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Pedagogical Implication of Spatial Visualization Ability: A Correlate of Students' Achievements in Physics

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ABSTRACT
This study investigated pedagogical implication of spatial visualization as correlate of students' achievement in physics. Ex post facto research of the co-relational type with 857 senior secondary school three (S. S. 3) participants comprising of male and female students from both public and private-schools from Kwara State, Nigeria. Four research questions with corresponding hypotheses were raised and answered in this study. Pro forma of physics result of respondents at WASSCE formed the achievement component of the data analysed. Students' Spatial Visualization Test (SSVT) had reliability index of .78 with 30 minutes duration of administration as the other instrument. Pearson's Product Moment Correlation (PPMC) and Multivariate Analysis of Variance (MANOVA) were statistical tools employed to analyze data that answered the research hypotheses. Spatial visualization ability is a correlate of students' achievement in physics in this study. Score levels and gender were found to influence the prediction between spatial visualization ability and physics achievement. Furthermore, school type influenced the prediction between spatial visualization ability and students' achievement in physics in favour of the private-schools that participated in this study. The pedagogical implication of this pattern is that, students trained in spatial ability own the possibility of better achievement in STEM fields as identified in the literature and this study. Among others, this study recommends that spatial visualization tests should be embedded in the pedagogical approach of physics teaching and learning to foster achievement in physics and STEM-related fields.

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Introduction

The knowledge a teacher acquires in training is distinct, professional and transferable. The transfer component of the knowledge acquired requires systemic breakdown to accommodate learners of all kinds during teaching. In this instance, the practical experience of the teacher comes into play in improving each learner irrespective of their differences. The ability to achieve the objectives of a lesson with all learners requires pedagogical rigour. Knowing what to teach and having experiential competence to teach it across to students with different abilities is a component of pedagogy.

Pedagogy may be referred to as the art of teaching which aims at bringing about characteristic societal impact through systemic delivery of learning and practice. Pedagogy is the science of imparting knowledge. Pedagogy has its application in science and science education. For there to be meaningful science teaching, there is the need to pre-plan logical means of subject delivery to meet the primary objective of a lesson and beyond. Pedagogy in science education should foster explicit delivery of science teaching, explain the way teaching approaches can have direct implications on students' learning, expose the knowledge of science to learners in a qualitative manner and gain encompassing, consistent and quality experience (Koç & Büyük, 2021; Kumar & Refaei, 2017)

Science, Technology, Engineering and mathematics (STEM) education is an important component of national development. The role it plays in the socio-economics advancement of nations is immeasurable. Numerous reasons may be attributed to the challenges encountered in science education. Although, the list of possible challenges ranges from unqualified practising teachers, poor approaches to teaching, budgetary allocation for education, unfriendly state of classrooms and laboratories to mention a few of numerous but surmountable challenges. The implication of poor implementation of educational policies brings about haphazard development, leading to underdevelopment. Sustainable science education could be catalytic to social and public awareness of values, behaviour and lifestyles required for a sustainable future. Spatial development has been reported to improve students in science, STEM-related fields. Spatial ability in students can be developed through training that is targeted to examine specific aspects of STEM education (Sorby et al., 2018; Stieff & Uttal, 2015).

There are three core components of science at the secondary level of education in Nigeria, Physics, Chemistry and Biology. Despite the importance of Physics in present-day careers, students' low enrolment and poor performance in physics is indicative of a serious variance between the expectations of the Nigerian government as spelt out in the National Policy on Education (Federal Republic of Nigeria, 2013) and the actual state of physics education in schools. The teaching and learning strategies need a significant review. Understanding the various components and contributors to students' achievement is imperative for improvement and policy direction. Spatial visualization has been identified as a contributor to achievement in mathematics, architecture and other subjects and disciplines alike.

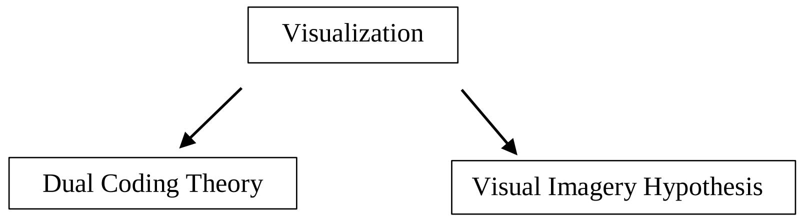
Visualization is the formation of mental images or the act or process of interpreting in visual terms or of putting them into visible form. Visual literacy refers to the ability to recognize and understand ideas conveyed through visible actions or images. Spatial visualization may be described as a basic skill for understanding and developing primary mathematical skills and a gateway to superior problem-solving abilities in science. The process of identifying, manipulating and deducing from spatial elements of objects and the spatial components among objects/diagrams is referred to as spatial ability (Joori & Ji, 2020; Mulligan, 2015; Reilly, Neumann & Andrew, 2016).

Visualization in science education can be explained from two distinct perspectives: Dual-Coding Theory (DCT) and Visual Imagery Hypothesis (VIH) (see Fig. 1). The differences in these two perspectives lie in the function of or purpose for visualization. DCT focuses on visualization as a means for understanding how verbal information (words and sentences) and visual information (images) are encoded by two independent mental systems, a verbal one and a nonverbal one. Similarly, the combination of verbal information and visual information provides dual support for learning and knowledge acquisition (Cuevas, 2016). DCT provides important insights into how visual perception affects memory and how visualization can be used to enhance learning and understanding (Luo, 2019; Paivio, 2014).

VIH focuses on visualizing objects or graphical information which allows them to be processed more efficiently than the verbal one and in all reduce the demand on working memory (Csíkos & Kárpáti, 2018). VIH underscores several important functions of visualization objects, such as organizing and highlighting key concepts, making information accessible for manipulation and comparison in order to generate inferences to solve problems, and identifying logical and complex interconnections and relationships (Csíkos & Kárpáti, 2018; Paivio, 2014). Basically, VIH provides the necessary information and concepts that facilitates the application of knowledge and skills for solving problems.

Figure 1

Division of Visualization



Note. Adapted from Luo, 2019 and Paivio, 2014

Furthermore, spatial orientation and spatial visualization are used interchangeably. Spatial orientation describes the measure of the ability to remain unconfused by changes in the orientation of visual stimuli and involves only a mental rotation of configuration. Spatial visualization measures the ability to mentally restructure or manipulate the components of the visual stimulus and involves recognizing, retaining and recalling configurations when the figure or parts of the figure are moved (Joori & Ji, 2020; Ramful & Lowrie, 2015). For this study, spatial visualization is more appropriate as visual orientation is not adequate at senior school three to assess the required cognitive development.

Over the years, the debates on the importance of spatial visualization and thinking processes in science had ensued, though unsurprising, spatial ability relates to life and academic success in science. Longitudinal studies of intellectually talented students indicate that spatial ability accounts for a statistically significant proportion of the variance among science and technology students, over and above Scholastic Aptitude Test (SAT) Mathematical and SAT Verbal scales (Ramful et al., 2017; Ramful & Lowrie, 2015). The application of spatial visualization is most evident in the field of architecture, engineering, physics and mathematics.

The performance level is important in academics. It forms the basis upon which students are graded which thereafter cumulates to their achievement. Basically, students are grouped/categorized as high, medium and low scorers having met a certain benchmark based on certain criteria accounting for such student's achievement in prescribed test or examination. Performance level describes the range of marks obtained by students after being subjected to a test or tests which qualifies them into the three aforementioned groups (high, medium and low performer). In some instances, the high performers may be those students who scored between 70% - 100% on Achievement Test. The medium performers may be students who scored between 50% - 69% while low performers may be students who scored between 0% and 49% depending on the rating scale. Evidently, students are not the same especially when we find out the rate at which facts and principles in sciences are being assimilated. This may explain the disparity in students' abilities to perform specific tasks and expose gender disparity with regards to performance.

Gender as a psychological construct has been used to describe maleness and femaleness. Gender describes the behaviour and attitude expected of an individual on the basis of being born either male or female. Evidence has shown that studies on gender as a factor in STEM achievement have focused mainly on variables such as gender stereotype in training and assessment, and that very few studies have investigated how gender interacts with the spatial ability of students and their achievement (Ramful & Lowrie, 2015; Sorby et al., 2018).

Maeda and Yoon (2013) posited that gender differences in the achievements of students (boys and girls) in STEM and by extension spatial ability show a line of difference in favour of male and female at another instance. Similarly, female students' attitude towards spatial ability and STEM is more positive than the male students as reported. Although, female students have had strides in law, medicine and social science professions, very few can be found in graduate programs or professions in mathematics, physics, engineering, or information technology jobs (Reilly et al., 2017; Sharobeam, 2016). Gender and school type are moderator variable that permeate the parlance of STEM research in developing countries across the world.

The trend in Nigeria's public and private-schools with regards to science equipment, enabling environment and standard practices remains paramount, especially in physics teaching. Researchers have established diverse views regarding school type, while some reported significant difference in respect of performance, others have posited differently. School type has both direct and indirect causal linkages on students' achievement in physics. The majority of the parents believed that public-schools do not provide a safe, orderly environment and teaching of the basics while private-schools have higher academic standards, secure and conducive environment and the likelihood to encourage honesty and sense of responsibility. Noticeably, public-school students attend additional coaching classes while others just play out and about, or go to after school programs which is often not the case with private-school students (Ariyo & Ibeagha, 2011).

Jolly et al., (2012) posited that the sharp decline in academic achievement at various levels of educational system in Nigeria is largely attributed to the poor conditions in educational institutions which are more pronounced in public-schools. Lack of modern instructional technology, poor classroom conditions and lack of adequate training programs for teachers are frequent characteristics found in most public-schools. The type of schools, (single-sex or mixed, private or public) has an effect on the academic performance of students (Bicer et al., 2018).

Holding demographic factors constant, public-schools perform just, as well, if not better than private-schools in STEM-related subjects. Noteworthy is the fact that the characteristics associated with private-schools are not exclusive, rather, public-school with similar characteristics exist. School types differ from country to country as education policy may also differ. The report of significant difference existing in STEM-related achievement of public and private-school pupils in which private-school pupils performed better than public-school counterparts and vice versa in STEM has been substantiated (Bicer et al., 2018; McCunn & Cilli-Turner, 2020; Yoon & Min, 2016).

This study seeks to add to the body of literature spatial ability and students' achievement in STEM-related subjects. Provide empirical evidence of spatial visualization ability on students' achievement in physics. Unlike several studies reviewed, this study delves into the visualization aspect of the spatial ability which is evident in the instrument. This study is unique in terms of locale, methodology, approach and moderator variables examined. No study among the reviewed works had the rudimentary attributes of this study. -Specifically, physics remains one of the fields which requires deductions from diagrams, diagrammatic representation of statements among others. As such, it is imperative to examine the correlation between spatial visualization ability and physics achievement.

Literature Review

McCunn and Cilli-Turner (2020) in a study titled spatial training and calculus ability: investigating impacts on student performance and cognitive style. The study builds which was founded on trends showing malleability in spatial ability by investigating improvement in students' spatial and mathematics ability after implementing spatial training in calculus courses. The researchers measured associations between spatial training and self-reported cognitive style. The study found no significant improvement in students in calculus and spatial skills after undergoing spatial training. Also, the impact of a psychological correlate of cognitive learning style was studied as the researchers considered it an important non-spatial cognitive preference. The instrument comprised dynamic information encapsulated in graphical images which were not recognized by respondents in the study. The study concluded that spatial training and calculus ability may help to narrow the gender gap in STEM fields.

Lowrie et al., (2019) researched the influence of spatial visualization training on students' spatial reasoning and mathematics performance. The study examined the effectiveness of spatial visualization intervention on student spatial reasoning and mathematics performance. A total of 327 students from 17 classrooms across schools with nine experimental and eight control from 10 classes took part in the study. The treatment lasted for a three-week period by classroom teachers, while the control classes received standard mathematics instruction. The intervention group improved significantly on their spatial reasoning performance, and specifically on spatial visualization and spatial orientation. The treatment group also significantly improved on their mathematics test performance, with those in the treatment group outperforming their counterparts in the control group on geometry and word problems but not on mathematics questions requiring the decoding of graphics (non-geometry graphics tasks). Evidence from the study, spatial visualization program implemented by teachers enhanced both spatial reasoning and mathematics performance of respondents.

Gender difference permeates spatial ability among research in fields of psychology as well as education. Differences have been established in the spatial ability of both male and female learners. A test of spatial ability was administered to over 3000 hundred level engineering students for a period of five years with students divided into experimental and control groups on the basis of their test score in spatial ability. Low spatial ability students in the study were assigned to offer a remedial 1-credit course over one semester. Students with moderate and high belonged to the control group in the study. Regression analysis of discontinuity was employed to determine the effectiveness of the intervention over the said period. The experimental group had improved performance in Engineering problem-solving and overall improvement in STEM-related courses. The improvement experienced was due to the discontinuity of the cutoff score. It can be deduced from the study that the experimental group out-performed their expected outcome if they had not taken part in the intervention course. An examination of retention over the same period yielded positive, especially for female students in engineering courses. The study recommended that spatial ability should be a component of instruction to improve gender diversity in STEM-related fields (Sorby et al., 2018)

Yurt and Tünkler (2016) investigated the spatial abilities of prospective teachers in mixed research comprising of 234 prospective teachers. Respondents were attendees of Social Studies Teaching departments at Education Faculties of two universities in Central and Southern Anatolia. A two-stage research design was employed with causal-comparative design and descriptive survey. Data collected from the "Mental Rotation Test" and "Surface Development Test" were analyzed using descriptive statistics, MANOVA and ANOVA. The second phase involved a questionnaire "Opinion Form for Spatial Ability Tests" with 37 prospective teachers (Female:20, Male:17) identified via purposive sampling method. The qualitative data obtained were analyzed using the content analysis technique. The study found that spatial visualization and mental rotation abilities of the respondents were low with male prospective teachers having better results than their female counterparts in mental rotation but gender did not influence spatial ability. Furthermore, prospective teachers with higher academic averages had the highest spatial abilities in the study.

Yarden and Yarden (2010) compared the comprehension of the polymerase chain reaction (PCR) by Grade 12 students using animations as aid with that of students using still images. The finding was that PCR animations showed a distinct advantage over still images for student learning. However, the researchers caution that although the animation was effective for demonstrations of molecular phenomena, the results may not generalize to other physical phenomena, such as motion and others.

Abu-Mustafa (2010) researched 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 sampled students in 6 classes of sixth grade (228 students) with three female and three male classes. The study employed the spatial orientation Test-Card Rotation-by Whitley Test. The results informed a positive correlation between mathematics achievement and students' 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 genders. In addition, the results showed that high achievers possess high spatial abilities compared to their average and low achieving counterparts.

Furthermore, Meyer et al., (2010) researched the differential contribution of a particular working memory component to the mathematical achievement of 98 students enrolled in the San Francisco Bay Area. The study sample was required to take Intelligence Quotient (IQ) assessments through the Wechsler Abbreviated Scale of Intelligence. The results showed that spatial visualization component was a predictor of mathematical reasoning and numerical operations skills.

A tenable position among scholars is the need to improve students' performance in physics. The teaching and learning of physics are however not perfect. As such, students centred approaches in learning have been encouraged. Spatial training has been reported to be malleable and possesses the ability to improve students' achievement in STEM-related fields, physics inclusive. West African Examinations Council (WAEC) Chief Examiners' Reports (CER) of Physics exposed students' inadequacy in effectively handling scale drawing problems (WAEC, 2019, 2015), students' inability to interpret graphical representation of physical quantities (WAEC, 2018, 2017, 2014), students' carelessness in symbol identification and inability to interpret statements in workable diagrams (WAEC, 2018, 2013) and students' inability to plot graphs correctly (WAEC, 2019, 2017). The identified areas of students' weaknesses vis a vis drawing, symbols, diagrams, images and the ability to make sense (induce), elicit (deduce) and interpret the afore-listed relates to student spatial visualization ability. Concepts such as a circuit diagram in electricity, velocity-time graph in motion, vector among a few, requires a great deal of spatial visualization ability (McCunn & Cilli-Turner, 2020; Lowrie et al., 2019).

To resolve the problems identified by the WEAC, the relevance of pedagogy in the teaching of physics remains valid to date. Categorization of students with respect to performance and what culminates into how well they perform remain valid in the literature. Spatial visualization as established in the literature reviewed in this study correlates with students' performance. While spatial visualization tests are a significant component of intelligence measurement across the world, their direct application and implication in the physics classroom at the moment leaves a gap that requires answers. Noticeable in the literature reviewed is the empirical gap, locale-centric presentation of empirical data. The need to permeate predictively the relationship between students' spatial ability and achievement in physics informed this study. The focus is to examine the predictive relationship between spatial visualization and students' achievement in physics with a view to integrating its pedagogy in physics teaching, training and development for STEM-related tertiary education opportunities. Therefore, this study investigated the pedagogical implication of spatial visualization as a correlate of students' achievements in Physics.

Research Questions

The following research questions were raised in this study;

1. Do students' spatial visualization ability predict their achievement in physics?
2. Is the prediction between students' spatial visualization and their achievement in physics based on score level?
3. Will the prediction between students' spatial visualization and their achievement in physics be based on gender?
4. What influence will school type have on the prediction between students' spatial visualization ability and their achievement in physics?

Research Hypotheses

H0$_1$: There is no significant difference in students' spatial visualization ability and their achievement in physics.

H0$_2$: Score level will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

H0$_3$: Gender will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

H0$_4$: School type will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

Methods

This study is co-relational ex post facto research. the ex-post facto research type was considered appropriate for this study because the subjects were not randomly assigned, rather, are purposively selected based on peculiar characteristics or traits. The researcher had no direct control over the dependent variable, testing for the relationship with independent variables was observed.

The population for this study were students from senior secondary schools in Kwara State, Nigeria. The target population consists of Senior school III (SS 3) students with an age range between 15-17 years. The initial sample for this study was sixteen (eight public and eight private) senior secondary schools per senatorial district in Kwara state, Nigeria. Two issues arose which affected the initial intent of this study. The first was the uneven distribution of public-schools that met the criteria for this study in Kwara State. Secondly, the willingness of the schools to participate and also make available West Africa Senior School Certificate Examination (WASSCE) results of the students.

The WASSCE is an examination conducted by the WAEC. This council conducts examinations across 5 West African countries at the same time and with the same curriculum, namely; Ghana, Nigeria, Sierra Leone, Gambia and Liberia. WAEC was established in 1952 with its regional headquarter in Accra, Ghana. In this study, the results of students in physics subject in WASSCE is termed physics achievement. This examination has a basis for comparison as all students across the 5 countries sit for the same examination. WAEC examinations are standardized, reliable and valid in most countries of the world. Subjects offered and passed at credit level serves as an entry requirement for tertiary education in various universities across the world.

The choice of S. S. 3 students was informed because they have undergone a greater part of the SSCE physics syllabus and have the content maturity for the variables considered in this study. The purposive sampling technique was employed in the selection of senior secondary schools that met the criteria enumerated in this study. A total of twenty-two (22) senior secondary schools participated in this study from all the three senatorial districts while 875 students took part in the study. Intact classes of the selected schools were involved in the study. In identifying eligible schools for this study, the researcher took into cognizance the following factors: participating schools must have been in existence for not less than ten years; participating schools must have at least ten physics students in SS III and at least three female students in the same class; participating schools must have at least a qualified physics teacher; participating schools must be willing to provide SSCE pro forma of students in physics, participating students must have promoted from SS II to SS III in the same school.

The total mark obtainable from the ten questions = 50marks

A pilot study was conducted in two senior secondary schools (one public and one private) outside the scope of the study to test the reliability of the instruments. A test-retest method was employed in administering SSVT with an interval of two weeks. Pearson's product-moment correlation statistical tool was employed to compute the reliability indexes which was .78 and .71 respectively. The pro forma Physics result of students in WASSCE requires no validation. The SSVT is a 2D item that was printed on plain sheets of paper and administered to students. It should be noted that most public-schools participating in this study do not have an adequate number of computer devices and a consistent power supply, hence the printing of the items.

The Pearson product-moment correlation coefficient (or Pearson correlation coefficient) was employed in this study to measure the strength of a linear association between students' achievement scores in physics and spatial visualization ability among respondents. In application, Pearson product-moment correlation in this study drew a line of best fit through the data of physics achievement and students' spatial visualization ability. Pearson correlation coefficient, *r*, was employed to check the delineation of these data points to ascertain the line of best fit.

Ethical Issue

A letter of introduction was obtained by the researcher from the Head of Department of Science Education, the University of Ilorin to principals of the selected secondary schools. Then, consent of physics teachers, parents and students in the schools participating in the study was sought before the administration of the instrument. See appendixes for consent forms.

Results

Table 1 presents the demography of participants. A total of 857 students participated in the study, 428 students representing (49.9%) were male students, while 429 students representing (50.1%) were female students. Furthermore, 531 students representing (62.0%) were from public secondary schools, while 326 students representing (38.0%) were from private-schools.

Table 1

Distribution of Sudents by Gender and School Type

Variables	Frequency	Percentage (%)
Gender		
Male	428	49.9
Female	429	50.1
Total	857	100.0
School Type		
Public	531	62.0
Private	326	38.0
Total	857	100.0

H_{01}**:** Spatial visualization ability will not significantly predict students achievement in physics.

To test hypothesis one, participants' scores on the Spatial Visualization test and WASSCE result of students in Physics were correlated as shown in Table 2.

Table 2

PPMC Analysis of the Prediction on Students' Spatial Visualization and their Achievement in Physics.

Variable	No	Mean	Std	df	Cal.r	Sig.(2-tailed)	Decision
Students' Spatial Visualization	857	34.34	13.33	855	.09	.01	H_{01} Rejected
Achievement Physics	857	64.01	10.87				

Note: $\varrho < 0.05$

The calculated r-value was .09, calculated significance value is .01 and df of 2/855 at the alpha level of .05. Consequently, null hypothesis one was rejected. This means that students' Spatial Visualization Ability significantly predicted their achievement in Physics. The reason was that the calculated significance value (.01) was less than the .05 alpha level ($\varrho < .05$). Physics achievement has a mean score of 64.01 greater than the mean score of 34.34 of students' spatial visualization.

H_{02}: Score level will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

Table 3

Multivariate Analysis of Score Level Prediction of Students' Spatial Visualization and their Achievement in Physics

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.982	22853.666^{b}	2.000	853.000	.000
	Wilks' Lambda	.018	22853.666^{b}	2.000	853.000	.000
	Hotelling's Trace	53.584	22853.666^{b}	2.000	853.000	.000
	Roy's Largest Root	53.584	22853.666^{b}	2.000	853.000	.000
School Type	Pillai's Trace	.707	233.490^{b}	4.000	1708.000	.000
	Wilks' Lambda	.295	358.989^{b}	4.000	1706.000	.000
	Hotelling's Trace	2.386	508.144^{b}	4.000	1704.000	.000
	Roy's Largest Root	2.383	1017.554^{b}	2.000	854.000	.000

Note. a. Design: Intercept + Score Level; b. Exact statistic; c. Computed using alpha = .05

Table 3 shows that score level significantly influenced the prediction between students' spatial visualization and their achievement in Physics. This is evident from the F-calculated value of 22853.666 and p-value of .00 for score level which is less than .05 level of significance (.00 < .05). Since the p-value is lower than .05 level of significance, the null hypothesis is rejected. The translation is that score level significantly influenced the prediction between students' spatial visualization and their achievement in Physics.

Table 4

Tests of Between-Subjects Effects (Differences)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Spatial Visualization	1255.250^{a}	2	627.625	3.555	.029
	Physics	71209.066^{b}	2	35604.533	1017.519	.000
Intercept	Spatial Visualization	475403.658	1	475403.658	2692.750	.000

	Physics	1544070.827	1	1544070.827	44126.989	.000
Score Level	Spatial Visualization	1255.250	2	627.625	3.555	.029
	Physics	71209.066	2	35604.533	1017.519	.000

Table 4 shows that score level significantly influenced the prediction between students' spatial visualization and physics achievement. This is evident in the F-calculated value of 3.555 and p-value of .029 for spatial visualization and 1017.519 and p-value of .000 for achievement in Physics respectively. However, the difference lies most with the high scorers and the least with low scorers.

H_{O3}: Gender will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

Table 5

Multivariate Analysis of Gender Prediction on Students' Spatial Visualization and their Achievement in Physics

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.975	16963.770[b]	2.000	854.000	.000
	Wilks' Lambda	.025	16963.770[b]	2.000	854.000	.000
	Hotelling's Trace	39.728	16963.770[b]	2.000	854.000	.000
	Roy's Largest Root	39.728	16963.770[b]	2.000	854.000	.000
Gender	Pillai's Trace	.032	14.012[b]	2.000	854.000	.000
	Wilks' Lambda	.968	14.012[b]	2.000	854.000	.000
	Hotelling's Trace	.033	14.012[b]	2.000	854.000	.000
	Roy's Largest Root	.033	14.012[b]	2.000	854.000	.000

Note. a. Design: Intercept + Gender; b. Exact statistic; c. Computed using alpha = .05

Hypothesis 3, sought the significance between spatial visualization test and WASSCE result (Physics Achievement) of students based on gender. Table 5 revealed that gender significantly influenced the prediction between students' spatial visualization and their achievement in Physics. This is evident from the F-calculated value of 14.012 and p-value of .00 for score level which is less than the .05 level of significance (.00 < .05). Since the p-value is lower than the .05 level of significance, the null hypothesis is rejected. In essence, gender significantly influenced the prediction between students' spatial visualization and their achievement in Physics.

Table 6

Tests of Between-Subjects Effects (Differences)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Spatial Visualization	3681.903[a]	1	3681.903	21.221	.000
	Physics	1031.071[b]	1	1031.071	8.810	.003
Intercept	Spatial Visualization	1010788.479	1	1010788.479	5825.709	.000
	Physics	3511943.817	1	3511943.817	30008.886	.000
Gender	Spatial Visualization	3681.903	1	3681.903	21.221	.000
	Physics	1031.071	1	1031.071	8.810	.003

Table 6 shows that gender significantly influenced the prediction between students' spatial visualization and physics achievement in favour of male students. This is evident in the F-calculated value of 221.221 and p-value of .00 for spatial visualization and 8.81 and p-value of .003 for Physics achievement respectively.

H_{O4}: School type will not significantly influence the prediction between students' spatial visualization ability and their achievement in physics.

Table 7

Multivariate Analysis of School Type Prediction on Students' Spatial Visualization and their Achievement in Physics

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.975	16467.541[b]	2.000	854.000	.000
	Wilks' Lambda	.025	16467.541[b]	2.000	854.000	.000
	Hotelling's Trace	38.566	16467.541[b]	2.000	854.000	.000
	Roy's Largest Root	38.566	16467.541[b]	2.000	854.000	.000
School Type	Pillai's Trace	.036	15.736[b]	2.000	854.000	.000
	Wilks' Lambda	.964	15.736[b]	2.000	854.000	.000
	Hotelling's Trace	.037	15.736[b]	2.000	854.000	.000
	Roy's Largest Root	.037	15.736[b]	2.000	854.000	.000

Note. a. Design: Intercept + School Type; b. Exact statistic; c. Computed using alpha = .05

Respondents scores in spatial visualization test and WASSCE result in Physics (Physics Achievement) were analyzed based on school type and analyzed as shown in Table 7. Table 7 shows that school type significantly influences the prediction between students' spatial visualization and their achievement in Physics. This is evident from the F-calculated value of 15.736 and p-value of .00 for score level which is less than the .05 level of significance (.00 < .05). Since the p-value is lower than the .05 level of significance, the null hypothesis is rejected. This means that school type significantly influenced the prediction between students' spatial visualization and their achievement in Physics.

Table 8

Tests of Between-Subjects Effects (Differences)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Spatial Visualization	1502.631[a]	1	1502.631	8.535	.004
	Physics	2877.893[b]	1	2877.893	25.053	.000
Intercept	Spatial Visualization	971006.780	1	971006.780	5515.402	.000
	Physics	3357727.363	1	3357727.363	29230.646	.000
School Type	Spatial Visualization	1502.631	1	1502.631	8.535	.004
	Physics	2877.893	1	2877.893	25.053	.000

Table 8 shows where the difference was observed. Table 8 shows that school type significantly influences the prediction between students' spatial visualization. Also, a significant influence of school type was observed with respect to physics achievement. This is evident in the F-calculated value of 8.535

and p-value of .004 for spatial visualization and 25.053 and p-value of .000 for achievement in Physics respectively.

Discussion

This study found spatial visualization a significant predictor of students' achievement in physics. This finding may be due to the nature of physics and by extension intelligence (Fluid or crystal) i.e., making meaning/interpretation of diagram, translation of words into diagram, induction and deducing from spatial images which involve spatial visualization ability. Also, the prediction may be as a result of the instrument employed which can be adduced to an aspect of intelligence testing called crystal intelligence. Expectedly, most recent research affirmed the contribution of spatial visualization ability as significant in the achievement of students in STEM related fields and subjects, mostly engineering and mathematics. However, this study substantiated empirically spatial visualization ability as a predictor and significant contributor to students' achievement in physics. The research of Joori and Ji (2020), McCunn and Cilli-Turner (2020), Lowrie et al., (2019), Sorby et al., (2018), and Yurt and Tünkler (2016) affirmed the position of this study that spatial visualization ability predicts students' achievement.

Furthermore, high scorers in spatial visualization ability were high scorers in physics achievement, medium and low scorers also shared these positions respectively. Score level was found to be a significant predictor of students' spatial visualization and achievement in physics. The nature of physics and the type of aspect of intelligence required favour both spatial visualization and physics as a subject. Since studies such as Joori and Ji (2020), Reilly et al., (2016) and Mulligan (2015) have all substantiated possibilities for the development of spatial ability, invariably, physics students' can be trained spatially for improved achievement in physics.

Gender was also found to significantly influence the prediction between spatial visualization and students' achievement in physics. The mean score of students on spatial visualization and physics achievement favoured the male students over the female students. This position may have arisen due to pre-existing phobia and lack of interest by female students in STEM-related fields to which physics belongs. Although, the position of recent literature has suggested, for and against this position. Studies of Sorby et al., (2018) Ramful and Lowrie (2015) Reilly et al., (2017), and Sharobeam, (2016) all posited for gender difference in the achievement of students in spatial ability with male students out-achieving. On the contrary, works of Joori and Ji (2020), McCunn and Cilli-Turner (2020) and Reilly et al., (2017) raise hope of equality in gender ability to achieve significantly in both STEM field and spatial ability.

School type significantly influenced students' spatial visualization ability and their achievement in physics. The mean score of students on spatial visualization and achievement in physics favoured private-schools over public-schools. -This possibility may have arisen due to a better environment, adequate instructional resources, family background, quality of life and remedial coaching which are all at the disposal of private-school pupils. However, this position may switch if all the aforementioned are also at the disposal of public-school students. The position of this research work is in line with the works of Bicer et al., 2018.

Conclusion and Implications

Spatial visualization ability remains a strong predictor of students' achievement in physics and as observed in the literature a determinant and an effective means of improving students' achievement in STEM-related fields. Since, spatial visualization is an ability that can be measured through testing, improved through training due to its malleable form. The indication is that learners with low ability levels in spatial visualization ability can be trained for overall improvement and career optimization. A pedagogical approach that has the possibility of improving students' achievement like spatial visualization should be embedded in the teaching of physics. From the findings of this study and many others, reported in the literature review, students with improved ability in spatial visualization achieved better in physics and by extension STEM fields across score levels, gender and school type.

Emphasis should be laid on teachers to train, develop and adopt spatial ability, integrate with the classroom to improve achievement in physics and by extension STEM subjects. Teachers and other stakeholders should intensify efforts to motivate female students in areas like spatial visualization ability to bridge the gap between gender/under-representation in STEM-related fields. The need to improve students' achievement transcends the barrier of school type, as such, both private and public-schools should be encouraged to indulge their students in spatial ability tests to improve their achievement in physics. This study recommends that further studies should be carried out in other STEM-related fields within the geographical scope of this study to establish a spatial culture among African students.

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