organizational structure radiating from the center, using lines, symbols, words, colors, and images in brain-friendly ways. This method transforms long lists of monotonous information into colorful, memorable, and highly organized diagrams that align with the brain's natural processes. Parikh (2015) defines the concept mapping teaching strategy as a convenient graphical tool that helps learners think and understand by simplifying complex or interconnected concepts. Concept maps can summarize notes, textbooks, and other learning aids, allowing learners to organize hierarchical conceptual frameworks. They enable brainstorming and structuring thoughts about concepts using graphics, diagrams, color, and mnemonics. Therefore, the study seeks to investigate the effect of concept mapping teaching strategy on chemistry students' achievement irrespective of gender (Maris, 2019).

Gender is a socio-cultural construct that differentiates feminine and masculine attributes, describing characteristics of men and women that are naturally, culturally, and socially determined, whereas those determined biologically are referred to as sex. Gender is one of several factors that interact with student performance in chemistry and other sciences. However, the influence of gender on academic performance remains a contentious issue, with researchers presenting varied and often contradictory findings. Research by Jahun and Mmoh (2011), Mari (2019) and Onah and Nnadi (2022) suggested that male students generally perform better in science subjects than their female counterparts. Factors contributing to these observed differences include sex-role stereotyping, the masculine image of science, and the socialization processes of females. Conversely, other studies have found that gender influences performance in favor of female students. Yet, some researchers argue there is no significant difference in performance between genders. Instead, they suggest that both male and female students' performances can be significantly influenced by teaching and learning styles, advocating for the adaptation of instructional approaches to enhance the academic performance of all students regardless of gender.

In line with the problems of the study, the following specific purposes were raised for the study:

1. To determine the difference between the mean achievement scores of students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching.

2. To determine the difference between the mean achievement scores of male and female students taught chemical bonding using concept mapping teaching strategy.
3. Interaction effect of teaching strategies and gender on students' achievement in chemical bonding.

In view of the purpose of the study, the following research questions were designed to guide the study

1. What is the difference in the mean achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching?
2. What is the difference in the mean achievement scores of male and female students' taught chemical bonding using concept mapping teaching strategy?

The following research hypotheses were formulated for the study; which were tested at 0.05 level of significance

1. There is significant difference in the mean achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching.
2. There is significant difference in the mean achievement score of male and female students taught chemical bonding using concept mapping teaching strategy.
3. There is significant interaction effect of gender and teaching strategies on students mean achievement scores in chemistry concept of chemical bonding.

Method

A pretest-posttest quasi-experimental research design, specifically non-equivalent control groups design was used for the study. The population of the study consisted of 4, 532 SS 2 Chemistry students in all the 33 public secondary schools in Enugu Education Zone. 82 SS II chemistry students (42 females and 40 males) drawn from two coeducational secondary schools in Enugu North Local Government Area were selected for the study using a purposive sample technique. Stage one involved selecting the Enugu North Local Government Area using a basic random sample approach. In the second stage, two coeducational schools in the local government area were chosen using purposive sampling. The selection process was based on the presence of well-equipped chemistry laboratories and qualified teaching chemistry instructors in those schools. Next, the schools were assigned to experimental and control treatments using a simple random sample procedure (precise balloting). The technique was used so as to provide classes where boys and girls work together under the same classroom environment. Intact classes were used in the sampled schools so as not to disrupt the normal school activities. Four weeks were used for the experiment. Each week had two periods (double periods each) of 40 minutes per period. The control group was taught using the lecture method which involves content-rich activities such as demonstrations, lecture, experiments and quantitative problem-solving which does not involve the students in concept mapping strategy and processes. For the experimental class, the same set of activities for the control group was carried out for both double periods; but in addition to discussing and writing schematic diagram of the concept, students were engaged in such cmap activities as:

a) ***Concept Maps***

Concept mapping is the use of schematic diagrams, which are visual aids. It enables students may link concepts and freely communicate their knowledge with others. This method activates both hemispheres of the brain by using important concepts and codes related to the subject matter, as well as visuals and figures. It is simpler for students to correlate concepts with other knowledge structures and to see all the aspects of the subject matter as a whole when ideas are presented on a schema linked to a particular knowledge structure. Concept maps are conceptual diagrams that are intended to illustrate the significant connections between ideas in a form of propositions. The idea map is a useful tool for teaching scaffolding because it enables students to make connections between what they already know and what they are learning.

b) ***Word Association Test***

It is the most widely used and traditional approach in the study of cognitive structure, having been employed by several scholars. This method of idea memorization uses mnemonics.

c) ***Clinical Interview***

Researchers have used this to gauge pupils' levels of interest. The purpose of the expert-student conversation is to assess the student's understanding of natural phenomena or social occurrences through a series of line diagram-based questions. It allows students to have close conversations with specialists, like the researcher.

The Chemistry Achievement Test (CAT), which was taken from WAEC earlier, was the instrument utilized to gather the data. There were 25 multiple-choice items with four alternatives (prep-50) in the questions from 2015 to 2023. Three experts validated the instruments' face and content, and Kuder Richardson 20 (KR-20) was used to verify the instruments' reliability. The results showed a coefficient of 0.92. The device is dependable and appropriate for data collecting, as evidenced by its excellent dependability index. Students were given the test as a pretest and a posttest, respectively, before and after the treatment. The researcher graded the exam in order to prevent bias. Analysis was done using the results. The mean and standard deviation (SD) were used to answer the research questions, and ANCOVA using SPSS version 24 was used to test the hypothesis and the analysis.

Procedure/ Authorization

Data was gathered following official authorization from relevant authorities like school principal through the classroom teacher and laboratory assistant. A consistent set lesson plan as tools and guidelines were provided to research assistants and respondents for completing research instruments. Additionally, research assistants underwent thorough training. All data collecting sessions were conducted under identical class settings to reduce disparities and potential mistakes. The research instrument was distributed to students during a single class session, with a designated 30-minute time frame for completion, although most students finished within approximately 25 minutes.

Results

Research Question 1: What is the difference in the mean achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching?

Answer to Research question 1 is presented in Table 1

Table 1: Mean and Standard deviation of achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching.

Teaching Strategy	Pretest			Posttest			
	N	Mean	SD	N	Mean	SD	Mean Gain
Concept mapping	40	25.10	13.25	40	63.60	15.37	38.50
Lecture method	42	25.43	10.85	42	51.81	16.56	26.38

Table 1 shows the pretest and posttest mean achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy were 25.10 and 63.60 while the gain in mean score was 38.50. Their counterpart taught using the lecture method had 25.43, 51.81 and 26.38 as pre-test, post-test and gain in mean scores respectively. This shows a 12.11 difference in gain in mean scores between the two groups in favor of the students taught with concept mapping teaching strategy. The result also shows a remarkable difference in mean gain scores between students taught chemistry using concept mapping teaching strategy than their counterparts in lecture method.

Research Question 2: What is the difference in the mean achievement scores of male and female students' taught chemical bonding using concept mapping teaching strategy?

Answer to Research question 2 is presented in Table 2

Table 2: Mean and Standard deviation of achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy

Gender	Pretest			Posttest			
	N	Mean	SD	N	Mean	SD	Mean Gain
Male	24	27.00	14.89	24	60.67	14.14	33.67
Female	16	22.25	10.12	16	68.00	16.52	45.75

Table 2 shows the pretest and posttest mean achievement scores of male students (27.00 and 60.67) and their female counterpart (22.25 and 68.00) taught chemical bonding using concept mapping teaching strategy. The gain in mean score for male students was 33.67 while that of the female counterpart was 45.75. This indicates a mean difference of 12.08 in favor of the female students.

Hypothesis 1: There is significant difference in the mean achievement scores of chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using lecture method of teaching.

Table 3: Summary of Analysis of Covariance of effect of concept mapping teaching strategy on students' achievement in chemistry by Treatment and Gender

Dependent Variable: Posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5952.658 ^a	4	1488.164	6.606	.000	.255
Intercept	32255.200	1	32255.200	143.187	.000	.650
Pretest	2514.411	1	2514.411	11.162	.001	.127
Strategy	3030.259	1	3030.259	13.452	.000	.149
Gender	171.298	1	171.298	.760	.386	.010
Strategy * Gender	831.910	1	831.910	3.693	.058	.046
Error	17345.538	77	225.267			
Total	294986.000	82				
Corrected Total	23298.195	81				

a. R Squared = .255 (Adjusted R Squared = .217)

Table 3 shows that at .05 level of significance, there was a significant main effect of the teaching strategy on students' academic achievement in chemistry concept of chemical bonding, $F(1, 77) = 13.452$, $P(.000) < .05$. Therefore, the Research hypothesis was confirmed and accepted. Thus, there is significant difference in mean achievement scores of students taught Chemistry concept of chemical bonding using concept mapping teaching strategy and those taught using lecture method.

Hypothesis 2: There is significant difference in the mean achievement score of male and female students taught chemical bonding using concept mapping teaching strategy.

Table 3 shows that at .05 level of significance, there was no significant influence of gender on the effect of teaching strategy on students' academic achievement in chemistry concept of chemical bonding, $F(1, 77) = .760$, $P(.386) > .05$. Therefore, the research hypothesis was rejected. Thus, gender has no significant influence on the academic achievement of students in Chemistry concept of chemical bonding.

Hypothesis 3: There is significant interaction effect of gender and teaching strategies on students mean achievement scores in chemistry concept of chemical bonding.

Table 3 further revealed that at .05 level of significance, there was no significant interaction effect of gender and the teaching strategy on students' academic achievement in chemistry, $F(1, 77) = 3.693$, $P(.058) > .05$. Therefore, the research hypothesis was rejected. Thus, there is no significant interaction effect of gender and the teaching strategy on students' academic achievement in chemistry.

Discussion

Firstly, the revealed that there is no significant difference in the achievement scores of the chemistry students taught chemical bonding using concept mapping teaching strategy and those taught using a lecture method before the treatment, this was evident in their pretest scores. Then, after the treatment, the findings revealed that there was a statistical significant

difference in the mean achievement scores of the students taught chemistry concept of chemical bonding using concept mapping teaching strategy and those taught using lecture method. The finding of the study is in consonance with Ezeudu (2011) who observed that concept mapping had a significant effect on students' performance in the selected Chemistry concepts. It was also discovered that concept mapping was more effective than the lecture method of teaching science in terms of students' overall performance in Chemistry concepts and other science related subjects. The study also agreed with Francis and Baba (2023), Ezeugo and Agwagah (2018) and Parikh, (2015), who in their independent studies revealed that students taught science concept with concept mapping performed significantly better than those taught with the traditional teaching method. The study's findings revealed that there is no significant difference in the mean achievement scores of male and female students taught Chemistry concept of chemical bonding using concept mapping strategy among Senior Secondary School students 2 in Enugu Education Zone of Enugu State. The finding of the study is in agreement with Onah (2022), who noted that gender is not factor with teaching approach in physics. Meanwhile the find does not agree with Ezeugo and Agwagah (2018) who revealed that the male students taught with concept mapping performed significantly better than their female counterparts taught with concept mapping.

The study also showed that there is no discernible relationship between gender and instructional strategy and students' academic achievement scores in chemistry. This conclusion concurred with Onah (2022), which found no evidence of a significant interaction between gender and instructional peer strategy on students' physics conceptual understanding of waves. Onah and Nnadi (2022), on the other hand, observed a noteworthy interaction on students' academic progress in current electricity between gender and instructional treatment. It is clear that the scientific community cannot agree on how gender and instructional practices interact to affect students' conceptual grasp of science, particularly physics ideas. The impact of location may account for variations in observations made by various researchers and some other extraneous threats to the experiment. There is therefore a great need to embark on more studies in order to shed further light on this issue.

Conclusion/ Recommendations

Students' academic progress in Chemistry is increased when the concept mapping teaching approach is used in science classes. This is due to the fact that while teaching chemical bonding using concept mapping, students' outperformed those who were taught the identical concept through lecture in terms of post-test results. Nonetheless, the results indicated that there is no discernible gender gap in students' academic achievement levels. Based on the findings of the study, the following recommendations were made:

- 1) The primary goal of teacher educators in universities and colleges of education should be to provide chemistry instructors with the knowledge and abilities necessary to implement the concept mapping teaching technique.
- 2) Instead of employing the lecture method of instruction delivery, the Federal Ministry of Education should use concept mapping as a teaching strategy and base its decision on the best instructional strategies to be adopted in the Chemistry curriculum of Nigerian secondary schools. This information can be gathered here. This is true since the goal of activity-based learning methodologies is to make science (particularly chemistry) instruction engaging and fascinating, which raises academic achievement.

- 3) The curriculum of teacher-training programs should include a course on the concept mapping teaching strategy, including seminars, workshops, and other opportunities for working teachers to get refresher training in the method.
- 4) Curriculum should be reviewed by curriculum planners to reflect the approach while textbook authors should be encouraged to incorporate the approach in Physics textbooks.

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