



Predictive Power of Spatial Ability on Secondary School Students' Academic Achievement and Interest in Organic Chemistry

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Abstract

The study aimed at analyzing the predictive power of spatial abilities on secondary school students' academic achievement and interest in Organic Chemistry. The predictive correlational research design was used for this study. The study was conducted in Enugu North Local Government Area, Enugu State, Nigeria. The study was guided by two research questions and two hypotheses. A sample size of 335 SS II was drawn from the population 2046 Senior Secondary two students following a multistage sampling procedure. The Chemistry Students' Spatial Ability Test (CSSAT), Organic Chemistry Achievement Test (OCAT) and Chemistry Interest Inventory (CII) were used for data collection. The reliability of CSSAT and OCAT using Kuder Richardson formula (KR-20) were 0.91 and 0.90 respectively, while the reliability of CII using Cronbach alpha method was 0.93. Data was analyzed using regression analysis. Findings of the study showed that the correlation between spatial ability and students' achievement in Organic Chemistry was statistically significant ($r^2 = 0.689$, $p < 0.001$). The findings further revealed that the correlation between spatial ability and students' interest in organic chemistry was statistically significant ($r^2 = 0.745$, $p < 0.001$). It was recommended among others that government should organize periodic training for teachers to enhance their capacity to stimulate students' development of spatial abilities for improved achievement and interest in Organic Chemistry.

Keywords: Spatial ability, Academic Achievement, Interest, Organic Chemistry.

Introduction

Chemistry is one of the major branches of science that occupies a key position in assisting candidates seeking admission into engineering, industrial Chemistry, medicine, food science and other applied fields of study (Ngozi-Olehi, Duru, Uchegbu & Amanze, 2018). Generally, Chemistry is an abstract, complex and visually demanding subject. The abstract concepts of Chemistry require deeper thinking at different levels and Organic Chemistry is no exception to this (Ngozi-Olehi, et al., 2018). Organic chemistry is a major component of the NERDC general Chemistry curriculum for senior secondary two. At this level, Organic Chemistry is not only difficult but confusing because it requires 3-dimensional (3D) representation of structures which are often complex to handle.

Students usually find it difficult to understand 3D molecules through the 2D representations. This is because Organic Chemistry contains a lot of new

vocabulary which usually promotes students' misconceptions especially in symbolic representations of molecular structures and functional groups which conventional teaching method has failed to address. This difficulty makes many students abandon Chemistry and its related fields for non-science courses. Next to proper understanding is rote or memorization of the concepts without understanding the fundamentals. Recently, science researchers have developed tools that support and aid various types of spatial visualization, including "concretizing" the abstractness of Organic Chemistry concepts to "understanding spatial relationships". Students can now visualize and simulate experiments or even erect different types of models with subtle existence.

Visualization is the capacity to mentally manipulate image(s) of objects or something. It is a key factor for mastering 3D molecular concepts. Visualization is any technique for creating images,



diagrams, or animations to communicate a message” (Ngozi-Olehi et al., 2018). According to the authors, imagery visualization is as old as man as an effective method of communicating both abstract and concrete concepts. With high visualization skills students visualize complex relationships directly from computer-generated visualization tools to enrich teachers. They also maintained that those technological tools which allow for integration of multiple representations provide students with opportunities to visualize Chemistry thus enhancing conceptual understanding. Spatial ability is one of the key skills required for 2D visualizations representing 3D molecular structures and stereochemistry. Students with strong spatial ability interpret 3D molecular arrangements as well as predict reaction paths better than those with low spatial ability (Stull, Gainer & Hegarty, 2023). Rahmawati, et al. (2021) spatial ability as a mental capacity to manipulate, visualize and transform spatial information necessary for understanding structural molecular geometry and reaction paths can be developed over time through learning. That is, they have challenges trying to convert or see 3D in the 2D structures as represented in the textbooks, chalk boards or even the drawings used in the representation of molecular structures. Students’ ability to link these levels enhances their development of deep and better understanding of conceptual problems of Organic Chemistry.

Students with poor spatial ability struggle with visualization and understanding the complex concepts like arrangement of molecular structures in space, reaction paths and prediction of reaction products. This could result in students’ poor academic performance in Organic Chemistry courses & a lack of confidence in their ability to succeed in this subject. Researchers like Oliver-Hoyo et al. (2017) have reiterated the correlation of spatial skills with achievement in Chemistry and choosing a career, few have examined how this cognitive skill predicts achievement and interest specifically in the context of Organic Chemistry. This is the main concern of this study which adopted a correlational method to ascertain the impact of students comparing their visualization capacity to the 2D objects in the questionnaires. Though the study was conducted using a small sample and as such it is not good for generalization. It, however, provides directions for further studies to investigate more with respect to the spatial ability being a predictor for students’ interest and learning outcomes in Organic Chemistry.

Scientific visualization is the use of interactive, sensory representations, typically visual, of abstract data to reinforce cognition, hypothesis building, and reasoning. At the core of these technological tools are unique opportunities for teaching and learning science by which students visualize complex relationships directly from instructional materials such as computer-generated visualization tools to enrich traditional methods. Specifically, the study employed visualization-based problems which may demand higher order visualization ability of senior secondary students.

Research Questions

1. What is the significant correlation between students' spatial ability and their achievement in Organic Chemistry?
2. What is the significant correlation between students' spatial ability and their interest in Organic Chemistry?

Hypotheses

1. The positive correlation between spatial ability and achievement in Organic Chemistry among secondary school students in Enugu North LGA is not significant.
2. The positive correlation between spatial ability and interest in Organic Chemistry among secondary school students in Enugu North LGA is not significant.

Methodology

Design and Participants

The study adopted a predictive correlational research design. The study was conducted in Enugu North Local Government Area, Enugu State, Nigeria. The population of the study was made up of population 2046 (1028 males, 1018 females) Senior Secondary two (SSII) students offering chemistry in public secondary schools in the study area. A sample size of 368 (185 males, 183 females) SS II was drawn from the population following a multistage sampling procedure involving purposive, random and stratified random sampling techniques. In the first stage, purposive sampling technique was used to select two Local Government Areas out of the three in the zone. In the second stage, purposive sampling technique was used to select all the co-educational schools totalling 10 from the two Local Government Areas selected. The choice of the sampling technique was to accommodate both male and female students. In the

third stage, proportionate stratified random sampling technique was used to draw a representative number of both male and female students in the sample. This was to ensure equal representation of both male and female students in the sample. In the fourth stage, simple random sampling technique was used to draw a total of 368 (185 males and 183 females) students offering Chemistry for the study.

Instrumentation

The Chemistry Students' Spatial Ability Test (CSSAT), Organic Chemistry Achievement Test (OCAT) and Chemistry Interest Inventory (CII) were used for data collection. The CSSAT was used to collect data on students' spatial abilities. The CSSAT contained 25 multiple choice items with five response options lettered A - E. Each correct answer got four (4) marks, any incorrect answer was marked zero. The CSSAT was adapted from Purdue Spatial Reasoning Instruments (SRI) developed by Ramful et al. (2017). The original instrument (SRI) had 30 items. Items were adapted to suit the language and culture of the respondents, and context of the study. The CII elicited information based on students' interest in chemistry. The CIS was adapted from Development and Validation of the Student Interest and Engagement Scales (Mazer, 2016). The original scale had 25 items which were retained with minor adjustments in the adapted version. The CII was structured based on a four-point Likert-type scale of Strongly Agree (SA) = 4, Agree (A) = 3, Disagree (D) = 2 and Strongly Disagree (SD) = 1. The OCAT was developed by the researcher. The instrument was developed using a table of specification, introduction to organic compounds, hydrocarbons, and Petroleum (crude oil). The OCAT consists of 25 multiple-choice items with four response options lettered A – D. Each correct

answer was assigned four (4) marks; incorrect answer was assigned zero (0) mark, giving a maximum of 100% and a minimum of 0%.

Validity and Reliability of Instruments

The CSSAT and OCAT were face and content validated by experts in Science Education, University of Nigeria, Nsukka. The construct validity of CII was carried out using factor analysis. The reliability of the instruments was determined after trial testing involving 30 SSII students offering chemistry. The KR-20 formula was used to determine the internal consistency reliability coefficients of the CSSAT ($r = 0.91$) and OCAT ($r = 0.90$). The internal consistency of CIS was determined using Cronbach Alpha method ($\alpha = 0.93$). All instruments were considered reliable for measuring the variable of interest.

Method of Data Collection and Analysis

The instruments were administered to the participants and retrieved with the help of chemistry teachers who served as research assistants. Data obtained were analyzed using regression analysis. Regression correlation coefficient (r) was used to determine the nature of the relationship between the variables of the study. Consequently, $r = 0.90-1.00$ showed very high correlation, $0.70-0.89$ showed high correlation, $0.40-0.69$ showed moderate correlation and $0.10-0.39$ showed weak correlation (Schober, Boer & Schwarte, 2018). The coefficient of determination (r^2) was used to determine the amount of variation in students' interest and academic achievement in organic Chemistry that can be accounted for by students' spatial ability. Hypotheses were tested using regression ANOVA at 0.05 level of significance.

Results

Research Question one

Table 1: Regression analysis of the correlation between students' spatial ability and their academic achievement in organic Chemistry

Model	N	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	335	.830 ^a	.689	.689	9.97657

a. Predictors: (Constant), Spatial Ability

b. Dependent Variable: Academic Achievement

The result of the data analysis in Table 1 shows the predictive power of students' spatial ability

on their academic achievement in organic Chemistry. It reveals that the correlation coefficient (r) between

spatial ability and academic achievement of students in Chemistry is 0.830, indicating a high and positive predictive power (correlation) with associated coefficient of determination (r^2) of 0.689. This coefficient of determination (r^2) shows that 69% of the

variance in students' academic achievement can be attributed to spatial ability while 31% of the variance in students' academic achievement in Chemistry can be attributed to other variables not considered in this study.

Hypothesis one

Table 2: ANOVA results of the correlation between students' spatial ability and their academic achievement in organic Chemistry

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	80843.291	1	80843.291	812.235	.000 ^b
	Residual	36428.665	366	99.532		
	Total	117271.957	367			

- a. Dependent Variable: Academic Achievement
b. Predictors: (Constant), Spatial Ability

The result in Table 2 is the regression ANOVA of the predictive power of students' spatial ability on their academic achievement in organic Chemistry. An F-ratio of 812.235 was obtained. Since the p-value of 0.000 obtained is less than 0.05 level of

significance set for decision making, the null hypothesis was rejected. Thus, it can be concluded that the predictive power of secondary school students' spatial ability on their academic achievement in organic Chemistry was significant.

Research Question Two:

Table 3: Regression analysis on the correlational power between secondary school students' spatial ability and their interest in organic Chemistry

Model	N	R	R. Square	Adjusted R Square	Std. Error of the Estimate
1	335	.803 ^a	.645	.644	11.54591

- a. Predictors: (Constant), Spatial Ability
b. Dependent Variable: Interest

The result of the data analysis in Table 3 shows the predictive power of secondary school students' spatial ability on their interest in organic Chemistry. It reveals that the correlation coefficient (r) between spatial ability and interest of students in Chemistry is 0.807, indicating a high and positive predictive correlation with associated coefficient of

determination (r^2) of 0.645. This coefficient of determination (r^2) shows that 65% of the variance in students' interest can be attributed to spatial ability while 35% of the variance in students' interest in Chemistry can be attributed to other variables not considered in this study.

Hypothesis Two

Table 4: ANOVA result of the predictive power of students' spatial ability and their interest in organic Chemistry

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	88538.428	1	88538.428	664.164	.000 ^b
	Residual	48790.779	366	133.308		
	Total	137329.207	367			

- a. Dependent Variable: Interest
- b. Predictors: (Constant), Spatial Ability

The result in Table 4 is the regression ANOVA of the predictive power of secondary school students' spatial ability on their interest in organic Chemistry. An F-ratio of 664.164 was obtained. Since the p-value of 0.000 obtained is less than 0.05 level of significance set for decision making, the null hypothesis is rejected. Thus, it can be concluded that the predictive power of secondary school students' spatial ability on their interest in organic Chemistry is significant.

Results and Discussion

The result showed that there is a positive and high predictive power of secondary school students' spatial ability on academic achievement in Organic Chemistry. The supporting hypothesis concluded that the predictive power of secondary school students' spatial ability on academic achievement in organic Chemistry is significant. This is expected because organic Chemistry depends highly on visualization of geometric structures (Kramer, 2024). This intellectual ability promotes achievement. This finding is in agreement with the study of Jakubowska and Terczynska (2023) who found out that many students with low spatial ability have difficulties in perceiving and working with 3D objects. It also agrees with Salame and Kabir (2022) findings that use of modeling kits greatly improved students' spatial ability just as constant practice increases students' spatial skills thereby enhancing their achievement in Stereochemistry.

The result showed that there is a positive and high predictive power of secondary school students' spatial ability on interest in Organic Chemistry. The equivalent hypothesis concluded that the predictive power of secondary school students' spatial ability on interest in organic Chemistry is significant. This result is not surprising because such high level of spatial ability is required for visualization of symbolic representation of molecular structures in organic Chemistry and can enhance students' interest in Organic Chemistry. A student with interest in Organic Chemistry will engage fully in learning activities for high academic achievement. This result strengthens the findings of Cole, Wilhelm, Vaught, Fish, and Fish (2021) who showed that high spatial abilities increased students' interest in Chemistry. The finding of this study disagrees with the study of

Hacıömeroglu (2017) which found weak correlation between spatial ability and interest of students in sciences and Mathematics.

Conclusion

Based on the results of the findings, it was concluded that there is a positive correlation between spatial ability and achievement, suggesting that students with higher spatial ability tend to perform better in Chemistry. Deep understanding of spatial skills enables students to navigate through the complex world of Organic Chemistry, developing interest in the process as well as achieving their goals in that field.

Recommendations

1. Government should organize periodic training for teachers to enhance their capacity to stimulate students' development of spatial abilities for improved achievement in Organic
2. Computer simulations and animations to visualize complex reaction mechanisms and molecular interactions should be utilized by teachers to stimulate students' interest in organic chemistry.

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