International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Senior secondary school Students' Metacognitive Awareness and its Relatedness to Academic achievement in Geometrical Optics

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A B S T R A C T

The role metacognition plays in the teaching and learning of science concepts cannot be over emphasized. This is evident due to several reports on improved conceptualization and understanding of concepts related to difficult topics in science Education. This study investigated the level of metacognition of senior secondary school students and its relatedness to academic achievement in geometrical optics. The design of the study was Correlational survey and the sample consisted of 156 SSII students from two selected senior secondary schools in Bauchi metropolis. Metacognitive Awareness Inventory (MAI) and Geometrical Optics Achievement Test (GOAT) were used as instruments for data collection. Simple frequency and Pearson Product Moment of Correlation (PPMC) were used to answer the research questions while simple regression analysis was used to test the hypothesis at 0.05 level of significance. Findings from the study revealed that, the metacognitive awareness of senior secondary school students was weak and there was a low positive correlation between students' metacognitive awareness and their academic achievement in geometrical optics. The test of hypothesis further revealed that there was no significant relationship between students' metacognitive awareness and academic achievement in geometrical optics. The study therefore recommends a follow up intervention that incorporates the use of metacognitive strategies for the learning of geometrical optics.

Keywords: Metacognition, Academic Achievement, Geometrical Optics

1.0 INTRODUCTION

The Nigerian senior secondary school system plays a crucial role in preparing students for higher education and the workforce. However, a concerning decline in student performance has been observed in Bauchi state, particularly in subjects like geometrical optics and across both internal and external examinations (WAEC Chief Examiners Report, 2023). Several factors have been identified as contributing to this decline, with a focus on teacher-related factors like pedagogical strategies. While teacher-related aspects are important, less emphasis has been placed on investigating student-related factors that might influence their learning outcomes. One of such crucial factor is metacognition. According to Wilson (2001), Metacognition is used to refer to the awareness learners have of their own thinking; their evaluation of that thinking; and their regulation of that thinking. Ormrod (2004) defines Metacognition as what students know about their own cognitive processes and how they use these processes in order to learn and remember. Various frameworks of Metacognition have been developed by different researchers from their study of Metacognition which have led to the categorization of Metacognition into different components. But generally metacognition have been categorized into two components to include knowledge of cognition and regulation of cognition. The study of metacognition and its benefits have been found to be effective in enhancing students' problem solving skills (Balta, 2016; Ozsoy & Ataman, 2009), enhancing conceptual understanding of science concepts (Colthorpe et al., 2018), developing higher order thinking skills (Ghanizadeh, 2017) and improve their attitude towards science in order to improve the students' learning outcomes in science (Jahangard et al., 2016). Metacognition has also been found to have a positive correlation with academic achievement (Merchan Garzan et al, 2020; Khalid et al., 2023; Özçakmak et al, 2021; Alotaibi et al, 2017; Aloqleh, 2019).

Geometrical optics is a subject area that demands strong visualization skills, problem-solving abilities, and the capacity to apply learnt concepts to new situations. Difficulties in understanding concepts related to geometrical optics have been identified in the literature. Particularly, difficulties have been identified in optics due to the abstraction of the content, description of physical phenomena and process in the classroom (Jiao et al, 2017), misconceptions about the direction of light and how to determine its position from image (Kaewkhong, 2009). Developing metacognitive skills can significantly enhance students' learning experiences in geometrical optics by promoting self-awareness in such a way that students can identify their strengths and weaknesses in specific concepts, allowing them to focus on areas that need improvement (Lestari et al, 2019; Permana & Chamisijatin, 2019). Through the development of metacognitive skills, students' can actively choose and adapt learning strategies that are most effective for them in mastering geometrical optics. Students can also monitor their understanding and take initiative to seek help or clarification when needed thereby promoting self regulation.

While research on factors influencing geometrical optics performance exists, there's a clear lack of exploration regarding the role of metacognition, particularly within the context of Bauchi State. Most studies have focused on teacher-related factors like pedagogical approaches. This research aims to address the knowledge gap by exploring the potential role of metacognitive skills in improving student performance in geometrical optics within the Bauchi state senior secondary school Education. By investigating the link between metacognition and learning outcomes, this study can offer valuable insights for educators and policymakers.

Research Objectives

i. To assess the level of metacognitive awareness among senior secondary school students in Bauchi state regarding geometrical optics.

ii. To investigate the relationship between students' metacognitive awareness and their academic achievement in geometrical optics.

Research Hypothesis

The following null hypothesis was formulated and tested at 0.05 level of significance.

i. There is no significant relationship between senior secondary school students' metacognitive awareness and their academic achievement in geometrical optics.

2. LITERATURE REVIEW

2.1. Problem and introduction to metacognition

The main aim of the study is to investigate the metacognitive awareness of senior secondary school students for the learning of geometrical optics and its relationship with the academic achievement in geometrical optics. This is necessitated due to the poor conceptual understanding and performance of students in concepts related to geometrical optics. Metacognition according to Flavel (1979) is defined as thinking about one owns thinking. It has been defined as the awareness and control students have over their cognitive processes. Various frameworks of Metacognition have been developed by different researchers from their study of Metacognition which have led to the categorization of Metacognition into different components (Flavel, 1976; Meijer et al, 2013; Akyol & Garinnson, 2013; Taasoobshirazi & Farley, 2013). Regardless of the different categorization of metacognition in the cognitive psychology literature and general science education literature, several strategies have been identified to be metacognitive strategies, they include; error analysis, think aloud protocols, know want to know chat, modeling, concept maps, self asking checklist, time management, metacognitive prompts, journal writings as homework and regulatory checklists.

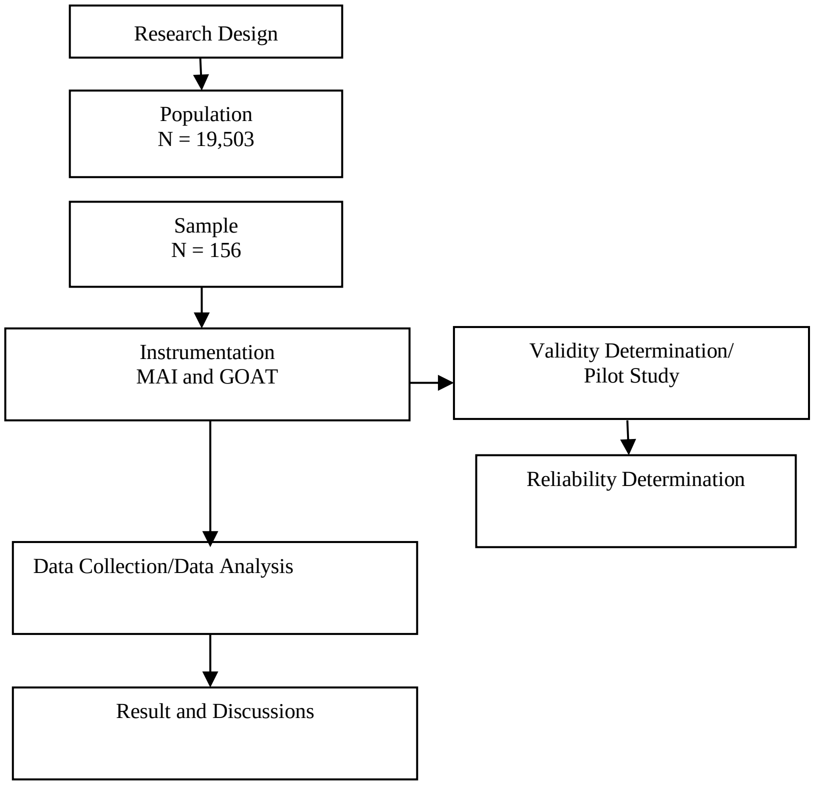
2.2 Metacognition and its influence to science education literature

All these strategies have been used and they have been found to enhance students learning outcomes. This can be found in the study linking Metacognition and learning in related areas, such as reading comprehension of physics texts and scientific inquiry skills (Zion et al., 2005). Paris and Winograd (1990) in Jones and Idol (Eds) similarly argued that students' learning can be enhanced by becoming aware of their own thinking as they engage into reading, writing, and solving problems in school, and that teachers should encourage this awareness directly by informing their students about effective problem-solving strategies and discussing cognitive and motivational characteristics of thinking.

According to Balta et al., (2016), Metacognitive skills possessed by students likely and determinant factor for adequate problem solving skills in physics. This means that developing students' metacognitive skills will amount to enhancing science learning, especially to improve students' problem-solving ability. Metacognition can also enhance conceptual understanding of science (Colthorpe et al., 2018), develop students' higher-order thinking skills (Ghanizadeh, 2017), and improve their attitude towards science in order to improve the students' learning outcomes in science (Jahangard et al., 2016). Metacognition can also be a determining factor for students' success in solving problems (Balta et al., 2016). Several studies have also shown how metacognition is positively correlated to academic achievement in science (Özçakmak et al., 2021; Alotaibi et al., 2017; Aloqleh & Teh, 2019; Bahri & Corebima, 2015).

3. METHODOLOGY

The flowchart for the methodology of the research can be seen in the figure below



3.2. Design, population and sample

Correlational Survey research design was used for the study. Correlational Survey research design is a combination of Correlational and Survey research designs. According (Creswell, 2014), a Correlational research design is used to assess the relationship and patterns of relationships among variables in a single group while a survey research design provides a quantitative or numeric description of trends, attitudes or opinions of a population by studying a sample of that population (Creswell & Creswell, 2018). The population of the study comprised of all 19,503 SSII students in the 215 public senior secondary schools offering Physics in Bauchi State. The sample of the study consists of 156 students drawn from two selected senior secondary schools in Bauchi State.

3.3. Instrumentation

The instruments used for data collection were a Metacognitive Awareness Inventory (MAI) and a Geometrical optics Achievement Test (GOAT). MAI was developed by Schraw and Dennison (1994) and was adapted and used for the study. MAI is a dichotomous scale questionnaire categorized as True or False and consisted of 52 items spread across the two components and sub – components of metacognition (see table 1). GOAT was developed by the researchers and consisted of 2 sections. The first section elicited students demographic information while the second section consisted of 4 essay type questions adapted from past senior secondary school certificate examination.

Table 1: Number of Items in Each Component and Sub-Component of Metacognition

SN	**COMPONENT**	**Sub-Components**	**Items in Sub-Components**	**Number of Items in Each Component**	**Total Number of Items in MAI**
1	Knowledge of Cognition	Declarative	5,10,12,16,17,20,32,46	17	
		Procedural	3,14,27,33		
		Conditional	15,18,26,29,35		
2	Regulation of Cognition	Planning	4,6,8,22,23,42,45	35	**52**
		Information Management	9,13,30,31,37,39,41,43,47,48		

	Comprehension Management	1,2,11,21,28, 34,49
	Debugging	25,40,44,51,52
	Evaluation	7,19,24,36

3.4 Data analysis

The students' responses of MAI and GOAT were quantitatively analysed using simple percentages, mean, standard deviation, Pearson Product Moment of Correlation (PPMC) and simple regression. For the purpose of this study, the researchers decide to categorize the response of the students into (See table 2)

Table 2: Definition, Categorization and Interpretation of Students Response

SN	Interval in %	Interpretation
1	Below 50	Weak
2	51 – 70	Moderate
3	71 – 90	Fair
4	91 – 100	Strong

3.5. Validity and reliability

A Pilot study was carried out in an area outside the area of the study due to similarities in demographics between the area and that of the main study. Kuder-Richardson reliability coefficient of 0.86 was obtained for Metacognitive Awareness Inventory (MAI) while a Split half reliability coefficient of 0.79 was obtained for Geometrical Optics Achievement Test (GOAT) making the instruments good and reliable to conduct the study.

4. RESULTS AND DISCUSSION

In order to address all the research questions and hypothesis, preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances and homogeneity of regression slopes.

Research Question 1

What is the level of metacognitive awareness among senior secondary school students in Bauchi state regarding geometrical optics?

Table 3: Metacognitive Awareness of Senior Secondary School Students (N = 156)

SN	Item Statements	TRUE	FALSE
1	I ask myself periodically if I am meeting my goals in optics	52.6	47.4
2	I consider several alternatives to a problem before I answer in optics.	51.2	48.8
3	I try to use strategies that have worked in the past in optics.	43.1	56.9
4	I pace myself while learning in order to have enough time in optics.	46.9	53.1
5	I understand my intellectual strengths and weaknesses in optics.	37.0	63.0
6	I think about what I really need to learn before I begin a task in optics	53.3	46.7
7	I know how well I did once I finish a test in optics.	43.8	56.2
8	I set specific goals before I begin a task in optics.	40.4	59.6
9	I slow down when I encounter important information in optics.	37.2	62.8
10	I know what kind of information is most important to learn in optics.	53.2	46.8
11	I ask myself if I have considered all options when solving a problem in optics.	43.6	56.4
12	I am good at organizing information in optics.	47.9	52.1

13	I consciously focus my attention on important information in optics.	47.7	52.3
14	I have a specific purpose for each strategy I use in optics.	41.0	59.0
15	I learn best when I know something about optics.	52.5	47.5
16	I know what the teacher expects me to learn in optics.	40.8	59.2
17	I am good at remembering information in optics.	44.2	55.8
18	I use different learning strategies depending on the situation in optics.	42.2	57.8
19	I ask myself if there was an easier way to do things after I finish a task in optics.	44.8	55.2
20	I have control over how well I learn optics.	43.0	57.0
21	I periodically review to help me understand important relationships in optics.	45.6	54.4
22	I ask myself questions about the material before I begin in optics.	50.5	49.5
23	I think of several ways to solve a problem and choose the best one in optics.	52.6	47.4
24	I summarize what I've learned after I finish in optics.	43.0	57.0
25	I ask others for help when I don't understand something in optics.	43.1	56.9
26	I can motivate myself to learn when I need to in optics	43.0	57.0
27	I am aware of what strategies I use when I study optics.	40.6	59.4
28	I find myself analyzing the usefulness of strategies while I study optics.	40.1	59.9
29	I use my intellectual strengths to compensate for my weaknesses in optics.	35.3	64.7
30	I focus on the meaning and significance of new information in optics.	41.3	58.7
31	I create my own examples to make information more meaningful in optics.	45.9	54.1
32	I am a good judge of how well I understand something in optics.	49.1	50.9
33	I find myself using helpful learning strategies automatically in optics.	48.4	51.6
34	I find myself pausing regularly to check my comprehension in optics.	34.0	66.0
35	I know when each strategy I use will be most effective in optics.	34.1	65.9
36	I ask myself how well I accomplish my goals once i finished my task in optics.	49.1	50.9
37	I draw pictures or diagrams to help me understand while learning optics.	47.6	52.4
38	I ask myself if I have considered all options after I solve a problem in optics.	47.7	52.3
39	I try to translate new information into my own words in optics.	47.2	52.8
40	I change strategies when I fail to understand concepts optics.	32.1	67.9
41	I use the organizational structure of the text to help me learn optics.	46.5	53.5
42	I read instructions carefully before I begin a task in optics.	55.2	44.8
43	I ask myself if what I'm reading is related to what I already know in optics.	42.9	57.1
44	I reevaluate my assumptions when I get confused in optics.	36.2	63.8
45	I organize my time to best accomplish my goals in optics.	49.4	50.6
46	I learn more when I am interested in the topic in optics.	50.3	49.7
47	I try to break studying down into smaller steps in optics.	37.4	62.6
48	I focus on overall meaning rather than specifics in optics.	34.6	65.4
49	I ask myself questions about how well I am doing while I am learning something new in optics.	47.4	52.6
50	I ask myself if I learned as much as I could have once I finish a task in optics.	46.0	54.0

51	I stop and go back over new information that is not clear in optics.	40.7	59.3
52	I stop and reread when I get confused in optics.	36.6	63.4
Mean Percentage% =		**44.2**	**55.8**

Data presented in table 3 shows that all the 52 items in MAI had a percentage of 32.1 to 55.2. A grand mean percentage for all items in MAI was found to be 44.2 for True which falls below 50% and therefore indicates that the students' possession of metacognitive awareness is weak. This further indicates that only 44.2 percent of respondents tend to possess one form of metacognitive strategies to the other.

Table 4: Metacognitive Awareness of Each Sub-Component of Senior Secondary School Students (N = 156)

SN	COMPONENT	Sub-Components	Mean Percentage %		
			True	False	Interpretation
1	Knowledge of Cognition	Declarative	45.7	54.7	Weak
		Procedural	43.3	56.7	Weak
		Conditional	41.4	58.6	Weak
2	Regulation of Cognition	Planning	49.8	50.2	Weak
		Information Management	42.8	57.2	Weak
		Comprehension Management	44.9	55.1	Weak
		Debugging	37.7	62.3	Weak
		Evaluation	45.5	54.5	Weak

Data presented in table 4 indicates that each sub-component of metacognition had a mean percentage that falls between 37.7 to 49.8 indicating that all the sub-components mean percentage fell between the benchmark for weak possession of metacognition awareness.

Research Question 2

What is the relationship between students' metacognitive skills and their performance in geometrical optics examinations?

Table 5: Mean and Standard Deviation and Relationship Between Senior Secondary School Students' Metacognitive Awareness and their Academic Achievement in Geometrical Optics.

Variable	N	Mean	Std. Deviation	r_{value}
Metacognitive Awareness	156	44.2	8.743	
				0.122
Academic Achievement	156	38.6	10.532	

Table 5 above shows that the metacognitive awareness of senior secondary school students was found to have a mean score of 44.2 and standard deviation of 8.743 while the mean and standard deviation of senior secondary school students' academic achievement in geometrical optics is 38. 60 and 10.532 respectively. An $\mathbf{r_{value}}$ of 0.122 was however established as the coefficient of relationship between senior secondary school students' metacognitive awareness and their academic achievement in the learning of geometrical optics. The obtained correlation value of 0.122 indicates that, there exist a low positive relationship between senior secondary school students' metacognitive awareness and their academic achievement in geometrical optics.

Research Hypothesis

There is no significant relationship between senior secondary school students' metacognitive awareness and their academic achievement in geometrical optics.

Table 6: Regression Analysis of the Relationship between Metacognitive Awareness and Academic Achievement in Geometrical Optics (N = 156)

Std Coefficient Beta	T	R	R Squared	Adjusted R Square	P_{value}	Remark
.122	2.414	.122	.215	.012	.007	Rejected

a. Predictors: (Constant), Metacognitive Awareness

b. Dependent Variable: Academic Achievement

The regression analysis on the test of null hypothesis in table 6 established a standardized coefficient beta value of 0.122 and t = 2.414 suggesting that the relationship between senior secondary school students metacognitive awareness and their academic achievement in geometrical optics is positive. An R value was found to be .122 with an R – squared value of 0.215 indicating a low relationship between them. A p value of .000 < 0.05 was also established indicating that there exists a significant relationship between senior secondary school students metacognitive awareness and their academic achievement in geometrical optics. The hypothesis was therefore rejected.

DISCUSSION

The main aim of the study is to investigate the metacognitive awareness of senior secondary school students for the learning of geometrical optics and its relationship with the academic achievement in geometrical optics. Based on the analysis conducted for this study, it was found out that the metacognitive awareness of senior secondary school students in geometrical optics was weak. The analysis of all components and the formative constructs that make up metacognition like declarative, procedural, conditioning, planning, execution, reflection and evaluation indicated a weak level of metacognition for all them. This indicates that students had always have a poor conceptualization of physics task, wrong choice of strategies to use in solving the problem, no any evidence of connectedness between physics principles and equations and they are no provision reflection skills through error analysis.

Findings also from the study indicated that there was a low positive correlation between senior secondary school students' metacognitive awareness and their academic achievement in geometrical optics. To answer this question, one hypothesis was formulated and tested at 0.05 level of significance. Findings from the result indicate that there was a low positive relationship between senior secondary school students' metacognitive awareness and their academic achievement in geometrical optics. The result also indicates that, the students' low performance in the achievement test was as a result of their weak metacognitive awareness. These findings are in-line with the findings of Özçakmak, Köroğlu, Korkmaz and Bolat (2021), Alotaibi, Tomaz and Jabak (2017), Aloqleh and Teh (2019), Khalid et al., (2023) in their separate studies on the relationship students metacognitive awareness and academic achievement, found that there exist a positive relationship or effect between metacognition and academic achievement.

CONCLUSIONS

This study sought to investigate the metacognitive awareness of senior secondary school students and its relationship with academic achievement in geometrical optics in Bauchi state. Analysis of the data obtained from the study indicates that the mean and standard deviation of (*M = 44.2 and SD = 8.743*) for MAI and (*M = 38.60 and SD = 10.532*) for GOAT. Base on the findings of this it was concluded that senior secondary school students' metacognitive awareness is weak and also there was a low positive relationship (*r- value = 0.122*) between their metacognitive awareness and academic achievement for the learning of geometrical optics in Bauchi State.

RECOMMENDATIONS

Based on the findings of this study, it was recommended that results from the study should be used as a baseline data for the conduct of an intervention for both teachers and students in order to teach or sensitize teachers on the role of metacognition in the learning of conceptually abstract and difficult topics in topics. The intervention would also expose students on the positive benefits of the use of metacognitive strategies for learning.

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