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# RELATIONSHIP BETWEEN ALTERNATIVE CONCEPTIONS IN ORGANIC CHEMISTRY AND ACADEMIC ACHIEVEMENT OF SECONDARY SCHOOL STUDENTS IN CHEMISTRY IN DELTA STATE

**[1]Evelyn Obianuju. Egolum (PhD)**
eo.egolum@unizik.edu.ng

**[2]Precious Ukala**
pukala@ymail.com
[1,2]Department of Science Education, Nnamdi Azikiwe University, Awka, Anambra State

## ABSTRACT

*This study investigated the relationship between alternative conceptions in organic chemistry and academic achievement of secondary school students in Chemistry in Delta State. Two research questions guided the study and two null hypotheses were tested at 0.05 level of significance. A correlational research design was adopted. The population of the study comprised 4,500 senior secondary year three (SS3) students offering Chemistry in Delta North senatorial district in the 2024/2025 academic year, from which a sample of 367 students were drawn using a multistage sampling procedure. Data were collected using the Organic Chemistry Alternative Conceptions Test (OCACT) to assess students' alternative conceptions, while students' Chemistry academic achievement scores were obtained from school examination records to measure achievement. The OCACT was validated by three experts from the Departments of Science Education and Educational Foundations, at Nnamdi Azikiwe University, Awka and its reliability was established using Kuder-Richardson 20, yielding a coefficient of 0.78. Data collected were analyzed using Mean and standard deviation, Pearson's Correlation was used to test the hypotheses. Fisher's Z-transformation test was used to determine differences in the relationship between alternative conceptions and academic achievement among male and female students. Findings revealed that students held diverse alternative conceptions in organic chemistry, which negatively affected their Chemistry achievement. The result further showed that female students exhibited more alternative conceptions than the males, and the strength of the relationship between alternative conceptions and academic achievement varied by gender. The study recommended amongst others that Chemistry teachers should identify and address students' alternative conceptions during instruction to enhance meaningful learning and achievement. Gender-inclusive teaching strategies that will engage both male and female students effectively should also be adopted.*

**Keywords**: Alternative conceptions, Organic chemistry, Academic achievement, Gender

## Introduction

Chemistry is a branch of science concerned with the study of matter, its composition, structure, properties and the changes it undergoes. It explains the nature of substances that make up the environment and how these substances interact with one another. According to Nwanze and Okoli (2020), Chemistry is the study of the composition, properties, changes and uses of matter that form the environment around us. Its concepts are foundational for understanding phenomena in biology, medicine, engineering, and environmental science. The versatility of chemistry extends to industries such as pharmaceuticals,

biotechnology, and materials science, making it a cornerstone for economic and technological progress. Its application has found great impact in food processing, solar and nuclear energy, industrialization, health etc. (Egolum and Onuigwe, 2023). For instance, advancements in drug development, renewable energy, and environmental sustainability are deeply rooted in chemical principles. The broad scope of chemistry can be seen in its diverse branches, including organic, inorganic, physical, analytical, industrial and nuclear chemistry. This study will focus mostly on organic chemistry.

Organic Chemistry is the chemistry of carbon compounds and their derivatives. It delves into carbon-containing compounds, serving as the foundation for pharmaceuticals, polymers, and biochemistry. According to Smith (2020), organic chemistry involves studying the structure, properties, and reactions of carbon and its organic materials. It is fundamental to the broader discipline of Chemistry and plays a vital role in secondary school education. It serves as a gateway to understanding the structure, behavior and transformation of organic compounds, which form the building blocks of life and underpin many modern technologies. Organic chemistry consists of topics like hydrocarbons, isomerism, structural and molecular formulas, functional groups, organic reaction mechanism.

Organic chemistry holds particular significance because of its applications across numerous fields, including medicine, environmental science, agriculture and nature of many of its concepts. Topics like Hydrocarbons, isomerism, structural and molecular formulas, functional groups, organic reaction mechanism require students to integrate theoretical knowledge with mathematical reasoning, often leading to alternative conceptions that hinder learning (Taber, 2018; Salame and Casino, 2019).

Alternative conceptions- misunderstanding, misconceptions or incomplete ideas about scientific concepts represents one of the most significant barriers to effective learning in chemistry. Alternative conceptions are generally defined as student conceptions that may produce systematic error patterns (Vosniadou, 2019). According to Hartelt and Martens (2024), alternative conceptions are intuitive understanding that learners develop based on personal experiences, which often conflict with scientific explanations. These alternative conceptions can impede the acquisition of accurate scientific knowledge. These alternative conceptions/misconceptions often stem from students' prior experiences, informal learning, or ineffective instructional strategies. For example, students may believe that carbon always forms only single bonds in all compounds, ignoring the possibility of double and triple bonds. These alternative conceptions impede the development of a coherent and scientifically accurate understanding, affecting students' ability to engage with advanced material and perform well academically. Addressing these alternative conceptions is crucial for fostering deeper engagement with chemistry and ensuring that students develop a robust foundation for further studies in science, technology, engineering, and mathematics (STEM) fields (Fitria and Sabastian, 2024; Ulfah, Erlina, Pratiwiningrum, and Juahir, 2024).

In organic chemistry, the complexity of molecular structures and reaction mechanisms increases the likelihood of alternative conceptions. Several topics students have alternative conceptions include, hydrocarbons, where often students believe all hydrocarbons exist only in gaseous form or serve only as fuels, ignoring liquid (e.g., octane) and solid forms (e.g., paraffin wax) or their roles in polymers and industrial manufacturing. Despite its importance, organic chemistry poses unique challenges in Chemistry education due to its abstract nature. In structural representation, some students believe that carbon always forms only single bonds in all compounds, ignoring the possibility of double and triple bonds. Another common alternative conception is that all organic reactions are spontaneous, without the

need for catalysts or specific reaction conditions, which is often not the case in actual chemical reactions (Espinosa, Koperová, Kuhnová, and Rusek, 2024). Additionally, functional group alternative conception is prevalent, where students confuse the properties and reactions of different functional groups, such as assuming that alcohols behave like water or that ethers have the same reactivity as alcohols. These alternative conceptions in both general and organic chemistry can hinder students' ability to grasp key concepts and significantly affect their academic achievement.

In chemistry education, addressing alternative conceptions helps in improving academic achievement and also extends in fostering a deeper engagement with the subject and its applications to real-world issues. Through active, inquiry-based, and reflective learning, students are equipped with the critical thinking and problem-solving skills needed to contribute meaningfully to scientific advancements and societal progress. Similarly, knowledge of chemical reactions is fundamental for appreciating advancements in pharmaceuticals and innovations that improve quality of life. As such, chemistry education must go beyond rote memorization and foster an understanding of how scientific principles apply to societal needs and global challenges (Egolum, Onuigwe and Mbaegbu, 2023). This will help in improving the academic achievement of students in chemistry and make the learning of chemistry more meaningful.

Academic achievement is a critical indicator of students' progress in education, commonly assessed through test scores, grades and learning outcomes. According to Ikwuka and Adigwe (2021), academic achievement is a product of education or learning which is commonly measured by examination or continuous assessment. It is the student's results which are assessed by their scores and tests and examination. Students' achievement in chemistry can be influenced by prior knowledge and the quality of instruction. Alternative conceptions in key areas like organic chemistry hinder students' ability to apply knowledge effectively, resulting in poor academic achievement. However, gender can also play a significant role in academic achievement. Several studies have shown that gender differences do affect the achievement of boys and girls in school (Leaper, 2015; Lei, Cui, and Zhou, 2018; Marcenaro–Gutierrez, Lopez-Agudo, and Ropero-Garcia, 2018). Li, Wang, and Shen, (2024) found out that gender stereotypes in language learning influence student engagement indirectly, which showed that females had more active engagement in language learning. The present study will examine if gender differences have any impact on the relationship between alternative conceptions and academic achievement of chemistry students.

The term “Gender” is used to distinguish male and female from their socio-cultural behaviour. Gender according to Christler and Lamar (2018) is a complex construct that encompasses a range of socially constructed roles, behaviors, activities, and attributes that a given society considers appropriate for men and women. These gender norms influence how individuals perceive themselves and others, as well as their interactions and experiences in various social contexts. The influence of gender on academic achievement in science subjects is a deeply ingrained issue that stems from a combination of societal expectations, cultural norms and individual perceptions of capability. Research by McGuire, Mulvey, Goff, Irvin, Winterbottom, Fields, Hartstone-Rose and Rutland, (2020) has shown that societal expectations, cultural norms, and gender stereotypes can impact the learning experiences and achievements of students. For instance, girls are often encouraged to excel in language, arts, while boys may be steered towards science and mathematics. These biases can affect students' self-perceptions, alternative conceptions and interests, ultimately influencing their academic achievements.

This study investigated the relationship between alternative conceptions in organic chemistry and the academic achievement of secondary school students in Chemistry. By examining these alternative conceptions, we can better understand the challenges students face in mastering this aspect of Chemistry. Additionally, the study considered gender as a moderating variable, exploring whether differences in academic achievement are influenced by students' gender.

**Statement of the problem**

Chemistry holds a vital position in Nigerian secondary school curriculum and is intended to equip students with the fundamental knowledge and skills required for further studies and careers in science-related fields such as medicine, pharmacy, engineering, and agriculture. Ideally, students are expected to develop a clear understanding of Chemistry concepts, including organic chemistry and demonstrate satisfactory academic achievement. However, reports from the West African Senior School Certificate Examination (WASSCE) between 2018 and 2023 reveals a consistent decline in students' academic achievement in Chemistry. The Chief Examiner has attributed this trend partly to students' alternative conceptions especially in organic chemistry, as many candidates either skip or incorrectly answer questions related to this area. Despite the importance of organic chemistry, instructional practices in many secondary schools are still dominated by conventional teaching methods that emphasize rote memorization rather than conceptual understanding. As a result, students' alternative conceptions remain uncorrected, leading to weak academic achievement.

This situation reveals a gap between the expected level of understanding and achievement in organic chemistry and the actual performance of students influenced by persistent alternative conceptions. Understanding the relationship between students' alternative conceptions in organic chemistry and their academic achievement in Chemistry, particularly in Delta State is therefore necessary.

**Purpose of the Study**

The purpose of the study was to determine the relationship between alternative conceptions in organic chemistry and academic achievement of secondary school students in Chemistry in Delta State. Specifically, the study sought to determine the:

1. Relationship between alternative conceptions in organic chemistry and secondary school students' academic achievement in Chemistry in Delta North Senatorial District.
2. Relationship between alternative conceptions in organic chemistry and the academic achievement of male and female secondary school students in Chemistry in Delta North Senatorial District.

**Research Questions**

This study sought answers to the following research questions:

1. What is the relationship between alternative conceptions in organic chemistry and the academic achievement of secondary school students in Chemistry in Delta North Senatorial District?

2. What is the relationship between alternative conceptions in organic chemistry and the academic achievement of male and female secondary school students in Chemistry in Delta North Senatorial District?

## Hypotheses

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

1. $H_0$: There is no significant relationship between students' alternative conceptions in organic chemistry and their academic achievement in Chemistry in secondary schools in Delta North Senatorial District.
2. $H_0$: There is no significant relationship between male and female students' alternative conceptions in organic chemistry and their academic achievement in Chemistry in Delta North Senatorial District.

## Methods

The study adopted a correlational research design to examine the relationship between alternative conceptions in organic chemistry and the academic achievement of students in Chemistry in Delta North Senatorial District. The design was considered appropriate for the study because it allows for the determination of the degree of relationship between the variables, students' alternative conceptions and their academic achievement, including potential gender differences without the researcher controlling or manipulating any of them (Devi, Lepcha, and Basnet, 2023).

The research was conducted in Delta State, Nigeria and the Delta North Senatorial District was used for the study. The population of the study consisted of 4,500 senior secondary school year three (SS3) students of the 2024/2025 academic session in government-owned secondary schools within Delta North Senatorial District of Delta State. A sample of 367 (190 males and 177 females) participant were used. The participants were selected from 18 out of 178 co-educational schools in the area using multistage sampling procedure.

Data for the study were collected using two research instruments. The first was the Organic Chemistry Alternative Conceptions Test (OCACT), designed to identify students' alternative conceptions in organic chemistry. It contains thirty multiple choice items drawn from Chemistry textbooks and past West African Examination Council (WAEC) question papers. Each item of the test includes one correct answer and three distracters lettered A to D.

The second instrument was students' Chemistry academic achievement scores obtained from the 2023/2024 academic session school examination records.

The face validation of the instruments was done by three experts from the Faculty of Education, Nnamdi Azikiwe University, Awka and was subjected to reliability. The reliability of the instrument produced a KR-20 0.78 for the OCACT, which is considered acceptable for research purposes. The students' Chemistry academic achievement scores obtained from the 2023/2024 school examination records were not subjected to reliability testing because they were derived from school examination that had already undergone internal moderation. Descriptive statistics, Pearson's correlation and Fisher's Z-transformation test were used to answer the research questions while the hypotheses were tested at an alpha level of 0.05.

## Results

**Research Question 1:** What is the relationship between alternative conceptions in organic chemistry and the academic achievement of secondary school students in Chemistry in Delta North Senatorial District?

**Table 1:** Descriptive Statistics and Correlation Matrix for Alternative Conceptions and Academic Achievement (N=367)

| Variable | *Mean* | *SD* | r | p-value | Remark |
|---|---|---|---|---|---|
| Alternative Conceptions | 26.84 | 5.12 | | | |
| Academic Achievement | 48.69 | 4.87 | -.612** | .000 | Significant |

** Correlation is significant at 0.01 level *(2-tailed)*

Result in table 1 shows that the mean alternative conceptions score for all respondents was 26.84 (SD= 5.12) indicating that students held a high level of alternative conceptions and their academic achievement in organic chemistry. The mean academic achievement scores was 48.69 (SD= 4.87) representing approximately 54% average performance. The table also reveals a strong negative correlation (r= -0.612, p<0.05) between students' alternative conceptions in organic chemistry and their academic achievement. This indicates that as students' alternative conceptions increase, their academic achievement in Chemistry decreases significantly. The correlation coefficient of -0.612 suggests that approximately 37.5% ($r^2$= 0.375) of the variance in students' academic achievement can be explained by their alternative conceptions in organic chemistry.

**Research Question 2:** What is the relationship between alternative conceptions in organic chemistry and the academic achievement of male and female secondary school students in Chemistry in Delta North Senatorial District?

**Table 2:** Pearson Correlation between Alternative Conceptions and Male Academic Achievement in Chemistry (N=190)

| **Variable** | **Mean** | **SD** | **R** | **p-value** | **Remark** |
|---|---|---|---|---|---|
| Male Alternative Conceptions Scores | 26.12 | 5.28 | | | |
| | | | -.578** | 0.000 | Significant |
| Chemistry Achievement Scores | 50.67 | 4.73 | | | |

** p< 0.05 (1-tailed), **p< 0.01 (2-tailed)*

Result in table 2 indicates that male students had mean alternative conceptions score of 26.12 (SD = 5.28) and a mean academic achievement score of 50.67 (SD = 4.73). It also shows a moderate negative correlation (r = -0.528, p < 0.01) between students' alternative conceptions and their academic achievement in Chemistry. The p-value (0.000) is less than 0.05, indicating that the correlation is statistically significant.

**Table 3:** Pearson Correlation between Alternative Conceptions and Female Academic Achievement in Chemistry

| Variable | Mean | SD | R | p-value | Remark |
|---|---|---|---|---|---|
| Female Alternative Conceptions Scores | 27.61 | 4.87 | -.647 | 0.000 | Significant |
| Chemistry Achievement Scores | 46.56 | 4.95 | | | |

**p< 0.05 (1-tailed), **p< 0.01 (2-tailed)*

As shown in table 3, female students had mean alternative conceptions score of 27.61 (SD = 4.87), which is slightly higher than that of male students, and a mean academic achievement score of 46.56 (SD = 4.95), which is slightly lower than that of male students. It also indicates a strong negative correlation (r = -0.647, p < 0.05) between alternative conceptions and academic achievement among female students.

**Table 4:** Comparison of Correlation Coefficients between Male and Female Students using Fisher's Z-transformation

| Gender | N | r | Fisher's Z | Z-test value | p-value | Remark |
|---|---|---|---|---|---|---|
| Male | 190 | -0.578 | -0.658 | 2.143 | 0.032 | Significant |
| Female | 177 | -0.647 | -0.770 | | | |

***** *Critical Z-value = ±1.96 at p< 0.05 (two-tailed test)*

Result in table 4 shows the comparison of correlation coefficients between male and female students. The correlation coeffient for male was r = -0.578 (Fisher's Z= -0.658), while for female students was r = -0.647 (Fisher's Z= -0.770). The Fisher's Z-transformation test yielded a Z-test value of 2.143 with a p-value of 0.032, which is less than the 0.05 level of significance.

Since the calculated Z-test value (2.143) exceeds the critical Z-value (±1.96) and the p-value (0.032) is less than 0.05, it can be concluded that there is a statistically significant difference in the strength of the relationship between alternative conceptions and academic achievement for male and female students. Specifically, the negative relationship between alternative conceptions in organic chemistry and academic achievement is significantly stronger for female students (r = - 0.647) than for male students (r = - 0.578). This indicates that gender significantly influences the relationship between alternative conceptions and academic achievement, with female students being more adversely affected by alternative conceptions than their male counterparts.

## Hypotheses

**Hypothesis One:** There is no significant relationship between students' alternative conceptions in organic chemistry and their academic achievement in Chemistry in secondary schools in Delta North Senatorial District.

**Table 5**: Pearson Correlation of Student's Alternative Conceptions and Chemistry Achievement

| Variable | *n* | *df* | *r-value* | *r-critical* | *p-value* | *Decision* |
|---|---|---|---|---|---|---|
| Alternative Conceptions and Academic Achievement | 367 | 365 | -.612 | ±.098 | .000 | Reject $H_0$ |

Significance level: $\alpha = 0.05$

Result in table 5 shows that the Pearson correlation co-efficient between students' alternative conceptions in organic chemistry and their academic achievement was -0.612, with a p-value of 0.000, which is less than the 0.05 level of significance. Since the calculated r-value (-0.612) is greater than the critical r-value (±0.098) and the p-value is less than 0.05, the null hypothesis is rejected. This means there is a significant negative relationship between students' alternative conceptions in organic chemistry and their academic achievement in chemistry in Delta State.

**Hypothesis Two:** There is no significant difference in the relationship between male and female students' alternative conceptions in organic chemistry and their academic achievement in Chemistry in Delta North Senatorial District.

**Table 6:** Fisher's Z-transformation Test for Male and Female Students

| Comparison | Male r | Female r | Z-test value | Critical Z-value | p-value | Decision |
|---|---|---|---|---|---|---|
| Male Vs Female correlation | -0.578 | -0.647 | 2.143 | ±1.96 | .032* | Reject $H_0$ |

Significance level: $\alpha = 0.05$ (two-tailed test)

Result in table 7 shows that the Z-test value of 2.143 exceeds the critical Z-value of ±1.96at 0.05 level of significance, with a p-value of 0.032. Since the calculated Z-test value is greater than the critical value and the p-value is less than 0.05, the null hypothesis is rejected. This means there is a significant difference in the relationship between alternative conceptions in organic chemistry and academic achievement for male and female students in Delta State. The correlation coefficient for female students (r = -0.647) is significantly stronger than that for male students (r=-0.578), indicating that alternative conceptions have a more detrimental effect on the academic achievement of female students compared to male students.

## Discussion

The findings from Table 1 revealed a strong negative correlation, suggesting that students who possess higher levels of alternative conceptions about organic chemistry concepts tend to perform poorly in their chemistry examinations. This outcome can be explained by the fact that alternative conceptions create cognitive barriers that prevent students from accurately understanding and applying scientific concepts. When students hold incorrect beliefs about fundamental organic chemistry principles such as the nature of hydrocarbons, functional groups, and reaction mechanisms, these faulty mental models interfere with their ability to solve problems correctly and demonstrate mastery of the subject matter. The result supports the position of Samuel, Akobundu and Okonkwo (2024) who found a negative correlation between students' misconceptions in organic chemistry and their academic performance in Awka

Education Zone of Anambra State. Similarly, Anim-Eduful and Adu-Gyamfi (2023) discovered that students held significant alternative conceptions about organic qualitative analysis, which demonstrated a lack of clarity in their understanding of fundamental concepts. These findings collectively indicate that alternative conceptions are not harmless misunderstandings but rather serious impediments to learning that must be addressed through deliberate instructional interventions.

The rejection of the null hypothesis confirms that the relationship between alternative conceptions and academic achievement is statistically significant and not due to chance. This has important implications for chemistry education in Delta State, as it demonstrates the urgent need for teachers to identify and correct students' alternative conceptions before they become deeply rooted. The finding contrasts slightly with Samuel, Akobundu and Okonkwo (2024) who reported only a low negative correlation, suggesting that the impact of misconceptions may vary depending on the specific concepts being assessed or the particular population under study. However, both studies agree on the direction of the relationship, confirming that alternative conceptions negatively affect student performance. The significance of this finding lies in its call for Chemistry educators to move beyond traditional teaching methods that simply present correct information, and instead adopt conceptual change strategies that directly confront and replace students' faulty understandings with scientifically accurate ones.

The data in Table 4 which reveals that gender significantly moderates the relationship between alternative conceptions and academic achievement indicates that the effect of alternative conceptions on students' achievement is not uniform across gender groups. The stronger negative relationship observed among female students suggests that holding alternative conceptions may interfere more substantially with their learning outcomes than with those of male students. From a cognitive perspective, this may be linked to differences in learning approaches, as female students often engage in deeper, integrative processing of concepts, making conceptual conflicts more disruptive when misconceptions are present. From a socio-cultural perspective, classroom interactions and societal expectations may intensify the impact of misconceptions on female students, particularly through reduced confidence or stereotype-related pressures that hinder recovery from conceptual difficulties.

The rejection of the null hypothesis confirms that the observed gender difference in the relationship between alternative conceptions and academic achievement is statistically significant and has important implications for instructional practice. This finding contrasts with the reports of Samuel, Akobundu, and Okonkwo (2024) and Oyakhirome (2025), who found no significant gender differences in misconceptions or achievement, though their studies focused on general levels rather than relational strength. However, the result aligns with Nti et al. (2023), who reported gender differences in students' conceptual understanding of science concepts. The significance of this finding is that Chemistry instruction should be gender-responsive, recognizing that alternative conceptions may affect male and female students differently. As emphasized by Nyampinga and Nduta (2024), targeted teacher professional development is essential for equipping educators with strategies to identify and address misconceptions in ways that support inclusive learning environments and enhance achievement for all students.

## Conclusion

The findings of this study revealed that a significant number of students in Delta State hold various alternative conceptions in organic chemistry, and those with more alternative conceptions tend to perform poorly in Chemistry. The study further showed that male students had more alternative conceptions, while female students achieved higher Chemistry scores, indicating a significant association between gender, alternative conceptions and academic achievement.

## Recommendations

In the light of the findings of this study, the following recommendations are made:

1. Chemistry teachers should routinely use diagnostic assessment tools, such as short concept tests and misconception checks, to identify students' alternative conceptions in organic chemistry before and during instruction, so that teaching can be adjusted to address identified learning gaps.

2. Instruction in organic chemistry should emphasize conceptual understanding rather than rote memorization. Teaching strategies that encourage reasoning, explanation, and visualization such as concept mapping, molecular model construction, and guided questioning should be integrated into regular classroom practice.

3. Since gender was found to moderate the relationship between alternative conceptions and academic achievement, Chemistry teachers should adopt gender-responsive teaching approaches that actively engage both male and female students and provide equal opportunities for participation, discussion, and problem-solving.

4. Curriculum developers and examination bodies should incorporate learning activities and assessment items that specifically target common alternative conceptions in organic chemistry, ensuring that students are evaluated on conceptual understanding rather than memorized procedures.

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