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Cognitive Flexibility and Academic Performance of Secondary School Students in Mathematics in Ekiti State, Nigeria

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Abstract
This study investigated the influence of cognitive flexibility on the academic performance of senior secondary school students in Mathematics. The study also looked into the influence of gender and age on the students' cognitive flexibility in mathematics. A descriptive survey design was adopted, and a sample of 500 students was selected from Ekiti State, Nigeria, using a multi-stage sampling procedure. Data were collected with the Mathematics Achievement Test (MAT) and the Mathematics Cognitive Flexibility Scale (MCS). The MAT's content validity was ensured through a table of specification, and its reliability coefficient of 0.76 was obtained using Kuder-Richardson formula 20 (KR-20) reliability method while the content validity of MCS was ensured using Lawshe Ratio and its reliability coefficient of 0.75 was ascertained using Cronbach's Alpha reliability method. Research questions were analysed using frequency counts, means, and standard deviation, while hypotheses were tested with t-test. Findings revealed that less than half of the students attained high performance in Mathematics, while most displayed above-average cognitive flexibility. Results also showed a significant effect of cognitive flexibility on Mathematics performance. Age significantly influenced cognitive flexibility, whereas gender did not. The study recommends that Mathematics teachers adopt practical and sequential teaching approaches to enhance students' cognitive flexibility, considering age differences but promoting gender-inclusive while considering cognitive flexibility in the teaching and learning of mathematics.
Keyword: Cognitive flexibility, Mathematics, Gender, Age

Introduction
Mathematics is an essential subject in virtually all areas of study especially in Science, Technical and Commercial related disciplines. Mathematics is one of the compulsory subjects in senior secondary school certificate examinations. The knowledge of Mathematics is needed for success in academics and day-to-day activities. Aborisade (2009) defined Mathematics as the king and queen of all other subjects. According to Fajobi (2024), Mathematics is fundamental to the understanding of Science and Technology.
Mathematics is logical due to its cognitive and multi-tasking nature. Mathematics is more of cognitive than affective or psychomotor. It requires shifting from one concept to another, thereby, making it cognitively flexible.

Cognitive flexibility is defined as the mental capacity to alternate between contemplating two or more distinct or interconnected concepts concurrently. Cognitive flexibility pertains to the ability to transition between tasks. Uddin (2021) defines cognitive flexibility as being able to alternate between contemplating two distinct ideas or several conceptions concurrently. Archambeau and Gevers (2018) assert that the function in numerical cognition is heterogeneous. Diamond (2013), Miyake and Friedman (2012) defined cognitive flexibility as the ability to transit between various mental systems, tasks, or methods.

Cognitive flexibility is essential for mathematical performance to facilitate the transition between mathematical operations, such as the shift between addition and subtraction concept is required in solving 1/2 + 2/3 - 3/4 Hardly is there a problem in Mathematics that would not require switching from one mathematical operation to another. It seems students usually find mathematical problems that require multiple switching from one operation to another operation difficult. The more cognitive flexibility requires in a mathematical problem, the more it becomes difficult to solve. Therefore, it seems the more cognitively flexible a student or testee is, the more his/her success in Mathematics.

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Mathematics is multi-tasking in nature perhaps it requires ability to perform many tasks simultaneously. A problem in Mathematics may involve many tasks to solve it, for instance, solving quadratic equation; $\pi^2 + 5\pi + 6 = 0$ will involve switching from multiplication to addition tasks or vice-versa intermittently. Therefore, cognitive flexibility is essential if students are to apply mathematical knowledge to new concept, and therefore, a key ingredient in Mathematics problem solving.

Solving problems in Mathematics requires connection between different Mathematics concepts. The connection between different Mathematics concepts cannot be overemphasized (Training Manual UBEC, 2025) as addition has a connection with multiplication, subtraction and division. Mathematics is spiral in nature, and, therefore, no concept in Mathematics can be in isolation of others. Hence, problem solving in Mathematics involves shifting from on mathematical principle to another which requires cognitive flexibility.

Researches have shown that gender could have influence on students' cognitive flexibility. Artawijaya and Supratiwi (2024) found a disparity in the cognitive flexibility mean score of female with male adolescents having higher cognitive flexibility than their female counterparts though the difference is not statistically significant. However, Kercood, et al. (2021) posited that gender could influence cognitive flexibility among college students.

There is a general belief that age has influence on cognitive development. Bertiz and Kocaman (2020) reported that there is statistically significant relationship between students' cognitive flexibility level in relation to their age. Putri, et al. (2024) asserted that age significantly influences the cognitive flexibility of students. Nevertheless, certain studies have indicated that students age does not influence their cognitive flexibility levels (Altunkol, 2011; Asici and Ikiz, 2015).

Statement of the Problem

Mathematics is a logical subject that requires critical thinking, especially in some topics that require knowledge of multiple concepts. It has been observed that students find some topics in senior secondary school Mathematics difficult because of its complexity, some topics in Mathematics require shifting from one concept to another. Mathematics is a subject that links one concept to another, therefore, when a Mathematics problem involves linking multiple concepts, it becomes difficult for the students.

Senior Secondary School Certificate Examinations examiners' reports have shown that candidates found some topics difficult in their Mathematics examination, thereby affecting their performance in the subject. Researchers have looked into some factors such as teaching methodology, use of instructional materials, teachers' qualification among others as reasons for making some topics difficult for the students. Yet the performance of the students in the subject is still not encouraging. Therefore, it seems the problem may not really be pedagogical but rather cognitive and it seems little have been done in the area of cognitive flexibility as it affects students' performance in Mathematics.

This study, therefore, looked into the cognitive flexibility of the students viz-a-viz their performance in Mathematics. It also looked into whether gender and age of the students influence their cognitive flexibility.

Purpose of the Study

The study examined the influence of cognitive flexibility of students in Senior Secondary Schools on their performance in Mathematics. Also, it looked into the influence of gender and age of the students on their cognitive flexibility in mathematics.

Research Questions

These research questions were raised for this study:

1. What is the level of performance of the students in Mathematics?
2. What is the cognitive flexibility level of the students in Mathematics?

Research Hypotheses

These research hypotheses were formulated to guide the study:

1. There is no significant influence of students' cognitive flexibility on their academic performance in Mathematics.

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2. Gender will not significantly influence students' cognitive flexibility in Mathematics.
3. Age will not significantly influence students' cognitive flexibility in Mathematics.

METHODOLOGY

Research Design

The study employed a descriptive research design with a survey approach. The design allows the researcher to look into the influence of cognitive flexibility and performance of students in Mathematics. The design is also suitable to describe the characteristics of gender and age of the students on their cognitive flexibility in Mathematics.

Population and Sample

The study population comprised Public Senior Secondary School Three (SSS3) students in Ekiti State, Nigeria. The selection of SSS3 students was premised on the consideration that they were already preparing for the external examination and should have been taught topics that require higher cognitive flexibility. The sample for the study comprised 500 students using multistage sampling procedure. The very first stage involves selecting a local government area from each senatorial district within the state, with the use of a simple random sampling technique. The second stage entails selecting three senior secondary schools from each of the sampled local government areas within two senatorial districts that have a smaller number of secondary schools. In contrast, four schools were chosen from the remaining local government area that has a larger number of secondary schools, utilising simple and proportionate sampling techniques. In the fourth stage, a random selection of 50 students was made from each of the sampled schools, employing proportionate and stratified sampling techniques to account for the students' gender and age.

Research Instruments

The study employed two research instruments for the study. A 4-point cognitive flexibility scale of 15 items adapted from the scale developed by Martin and Rubin (1995) was used to measure the students' cognitive flexibility while the 2022 West Africa Senior Secondary School Mathematics Certificate Examination objective test was adopted to measure students' performance in Mathematics. The reliability coefficient of the instruments was 0.75 and 0.76 respectively using Cronbach's Alpha and Kuder-Richardson formula 20 (KR-20) reliability methods respectively.

Method of Data Collection

Data were collected after taking administrative approvals from the sampled schools. Each instrument was administered on the students with the aid of well-trained research assistants.

Data Analysis

Descriptive statistics such as percentage, frequency count were used to answer the research questions. The hypotheses postulated were analysed using students' t-test statistical tool.

Results

Research Question

Research Question 1: What is the level of students' performance in the mathematics test?

Table 1: *Frequency and Percentage showing level of students' performance in mathematics test*

Students' performance Mathematics test	Frequency	Percentage
Low (0.00 – 17.00)	99	12.40
Moderate (18.00 – 33.00)	197	42.18
High (34.00 – 50.00)	204	45.42

Students' performance in the Mathematics Achievement test is presented in Table 1. The responses were scored to assess performance levels categorised as low, moderate, or high. The low performance was calculated by taking the mean and subtracting the standard deviation (15.55 – 5.68 = 9.86). The moderate performance was assessed using the mean mark of 15.55, whereas the high performance was calculated with the addition of standard

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deviation and mean mark (15.55 + 5.86 = 21.24). The level of students' performance in the Mathematics Achievement test are categorised as follows: low performance is indicated by scores ranging from 0.00 to 17.00, moderate performance is represented by scores from 18.00 to 33.00, and high performance is denoted by scores ranging from 34.00 to 50.00.

The results revealed that out of 500 respondents, 99 of the respondents representing 19.80 percent had low performance in the Mathematics test. Those with moderate performance in the Mathematics test were 197 representing 39.40 percent while 204 respondents representing 40.80 percent had high performance in Mathematics test. This shows that less than average of the students had high performance in the Mathematics test.

Research Question 2: What is the Cognitive flexibility level of the students in mathematics?

Table 2: *Frequency, Percentage, Mean and Standard Deviation showing Cognitive level of students in Mathematics Achievement test*

S/N	Items	SA		A		D		SD		Mean	SD
		f	%	*f*	%	*f*	%	*f*	%		
1.	I don't find it hard deciding when faced with complicated Mathematics problems	235	47.0	189	37.8	58	11.6	18	3.6	3.28	0.81
2.	When I face challenging issues in mathematics, I do not find myself losing control.	169	33.8	262	52.4	47	9.4	22	4.4	3.16	0.76
3.	I have fun looking at difficult mathematical issues from different viewpoints.	192	38.4	193	38.6	66	13.2	49	9.8	3.06	0.95
4.	I don't find Mathematics problems that requires knowledge of multiple concepts difficult	183	36.6	209	41.8	69	13.8	39	7.8	3.07	0.90
5.	I can imagine multiple ways to resolve a difficulty Mathematics problem.	197	39.4	197	39.4	71	14.2	35	7.0	3.11	0.89
6.	I don't find mathematics problems that requires shifting from one numerical operation to another difficult	198	39.6	192	38.4	70	14.0	40	8.0	3.09	0.92
7.	I don't find mathematics difficult because it requires much thinking	165	33.0	201	40.2	84	16.8	50	10.0	2.96	0.94
8.	I don't become so stressed when I am solving difficult mathematics problems	154	30.8	199	39.8	92	18.4	55	11.0	2.90	0.96
9.	When I come across difficult mathematics issues, I stop and attempt to think of different approaches to solve them.	197	39.4	209	41.8	61	12.2	33	6.6	3.14	0.87
10.	I like mathematics because it requires performing multiple tasks at a time	168	33.6	182	36.4	84	16.8	66	13.2	2.90	1.01
11.	Solving mathematics problems do not take a lot of time despite its complexity	237	47.4	177	35.4	58	11.6	28	5.6	3.25	0.68
12.	I find additional information immediately when solving mathematics problems	195	39.0	170	34.0	70	14.0	65	13.0	2.99	1.02
13.	I quickly think of how to solve difficult mathematics problems	125	25.0	182	36.4	130	26.0	63	12.6	2.74	0.97
14.	I don't find it difficult to think of many concepts in mathematics at a time	148	29.6	143	28.6	97	19.4	112	22.4	2.65	1.13
15.	I don't see mathematics as too logical	180	36.0	161	32.2	82	16.4	77	15.4	2.89	1.06
									Grand Mean	**3.01**	

Mean Cutoff = 2.50

The result of table 2 show that 235 (47.0%) of the sample strongly agreed, 189 (37.8%) agreed, 58 (11.6%) disagreed and 18 (3.6%) strongly disagreed that students do not find it hard making decisions when faced with difficult Mathematics problems, while 169 (33.8%) of the sample strongly agreed, 262 (52.4%) agreed, 47 (9.4%) disagreed and 22 (4.4%) strongly disagreed that When students face challenging issues in mathematics they do not feel like losing control, while 192 (38.4%) of the sample strongly agreed, 193 (38.6%) agreed, 66 (13.2%) disagreed and 49 (9.8%) strongly

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disagreed that students have fun looking at difficult mathematics issues from many different viewpoints, while 183 (36.6%.) of the respondents strongly agreed, 209 (41.8%) agreed, 69 (13.8%) disagreed and 39 (7.8%) strongly disagreed that students do not find Mathematics problems that requires knowledge of multiple concepts difficult, while 197 (39.4%) of the respondents strongly agreed and 197 (39.4%) agreed, 71 (14.2%) disagreed and 35 (7.0%) strongly disagreed that students can use multiple ways to resolve a difficulty Mathematics problems, while 198 (39.6%.) of the respondents strongly agreed, 192 (38.4%) agreed, 70 (14.0%) disagreed and 40 (8.0%) strongly disagreed that students don't find mathematics problems difficult if it does not requires shifting from one numerical operation to another, while 165 (33.0%) of the sample strongly agreed and 201 (40.2%) agreed, 84 (16.8%) disagreed and 50 (10.0%) strongly disagreed that students do not find mathematics difficult because it requires much thinking, while 154 (30.8%) of the sample strongly agreed, 199 (39.8%) agreed, 92 (18.4%) disagreed and 55 (11.0%) strongly disagreed that students do not become so stressed when they are solving difficult mathematics problems, while 197 (39.4%) of the sample strongly agreed, 209 (41.8%) agreed, 61 (12.2%) disagreed and 33 (6.6%) strongly disagreed that when students come across difficult Mathematics issues, they stop and attempt to think of different approach to solve them, while 168 (33.6%) of the sample strongly agreed, 182 (36.4%) agreed, 84 (16.8%) disagreed and 66 (13.2%) strongly disagreed that students don't hate mathematics because it requires performing multiple tasks at a time, while 237 (47.4%.) of the sample strongly agreed, 177 (35.4%) agreed, 58 (11.6%) disagreed and 28 (5.6%) strongly disagreed that solving mathematics problems do not take a lot of time due to its complexity, while 195 (39.0%) of the sample strongly agreed and 170 (34.0%) agreed, 70 (14.0%) disagreed and 65 (13.0%) strongly disagreed that students find additional information immediately when solving mathematics problems, while 125 (25.0%.) of the sample strongly agreed, 182 (36.4%) agreed, 130 (26.0%) disagreed and 63 (12.6%) strongly disagreed that students do quickly think of how to solve difficult mathematics problems, while 148 (29.6%) of the sample strongly agreed and 143 (28.6%) agreed, 97 (19.4%) disagreed and 112 (22.4%) strongly disagreed that students find it difficult to think of many concepts in mathematics at a time, while 180 (36.0%) of the sample strongly agreed and 161 (32.2%) agreed, 82 (16.4%) disagreed and 77 (15.4%) strongly disagreed that students do not see mathematics as too logical. The grand mean score of 3.01 is greater than the mean cut off 2.50 this implies that; the students' cognitive level is high.

Research Hypotheses

Research Hypothesis 1: There is no significant influence of students' Cognitive Flexibility on their Academic performance in Mathematics

Table 3: *Summary of t-test statistics between cognitive flexibility and students' Academic performance test in Mathematics*

Variables	N	Mean	SD	df	t cal	si g. value
Cognitive Flexibility	500	45.200	5.274	998	85.453	0.000
Academic Performance	500	15.552	5.689			

P<0.05

Table 3 indicated that the significance value of 0.000 is less than 0.05 at the 0.05 level of sig. The hypothesis is hence rejected. This indicates a significant influence of students' Cognitive Flexibility on their Academic Performance in Mathematics.

Research Hypothesis 2: Gender will not significantly influence students' cognitive flexibility in mathematics

Table 4: *Summary of t-test statistic on gender and students' cognitive flexibility in mathematics.*

Cognitive flexibility	N	Mean	SD	df	t-cal	sig. value
Male	207	45.425	5.424	498	0.802	0.423
Female	293	45.041	5.168			

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P>0.05

Table 4 indicates that the significance value of 0.423 is greater than the 0.05 level of sig. The hypothesis is hence not rejected. This suggests that gender will not significantly influence students' cognitive flexibility in mathematics.

Research Hypothesis 3: Age will not significantly influence students' cognitive flexibility in mathematics.

Table 5: *Summary of t-test statistic on age and students' cognitive flexibility in mathematics*

Cognitive flexibility	N	Mean	SD	df	t-cal	sig. value
Less than 17 years	132	46.537	4.794	498	3.434	0.001
17 years and above	368	44.720	5.361			

P<0.05

Table 5 indicates that the significance value of 0.001 is below the 0.05. The hypothesis is therefore rejected. This suggests that age will have a considerable impact on students' cognitive flexibility in mathematics.

Discussion

The finding revealed that the students' cognitive flexibility has significant influence on their academic performance in Mathematics. The result is in conformity with the findings of Santana, et al (2022) that cognitive flexibility could influence students' performance in mathematics .

This could be as a result of the fact that knowledge in Mathematics requires ability to shift from one principle to the other and the spiral nature of Mathematics as a subject.

The result also indicated that gender does not significantly influence the cognitive flexibility of students in Mathematics. The result is in conformity with the finding of Artawijaya and Supratiwi (2024) in their study that though male adolescents have higher mean cognitive flexibility scores than the female adolescents but the difference is not statistically different. However, the finding is at variance with the finding of Kercood et al (2021) which posited that gender could influence cognitive flexibility among college students. The result of this study might be because human cognition does not depend on gender.

The study revealed that the age of the students significantly influences their cognitive flexibility in Mathematics. This finding aligns with the results of Bertiz and Kocaman (2020), who reported a statistically significant relationship between students' age and cognitive flexibility level. Nonetheless, the results of this study contradict the conclusions drawn by Altunkol (2011), Asici and Ikiz (2015), Kardes (2016), and Bassu (2016), which indicated there is a relationship between age and cognitive flexibility level. This may be attributed to the influence of age on human neurological development.

Conclusion

The findings indicate that cognitive flexibility plays a crucial role on the performance of senior secondary school students in Mathematics. Likewise, gender of the students does not influence their cognitive flexibility, whereas their age does have an influence on cognitive flexibility in Mathematics.

Recommendations

The study's conclusions lead to the following recommendations:

1. In order to concretize students' understanding of the subject and increase their mathematical cognitive flexibility, teachers should always teach mathematics topics from easy to difficult. This will help students perform better in the subject.
2. The age of students must be taken into consideration when teaching mathematics, particularly when advanced mathematical skills are required since age of students influences their Mathematics cognitive flexibility.
3. Gender of students is not necessary to be taken into consideration while considering the influence of students' cognitive flexibility on their performance in mathematics.

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