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RELATIONSHIP BETWEEN SPATIAL ABILITY AND ACHIEVEMENT IN STEREOCHEMISTRY AMONG COLLEGE OF EDUCATION STUDENTS IN SOUTH-WEST OF NIGERIA

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Abstract
The study investigated the relationship between spatial ability and achievement in chemistry among college of education students in southwest of Nigeria. Two research questions with their corresponding hypotheses guided the study. A correlational research design was adopted for the study. A sample of 124 Chemistry students consisting of 58 male and 66 female students drawn randomly from 2 out of 5 federal colleges of education in south-west of Nigeria participated in the study. Purdue visualization of rotation test (PVRT) and test of understanding stereochemistry (TUS) were the instruments used for data collection. The reliability coefficients of PVRT and TUS items were established using KR-20 as 0.82 and 0.78 respectively. Data collected were answered using Pearson's Correlation Coefficient (r), Hayes Process Analysis and t-test. Findings of the study revealed that the relationship between students' spatial ability and their achievement in stereochemistry was moderate, positive and significant. There was high, positive and significant relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender among others. Based on the findings of the study, it was recommended amongst others that Chemistry teachers should try to establish a classroom environment that facilitates the use of images in teaching of Chemistry concepts.

Keyword: Achievement, stereochemistry, chemistry, Spatial Ability, gender

Introduction

Science learning deals with abstract, conceptual thinking, visualization and generalization of facts. All of these require the use of cognitive process (Adeyemo, 2010). For students to achieve this, they must be able to combine ideals, solve verbal and hypothetical problems, and visualize invisible concepts, proportions and conservation of movement. They can transfer understanding from one situation to the other. Most of what is taught in chemistry requires ability to think. Adeyemo further stated that many students find abstract subjects such as Physics and Chemistry difficult to learn, this is believed to be associated with their cognitive development. The difficulty is due to not having appropriate cognitive level of comprehension and application. Chemistry is a subject that has topics that need high spatial ability to understand the concepts (Alfonso, 2015). Spatial ability is the capacity to understand, reason and remember the visual and spatial relations among objects or space. Students with low spatial abilities find it difficult to mentally process the abstract information in chemical structures into three-dimensional materials (Harris, 2019). Various different

abilities are incorporated together in spatial ability. According to Hoffler and Leutner (2011), the three main factors in spatial ability are spatial relation, spatial visualization and multiple object dynamic spatial ability (MODSA). They defined spatial rotation as the ability to be able to rapidly visualize two-dimensional and three-dimensional objects accurately in a single step. They, along with Berney et al. (2015), defined spatial visualization as the ability to transform mental representations and to imagine, encode, and manipulate motion. Finally, MODSA was defined as the ability to spatial track the movements of an object with time (Harris, 2019).This cognitive ability mediates individual differences in the capacity for higher level spatial abilities such as mental rotation. Studies revealed that mental reasoning abilities of students is a factor that predicts their understanding of many abstract and scientific concepts and supporting students' reasoning may lead to scientific learning outcomes that requires such skills and abilities (Kozhevnikov et al., 2017; Lyna & Gavin, 2014). Lyna and Gavin, further explained that visual-spatial ability is one of the abilities that is vital for understanding abstract concepts requiring the ability to imagine and visualize many invisible phenomena. Bayram (2016) defined spatial ability as skills required in representing, transforming, generating and recalling symbolic and non-linguistic information. Spatial ability also could be viewed as a unique type of intelligence that can be differentiated from other forms of intelligence or cognitive abilities, such as verbal ability, reasoning ability and memory ability (Onootu, Hassan & Gana, 2021). Operationally, spatial ability refers to the ability to generate, retain, and transform well-structured visual images.

Visual-spatial skills are of immense benefit in problem-solving in life. For example, using a map to guide you through an unfamiliar city, orientating yourself in your environment, packing (when you are deciding if certain box is large enough for objects you want to put into it and using images (as when you are combing your hair while looking into mirror) are activities that involve spatial ability. Visual-spatial ability is becoming increasingly important with the development and proliferation of new technologies such as imaging, computer graphics, data visualization, and supercomputing. Highly demanding spatial tasks include the construction of mental representations of object configuration from images on several screens representing different perspectives (Wai, Lubinski & Benbow, 2019).Representations of molecular structures, reactions, and theories require spatial ability in almost all fields of chemistry education. For example, in general chemistry, spatial ability is required to learn the valence shell electron pair repulsion (VSEPR) and molecular geometry, and crystal and lattice structure in organic chemistry. Spatial ability is required to understand the mechanisms of SN_2 reactions, stereochemistry, chirality, molecular representations, and various structural representations such as boat and chair conformers, and in biochemistry, the shape of biomolecules such as proteins and nucleic acids, as well as enzyme substrate reactions require spatial ability (Harle & Towns, 2011). Students with low spatial abilities find it difficult to mentally process the abstract information in chemical structures into three-dimensional materials (Harris, 2019). In some cases, students might have created an incorrect mental image of the problem to begin with, and this misconception, not the lack of content knowledge, that has caused the students to arrive at an incorrect answer (Alfonso, 2015). A study found that high school chemistry students have difficulties in translating chemical formula, electronic configuration, identifying molecular structures from given empirical

formula (Furio et al., 2015).It could be that they translated representations based on their conceptual understandings of representation rather than their visual-spatial abilities. In stereochemistry, students need to analyse the three-dimensional atomic arrangements, mentally manipulate molecular models and picture them in chemical reactions (Salame & Kabir, 2022). Researchers have proved that there could be positive relationship between students' science accomplishments and their spatial capacities**.** For example, Lyna and Gavin (2014) examined the relationship between students' general visual-spatial ability and their understanding of electricity and electromagnetism in physics. Barrett and Hegarty, (2016) found strong correlation between three-dimensional visual graphs and students' performance in organic chemistry. Similarly, Kozhevnikov et al. (2010) carried out research on the relation of spatial visualization to solving physics problems and the result indicated strong relationship between spatial visualization ability and solving problems in physics with multiple spatial parameters. Also, Behzat (2016) examined the relationship between students' spatial ability and kinematics graph interpretation skills and result showed that students' ability to determine the slope in kinematics graph was significantly associated with spatial ability. Omar and Petek (2011) found moderate significant relationship between students' spatial ability and physics achievement. However, Michael, (2017) found no significant relationship between students' spatial abilities and their success in high school physics. In line with this, Duffy, Farrell, Harding, Behan and Raighue (2015) conducted research on the effects of spatial skills on academic performance in Science, Technology, Engineering and Mathematics (STEM) education which included chemistry and the result of the study showed no significant effect of spatial ability on STEM education. The implication of this could be that spatial ability and success in chemistry are not always related. For some reasons, the relationship between spatial ability and chemistry as well as other science subjects could be affected, resulting in no relationship between the two variables at all.

Over the years, researchers have found that many factors could affect students' spatial abilities. These include the learning characteristics of students (Hauptman & Cohen, 2011), subject anxiety (Ferguson et al., 2015), their problem-solving strategies (Bilge & Taylor, 2016), negative achievement expectations (Tarampi et al., 2016) and gender (Yuan et al., 2019). The moderating variable such as gender could affect the spatial ability and achievement in stereochemistry. Gender related differences in cognitive abilities are of considerable interest to educators and cognitive researchers alike, relatively little progress has been made in understanding the psychological processes that lead to them (David & David (2013). Researchers have frequently observed gender differences in more specific components of cognitive abilities (Boyle, Neumann, Furedy &Westbury, 2010). David and David investigated gender-role differences in spatial ability and discovered that male participants tend to have a higher spatial ability than their female counterparts. Similarly, Behzat (2016) revealed that male students perform significantly better than female students in spatial ability test. In a Mathematics study, a moderate and significant correlation was observed between male and female students' spatial ability on their achievement in favour of the males (Dawson, 2019). This could be one of the reasons why there are lesser female than male in STEM fields. Valerie, (2018) found out that there are relatively fewer number of females in field of physics at graduate level compared to the number of males. Robert and

Katherine (2016) investigated gender effects in physics assessments kinematics graphs and found that male students perform better than females in the test of understanding kinematics. The implication of this could be that the achievement gap between male and female students is also as a result of their spatial ability. The studies reviewed on the effect of students' spatial ability or gender on their achievement in different subject areas revealed contradictory results.

However, many studies are often carried out to determine the factors that are related to students' achievement in education. Chemistry is one of the science subjects considered as having abstract concepts which students find difficult. Factors frequently investigated in Nigeria are mostly related to the method of instruction and teachers' personality related. Students' mental reasoning ability is important factor that could predict students' understanding and consequently their achievement in science subjects, particularly in chemistry which is seen as abstract science. Visual spatial ability likely plays an important role in students learning of chemistry problem solving. Despite this important, the number of studies carried out on spatial ability and students' achievement in science subjects were mostly in other parts of the world, very few have been carried out in Nigeria in other subjects. None to the best knowledge of the researchers has investigated on the relationship between spatial ability and their achievement in stereochemistry using gender as moderating variable among college of education students in south-west of Nigeria. Therefore, the problem of the study, put in form of a question is: what is the relationship between students' spatial ability and their achievement in stereochemistry among college of education students as moderated by gender in south-west of Nigeria?

Purpose of the study

In line with the problem the study, the purpose of the study was to investigate the relationship between spatial ability and achievement in chemistry among college of education students. Specifically, the study sought to:

1. Ascertain the relationship between students' spatial ability and their achievement in stereochemistry.
2. find out the relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender.

Research Questions

In line with the specific purposes, the study sought to answer the following research questions:

1. What is the relationship between students' spatial ability and their achievement in stereochemistry?
2. What is the relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender?

Hypotheses

Based on the purposes of the study, the following null hypotheses were formulated and tested at 0.05 level of significance:

1. There is no significant relationship between students' spatial ability and their achievement in stereochemistry.

2. There is no significant relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender.

Methodology

The study employed a correlational survey research design. The population of this study consisted of 3,200 Nigeria certificates in education one (NCEI) chemistry students from 5 federal colleges of education in south-west of Nigeria in the 2021/2022 academic session. The choice of this area was based on research reports by Abimbola (2013), Aina and Ayodele (2018) and Ganiyu (2021) which revealed unsatisfactory achievement of colleges of education students in science subjects. In addition, to the best of the knowledge of the researchers, study on the relationship between spatial ability and achievement in chemistry among college of education students has not been carried out in south-west of Nigeria. The choice of these NCEI chemistry students was because the topic "stereochemistry" falls in their minimum standard. A sample of 124 Chemistry students consisting of 58 male and 66 female students were used for the study. Two stage sampling was involved. First, two colleges of education were drawn randomly from 5 federal colleges of education in south-west of Nigeria. In addition, purposive sampling technique was used to select NCEI chemistry students. Two instruments used for data collection were paper-and-pencil tests measuring spatial ability (Purdue Visualization of Rotation Test (PVRT) adopted from Bodner and Guay (1997) and multiple-choice stereochemistry problem-solving test (Test of Understanding Stereochemistry (TUS) adapted from Salame and Kabir, (2022).The reliability Coefficients of Purdue Visualization of Rotation Test (PVRT) and Test of Understanding Stereochemistry (TUS) were calculated using Kuder-Richardson coefficient (KR-20) as 0.80 and 0.83 respectively. The first week of the research was used to seek permission from the schools. This was done to get the maximum cooperation from the school authority, teachers and students of the schools. After the visiting period, the Purdue Visualization of Rotation Test was administered to the students by the researchers and followed by the Test of Understanding Stereochemistry. The Purdue Visualization of Rotation Test consisted of 10 questions and each correct answer carried 1mark making a total of 10 marks, while the Test of Understanding Stereochemistry contained 14 questions with each correct answer carrying 1mark marking a total of 14marks. The students' scores were standardized by converting them to percentages before they were taken for analysis. Data collected were answered using Pearson's Correlation Coefficient (r), Hayes Process Analysis and t-test. The degree of the relationship was interpreted in accordance with Okoye (2015) as follows: $r = 0.00$, no relationship, $r = 0.00$ to ± 0.20, very low relationship; $r = \pm 0.20$ to ± 0.40, low relationship; $r = \pm 0.40$ to ± 0.60, moderate relationship; $r = \pm 0.60$ to ± 0.80, high relationship and $r = \pm 0.80$ to ± 1.00, very high relationship.

Results

Research Question One: What is the relationship between students' spatial ability and their achievement in stereochemistry?

Table 1: Pearson's Correlation Coefficient and t-test Comparison of the Mean Scores of Students' Spatial Ability and their Achievement in Stereochemistry

Variables	N	Mean	SD	r-val	df	*t*-cal	t-crit.	p-val.	Decision
Spatial ability	124	53.52	11.21	0.52	246	2.08	2.01	0.04	Not Accepted
Achievement	124	49.41	9.42						

The data in table 1 revealed a moderate positive and significant relationship of r = 0.52 between the students' scores in spatial ability and their achievement in stereochemistry

Hypothesis One: There is no significant relationship between students' spatial ability and their achievement in stereochemistry.
From table 1, in respect of the relationship between the students' spatial ability and achievement in stereochemistry, the t-calculated value of 2.08 is greater than the t-critical value of 2.01 and the probability value of 0.04 is less than Alpha value. Therefore, the null hypothesis (HO_1) is not accepted. This implies that there is significant relationship between students' spatial ability and their achievement in stereochemistry.

Research Question Two: What is the relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender?

Table 2: Hayes Process Analysis of the relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender

Model	Interaction	N	r	R^2	SE	t	P	Dec
1	Spatial Ability×gender	124	0.64	0.41	7.12	1.66	0.00	Not accepted

The data in table 2 revealed that there is a high positive relationship of r=-0.64 between students' scores in spatial ability and their achievement in stereochemistry as moderated by gender.

Hypothesis Two: There is no significant relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender.
From table 2, in respect of the relationship between the students' spatial ability and achievement in stereochemistry, indicates that a t-value of 1.66 with associated probability value of 0.06 was obtained. Since the probability value of 0.00 is less than 0.05 set as the level of significance, the null hypothesis (HO_2) is not accepted. This implies that there is significant relationship between students' spatial ability and their achievement in stereochemistry as moderated by gender.

Discussion of findings

Analysis of research question one and the corresponding hypothesis one showed that there was a moderate positive relationship which was significant between the students' scores in spatial ability and their achievement in stereochemistry. This could be so since spatial visualization is characterized by multi-step manipulations of spatially presented information which is common in stereochemistry. Hence, it could be reasonable to expect students who

possess moderate level of spatial ability to process the abstract information in chemical structures into three-dimensional materials in stereochemistry. This finding is in agreement with the findings of Behzat (2016), Kozhevnikov, Motes and Hegarty (2017) and Onootu, Hassan and Gana, (2021), whose findings revealed significant relationship between students' spatial ability and their achievement in kinematics. However, the finding was not in accordance with the finding of Micheal (2017) which indicated no significant relationship between spatial ability and physics achievement variables.

The analysis of research question two and the corresponding hypothesis two showed that there was a high positive relationship which was significant between students' scores in spatial ability and their achievement in stereochemistry as moderated by gender. Students' spatial ability could result in different their achievement in stereochemistry based on gender since reviewed works indicated that male students perform better in science activities than the female students. Hence, male and female students' display of different level of understanding the arrangement of atom in a compound might have resulted in the significant difference.This is in agreement with the findings of Roberts and Katherine (2016); Behzat (2016) and David and David (2018) who found significant relationship between male and female students' spatial ability and achievement in kinematics. This suggests that students' spatial ability on achievement in stereochemistry could be dependent on person's gender.

Conclusions

This study has established the fact that students' spatial ability has positive and significant relationship with their achievement in stereochemistry. In addition, there was a high, positive and statistically significant relationship between spatial ability and achievement in stereochemistry as moderated by gender. The implication of the findings to the Chemistry teachers is that the teachers are expected to improve their students' potentials through the knowledge of the fact that spatial ability is important factors that influence students' achievement in stereochemistry and put it into consideration in the teaching process. This could be done by incorporating images in teaching stereochemistry. This study adds to the notion of gender disparity in chemistry achievement.

Recommendations

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

1. Chemistry teachers should try to establish a classroom environment that facilitates the use of images in teaching of Chemistry concepts.
2. The teachers should be aware of the different levels of spatial ability and put extra help to improve low spatial ability students in understanding of stereochemistry.
3. There is need for chemistry teachers to avoid gender disparity in the teaching and learning chemistry.

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