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Influence of Spatial Ability Levels on the Performance and Attitude of Physics Students

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ABSTRACT
The concept of spatial ability has been viewed within the boundary of technology and engineering by many researchers and education experts undermining its relevance to Physics at the secondary schools level. Spatial ability gives a wider ability to the use of higher order thinking skills which are accounted valuable for analysis, synthesis and evaluation needed in solving problems and has the tendency to influence students' attitude. Therefore, the study examined the influence of spatial ability levels on the performance and attitude of Physics students in public secondary schools in Osun State, Nigeria. A descriptive survey design was used for the study. The population for the study consisted of all the students in public secondary schools in four Local Government Areas (LGAs) of Ife in Osun State of Nigeria. A representative sample of 270 Physics students was selected using multi-stage sampling technique. Three instruments used for data collection are: Adapted Spatial Ability Test (ASAT), Performance Test in Physics (PTP) and Students' Attitude Physics Questionnaire (SAPQ). Content validity of the three instruments was ensured by experts' judgments. The reliability coefficient of 0.75, 0.85 and 0.82 were obtained for ASAT, PTP and SAPQ respectively. The results of the study classified students' spatial ability to low, average and high levels and many students had low spatial ability. The results of the study further showed that that there is statistically significant influence of spatial ability levels on the performance of physics students in the study areas. The finding showed that there is no statistically significant influence of spatial ability levels on attitude of students towards Physics in the study areas. Consequently, it was recommended that there should be ongoing research on spatial ability to provide information for physics teachers and that Physics students should be encouraged to take lesson on various spatial ability activities.

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1. INTRODUCTION

The understanding of the physical world can be best understood and explained through scientific principles and laws in which it was formed and operates. Principles and laws are essential tools often use in natural sciences especially in Physics to interpret and explain ranging phenomena on this planet earth; and observations made on minute objects to extreme larger ones are explained through various concepts, practical and mathematical illustrations. Physics interprets natural phenomenon through principles, laws and mathematical concepts and its application has created comfort to the universe (Adebisi,2016). Given the application of physics in life, industry and a vast number of professions (NERDC, 2008; Young & Freedman, 2008), it is necessary that every physics student is given the opportunity to

acquire concepts, principles and skills of physics. (Macmillan & Celina, 2019), needed to sustain the society.

The understanding of Physics knowledge involves metacognitive skills which might be the reason why the subject appears alien to many students at all levels of education. To many students Physics is abstract, mathematical and difficult because of inability to utilise needed skills during problem solving. The uniqueness of learning Physics encapsulates problem solving, appropriating laws and principles to solve questions in the classroom and experimenting which demands students to observe, measures, interpret and plot graph are all revolving around spatial ability (Adebisi, 2022). Spatial skills are needed in understanding most of Physics concepts, and by extension in Physics it is used in hologram in Medicine and is also used for marketing of goods. According to Hemba, Trisma, Kak'mena &Josiah (nd) in Medicine, a hologram of a living brain can detect exact size and location of a tumour. Holography may also lead to the development of extremely space-efficient storage for documents for documents or other information in the form of photographs(Fu llick,1994).

Visual-spatial skills tasks are being used in everyday life, so it is important to give it a good attention to strengthen its applications In a familiar and simplified term, Onootu, Hassan, & Gana (2021) remark that spatial ability involves using a map to guide you through an unfamiliar city, orienting yourself in your environment (as when you are learning your way around a new school building), packing (as when you must decide if a certain box is large enough for the objects you want to put into it) and using mirror images (as when you are combing your hair while looking into a mirror) are all activities that involves the use of spatial ability. From this, spatial ability involves spatial perception, spatial orientations, mental folding and rotation which can help in problem solving. According to Mac Raighne (2015), problem solving in Physics often requires visualising complex situations, abstract concepts, and graphical representations alongside imagining a change in parameters. Physics has many concepts that require observation, visual interpretation, thinking skills and non-linguistic skills. This implies that acquiring Physics knowledge is not unconnected with spatial ability. According to Pallrand and Sbeer (1984) spatial ability is important to acquisition of Physics knowledge.

Spatial ability entails processing, visualising, and manipulating of visual images. Child Development (2002) refers to spatial ability as skills in perceiving the visual world, transforming and modifying initial perceptions, and mentally recreating spatial aspects of one's visual experience. In other word, spatial ability is made up of multifaceted and interrelated skills of spatial processes of objects in space asides from mathematical skills. Jones and Burnette (2008) consider spatial ability as a heterogeneous cluster of skills considered to be a dimension of intelligence distinct from verbal and mathematical skills. Spatial ability is a dimension of skills for manipulating, explaining as well in graphical representations in spatial domain. Halpern (2000) defines spatial ability as a cognitive characteristic that gives a measure of the ability to conceptualise the spatial relations between objects. Essentially, there are instances in Physics when learners visulise objects in space during problem solving. This might be the sole reason why the performance of students in Physics on the average over the years has not been encouraging.

Academic performance takes significant focus in the course of education for the fact that teachers, parents, policy makers, governments and the students are aware of its importance because is a measurable outcome of education, that is, can be easily interpreted by all. The academic performance of students is a and prominent goal (Narad and Abdullah, 2016) of education, which can be explained as the knowledge acquired by the students which is assessed by a teacher's mark and/or educational goals set to be achieve d over a specific period of time (Kumar, Agarwal, & Agarwal, 2020). There are many variables that go into students' performance such as cognitive dispositions which have attracted many researches, besides, academic performance has been viewed to have been influenced also by students'

attitude. Arsaythamby, Rahimah and Rozalina (2015) pointed out that in schools, teachers have always commented that failure in Physics achievement by some students is due to their negative attitude and lack of interest towards the subject. Attitude affects preparation, perception and motivation of the learners towards or away from the learning. Oppenheim (1992) conceptualises attitude as an entity comprising the cognitive, the affective and the behavioural domains. Attitudes are not inborn trait but they can be learned in the course of experience and has capacity to influence skills and knowledge acquisition.

2. REVIEW OF LITERATURE

The knowledge of Physics together with that of Mathematics at secondary schools prepares students for Engineering and Technology courses in higher level of studies. This made it compulsory for Physics students to be proficient in Mathematics skills for solving problems. Literature abounds with researches on the importance of spatial ability in Mathematics and Engineering, therefore prompts it usefulness in studying Physics. A student's ability in Physics is determined by complex interrelated skills of reasoning ability, memory skills and visual ability as required also in Mathematics. The interrelated skills are basic to spatial ability. Spatial ability is a construct representing visual imagery (Presmeg, 2006) and spatial visualization (Jakubowski & Unal,2004). Physics students at secondary schools relatively need the aptitude of spatial ability in topics such as motions, locating and representing images in optical problems, data representation, vector diagrams and interpretation on the graph. From literature, positive and significant correlations were found between spatial ability and achievement in Physics (Kozhevnikov, Motes, & Hegarty, 2007; Delialioğlu & Aşkar, 1999). The assertion of spatial ability is germane and encompassing to dynamisms of science. The ability to retain, retrieve and transform visual images is referred to spatial ability (Marunic & Glzar, 2014). Physics students at secondary schools need a little bit of spatial ability to understand and remember spatial relations among symbolic representations of diagrams in circuit diagram and in crystal structures. According to National Research Council (2015) spatial abilities involve the capacity to understand an object's spatial relationship within surroundings and to understand representations of multidimensional figures in one dimensional display. Spatial ability enhances psychological factors such as attention and perception which are important for everyday demands on working memory to maintain and transform images (Kyllonen & Christal , 1990). The skills of spatial ability will enhance perception ability in different contexts in solving one or two dimensional problems in sciences. Spatial ability is generally defined as the ability to form well-constructed visual shapes, keep them in mind, and arrange and convert them (Lohman, 1996). Linn and Petersen (1985) classified spatial ability into spatial perception and mental rotation. Scientists define spatial perception as the ability to hold and manipulate two-dimensional and three-dimensional visual and verbal images in the mind (Lord, 1985; Purcell, 1984). While mental rotation involves the ability to perceive a whole shapes and rotate it.

Statement of the Problem

Evidences from researches have shown that performance of students in Science, Technology, Engineering and Mathematics (STEM) has a high positive correlation of improvement after spatial trainings. With the importance of spatial ability to enhance performance, it is obvious that little attention has been given to ascertain the spatial ability levels of Physics students in secondary schools, besides, the spatial ability levels on students' performance and attitude towards Physics in Secondary Schools. Although, research work on spatial ability has started in many countries of the world for long but Nigeria has few research findings to performance and attitude to Physics. However, scholars in the field of Science Education have equally asserted that students suffer setbacks in their academic performance is due to

their poor attitude towards science. Therefore, this demand for investigation on influence of spatial ability levels on the performance and attitude of Physics students in secondary schools.

Purpose of the Study

Specifically, the study examined the influence of spatial ability levels on the performance and attitude of Physics students in senior secondary schools in four local government areas of Osun State, Nigeria.

Research Questions

The following research questions guided the study: (i) What is the distribution pattern of spatial ability levels of physics students in secondary schools in Osun State, Nigeria?; (ii) Is there any significance influence of spatial ability levels on performance of Physics students in the study areas ?; (iii) Is there any significance influence of spatial ability levels on students' attitude towards Physics in secondary schools in the study areas?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

(i) There is no significant influence of spatial ability levels on the performance of Physics students in secondary schools in Osun State, Nigeria.

(ii) There is no significant influence of spatial ability levels on students' attitude towards Physics in secondary schools in study areas.

3. METHODS

The study was purpose-based classification type of descriptive survey design. The design was considered appropriate because the researcher collected data for this study in a systemic manner through the research questionnaires to examine the influence of spatial ability levels on the performance and attitude of representative sample of Secondary Schools II (SS II) Physics students in the study area. The population of the study consists of all Physics students in senior secondary schools in four Local Government Areas (LGAs) of Ife in Osun State of Nigeria. A representative sample of 270 Physics students was selected for the study using multi-stage sampling technique. Three LGAs were selected using simple random sampling technique from four local governments in Ife zone. Three senior secondary schools were purposively selected from each local government area on the criteria of having qualified Physics teachers, they are consistently following and up-to-date with the curriculum and enough students in Senior Secondary two (SSS2) for the research. Thirty students were selected from each school through simple random procedure. The sample consists of 141 males and 129 females for the study. Three research instruments were used to collect data and they are Adapted Spatial Ability Test (ASAT), Performance Test in Physics (PTP) and Students' Attitude toward Physics Questionnaire (SAPQ). ASAT consisted of two parts, the first part consisted of 8 items of mental rotation of Vandenberg & Kuse (1978), and each of the items has a figure with four options. The students were given instructions and examples of mental rotation figures. They are permitted to ask for clarification but not to request for the correct options. There is an object presented in the left hand side of the paper presented with four options (A, B, C and D) to the right. Two correct options in the four figures match the target figure after rotation in space. The maximum obtainable score is one for each figure while halve is scored for choosing one correct option and zero is scored if the two options chosen are wrong.

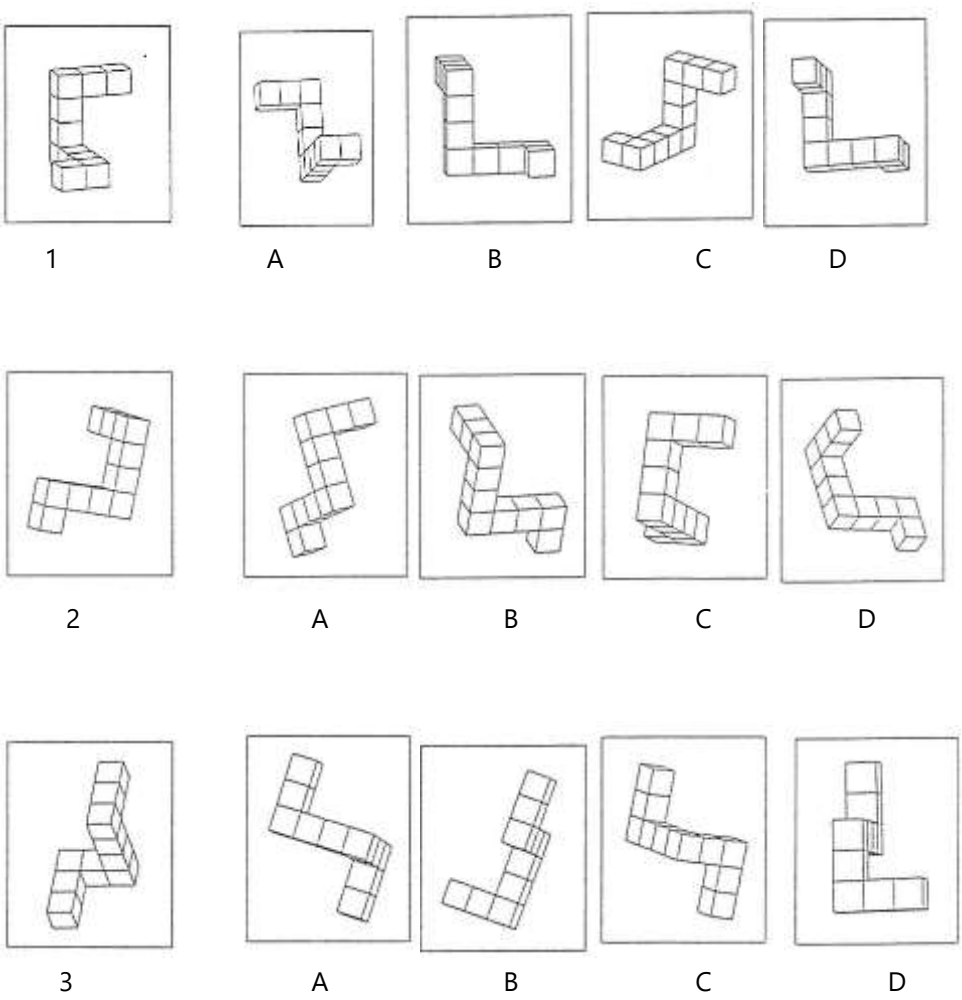

Figure1. Mental rotation drawing items: Vandenberg & Kuse (1978)

The second part of ASAT consisted of seven items of Spatial Orientation Test of Hegarty and Waller (2004), it determined ability to imagine different perspective of an array of objects provided in space. The instructions are given to imagine that one is standing at one object in the centre of the array and facing another named object, it is required to point to another object. One mark is given for correct option while zero for wrong option. The total maximum obtainable score for ASAT is 15.

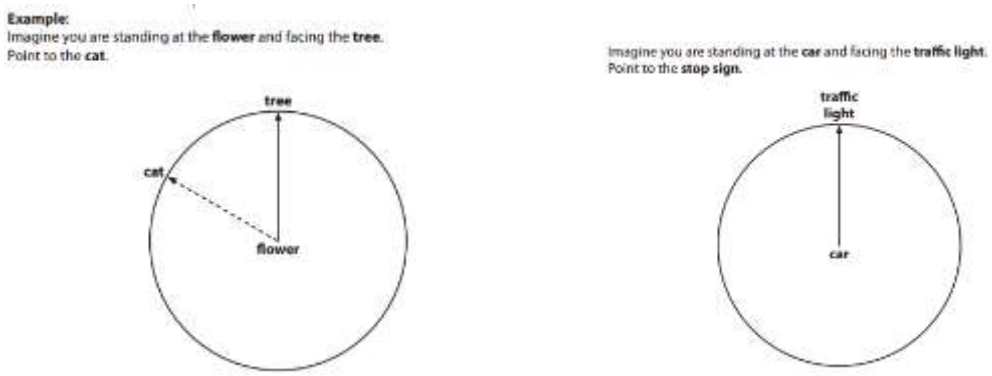

Figure 2. Mental rotation and perspective taking spatial abilities: Hegarty and Waller (2004).

PTP is a standardized multiple choice test from West African Examination (WAEC). PTP consists of twenty item questions; each question has four alternative answers in which the students were to choose one right option. The maximum obtainable score for PTP is 20. SAPQ was self-constructed test made of 10 statements that elicited responses on the attitude of students toward Physics. The rating of items in the positive directions was scored as follows: Never True =1, Sometimes=2, Always=3

Content validity of the three instruments were ensured by experts' judgments. This was done to establish the suitability of the items in the instruments. Two experts from Test and Measurement established contents validity of ASAT, while two physics teachers who have been teaching for ten years in secondary schools ensured content validity for PTP and SAPQ. To ascertain the reliability of the instruments, the ASAT, PTP and SAPQ were administered to thirty Physics students in a school which is not part of the study. Test-re-test method was used for ASAT, the scores of the tests were correlated and reliability coefficient of 0.75 was obtained and found reliable for the study. Reliability coefficients of 0.85 for PTP and 0.82 for SAPQ were obtained using Kuder Richardson 21 and Cronbach Coefficient alpha respectively.

The researchers with the help of class teachers administered the three instruments in succession; a short break of ten minutes was given to the respondents after each instrument so that they would not be bored in responding to the instruments. There was 100% retrieval of the instruments from the respondents. Completed copies of the questionnaire were coded by the researcher. The statistical package for social sciences was used to analyse the data collected.

4. RESULTS AND DISCUSSION

The results after analysing the data of the study were presented as follows:

Research Question 1: What is the distribution pattern of spatial ability levels of physics students in senior secondary school in Osun State, Nigeria?

Table1. Distributions pattern of spatial ability levels of physics students

Scores	Spatial Ability Level	Frequency (f)	Percent (%)
0-5	Low	213	78.9
6-10	Average	50	18.5
11-15	High	7	2.6
	Total	270	100

Table1 above shows distribution pattern of spatial ability levels of physics students in secondary schools. The table indicated that high numbers of students are represented within low spatial ability level of 78.9%, while students representing 18.5% are in the average of spatial ability level and students representing 2.6% are of high spatial ability level. From the distributions pattern, many of the Physics students have low spatial ability.

Hypothesis One: There is no significant influence of spatial ability levels on the performance of Physics students in secondary school in the study area.
The results are presented in Table 2 and 3.

Table 2. One-way Analysis of Variance of Physics Performance Test of Low, Average and High spatial ability levels of the Students

	Sum of Squares	df	mean square	F	Sig.
Between groups	190.131	2	95.065	12.179	0.000
Within Groups	2084.032	267	7.805		
Total	2274.163	269			

Table 2 shows that there is a statistically significant influence of spatial ability levels on the performance of physics students for the three groups (Low, Average and High) at the $p < 0.05$ level, [$F(2,267) = 12.179$, $p = 0.00$]. The null hypothesis is therefore rejected. Table 3 shows the results of Tukey multiple comparison tests to determine pair-wise difference among the groups.

Table 3. Tukey test analysis showing multiple Comparison of spatial ability levels

Spatial Ability (I) Level	Spatial Ability(J) Level	Mean Difference (I-J)	Std. Error	Sig.
Low	Average	-1.28488	0.43904	0.010
	High	-4.4963	1.07317	0.000
Average	Low	1.28488	0.43904	0.010
	High	-3.21143	1.12746	0.013
High	Low	3.21143	1.07317	0.013
	Average	4.49631	1.12746	0.000

The mean difference is significant at the 0.05 level
From Table 3 revealed significant mean difference between Low and Average spatial ability levels, Low and High spatial ability levels, Average and High spatial ability levels. With the relative mean spatial ability levels between these groups, the results suggested that students of high spatial ability levels performed better than others.

Hypothesis Two: There is no significant influence of spatial ability levels on students' attitude towards Physics in secondary schools in the study areas.

The results are presented in Table 4.

Table 4. One-way Analysis of Variance of Students' Attitude towards Physics

	Sum of squares	df	Mean Square	F	sig.
Between Groups	3.781	2	1.890	0.155	0.856
Within groups	325.519	267	12.1890		
Total	3256.300	269	1.890		

Table 4 shows that there is no statistically significant influence of spatial ability levels on students' attitude to physics in secondary for the three groups (Low, Average and High) at the $p< 0.05$ level, [$F(2,267)=0.155$, $p=0.856$]. This shows that irrespective of students level of spatial ability their attitude remain unaffected towards physics. Therefore, the null hypothesis is therefore retained.

Discussion

The results on research question one analysed in Table 1 shows that high percentage of students' distribution have low spatial ability levels. This implied from the observation of Carlisle (2012), that spatial properties are not explicitly taught to students, therefore the students have low spatial ability. Based on this, low spatial ability is an indication of deficient of logical reasoning, confused mental orientations, and inability to restructure information in different contexts.

Hypothesis one stated that there is no significant influence of spatial ability levels on Physics students' performance in secondary schools in the study areas. The results of hypothesis one analysed in Table 2 shows that there is a statistically significant influence of spatial ability on performance of physics students in secondary schools. The findings of the study is in support of preliminary data from Bodner and McMillen, (1986) as cited by Carter, Larussa, George and Bodner (1987) on the relationship between spatial ability and performance. Their findings showed significant correlation between spatial ability and performance which corroborated this research finding. The results of this study also tow along the submission of Lord and Rupert (1995) that spatial ability is a cognitive factor related with high performance in the areas of science and mathematics. Also the finding of this study corroborated the studies of Uttal & Cohen (2012) and Wai, Lubinski, & Benbow (2009) that small percentage, less than one quarter of all students have the spatial skills necessary to succeed in science subject. Spatial ability is a complex cognitive skills that students cannot be done away with in sciences and Mathematics. Recent longitudinal studies demonstrated visual as a key factor of academic success in Mathematics(Gilligan, Flouri, & Farran, (2017) ; Geer, Quinn, & Ganley, 2019). Anobile, Arrighi, Castaldi, Grassi, and Burr (2017) found that there was an intrinsic link between Mathmatics and Spatial perception and Mathematics is a language of Physics.

The second hypothesis stated that there is no significant influence of spatial ability levels on students' attitude towards Physics in secondary was retained. That shows that attitudes are characterised with personal involvement. The findings is in support of the report of Brown (2001) that attitudes are charaterise by large proportion of emotional involvement of self and feelings at different times of learning.

5. CONCLUSION

Based on the findings of this study large percentage of physics students had low spatial ability level. From the results, spatial ability levels of Physics students had influence on academic performances in Physics but attitude to Physics were not affected by spatial ability levels. Besides, the performance is very important in academics and the contributory factor of spatial ability cannot be neglected to students' performance because spatial ability is demanded in science especially in physics for identifying, manipulating and deducing from spatial elements of objects and components among objects/diagrams, therefore it is should be given attention to in schools.

Based on the findings of this study, the following recommendations were made:

1) There should be ongoing research on the influence of spatial ability to provide information for physics teachers and education policy makers on the need to enhance spatial ability levels of students for better performance.
2) Physics students should be encouraged to take lesson on various spatial ability activities to enhance their cognitive skills.
3) The education agencies should provide necessary instructional materials to facilitate the teaching of spatial ability activities in schools.
4) Classroom teacher should deliberately plan and structure their lessons and delivery in such a way so as train and improve the spatial ability of the students.

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