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Spatial Skill As Predictor Of Senior Secondary School Students' Mathematics Achievement And Attitude In Lagos State, Nigeria.

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Abstract
The contribution of spatial skills to a shared understanding of the world and the society is crucial to the development of Science, Technology, Engineering and Mathematics. Thus, the early development of the skills must be maximized. This study examined spatial skills as predictors of students' academic achievement in and attitude towards mathematics at the senior secondary school. Descriptive survey research was used for the investigation. Sample comprised of 1500 senior secondary school II (SS 2) students from thirty public schools in five local government areas in Lagos East Senatorial District of Lagos State using stratified and random sampling techniques. Tools used for data collection were Spatial Ability Test (SAT) with reliability coefficient of 0.84, Mathematics Achievement Test (MAT) with reliability coefficient of 0.76 and Students Attitude towards Mathematics Scale (SATMS) with reliability coefficient of 0.70. A research question was raised and two hypotheses were formulated and tested at 0.05 level of significance using regression analysis. Results revealed that the sampled students had low possession of spatial skills and the outcome of hypothesis 1 is statistically significant ($F=29.192$, $p< 0.05$) indicating that variation in the students' mathematics achievement was influenced by spatial skills. The outcome of hypothesis II was not statistically significant ($F=1.890$, $p> 0.05$) indicating that the difference in students' attitude towards mathematics is not greatly influenced by spatial ability. In conclusion, the results of the findings indicated that the low possession of spatial skill is responsible for the low achievement in mathematics. Hence, teachers are encouraged to prioritize spatial skill by integrating its training into their teaching so that students would be well groomed and grounded in the skill thereby improving achievement in mathematics.

Keywords: *Achievement, Attitude, Mathematics, Spatial skills, Student*

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I. Introduction

Mathematics is often regarded as the language of science and a fundamental discipline that underpins a broad array of fields, including science, engineering, economics, and technology. Its relevance is not limited to theoretical constructs; rather, it forms the foundation upon which modern technological advancements and scientific discoveries are built. Recently, mathematics is defined as a field of study that explores quantities, structures, space, and change, utilizing abstract concepts and logical reasoning to solve problems in both theoretical and practical contexts (Sigus and Mädamürk 2024). Beyond the academic and professional domains, mathematics plays a crucial role in everyday life. It is used in activities ranging from financial management, such as budgeting and investing, to decision-making processes that involve risk assessment and logical reasoning (Ozkale and Erdogan 2020).

In Nigeria, the importance of mathematics is underscored by the National Policy on Education, which mandates that mathematics must be a core subject in the curriculum at all levels of primary and secondary education. The policy emphasizes the role of mathematics in developing critical thinking, problem-solving skills, and the ability to apply knowledge in real-world situations (Federal Republic of Nigeria, 2013). This emphasis is driven by the recognition that mathematical competence is essential for individual and national development, particularly in a rapidly evolving global economy that increasingly relies on science and technology. Despite the significance of mathematics, there is a persistent challenge of poor achievement in mathematics, particularly at the secondary school level in Nigeria (Agwagah and Madueke 2023). The authors further argue that mathematics is crucial for developing critical thinking and problem-solving skills, which are essential for success in many professional fields and play a significant role in national development.

WAEC Chief examiner (2015-2018) reported the areas of weaknesses and strengths of students on selected mathematics questions and their responses. In quest to improve achievement, educational researchers have increasingly focused on identifying cognitive and non-cognitive predictors of students' achievement in mathematics. Among these predictors is spatial skills, which have garnered considerable attention. Spatial skills refer to the ability to visualize, manipulate, and reason about objects and their relationships in space. Gómez-Tone et al. (2021) defined spatial skill as a combination of abilities, such as imagining the movements of objects, mental rotation, and spatial visualization. Spatial skills enable individuals to manipulate, organize, and reason about spatial relationships in both concrete and abstract contexts, thereby facilitating complex scientific and mathematical problem-solving (Atit et al. 2020). According to the National Research Council (2006), the three key spatial abilities are the concept of space (e.g., the relationship between different units of measurement), tools of representation (e.g., organisation when reading from a graph or map), and process of reasoning (e.g., route distance in a rectangular street grid). Spatial skill supports a deeper understanding of abstract mathematical ideas, such as the relationships between geometric shapes, the visualization of functions, or the interpretation of graphs. Spatial visualization, which involves the mental manipulation of objects, is a key component in solving geometric problems and developing geometric thinking (Hidayat et al. 2023). Spatial skills are critical cognitive abilities that allow individuals to comprehend, reason, and remember the spatial relationships among objects. These skills are particularly integral to mathematical tasks, encompassing geometry, measurement, and visualization. The significance of spatial skills in STEM education cannot be overstated, as they play a fundamental role in how individuals conceive, express, and perform mathematical tasks (Zhu et al. 2023). Despite their importance, spatial thinking is often underemphasized in modern mathematics curricula, highlighting the need for more focused educational strategies to enhance these skills (Gilligan-Lee et al. 2022). These skills are critical for success in various mathematical domains, including geometry, trigonometry, and problem-solving (Mix & Cheng, 2020). These skills are crucial for navigating both real and virtual environments and are integral to a wide range of cognitive tasks, including problem-solving and spatial reasoning.

The relationship between spatial skills and mathematics is well-documented in the literature, with numerous studies highlighting the importance of spatial reasoning in mathematical problem-solving and conceptual understanding (Uttal et al., 2013). For instance, Lowrie and Logan (2023) found that interventions aimed at improving students' spatial skills led to significant gains in mathematics achievement. Similarly, Porat and Ceobanu (2024) emphasized the role of spatial training in enhancing students' abilities to grasp complex mathematical concepts, particularly in geometry and calculus.

Attitude refers to an individual's predisposition or tendency to evaluate objects, people, or situations either positively or negatively, which in turn influences behavior. It consists of three components: cognitive (beliefs and thoughts), affective (feelings and emotions), and behavioral (actions or intentions) (Eagly & Chaiken, 1993). Attitude is a critical factor influencing mathematics learning. Positive attitudes toward mathematics have been linked to higher academic achievement, better problem-solving skills, and a greater willingness to engage in mathematical tasks. Maloney et al. (2020) found that students with a positive disposition toward mathematics are more likely to approach complex problems with confidence, fostering deeper conceptual understanding. Also, Gunderson et al., (2022) discovered that students with positive attitudes toward mathematics are more likely to engage with spatially challenging tasks, improving their ability to visualize and manipulate mathematical concepts. He further argued students with negative attitudes tend to experience math anxiety, which can impair cognitive function and reduce performance.

Researchers have increasingly recognized that spatial skills are closely intertwined with mathematics learning, particularly in areas such as geometry, measurement, and problem-solving (Uttal et al., 2022). Based on reviewed literature, spatial skills are foundational to mathematical understanding and problem-solving training. For instance, Yang et al. (2020) conducted a meta-analysis that revealed the positive effects of early spatial skills on children's cognitive development, emphasizing the theoretical links between action and cognition. Similarly, Ishikawa and Newcombe (2021) found that spatial ability significantly contributes to academic achievement, particularly in mathematics and science, underscoring the importance of integrating spatial skills training in early education.Further studies have explored the impact of spatial cognition on learners' readiness and performance in STEM fields. Choudhary and Khushnood (2024) reviewed empirical studies and concluded that spatial skills facilitate learning by enabling better comprehension of spatial relationships, which are critical for understanding complex scientific concepts. Additionally, Gali (2021) highlighted the influence of spatial reasoning skills on understanding astronomical phenomena, further illustrating the broad applicability of spatial skills across different scientific domains. The role of spatial ability in learning with advanced technologies, such as virtual reality (VR), has also been examined. Lin & Suh (2021) conducted a comprehensive review of empirical research on the impact of spatial ability on VR learning, demonstrating that high spatial ability enhances the effectiveness of VR as an educational tool by facilitating spatial understanding and navigation in virtual environments. Overall, these studies collectively highlight the

integral role of spatial skills in enhancing learning outcomes and cognitive development across various educational contexts. However, the diversity of spatial skill levels among students presents significant challenges in educational contexts, particularly in STEM fields. The aim of the study is to explore the predictive power of spatial skills on students' achievement in and attitudes towards mathematics in Nigerian secondary schools. By examining the extent to which spatial ability influences mathematical achievement, this research aims to contribute to the ongoing discourse on improving mathematics education in Nigeria and beyond. A research question was raised, which states that what is the level of possession of the spatial skill by the secondary school students? Hypotheses that were formulated for the study are:

Ho1: spatial skill will not significantly predict senior secondary school students' achievement in mathematics.

Ho2: spatial skill will not significantly predict senior secondary school students' attitude towards mathematics.

II. Materials And Methods

This study examined number sense skill as determinant of senior secondary school students' achievement and attitude towards mathematics in Lagos State, Nigeria, using descriptive survey research approach. The achievement in and attitude towards mathematics are the dependent variables while spatial skill is the independent variable. The implementation of the research is secondary schools. A research question was raised and two hypotheses guided the study. Two different tests and a scale were used for instrumentation.

Participants

The study involved a total of one thousand and five hundred (1500) students from thirty (30) public senior secondary schools in Lagos East Senatorial District of Lagos State. The senatorial district is made up of five local Government areas which are Somolu, Kosofe, Ikorodu, Epe and Ibeju-Lekki. 30% proportion was used to select thity (30) schools from the existing schools in each local Government areas based on stratified sampling technique. Fifty (50) students were randomly selected each from the selected thirty (30) schools making one thousand and five hundred students in all. The students who took part were all in Senior Secondary School two (SS 2). Five research assistants were trained for three days and used in administering the tools.

Administration of Tools

All students were required to complete the two different tests and a scale given. The researchers with the help of research assistants administered the tools within six weeks. They made sure the time allotted to each tool was adhered.

Survey Instrument

Spatial Ability Test (SAT), Mathematics Achievement Test (MAT) and Students Attitude towards Mathematics Scale (SATMS) were the tools utilized to gather data for the study. The first tool is Spatial Ability Test (SAT) was adapted from Newton and Bristoll (2012). Its purpose was to measure students' capacity for mental shape manipulation. The original instrument was composed of forty-five (45) parts organised into four divisions. Among the tests are the PSVT: R (Pursue Spatial Visualisation Test: Rotations), MRT (Mental Rotation Test), DAT: SR (Differential Aptitude Test: Space Relations), and PRT (Picture Rotation Test). Two experienced psychologists from the Department of Psychology, Olabisi Onabanjo University perused the instrument for content and face validity. Some items were restructured while some were removed. In SAT, two-dimensional images are virtually projected in three dimensions. The final instrument consisted of 40 items each with four possible answers. PSVT: items 1-15, MRT: items 16-17, PRT: items 25-35, and DAT: items 18-24 and 36-40. The split-half method of reliability establishment was used to calculate the reliability coefficient of the instrument, and a sample of the instrument was given to fifty (50) students who were not involved in the study. SAT has the dependability coefficient of 0.84.

The second tool is Mathematics Achievement Test (MAT) consists of 40 multiple-choice questions, each with one correct answer and three incorrect answers. MAT was created to measure students' proficiency in mathematics. The questions were selected from New General Mathematics for Senior Secondary School II (SS2) to cover the following topics mensuration, trigonometry and calculus. The Mathematics Achievement Test (MAT) covers the blooms taxonomy of learning, which includes the area of knowledge, comprehension, and applications. The reliability and validity of MAT were keenly scrutinized for their appropriateness and correctness by creating a table of specification, the reliability was verified. The researcher initially prepared 120 item objective questions which were administered on 100 students aside the selected sample. This constituted the pilot test and their responses were used for item analysis.

The results of the analysis were used to pick items that were neither too difficult nor too easy (difficulty index between 40% and 60% was fixed). This discriminates positively between strong and weak students. MAT was comprised of 40 objective items based on item analysis process. A sample of 40 students apart from the selected sample were made to respond to the 40 item MAT. Split half reliability method was used

to measure the reliability of MAT and 0.763 was gotten. The items were re-arranged before administering to the sampled students.

The third tool is Students Attitude towards Mathematics Scale (SATMS) created to measure the attitudes of senior school students towards the learning of mathematics. The tool has thirty (30) items with a 4-point Likert scale type, i.e., Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). The instrument has 20 positively worded items and ten negatively worded items. It was validated and its reliability yielded 0.70. The data collected were analysed with the use of inferential statistics of regression analysis.

III. Results And Discussion

Table 1: Descriptive statistics with the independent (spatial) and dependent (achievement in and attitude towards mathematics) variables' means and standard deviations (N = 1500)

Variables	Mean Score	Standard Deviation	Minimum Score	Maximum Score
Spatial Skill	16.95	6.54	1	33
Achievement in Mathematics	11.87	5.32	1	40
Attitude towards Mathematics	91.00	12.02	17	126

The mean score for spatial skill is 16.95 with a standard deviation of 6.54. The wide range from the minimum score of 1 to the maximum score of 33 indicates significant variability in the spatial skills of the students. This variability is consistent with the earlier discussed distribution, where a large proportion of students had low spatial skills while a smaller yet notable group exhibited high spatial skills. The mean score for achievement in mathematics is 11.87 with a standard deviation of 5.32. This distribution suggests that, on average, students' mathematical achievement is moderate, with a considerable spread around the mean. The range from 1 to 40 further indicates the diversity in mathematical performance among the students. The mean score for attitude towards mathematics is 91.00, with a standard deviation of 12.02. The scores range from 17 to 126, showing a broad spectrum of attitudes towards mathematics among the students. This variable is crucial as it can influence both the engagement and performance in mathematics.

Research Question

Q1: What is the level of possession of the spatial skill by the Senior Secondary II students?

The data provided in the table 2 reveals a varied distribution of spatial skills among senior secondary school students, with 43.5% of the students exhibiting low spatial skills, 26.9% demonstrating medium levels, and 29.6% possessing high spatial skills.

Table 2: Distribution of Respondents' Level of Possession of Spatial Skill

Spatial Skill	Frequency(N)	Percent (%)
Low	652	43.5
Medium	404	26.9
High	444	29.6
Total	1500	100.0

$H_0$1: Spatial skill will not significantly predict Senior Secondary II students' achievement in Mathematics.

Table 3: Regression of Spatial Skill on Students' Achievement in Mathematics

Multiple R= 0.138 **MultipleR^2= 0.019** **Adjusted R^2 = 0.018** **Std. The error of the Estimate = 5.270**					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig. of F**
Regression	810.810	1	810.810	29.192	.000*
	41606.840	1498	27.775		
	42417.650	1499			
Residual					
Total					

* Significant F at α = .05

Table 3 displays the findings of the regression of spatial skill of respondents' scores on the mathematics achievement. The outcome is statistically significant ($F = 29.192$, $p < 0.05$). This suggests that the variation in the students' mathematics achievement was considerably influenced by their spatial skills. The outcome indicates that spatial competence accounted for 1.9% of the variance in the dependent variable (students' achievement in mathematics), with a multiple correlation coefficient of 0.138 and an R^2 value of

0.019. Therefore, null hypothesis 2 is rejected. Thus, accounting for around 2% of the variance in the dependent variable, spatial competence is a strong predictor of mathematics achievement for Senior Secondary II pupils

$H_0$2: Spatial skill will not significantly determine Senior Secondary II students' attitude toward Mathematics.

Table 4: Regression of Spatial Skill on Students' Attitude towards Mathematics

Multiple R= 0.035 **Std. Error of the Estimate = 12.016**					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig. of F**
Regression	272.828	1	272.828	1.890	.169
	216274.166	1498	144.375		
Residual	216546.994	1499			
Total					

*** Significant F at α = .05; MultipleR^2**= 0.001; **Adjusted R^2** = 0.001

The result of the spatial skill regression on respondents' attitudes towards mathematics scores is shown in Table 4. The outcome is non-significant ($F = 1.890$, $p > 0.05$). This suggests that the difference in the students' attitudes towards mathematics is not greatly influenced by spatial ability. As a result, the dependent variable (students' attitude towards mathematics) accounted for 0.1% of the variance, as indicated by the multiple correlation coefficient of 0.035 and the R^2 value of 0.001. Therefore, null hypothesis 2 is retained. As a result, spatial ability only explains less than 1% of the variance in the dependent variable, making it an insignificant predictor of Senior Secondary II students' attitudes towards mathematics.

Discussion of Results

The descriptive statistics highlight the diverse levels of spatial skills, mathematical achievement, and attitudes towards mathematics among senior secondary school students. The fact that a substantial proportion of students fall into the low spatial skill category is disheartening, as research consistently indicates that spatial abilities are critical for success in mathematics. Findings from the research of Wang et al. (2021) revealed that spatial reasoning is strongly linked to mathematical problem-solving and understanding, particularly in areas such as geometry, trigonometry, and algebra. Students with low spatial skills often struggle with visualizing and manipulating objects in space, which can hinder their ability to grasp abstract mathematical concepts.

More so, Uttal et al., (2022) who reported that low spatial skills have been associated with difficulties in understanding the spatial relationships in word problems, which are essential for solving complex mathematical tasks. The medium spatial skill group represents a significant portion of the student population. These students possess adequate but not exceptional spatial abilities. This is buttressed by Mix and Cheng (2020) who reported that students with little spatial knowledge are often able to perform well in routine mathematical tasks but may encounter challenges when faced with more complex problems that require advanced spatial reasoning. This supports the findings of Newcombe & Shipley (2022) who reported that high spatial ability is a strong predictor of success in STEM (Science, Technology, Engineering, and Mathematics) fields, particularly mathematics. These students are more adept at visualizing mathematical problems, understanding geometric relationships, and applying spatial reasoning to solve complex mathematical tasks. This also corroborates the findings of Wai et al. (2020) who reported that enhancing spatial skills could be particularly beneficial in fostering mathematical talent and encouraging students to pursue advanced studies in mathematics and related disciplines. Findings from the inferential statistics shows that spatial skill significantly predicts senior secondary school students' achievement in mathematics. This corroborates the findings of Wang et al. (2021) who reported a positive correlation between spatial skills and mathematical achievement, indicating that students with higher spatial skills tend to perform better in mathematics. Additionally, Ishikawa (2021), concluded that higher achievement in mathematics and science are facilitated by spatial ability. It is also supported by the findings of Alkouri (2022), that shows spatial skills facilitate learning by enabling better comprehension of spatial relationships, which are critical for understanding complex scientific concepts demonstrating that high spatial ability enhances the effectiveness and facilitates spatial understanding and navigation in mathematics.

The findings from the second hypothesis showed that spatial skill substantially does not predict senior secondary school students' attitude towards mathematics. This suggests attitudes are more strongly influenced by affective and contextual factors. This is similar to the report of Wang et al., (2023) that observed variability in attitudes could be influenced by personal interest, perceived difficulty of the subject, and past experiences with mathematics learning. Similarly, a study by Anderson et al. (2022) emphasizes that attitudes towards mathematics are multifaceted and influenced by emotional and social factors rather than purely cognitive skills. This is in agreement with the findings of Bulut and Kuzu (2023) reinforces these findings, suggesting that while

cognitive skills contribute to mathematical achievement, they have a negligible direct impact on students' attitudes.

IV. Conclusion

This study examined spatial skills as predictors of students' achievement in and attitude towards mathematics. A research question was raised and two hypotheses were tested at 0.05 level of significance in accordance with the study's objectives using regression analysis. Based on the quantitative analysis of the data from the respondents, the following the main findings of the study. Firstly, the findings revealed that the sampled students had low possession of spatial skills. Secondly, spatial skills statistically and significantly predicted students' achievement in mathematics and thirdly, spatial skill did not statistically significant in predicting students' attitude towards mathematics. In conclusion, the results of the findings indicated that low possession of spatial skills is responsible for the students' low achievement in mathematics. Hence, teachers' are encouraged to prioritize spatial skill and integrate it in their teaching so that students are properly grounded thereby, achievement in mathematics can be improved.

Declaration of Interest

The authors declare that there is no conflict of interest.

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