RELATIONSHIP BETWEEN SPATIAL ABILITY AND PHYSICS ACHIEVEMENT AMONG SECONDARY SCHOOL STUDENTS IN OKENE METROPOLIS, KOGI STATE.

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ABSTRACT
This study investigated the relationship between secondary school students' spatial ability and physics achievement, as well as the role of gender. Correlational research design was employed in this study. A total number of 123 students, consisting of 67 male and 56 female students participated in this study. Two stage sampling was involved. First, three schools were drawn randomly from the twelve senior secondary schools in Okene metropolis, and intact class of SS1 students were chosen purposively in the second stage of the sampling. Two instruments were used in this study, which are Purdue Visualization of Rotations Test (ROT) adopted from Guay (1980), and Test of Understanding Kinematics (TUG-K) adopted from Beichner (1994). The reliability of TUG-K as determined by Beichner (1994) using KR-20 was 0.83 while the reliability of ROT as determined by Guay (1980) using KR-20 was 0.85. Three hypotheses were generated to achieve the objectives of this study. The three hypotheses were tested using Pearson Product Moment Correlation Coefficient. Findings from the study showed that there was a significant relationship between spatial ability and kinematics achievement among secondary school students, there was a significant relationship between spatial ability and kinematics achievement among male secondary school students, and there was a significant relationship between spatial ability and kinematics achievement among female secondary school students. Based on these findings, it was concluded that there was a statistically significant relationship between spatial ability and physics achievement. It's then recommended that physics teachers should try to establish a classroom environment that facilitates the use of images in teaching and learning of physics concepts. Student's participation

and interest in physics may be aroused when they discover that the ability to compute mathematical formulas is not the only ability required to solve physics problems but one can also employ the use of images in solving problems in physics.

KEYWORDS: *Achievement, Kinematics, Physics, Spatial Ability*

INTRODUCTION

Science learning deals with abstraction, conceptual thinking, visualization and generalization of facts, all of which require the use of cognitive process (Adeyemo, 2010). For a student to achieve this, He must be able to combine ideals, solve verbal and hypothetical problems, visualize invisible concepts, proportions and conservation of movement. He can transfer understanding from one situation to the other. Most of what is taught in science requires ability to think. According to Adeyemo (2010), many students find abstract subjects such as

Physics and Chemistry difficult to learn, this is believed to be associated with their cognitive development. He also observed that the difficulty is due to not having appropriate cognitive level of comprehension and application.

Physics is a subject that examines topics that are highly spatial in nature (Alfonso, 2015). Historically, there is much evidence that mental imaging plays a central role in physics conceptualization process and in scientific discoveries. Research on the cognitive processes underlying physics discoveries such as Galileo's laws of motion, Faraday's visualization of lines of forces, Maxwell's laws or Einstein's theory of relativity, has implicated the extensive use of visual/spatial reasoning in these discoveries (Kozhevnikov, Motes & Hegarty, 2010).

Studies from the past have shown that the mental reasoning abilities of students is one of the factors that predicts their understanding of many abstract and difficult scientific concepts, and supporting students reasoning ability may lead to scientific learning outcomes that requires such skills and abilities (Kozhevnikov *et al*, 2010; Lyna & Gavin 2014). One of such general abilities that may be relevant for science education is visual-spatial ability, as understanding abstract scientific concepts requires the ability to imagine and visualize many invisible phenomenal (Lyna & Gavin 2014). According to Bayram (2009), spatial ability refers to skills required in representing, transforming, generating, and recalling symbolic, and non-linguistic information. Lohman, (1993) also defined spatial ability as the ability to generate, retain, and transform well-structured visual images. The definitions above both centered on the use of images. This ability can be viewed as a unique type of intelligence that can be distinguished from other forms of intelligence or cognitive abilities, such as verbal ability, reasoning ability, and memory skills. Spatial ability is not a static trait but permits individual variation, and made up of numerous sub skills, which are interrelated among each other and develop throughout one's life (Bayram 2009).

Visual-spatial skills are of great importance for success in solving tasks in everyday life. For instance, 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. Visual-spatial ability is becoming increasingly important with the development and proliferation of new technologies such as imaging, computer graphics, data visualization, and supercomputing. Highly demanding spatial tasks includes the construction of mental representations of object configuration from images on several screens representing different perspectives. (Wai, Lubinski, & Benbow, 2009).

In physics, students are required to visualize a system, manipulate that system, and then solve a given problem. Doing all of this simultaneously can lead to a cognitive overload causing the students to be unable to correctly solve the problem. Some difficulties may be rooted in conceptual difficulties, whereas other difficulties may arise from issues with spatial intelligence and visual cognition. In some cases, students might have created an incorrect mental image of the problem to begin with, and this misconception, not the lack of content knowledge, that has caused the student to arrive at an incorrect answer (Alfonso, 2015).Furthermore, the majority of physics problems involves manipulation of spatial representations in the form of graphs, diagram, or physical models and as a matter of fact, some country's employment services includes physics in its list of occupations requiring a high level of spatial ability, that is, the ability to perform spatial transformations of mental images or their parts (Kozhevnikov *et al*, 2010).

Results from past studies have shown that spatial ability is related to student's performance in science subjects. For example, Lyna and Gavin (2013) examined the relationship between student's general visual-spatial ability and their understanding of electricity and electromagnetism in physics and their findings revealed that there is a need for visualization instruction that can improve student's visual-spatial ability, because it may help the students to visualize the abstract phenomena, deepen their understanding and consequently improve their achievement. Similarly, Kozhevnikov *et al* (2010) also investigated the relation of spatial visualization to solving physics problems and the result of their study suggested an important relationship between spatial visualization ability and solving physics problems with multiple spatial parameters. Also, Behzat (2006) examined the relationships between student spatial ability and kinematics graphs interpretation skills and discovered that students' ability to determine the slope in a kinematics graph was significantly correlated with spatial ability. To support these findings, Omar & Petek (2011) emphasized that spatial ability was another important cognitive operation for success in physics courses and that there exists a significant relationship between students' spatial ability and the physics achievement of students. However, results from a number of studies couldn't establish a relationship between spatial ability and students' success in physics. For example, Michael (2012) carried out a study to investigate the relationship between student's spatial abilities and their success in high school physics and his finding does not support the previously reviewed ones. Findings from his study did not find any correlation between pre-existing spatial abilities and performance in high school physics. Similarly, Duffy, Farrell, Harding, Behan, & Raighne (2015) determined the effects of spatial skills on academic performance in STEM education which included physics and the result of their study showed no significant effect of spatial ability on STEM education. The implication of this could be that spatial ability and success in physics are not always related. For some reasons, the relationship between spatial ability and physics as well as other science subjects may be affected, resulting to no relationship between the two variables at all. Moderating variable like gender could affect the relationship between spatial ability and achievement in physics.

Gender-related differences in cognitive abilities are of considerable interest to educators and cognitive researchers alike, relatively little progress has been made in understanding the psychological processes that lead to them (David & David, 2013). Researchers have frequently observed gender differences in more specific components of cognitive abilities (Boyle, Neumann, Furedy & Westbury, 2010). The largest and most consistent gender differences are found in spatial ability (Halpern, 2011), who's reviews find effect sizes ranging from medium to large. Studies have shown that male perform better than their female counterparts in spatial ability tests. For instance, David & David (2013) investigated gender-role differences in spatial ability and discovered that male participants tend to have a higher spatial ability than their female counterparts. This finding is also supported by Behzat (2006) whose study showed that male students perform significantly better than female students in spatial ability test. This could be one of the reasons why there are lesser female than male in Science, Technology, Engineering and Mathematics (STEM) fields. Though progress has been made in closing gaps in recent decades, women still remain underrepresented in Science, Technology, Engineering and Mathematics (STEM)- related fields (David and David, 2013), particularly in physics. There is relatively fewer number of women in the field of physics at graduate level as compared to the number of men in the field (Valerie, 2018). Robert & Katherine (2016) equally investigated gender effects in physics assessments of kinematics graphs and discovered that male students perform better than female students in the Test of Understanding Kinematics (TUG-K). Behzat (2006) also discovered that male students performed significantly better than female students on the slope items of TUG-K in his study. The implication of this could be that the performance gap between male and female students is as a result of their spatial ability. In view of these, this study attempts to investigate the relationship between secondary school students' spatial ability and physics achievement, as well as the role of gender.

The relationship between two variables is referred to as the 'correlation coefficient' which was coined by Karl Pearson in 1896. According to Ratner (2010), the correlation coefficient, denoted by r, is a measure of the strength of the straight-line or linear relationship between two variables. The correlation coefficient can assume any value in the interval between +1 and −1, including the end values +1 or −1. These following points are the accepted guidelines for interpreting the correlation coefficient; 0 indicates no linear relationship, +1 indicates a perfect positive linear relationship, meaning as one variable increases in its values, the other variable also increases in its values through an exact linear rule, −1 indicates a perfect negative linear relationship, meaning as one variable increases in its values, the other variable decreases in its values through an exact linear rule, values between 0 and 0.3 indicate a weak positive linear relationship, values between 0 and −0.3 indicate a weak negative linear relationship, values between 0.3 and 0.6 indicate a moderate positive linear relationship, values between −0.3 and −0.6 indicate a moderate negative linear relationship, values between 0.6 and 1.0 indicate a strong positive linear relationship, and values between −0.6 and −1.0 indicate a strong negative linear relationship (Ratner, 2010). These points were used to guide the decisions made on findings of this study.

STATEMENT OF THE RESEARCH PROBLEM

Studies are often carried out to determine the factors that are related to students' performance and achievement in education. Science subjects have been one of the major areas of concern considering the abstract nature of science. Factors frequently investigated in Nigeria are mostly related to the method of instruction and teachers' personality related. For instance, Okoedion (2019) investigated perceived factors affecting students' academic performance in Nigeria and her findings indicated that the major factors affecting students' academic performance in Nigeria are teachers and instructional related factors. Similarly, Olufemi, Adediran & Oyediran (2018) investigated factors affecting students' academic performance in colleges of education in southwest, Nigeria and their findings showed that teachers related factors and method of instruction has a major effect on students' performance/achievement. Most studies are restricted to method of instruction and instructional aides as the factors that predicts students' performance and achievement in science education. Factors relating to students' spatial ability have fewer literatures in Nigeria as compared to other factors such as method of instruction and teachers' personality related.

Student's mental reasoning ability is an important factor that predicts students understanding and consequently students' performance in science subjects, particularly in physics which is seen as a visual science (Lyna & Gavin, 2014). Visual-spatial ability likely plays an important role in students learning of physics and physics problem solving. Despite this relationship, relatively little research has been conducted by educational researchers on visual-spatial ability in physics education as compared to other Science, Technology, Engineering, and Mathematics (STEM) disciplines (Kozhevnikov *et al*, 2010), and for the few literatures found, very little (or non) have been conducted in Nigeria. Little attention has been devoted to understanding the role of visual-spatial skills in topics within physics that are image related like kinematics in Nigeria. Despite the number of studies carried out on spatial ability as it relates to student's performance in science subjects in other parts of the world, very few or no attempt have been made to carry out this study in Nigeria to ascertain if the result will be in line with the result obtained from other countries or not. Hence, the need for this study, to investigate whether there is a relationship between spatial ability and physics achievement among secondary school students in Okene metropolis, Kogi State, Nigeria, as there are only a few literatures relating to spatial ability and students' success in physics in Nigeria

AIM AND OBJECTIVES

The aim of this research is to examine the relationship that exists between secondary students' spatial ability and student's physics achievement (kinematics).

For the purpose of this study, the following objectives are targeted to be achieved. They are to determine:

1. The relationship between spatial ability and kinematics achievement among secondary school students.
2. The relationship between spatial ability and kinematics achievement among male secondary school students.
3. The relationship between spatial ability and kinematics achievement among female secondary school students.

RESEARCH HYPOTHESES

The following hypotheses were formulated and tested at 0.05 alpha level of significance:

HO$_1$: There is no significant relationship between spatial ability and kinematics achievement among secondary school students.

HO$_2$: There is no significant relationship between spatial ability and kinematics achievement among male secondary school students.

HO_3: There is no significant relationship between spatial ability and kinematics achievement among female secondary school students.

METHODOLOGY

The research design employed in this study is a correlational research design. Correlational research involves collecting data to determine whether, and to what degree, a relationship exists between two or more quantified variables (Gay, Mills & Airasian, 2009). The population of the study was made up of the 449 SS I science students, comprising of 234 males and 215 females in the twelve public senior secondary schools in Okene metropolis, Kogi state, for the 2019/2020 academic session. SS 1 was chosen because the topic 'Kinematics' falls in SS 1 scheme of work and syllabus and the topic in physics chosen for the purpose of this study was kinematics. Two stage sampling was involved. First, three schools were drawn randomly from the twelve senior secondary schools in Okene metropolis, and SS1 was chosen purposively in the second stage of the sampling. A total number of 123 students, consisting of 67 male and 56 female students were sampled for this study.

The two instruments that were used in this study consist of paper-and-pencil tests measuring spatial ability (Purdue Visualization of Rotations Test (ROT)) adopted from Guay (1980), and a paper-and-pencil, multiple-choice kinematics problem solving test (Test of Understanding Kinematics (TUG-K)) adopted from Beichner (1994). The reliability of The Test of Understanding Kinematics (TUG-K) was calculated by Beichner (1994) using the Kuder Richardson coefficient (KR-20) and was determined to have a reliability of 0.83, and the reliability of the Purdue Visualization of Rotations Test (ROT) as determined by Guay (1980) was reported to be 0.80 using Kuder Richardson (KR-20).

The first week of the research was used to seek permission from the respective schools. This was done to get maximum cooperation from the students, school authority and the teachers of the schools. After the visiting period, the Purdue Visualization of Rotations Test was administered to the students by the researcher and followed by the Test of Understanding Kinematics. The Purdue Visualization of Rotations Test contained 10 questions and each correct answer carried 1mark making a total of 10marks, while the Test of Understanding Kinematics contained 14 questions with each correct answer carrying 1mark making a total of 14marks. The students' scores to the tests were collected after the stipulated time for submission, converted to percentages before they were taken for analysis. The relationship between the measures in the study stated in HO_1 to HO_3 was tested using the Pearson Product Moment Correlation Coefficient.

RESULTS

HO1: There is no significant relationship between spatial ability and kinematics achievement among secondary school students.

Table 1: Summary of Pearson Moment Correlation between secondary school students' spatial ability and kinematics achievement.

Variables	N	Mean ($\bar{x}$)	Standard Deviation (SD)	r	P_{value}
TUG-K	123	44.72	14.80	0.52	0.000
ROT	123	42.20	13.59		

Table 1 above shows the correlation between secondary school students' spatial ability and kinematics achievement. The students had a TUG-K Mean score of ($\bar{x}$=44.72 and SD=14.80), ROT Mean score of ($\bar{x}$=42.20 and SD=13.59), while the r=0.52. Hence null hypothesis 1(HO_1) which states that there is no significant relationship between spatial ability and kinematics achievement among secondary school students was rejected. Therefore, there was a positive moderate relationship between TUG-K and ROT among secondary school students at P=0.05.

HO_2:

There is no significant relationship between spatial ability and kinematics achievement among male secondary school students.

Table 2: Summary of Pearson Moment Correlation between male secondary school students' spatial ability and kinematics achievement.

Variables	N	Mean ($\bar{x}$)	Standard Deviation (SD)	r	P_{value}
TUG-K	67	43.73	15.23	0.46	0.000
ROT	67	42.69	13.99		

Table 2 above shows the correlation between male secondary school students' spatial ability and kinematics achievement. The students had a TUG-K Mean score of ($\bar{x}$=43.73 and SD=15.23), ROT Mean score of ($\bar{x}$=42.69 and SD=13.99), while the r=0.46. Hence null hypothesis 2 (HO_2) which states that there is no significant relationship between spatial ability and kinematics achievement among male secondary school students was rejected. Therefore, there was a positive moderate relationship between TUG-K and ROT among male secondary school students at P=0.05.

HO_3:
There is no significant relationship between spatial ability and kinematics achievement among female secondary school students.

Table 3: Summary of Pearson Moment Correlation between female secondary school students' spatial ability and kinematics achievement.

Variables	N	Mean ($\bar{x}$)	Standard Deviation (SD)	r	P_{-value}
TUG-K	56	45.91	14.31	0.60	0.000
ROT	56	41.61	13.18		

Table 3 above shows the correlation between female secondary school students' spatial ability and kinematics achievement. The students had a TUG-K Mean score of ($\bar{x}$=45.91 and SD=14.31), ROT Mean score of ($\bar{x}$=41.61 and SD=13.18), while the r=0.60. Hence null hypothesis 3 (HO_3) which states that there is no significant relationship between spatial ability and kinematics achievement among female secondary school students was rejected. Therefore, there was a positive strong relationship between TUG-K and ROT among female secondary school students at P=0.05.

DISCUSSION

In this study, the relationship between secondary school students' spatial ability and students' physics achievement (kinematics), and the effect gender on this relationship were investigated. Findings from table 1 which sought to find the relationship between spatial ability and kinematics achievement among secondary school students shows that there was a statistically significant relationship between spatial ability and kinematics achievement. This finding is supported by the studies of Behzat (2006) and Kozhevnikov, Motes and Hegarty (2010), whos' results established a significant relationship between spatial ability and kinematics. However, there were few literatures whose findings doesn't support the findings of this study. For example, Michael's (2012) study couldn't establish a significant relationship between spatial ability and physics achievement. To ascertain the generality of the relationship established in this study, the study further investigated the influence of gender on the relationship between the two variables.

Table 2 which sought to determine the relationship between spatial ability and kinematics achievement among male students showed that there was a positive moderate relationship between spatial ability and kinematics achievement among male students, and table 3 showed that there was a positively strong relationship between spatial ability and kinematics achievement among female students. The strength of the relationship was stronger among female students having a correlation coefficient of r=0.60. This implies that generally, there is a significant relationship between spatial ability and kinematics achievement among all secondary school students, but the relationship tends to be stronger among female students than male students. In addition to this, tables 2 and 3 showed that male students had a higher spatial ability test score than the female students. This is in support of David and David (2013) and Behzat (2006), whos' findings suggested that male has a higher spatial ability that female. The implication of this could be that males tends to be more exposed to activities that improve their spatial skills than their female counterpart. However, the kinematics achievement test scores for both male and female students showed that female had a higher mean score than male students. This contradicts the findings of Robert and Katherine (2016) and Behzat (2006) who discovered that male students performed significantly better than female students in kinematics tests. This suggests that there could be other factor(s), other than spatial ability that may have come to play, thereby putting the female students in this study at an advantage over the male students in the kinematics achievement test.

CONCLUSION

The aim of this study is to investigate the relationship that exists between spatial ability and physics achievement among secondary school students in Okene metropolis, Kogi State, Nigeria. Based on the results found in this study, it can be concluded that there is a statistically significant relationship between spatial ability and physics achievement, and the relationship tend to be stronger among female students than male students.

RECOMMENDATIONS

The following recommendations are made based on the findings of this study:

1. Physics teachers need to be aware of the importance of students' spatial ability in understanding physics concepts. He should put the students' spatial ability into consideration during the process of lesson delivery.
2. He should be aware that students have different levels of spatial ability; some students come to classroom with high level of spatial ability while some do not. The important point here is that teachers need to realize that student with low spatial ability may experience some problem understanding kinematics graph, these students may need some extra help to improve their spatial ability.
3. Teachers should try to establish a classroom environment that facilitates the use of images in teaching and learning of physics concepts. Student's participation and interest in physics may be aroused when they discover that the ability to compute mathematical formulas is not the only ability required to solve physics problems but one can also employ the use of images in solving problems in physics.

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