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SPATIAL VISUALISATION ABILITY AS CORRELATE OF SENIOR SCHOOL STUDENTS' ACHIEVEMENT IN PHYSICS IN SOKOTO STATE, NIGERIA

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This paper examined spatial visualisation ability as correlate of senior school students' achievement in Physics in Sokoto State, Nigeria. The objectives of the study were to: (i) examine the relationship between senior school students' spatial visualisation ability and their achievement in Physics; (ii) determine the relationship between senior school students' spatial visualisation ability and their achievement in physics based on gender; (iii) assess the relationship between students' spatial visualisation ability and their achievement in physics based on school type.

This research adopted ex post facto research of the co-relational type. The population for the study were Senior Secondary School II (SSS II) students in Sokoto State. Proportional sampling technique was used in sample selection. Seven hundred and thirty-one (731) SSS II students, offered Physics in senior secondary schools across the three senatorial districts in Sokoto State, Nigeria, formed the sample for the study. Research instruments, employed to elicit data for the study, were: Students' Spatial Ability Test (SSAT), and Physics Achievement Test (PAT). The instruments were validated by experts in science education, and Practicing Physics teachers in Sokoto, giving reliability coefficients 0.79 and 0.89 respectively. The data gathered were analysed using Pearson Product Moment Correlation Statistic and Z-test statistic, at .05 level of significance.

The findings of the study were that:

i. there was statistically significant relationship between students' spatial visualisation ability and their achievement in Physics ($r=0.32$, $p<0.05$);

ii. there was statistically significant difference in the strength of the relationship between students' spatial visualisation ability and their achievement in Physics based on gender as the Zobs – value (–2.01) was outside ±1.96 boundary in favour of female students; and

iii there was statistically significant difference in the strength of the relationship between spatial visualisation ability and achievement in Physics based on school type as the Zobs – value (–5.08) was outside ±1.96 boundary in favour of private schools.

It was concluded, that students' spatial visualisation ability positively predict their achievement in Physics. It was recommended, that students should be trained on spatial ability so as to be able to predict correctly their achievement in Physics

Keywords: *achievement, gender, physics, spatial ability, and school type*

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1. Introduction

Science is defined as a multidisciplinary human activity, which involves a planned systematic investigation and understanding of the world, nature and the universe [1]. Science is classified into physical, life, medical and technical sciences. Physical science has a dual nature. It is a body of knowledge; also, it is the process of acquiring and refining the knowledge. Examples of subjects under physical sciences are Chemistry, Mathematics, and Physics, while life sciences are Biology and Zoology. Medical sciences consist of fields of study, such as Medicine, Pharmacy and Medical Laboratory Science. Technical science, on the other hand, is primarily concerned with finding solutions to practical problems that confront human. Examples are Engineering, ICT and so on. Observation of the above meaning of science suggests the inquiry nature of science (Physics in particular) as it emphasises the practical nature of science since the subject cannot be meaningfully understood without students' active participation, which necessitates physical activities.

Physics is a major branch of science; it is concerned with the laws that govern the structure of the universe, the forms of matter, energy and their interactions [2]. Physics is a branch of science that is concerned with energy and their interaction [3]; it is the most basic of the sciences because its concepts and techniques corroborate the progress of all branches of science [4]. Physics is a cross-cutting discipline that has been implemented in many sectors of economic advancement, which includes health, agriculture, water, energy, technology and information and communication technology. In medicine, X-rays, radioisotope and resonance imaging are used. In addition, the design of machines and electronics all depend on advances, made from physics in technology [5].

The general objectives of the physics curriculum at the secondary school level of education as stated by [6] are to:

– provide basic literacy in Physics for functional living in the society;

– acquire basic concepts and principles of Physics as a preparation for further studies;

– acquire essential scientific skills and attitudes as a preparation for technological application of Physics; and

– stimulate and enhance creativity (p. ii)

The content of the senior school physics curriculum are spirally organised, while the guided-discovery method of teaching has been recommended in an effort to achieve the stated objectives. In order to stimulate creativity and develop process skills and correct attitude in students, the subject is student-activity oriented with emphasis on experimentation, questioning, discussion and problem-solving [6].

Physics is one of the science subjects, studied at the senior secondary education level in Nigeria. It lays the foundation for further studies in physics and other physics-related courses at the tertiary levels. Despite the importance of Physics to the scientific and technological development of Nigeria, senior school students' performance and understanding of the subject has fluctuated over the years. Researchers have identified causes of students' under achievement in physics to include inappropriate teaching and learning methods, abstract nature of physics concepts, lack of qualified teachers, poor infrastructure and inadequate laboratory facilities, teacher-centred instruction, non-availability and non-utilisation of physics instructional materials [7, 8]. In Sokoto State, students' low enrolment and poor performance in physics have been attributed to inadequate human and material resources and inappropriate presentation of materials to students [9]. This prompted the state Governor to declare a state of emergency in the education sector in that same year. Since then, series of intervention programmes, such as construction of new classrooms, laboratories, training and retraining of the existing teachers and recruitment of new ones have been a priority to the incumbent government.

Improving the learning and achievement of Physics requires a lot of input from the teachers because the role of the teacher in the classroom is important. The teaching approach that a teacher adopts and the available instructional materials may affect students' achievement [10]. Therefore, it can be deduced, that the use of appropriate teaching strategies with relevant illustration is critical to the successful teaching and learning of Physics. Illustrations in physics' classroom come in form of graphical representation/display or a more complex diagrammatical presentation of idea. The cognitive aspects of development that students require in understanding and interpreting these displays involve spatial activities in the brain.

Spatial visualisation ability is the capacity to understand and remember the spatial relations among objects. This ability can be viewed as a unique type of intelligence distinguishable from other forms of intelligence, such as verbal ability, reasoning ability, and memory skills. Spatial ability is not a monolithic and static trait, but made up of numerous sub-skills, which are interrelated and would be developed throughout one's life [11].

In general, spatial visualisation abilities are considered to be those mental skills, concerned with understanding, manipulating, reorganising, or interpreting relationships visually [12]. There are good evidences that indicated that spatial ability relates to specialised achievements in fields, such as mathematics, natural sciences, economic forecasting, meteorology, architecture, engineering, dentistry and medicine [13].

[14] Maintained that an abundance of empirical evidence exists, identifying a significant correlation between spatial ability and educational performance, particularly in Science, Technology, Engineering and Mathematics (STEM). [15] Observed that "individual differences in spatial ability contribute to learning, the development of expertise, and securing advanced educational and occupational credentials in STEM". There is therefore a need to define spatial ability relative to empirical evidence, which in this circumstance relates to its factor structure. Having a common conception of spatial ability to act as a framework to further investigate its relationship with STEM education has the potential to support research, attempting to identify the causal relationship [16].

Despite the importance of spatial visualisation ability in so many fields, spatial abilities rarely work in isolation from other abilities, such as critical thinking, efficient memory retrieval, and verbal skills, while deficit in one area can often be compensated by excellence in others. In view of these, a great deal of efforts had been made over the years by physics educators to remediate these problems [2, 17].

Despite the large number of studies on students' difficulties in physics problems-solving and students' achievement in physics [8, 10] very few attempts have been made to relate students' susceptibility to the errors in physics problem solving to their spatial visualisation ability and reasoning level. However, there is evidence that competing visual/spatial processing demands are more likely to arise as to-be-described physics problem-solving becomes more complex.

The need to improve students' achievement in physics that is inadequacies in spatial ability has so far elicited major areas of weakness, which requires immediate attention from the current literature reviewed. Relatively, few correlational studies have been done in recent times, relating spatial visualisation ability to senior school students' achievement in Physics. However, the extent, to which spatial ability influences academic achievement of students' in physics, has not been fully confirmed in Nigeria senior schools and in the area of physics. Thus, in order to bridge the gap and present efforts to rectify the staggering decline in students' achievement, this study investigated spatial visualisation ability as correlate of senior school students' achievement in Physics in Sokoto State, Nigeria.

2. Literature Review

Two experiments, carried out by [18], investigated the role of spatial ability in learning from an instructional animation versus a series of static pictures. In both experiments, a statistical interaction of spatial ability and type of visualization was obtained: Low-spatial ability students showed poor learning outcome when learning from pictures, while high-spatial students did not; when learning from animation, however, learning outcome was independent from spatial ability. The results are in line with an ability-as-compensator hypothesis, which states that constructing mental animations from non-dynamic materials needs spatial ability; with animated learning materials, however, spatial ability is not required. No overall differences between static pictures and animation were found.

The study by [19] examined spatial reasoning influences on students' performance on mathematics tasks. The sample of the study comprised 181 Year 5 and 6 students (91 boys and 90 girls) in four state primary schools in the Australian Capital Territory. Two instruments were used to collect data. The first instrument measured three constructs (students' spatial visualisation, mental rotation and spatial orientation.) within the spatial reasoning dimension; the second instrument measured two content and reasoning aspects of the mathematics curriculum. Mean, S. D. correlation, and Analysis of Variance (ANOVA) were used to test research questions and hypotheses. The results showed that there was no statistical difference between the achievement of boys and girls across the respective test constructs. Also there was a moderately high (positive) correlation between students' achievement on the two types of mathematics content and the three spatial reasoning constructs. It was also reported, that there were no gender differences in terms of performance on the three constructs that measured students' spatial visualisation, mental rotation and spatial orientation.

The study by [17] investigated senior school students' metacognition, spatial visualisation, mathematical ability and attitude as predictors of physics achievement in Kwara State. An *ex post facto* research of the correlational type was adopted for the study. The population of study was S.S.S. III students in Kwara State. The sample consisted of 857 students from intact classes, selected from 21 co-educational senior secondary schools across the three senatorial districts in Kwara State. Purposive sampling technique was employed for the selection of schools that participated in the study. Three research instruments were employed in data collections which are Students' Metacognition Inventory (SMI), Students' Spatial Visualisation Test (SSVT) and Students' Attitude toward Physics Inventory (ATPI). Mean score, One-way MANOVA, PPMC and multiple regression statistical tools were employed for data analysis at .05 level of significance. The findings of the study revealed that students' spatial visualisation ability significantly predicted their achievement in physics. Gender and school type as moderating variables significantly influence the prediction of relationship between students' spatial visualisation ability and their achievement in physics. It was recommended, that students should be trained to develop their spatial visualisation abilities as it helps to improve their achievement in physics.

In an investigation, carried out by [20], object-spatial visualisation and verbal cognitive styles among high school students and related differences in spatial ability, verbal-logical reasoning ability, and mathematical achievement in calculus in South-eastern United States were examined. Quantitative research design was employed for the study. Data were collected from 348 students, enrolled in Advanced Placement (AP) calculus courses at six high schools. Correlational analysis revealed that spatial ability, verbal-logical reasoning ability, and mathematical achievement were significantly correlated with each other. Also, spatial visualisation cognitive style was positively related to spatial ability and calculus performance, whereas object visualisation cognitive style did not correlate with spatial ability and was negatively related to achievement in calculus

The work of [21] studied mental rotation (MR) and spatial visualisation (SV) outcomes and their impact on orthographic drawing performance. The sample of the study comprised 98 secondary school students with 36 girls and 62 boys, randomly assigned into two experimental groups and a control group. The research instruments used were computerised versions of the Mental Rotation and Spatial Visualisation Tests. A significant performance gain in spatial visualisation and mental rotation accuracy were reported, but not in mental rotation speed. Moreover, gender was a significant variable with boys attaining differential improvement gains as opposed to girls. The experimental group, gaining higher than SV through training, performed better in solving an orthographic drawing task, indicating that the training method was related to the application of the received mental processes in solving the task.

Furthermore, [22] researched on the relationship between spatial ability and the achievement of sixth graders in mathematics in an attempt to determine the impact of the gender variable and to determine the students' diversity (in terms of high and low spatial abilities). The study sample was students in 6 classes of sixth grade, comprised of 228 students with three male and three female classes. The study employed the spatial orientation Test-Card Rotation by Whitley Test. The results informed positive correlation between students' achievement in mathematics and their spatial ability. The results also showed that male students have higher spatial abilities compared to their female counterparts in the application of one-way analysis of variance between the scores of both gender. In addition, the results showed that high scoring students possess high spatial abilities compared to their average and low scoring counterparts.

In a like manner [23] examined spatial ability development among Jordanian students. The study sample involved 221 students, selected randomly from various sections. The respondents took mental rotation test that gauged their spatial ability. The findings of the study showed no differences in achievement on the test of spatial ability due to study years. They also showed no significant differences in spatial ability test achievement due to social status or academic achievement.

The study of [24] examined the extent, at which school variables (school location, school type and school proprietorship) relatively and collectively contribute to students' performance in Mathematics. The *ex post facto* research was employed using stratified simple random sampling technique in selecting

853 students from 20 secondary schools in Akwa Ibom State. The instrument employed was a researcher-designed Mathematics Achievement Test (MAT) with 40 items. It was revealed, that school type and school location did not have any significant effect on Mathematics performance.

The work of [25] researched on senior secondary school students' science achievement in public and private schools in Katsina State, Nigeria. The study employed a descriptive survey using random sampling in selecting two hundred and four (204) senior secondary school students. Science Achievement Test (SAT) was used to collect data and the *t*-test was used to analyse the data. A significant difference was reported between the performance of public and private school students' science achievement. The outcome was in favour of private school students. Also, no significant difference was found between public and private senior secondary school students' achievement in biology and chemistry. However, a significant difference was noticed in the physics aspect of the SAT.

It has been established, that spatial visualisation ability predicts students' achievement in physics [19, 17]. In contrast, [23] found no significant relationship between spatial visualisation ability and students' achievement due to study year. However, there are more research works on spatial visualisation ability in countries outside Nigeria. Also, the extent, to which spatial visualisation ability influences Nigerian senior school students' achievement in physics, is yet to be fully explored. In addition, it was observed, that many of the studies were focused mostly on subjects, such as psychology, engineering and mathematics. Based on these facts, the present study investigated spatial visualisation ability as correlate of senior school students' achievement in physics in Sokoto State, Nigeria.

3. The aim and objectives of the study

The main purpose of this study was to investigate spatial visualisation ability as correlate of senior school students' achievement in physics in Sokoto State, Nigeria.

To achieve the goal, the following tasks were set:

1. to find out the relationship between students' spatial visualisation ability and their achievement in physics;
2. if the relationship between students' spatial visualisation ability and their achievement in physics is based on gender; and
3. if the relationship between students' spatial visualisation ability and their achievement in physics is based on school type

4. Materials and Methods

4. 1. Research Hypotheses

The following null hypotheses were formulated and tested in this study at .05 level of significance.

H_{01}: There is no significant relationship between students' spatial visualisation ability and their achievement in physics.

H_{02}: There is no significant relationship between students' spatial visualisation ability and their achievement in physics based on gender

H_{03}: There is no significant relationship between students' spatial visualisation ability and their achievement in physics based on school type.

4.2. Research Design

This research adopted *ex post facto* research of co-relational type because it is concerned with determining or measuring the degree of relationship between two or more variables for the purpose of making predictions about relationships. The justification for adopting *ex post facto* research was that the researcher had no direct control on the independent variables, so testing of the relationship between independent and dependent variables was observed. In this study, students' spatial visualisation ability was the independent variable, while students' achievement in physics was the dependent variable. Students' gender and school type were taken as moderating variables.

4. 3. Population, Sample, and Sampling Techniques

The population, covered by this study, was all Senior Secondary School students (45,991), offered physics in Sokoto State, Nigeria. The target population for the study was the entire Senior Secondary School two Students (SS II), offered physics in both public and private schools. The sample for this study was seven hundred and thirty-one (731) Senior Secondary School two Students (SS II), offered physics, proportionately selected using Research Advisors (2006) from Senior Secondary Schools across the three senatorial districts in Sokoto State, Nigeria.

Proportional sampling technique was used in selecting the participating schools across the three districts in accordance with the students' population in each of the selected schools based on school type (public /private schools). Fifty (50 i.e. SN=15, SC=18, SS=17) schools with qualified physics teachers that have been presenting candidates for Senior School Certificate Examinations (SSCE) for at least ten years, and not situated close to one another, were selected from the 272 schools in Sokoto State.

This study involved SS II students because they have been taught greater part of the SSCE physics syllabus and are matured enough for the variables, considered in this study, unlike SS I students that are still new in the system and SS III who are preparing for their external examinations.

4. 4. Research Instruments

Two instruments were employed in this study namely; Students' Spatial visualisation Ability Test (SSAT), and Physics Achievement Test (PAT).

Students' Spatial Ability Test (SSAT) was adapted from Mall (2012) "AFCAT Spatial Ability Test". The items were modified and re-arranged to meet the need of this study. SSAT was divided into two sections, namely; shape comparison test and surface development test. Each of these sections has four questions, totalling eight questions for students to respond to. Each correct answer was scored as one (1) mark.

The second instrument, Physics Achievement Test (PAT) was a researcher- designed test with items, structured to test students' knowledge, comprehension and application based on Bloom's taxonomy of educational objectives. These test consisted of 25 structured multiple choice questions on Physics topics. The content of the test was drawn in line with performance objectives, stated in the SSS Physics curriculum, after which the researcher conducted a visibility study to ascertain the level of coverage of the curriculum. The responses, retrieved from the sample schools, helped the researcher in developing the PAT. Each question has a maximum score of one (1) mark.

It is of worthy note, that students' names did not appear on any of the test pages or answer booklets. Students' participation was voluntary and their freedom to pull out of the research process at any stage was accommodated.

4. 5. Validation of Research Instrument

The face and content validity of the instruments were established by giving the instruments to three (3) experts in science education, and two (2) practicing physics teachers in Senior Secondary Schools in Sokoto to check and make necessary adjustment if the instruments fell within the subjects' (respondents') area of coverage. They also checked if the instruments aligned with the objectives of the study.

Consequently, the item analysis of PAT was conducted, where the difficulty and discrimination indices were calculated for items in the multiple choices. This was to ensure that these items were not too difficult or too easy and spread across different knowledge levels of the students. The initial drafts of 30 items were administered to SSII students in a non-participating school in Sokoto. However, 5 items were discarded because the difficulty indices were below 0.5. Thus, the final draft comprised 25 multiple choice items.

Also, in order to ascertain the reliability of SSAT, the instrument was trial tested with a sample of 30 non-participating SSII students in Sokoto. The resulting data from SSAT were analysed using the Cronbach's alpha. The reliability coefficients of SSAT were 0.79. Hence, the instruments were adjudged to be reliable.

4. 6. Procedure for Data Collection

A letter of introduction was collected from the Head of the Department of Science Education, University of Ilorin, Ilorin, Nigeria, by the researcher and presented to the principals of the sampled schools. This was to seek their permissions and consents to involve their schools, teachers and allow their students to take part in the study. The researcher interacted with the physics teachers, enlightened and acquainted them with the nature of the study, and formally sought their consents through the informed consent forms to serve as research assistants for the study.

Each student participant was given a copy of the consent form to sign, and their individual parents were to endorse their consent form so as to get their willingness to participate in the study or otherwise. This was done with the help of the physics teachers in the selected schools. The researcher employed the service of the physics teachers in the selected schools in order to enhance the administration of the research instruments. Students Spatial Ability Test (SSAT) and Physics Achievement Test (PAT) were administered to the students, which lasted for 50 minutes. The administered instruments were retrieved from the respondents for scoring and analysis.

Students' participation was voluntary and they were not exposed to any unfavourable conditions. The identity of the selected schools and participants were not disclosed at any point in this study. All gathered data were handled with utmost confidentiality and used exclusively for the purpose of this study. To avoid plagiarism, the researcher ensured that all citations were properly referenced in this study.

4. 7. Data Analysis Techniques

The data, collected from the field, were subjected to appropriate statistical techniques in order to test the formulated hypotheses. Hypotheses 1 were tested using Pearson Product Moment Correlation Coefficients (r). Hypotheses 2 and 3 were tested using the Fisher-*z* transformation (*Z*-test) statistic with the aid of IBM SPSS Statistical package (version 23). Appropriate recommendations were made and relevant conclusion was drawn based on the findings of the study.

5. Results

5. 1. Test of Hypotheses

Result on hypothesis 1

$H0_1$: There is no significant relationship between students' spatial visualisation ability and their achievement in physics.

From Table 1, the result of Pearson Product Moment Correlation (PPMC) shows that there was a positive correlation (r=0.32, p<0.05, df=729) between students' spatial visualisation ability and achievement in physics with p-value less than 0.05(0.00) significance level; thus, hypothesis 1 was rejected. This implies that the relationship between students' spatial visualisation ability and achievement in physics was weak; hence, having a positive impact in their achievement is largely minimal.

Table 1

PPMC Analysis of the Relationship between Students' Spatial Visualisation Ability and their Achievement in Physics

Variable	N	Mean	Std	*df*	*R*	*p*-value	Decision
Spatial Visualisation Ability	731	56.87	19.60	729	0.32	0.00	Rejected
Achievement in Physics	731	41.77	19.56				

Note: p<0.05

Result on hypothesis 2

$H0_2$: There is no significant relationship between students' spatial visualisation ability and their achievement in physics based on gender. From Table 2, after subjecting students' gender to *Z*-test to determine if truly there was a significant difference in the relationship between spatial visualisation ability and achievement in physics, the result shows that there was a statistically significant difference in the strength of the relationship between spatial visualisation ability and achievement in physics in favour of females with a higher correlation (r=0.40) compared with that of males with correlation (r=0.27) as the Z_{obs} – value (–2.01) is outside –1.96 and +1.96 boundary. Therefore hypothesis 2 was rejected. This implies that despite the relationship that existed between spatial ability and achievement in physics as observed in hypothesis 1 results, female students still perform better than their male counterparts.

Table 2

Z-test Analysis of the Relationship between Students' Spatial Visualisation Ability and their Achievement in Physics based on Gender

Variable	N	*df*	r_{scores}	z_{scores}	z_{obs}	Sig.	Decision
Male					-2.01	Sig.	Rejected
Spatial Ability	449	447	0.27	0.28			
Achievement in Physics	449						
Female							
Spatial Ability	282	280	0.40	0.43			
Achievement in Physics	282						

Note: $z_{obs}>\pm1.96$

Result on hypothesis 3

H0₃: There is no significant relationship between students' spatial visualisation ability and their achievement in physics based on school type.

From Table 3, having subjected students' school type to Z-test to determine if truly there was a significant difference in the relationship between spatial visualisation ability and achievement in physics, the result shows that there was a statistically significant difference in the strength of the correlation between spatial visualisation ability and their achievement in physics in favour of private schools with a higher correlation (r=0.50) compared with that of public schools with correlation (r=0.14) as the Z_{obs} – value (-5.08) is outside -1.96 and +1.96 boundary. Hence hypothesis 3 was rejected. This implies that private school students perform better than their public school counterparts.

Table 3

Z-test Analysis of the Relationship between Students' Spatial Visualisation Ability and their Achievement in Physics Based on School Type

Variable	N	*df*	r_{scores}	z_{scores}	z_{obs}	Sig.	Decision
Public					–5.08	Sig.	Rejected
Spatial Ability	478	476	0.14	0.15			
Achievement in Physics	478						
Private							
Spatial Ability	253	251	0.50	0.54			
Achievement in Physics	253						

Note: $z_{obs}>\pm1.96$

6. Discussion

This study found that students' spatial visualisation ability significantly predicted their achievement in physics. Thus, hypothesis 1 was rejected. The relationship between students' spatial visualisation ability and their achievement in physics was weak; hence, its positive impact on their achievement is minimal. This finding may be due to the nature of physics, which includes making meaning or interpretation of a diagram, which involves spatial visualisation ability. Also, the prediction may be as a result of the instrument employed, which can be adduced to an aspect of intelligence testing (crystallised intelligence). The students also see & visualize the objects of instruction clearly. This finding corresponds with the findings of [19] and [17] that students' spatial visualisation ability significantly predicted their achievement in physics. Contrarily, [23] reported no differences in achievement on the test of spatial ability due to study years.

From the demography of respondents, more male students participated in the study than female students. However, this study found that the female students outperformed the male students. The corresponding hypothesis confirmed the influence of gender on the relationship between students' spatial visualisation ability and their achievement in physics, which showed that there was a statistically significant difference in the strength of the correlation between students' spatial visualisation ability and their achievement in physics in favour of female students with a higher correlation compared with their male counterparts with a low correlation. Therefore, hypothesis 2 was rejected. This may hold for the sample of respondents and have likelihood of been debunked with a different sample. Also, literature in this area reported no significant difference in the achievement of male and female study on spatial ability and achievement in physics. The study of [22, 17], and [21] found gender as a significant variable with respect to the difference in the spatial ability between male and female students with males attaining differential improvement gains as opposed to females. Contrarily, [19] reported no statistical differences between the achievement of boys and girls across the respective test construct (students' spatial visualisation, mental rotation and spatial orientation).

Also, the analysis of school type influence on the relationship between students' spatial visualisation ability and their achievement in physics showed that there was a statistically significant difference in the strength of the correlation between students' spatial visualisation ability and their achievement in physics in favour of private schools with a higher correlation compared with that of public schools with a low correlation. Hence hypothesis 3 was rejected. This difference may be due to the better learning environment, with adequate instructional resources, with remedial coaching and better students' background, which are characteristics that favoured private schools than public schools in the study area. This finding was supported by [25] and [17] who reported that school type significantly influences the prediction of relationship between students' spatial visualisation ability and their achievement in physics. Contrarily, [24] reported no significant difference in the performance of public and private school students.

Limitations of the study. The study was limited to only Sokoto State because no evidence of studies on spatial ability as correlate of senior school students' achievement in physics in the area was documented. This study was limited to 50 selected senior secondary schools from all the senatorial districts of Sokoto North, Sokoto Central, and Sokoto South. Senior Secondary School two (SSS II) students from both private and public schools formed the sample for this study.

Prospects for further research. A similar study may be conducted in other science subjects, such as biology, chemistry and mathematics to ascertain the potency of the variable considered in this study and can also be replicated in both public and private schools in other states in Nigeria and outside Nigeria.

7. Conclusion

1. There was a positive relationship (r=0.32, p<0.05, df=729) between students' spatial ability and their achievement in physics with p-value less than .05 (.00), significance level. Thus, hypothesis 1 was rejected.

2. Gender significantly influences the relationship between students' spatial ability and their achievement in physics. Thus, hypothesis 2 was rejected. This is evident as the Z_{obs} – value (–2.01) is outside –1.96 and +1.96 boundary.

3. There was a statistically significant difference in the strength of the relationship between students' spatial ability and their achievement in physics based on school type in favour of private schools with a higher correlation (r=0.49) compared with that of public schools with correlation (r=0.143) as the Z_{obs} – value (–5.08) is outside –1.96 and +1.96 boundary. Hence, hypothesis 3 was rejected.

Recommendations:

1. Students' should be trained to develop their spatial visualisation ability as it helps to improve their achievement in physics.

2. Physics teachers should encourage both male and female students to participate actively in classroom instruction in order to improve their performance in physics and other Science subjects.

3. Parents, government at all levels and non-governmental organisations should as a matter of urgency provide necessary educational demands, such as payment of school fees and levies, buying of relevant textbooks and other required items. All these should be made available for each student so as to motivate them in order to study harder.

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