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Application of Brain-Based Learning Strategy for Students' Optimal Learning Outcomes in Mathematics

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Abstract

Broadly, mathematics is regarded as a pivot upon which industrial and technological developments rest. It is time to ensure that the pedagogical approach to the teaching and learning of mathematics would be the type that could guarantee creative thinking and optimal learning outcomes. Research evidence on quality of teaching showed that students' poor performance in mathematics stems mainly from inadequate instruction. Studies have shown that typical mathematics classroom is frosted with teaching techniques that are centered on explain-practice-memorize. Research evidence suggests that the adoption of learner-centered strategy based on the structure and functions of the brain can improve learners' academic performance. Therefore, this study investigated the application and appropriation of brain-based learning strategy for students' optimal learning outcomes in mathematics. Three research instruments were used for the study: Mathematics Attitude Questionnaire, Achievement Test in Mathematics and Cognitive Style Test. A sample size of 240 senior secondary school students was used for the study. The moderator effect of cognitive style was also examined on independent variable and dependent variable. The study adopted a pretest-posttest, non-equivalent control group design in a quasi-experimental setting. The results revealed significant main effect of treatment. The results showed that brain-based learning strategy is more sensitive at enhancing students' performance in mathematics. It is hereby recommended that teachers of mathematics should design classroom instructions in juxtaposition with brain-compatible instructional materials for students' optimal learning outcomes.

Keywords

Academic Achievement, Brain-Based Learning, Brain-Compatible Instructional Materials

1. Introduction

Mathematics is regarded as a pivot upon which industrial and technological developments rest. Knowledge of Mathematics is, therefore, a requirement for any nation aspiring to develop technologically and economically. Mathematics education is a subject or a thing of the mind that demands critical thinking. It has similar attributes of the engineering education which is a complex, multi-faceted process within which several internal and external factors interact to shape student performance (Winberg et al., 2016; Alabdulkarem et al., 2021). It is time to ensure that the pedagogical approach to the teaching and learning of Mathematics will be the type that can guarantee creative thinking and optimal learning outcomes.

Awofala (2002) points out that there have often been gaps between curriculum planners' intention and what goes on in Mathematics classroom. This is evident in the poor performance of Nigerian students in Mathematics at the end of their secondary education. The annual reports of the Chief Examiners in Mathematics indicate that students' performance in Senior Secondary School Certificate Mathematics examinations remains very low as many of the candidates scored zero or marks within zero range.

Summary of candidates' weaknesses in mathematics according to Chief Examiners Reports WAEC (2018-2021) candidates showed weaknesses in the following: Showing evidence of reading values from graphs, translating word problems into mathematical equations, solving problems on mensuration and geometry, drawing conclusions from logical statements. It was noted from the reports that the performance of candidates was quite good but declined significantly compared with the previous years.

Explanations for this lackluster performance abound. Sousa (2016) pointed out that Mathematics teachers claim that learning Mathematics is a little bit difficult because it is so abstract and requires more logical and ordered thinking. Education critics maintain that only a few students are really developmentally capable of handling Mathematics and that the poor performance stems mainly from inadequate instruction. Students' poor performance in certificate examinations in Nigeria calls for concern of stakeholders.

This apparently has made Mathematics educators to pay more attention at improving the process of teaching and learning of Mathematics in schools. These include the use of personalized system of instruction, clubs and games, combined strategies of concept-mapping and problem-solving, self-regulatory and cooperative learning strategies, and computer assisted programmed instruction among others.

While it is evident that these strategies are learner-centred and favour conceptual, sequential and logical aspects of Mathematics, none of them takes into consideration the function and structure of the brain. Research evidence suggests that the adoption of learner-centred strategy based on the structure and function of the brain can improve learners' academic performance (Sousa, 2016; Adebayo, 2005; Lucas, 2004; Lackney, 2003). Evidence abounds that brain activity is a suitable parameter for measuring cognitive load Cepeda-Freyre et al. (2020) and Paas, & van Merriënboer (2020).

According to Hart (1983), teaching without an awareness of how the brain works is like designing a glove with no sense of what a hand looks like; for instance, the shape of the hand and how it moves. He also pushes this analogy even further in order to drive home his primary point; if classrooms are to be places of learning, then "the organ of learning", the brain, must be understood and accommodated.

All around us are hard compatible tools and machines and keyboards, designed to fit the hand. We are not apt to think of them in that light because it does not occur to us that anyone would bring out some device to be used by human hands without being sure that the nature of hands is considered. A keyboard machine or musical instrument that called for eight fingers on each hand would draw instant ridicule. Yet, we force millions of children into schools that have never seriously studied the nature and shape of the human brain (Hart, 1983).

Brain-based learning strategy is a learner-centred and teacher-facilitated strategy that utilizes learners' cognitive endowments. Sousa (2004), Ryan Abott, 2022 opined that a brain-based approach integrates the engagement of emotions, nutrition, enriched environments, music, movement, meaning-making and the absence of threat for maximum learners' participation and achievement.

Proponents of brain-based instructional strategy (Sousa, 1995, 2004; Ryan & Abbot, 1999; Caine & Caine, 1997; Jensen, 1998) identified three instructional learning techniques of the strategy. These are:

1) **Relaxed Alertness:** It consists of low threat and high challenge. It is the technique employed to bring the brain to a state of optimal learning. It is a state that is present in classroom and learning environment in which emotional and social competence is the goal. Such an environment allows all students on-going opportunities, experience, competence and confidence accompanied by motivation linked to personal goals and interests.

2) **Orchestrated Immersion:** This is a technique of trying to eliminate fear in learners while maintaining a highly challenging environment. This corroborates the findings of the researchers Mayer (2017) who proposed nine approaches to reduce the cognitive load of learners, these approaches are to be implemented while designing a multimedia learning environment to create a conducive learning environment. It implies, the teacher becomes the orchestrator or the architect, designing experiences that will lead students to make meaningful connections by using various combinations of experience, reflection, conceptualization and experimentation. Real learning therefore comes from real doing. Learning is best accomplished when learning activity is connected directly to physical experience (Caine & Caine, 1997). Learner must be able to connect new knowledge effectively to what they already know and then put that new knowledge into practice. We remember best when facts and skills are embedded in natural, spatial memory, in real life activity,

in experiential learning.

3) Active Processing: This technique allows the learners to consolidate and internalize information by actively processing it. For a learner to gain insight into a problem there must be an intensive analysis of the different ways to approach it and about learning in general. The brain is a pattern maker. Pattern making is pleasing for the brain. The brain takes great pleasure in taking random and chaotic information and ordering it. The implication of this to learning and instruction is that presenting a learner with random and unordered information provide the maximum opportunity for the brain to order this information and form meaningful patterns that will be remembered, since the brain when allowed to express its pattern-making behaviour, creates coherency and meaning when a learner makes sense of an experience by immediately using the new information. This assertion is corroborated by the findings of Gao, et al. (2022) that it is a synergy of cognitive structure through events related potentials which enhances retention. Mayer (2017) posited that the total cognitive processing intended for learning comprises essential processing, incidental processing and representational holding. Carl et al. (2019) observed that in active processing, three stages are crucial viz: encoding, storage and retrieval (or recall). Encoding refers to the process through which information is learned. Vygotsky (1978) social development theory asserts that a child's cognitive development and learning ability can be guided and mediated by their social interactions.

Brain-based Learning Strategy! What is it all about? To many, the term "brain-based" learning sounds redundant. Isn't all teaching and learning brain-based? Advocates of brain-based teaching insist that there is a difference between "brain-compatible" education and "brain-antagonistic" teaching practices and methods which can actually impair learning.

Brain-based learning, sometimes called "Brain-Compatible learning" is an educational approach based on what current research in neuroscience suggests about how our brains naturally learn best (Luna, 2004). Aditya Shukla (2023) defines brain-based learning as a paradigm of learning which addresses student learning and learning outcomes from the point of view of the human brain. It involves specific strategies for learning which are designed based on how human attention, memory, motivation, and conceptual knowledge acquisition work. Brain-based learning and teaching can optimize learning holistically. The learning strategy derived from this research can easily be integrated into any learning environment, from a kindergarten classroom to a seminar for adults (Lucas, 2004).

With new technologies that allow scientists to observe brain's functions as they occur, we are gaining insights into how the brain learns, assimilates, thinks and remembers. From these findings, an approach to education, called the brain-based learning, has evolved.

This instructional strategy is based on the structure and functions of the brain. Lucas (2004) asserts that as long as the brain is not prohibited from fulfilling its normal processes, learning will occur since everyone is born with a brain that functions as an immensely powerful processor.

Understanding how the brain learns and relating it to the educational field resulted in the concept known as brain-based learning. It is defined as any teaching technique or strategy that utilizes information about the human brain to organize how lessons are constructed and facilitated with emphasis placed on how the brain learns naturally. Researchers, therefore, are of the view that if brain-based instructional strategy is adopted to teach Mathematics, learners could be better improved in terms of contextual thinking, creative reasoning, logical thinking, sequential learning, intuitive knowledge and insightful learning which are resistant to forgetting and these would aid better cognitive and affective learning outcomes in Mathematics.

Student's cognitive style has been found to mediate learning (Ige, 1998). Dan & Reiner (2017) opined that cognitive load indicates mental state during learning. Most of the differences encountered in students' learning could be described in terms of different manners in which students perceive and analyze a stimulus configuration (i.e. their cognitive styles). Each individual responds differently when exposed to a stimulus world. Some act on first impulse, some examine isolated components of what is presented to them before responding while others respond on the basis of contextual or holistic manner (Olajengbesi, 2006). This calls for its better understanding by the teacher in his choice and usage of teaching strategies.

Therefore, for learners to gain significantly from classroom interaction, there is a need to consider the cognitive styles of individual learners, and the instructional strategies that are most responsive to particular cognitive style.

Most of the studies did not make attempt to find the main and interaction effects of Brain-based learning strategy and cognitive styles on students' achievements in senior secondary school Mathematics. The crux of this study is anchored on the brain-compatible instructional materials designed by the researcher: Weekly Learning Terrain in mathematics, Needful Knowledge Package in Mathematics, Students' Knowledge Acquisition Card in Mathematics, Index Card Study Profile in Mathematics, Self-evaluation card in Mathematics.

Therefore, this study investigated the application of Brain-based learning strategy for students' optimal performance in Mathematics. The study also investigated the effect of cognitive styles as well as the interaction effect of brain-based learning strategy on students' achievements in senior secondary school Mathematics.

The following hypotheses were generated from the statement of the problem to guide the study and were tested at 0.05 alpha level of significance.

Hypothesis 1: There is no significant main effect of treatment on students' achievement in Mathematics.

Hypothesis 2: There is no significant main effect of cognitive style on students' achievements in Mathematics.

Hypothesis 3: There is no significant interaction effect of treatment and cognitive style on students' achievements in Mathematics.

2. Method

2.1. Research Design

The study adopted a pretest-posttest, non-equivalent control group in a quasi-experimental setting.

The research design is symbolically illustrated below:

Figure 1: Pretest—Posttest control group research design.

O_2 X_1 O_2 (E)

O_3 X_2 O_4 (C)

Where X_1 represents BBLS (treatment).

X_2 represents CST treatment

O_1 O_3 = Pre-test measures

O_2 O_4 = Post-test measures

The target Population was all Senior Secondary School Two (SS II) Students in Oyo State, Nigeria.

2.2. Sample and Sampling Technique

Using simple random sampling technique, one school was chosen from eight randomly selected local government areas to make a total of eight schools. 30 Senior Secondary School Two (SS II) students were randomly selected from each of the schools to make a total of two hundred and forty (240) students for the study.

2.3. Research Instruments

Three instruments were used for data collection:

1) Achievement Test in Mathematics (ATM);

2) Cognitive Style Test (CST);

3) Mathematics Attitude Questionnaire (MAQ);

The test items covered the three levels of cognitive domain of remembering, understanding and thinking as shown in Table 1.

Table 1. Test items specifications.

CONTENT AREA	COGNITIVE LEVELS			
	Remembering	**Understanding**	**Thinking**	**Total**
The sine and cosine rules	1	3	2	3
Angles of elevation and depression	4	6,9	5	4
Heights and distances	7	8, 10	11, 15	5
Bearings and distances	14	13	20	3
Angles between two places in the Earth's surface	18	12	17	3
Shortest distance between two points	16	17	-	2
Total	**6**	**8**	**6**	**20**

Note: The figures under Remembering, Understanding and Thinking are numbers of items.

2.4. Validation and Reliability of Achievement Test in Mathematics

The ATM was validated based on the contents of topics incorporated into the instructional design to see how the research instruments covered a representative sample of the content.

2.4.1. Cognitive Style Test (CST)

The CST is a reasoning test for measuring how students choose and analyse set of pictures of common objects, animals, plants or artifacts for the purpose of classifying them. The modification and revalidation were done by Onyejiaku, F. O. (1980) to reflect Nigerian environment. There is paucity of interaction effect of cognitive style studies, brain-based learning strategy and related fields. Bouiri, O. et al. (2021) & Abdelhadi et al. (2019) point out that cognitive style studies in engineering education are scare and seem to focus on the student's cognitive level, congitive operation personality traits, mental skills and learning styles. Bouri et al. (2021) opine that the cognitive style test also known as thinking styles assessment or learning styles tests helps to understand your preferred cognitive processing styles. It can guide personal learning strategies, enhance cognitive skills, and improve communication and collaboration in a team setting. The language students use in categorizing these phenomena presumably reflects their style of categorization. The statements made by the students regarding the way he/she perceives the pictures and classifies any two together could be categorized into three thus:

a) Analytic Descriptive (AD)—Students here place objects together based on their shared or common characteristics which are directly discernible. Example, in a card containing a man, a bed and a chair, students here placed together bed and chair because "they are made of wood."

b) Categorical Inferential (CI)—Students here place together objects on the basis of super-ordinate features which are not directly discernible (abstract) but are inferred. Example, students here will place a bed and chair together because "they are for relaxation".

c) Relational Contextual (RC)—Students here place together objects on the basis of feature establishing a relational link between them. Example, students here will place together "the man and the bed" or "the man and the chair" on the ground that, "the man can sit on the chair" or "sleep on the bed." This is in line with the findings of Pinna and Deiana (2018) and Wang and Guan (2022) which showed that coloured words may enhance performances. Although colourful numbers may induce more cognitive load for participants, there are different colours to process and hence may enhance performance of cognition. By implication, this number presentation strategy shows that although it adds colour information unrelated to mathematical computation, it may help learners focus on the information required for answering. In effect, categorizing students into Analytic cognitive style and non-analytic could empower the teacher to design suitable instructional materials for the two categories of the cognitive style (analytic and non-analytic) towards enhancing optimal learning in the subject.

In this study, analytic style students were those who scored above the median in AD and CI responses and below the median in RC responses. Non-analytic style students were those who scored above the median in RC responses and below the median in AD and CI responses.

2.4.2. Validation and Reliability of Cognitive Style Tests (CST)

Onyejiaku (1980) estimates the reliability estimates of items in the CST to range from 0.62 to 0.72. Onafowokan (1998) also trial-tested the CST using 137 Junior Secondary III students in four secondary schools in Nigeria. The trial-test results showed no ambiguities in the instrument.

2.4.3. Mathematics Attitude Questionnaire

This is an instrument of twenty items that elicits information from the participants on their attitude towards mathematics. The instrument is made up of two sections: A and B. Section A is designed to elicit responses in relation to student's name, age, gender, class and name of school. Section B is made up of twenty items (ten positive and ten negative statements), requesting participants to indicate their attitude towards the study of Mathematics based on a four-point Likert scale. Each participant was requested to tick an appropriate option weighted as follows:

Strongly Agreed (SA)	-	4
Agreed (A)	-	3
Disagreed (D)	-	2
Strongly Disagreed (SD)	-	1

This rating was meant to reflect how the participants felt about the particular statement.

2.4.4. Brain-Based Instructional Materials in Mathematics

The Brain-based Instructional Materials in Mathematics (Olaoluwa, 2009) are developed based on the findings of the following researchers, Jensen (1998), Nunley (2004). Their findings show greatest gain in achievement and attitude with the manipulative materials (right hemispheric) while the textbook approach (left hemispheric) resulted in the least gains. Sweller (2020) defines Cognitive load theory in the classroom as the application of an instructional theory that is based on human cognitive learning functions. Cognitive Load Theory (CLT) is an instructional design theory that reflects our "Cognitive architecture" or the way that we process information. During learning, information must be held in your working memory until it has been processed sufficiently to pass into your long-term memory. These materials are designed in consonance with cognitive load theory

1) NKPM—Needful knowledge package in Mathematics;
2) SKACM—Students' Knowledge Acquisition Card in Mathematics;
3) WLTM—Weekly Learning Terrain in Mathematics;
4) ISCP—Index Card Study profile in Mathematics;
5) SECM—Self-Evaluation Card in Mathematics;

1) "NKPM" (Needful Knowledge Package in Mathematics): The brain is pattern seeking. When new information enters the brain, it searches for familiar pattern and prior knowledge. Once it is located, the information makes an attachment to a neuron that creates an electrical spark, called a synopsis to another neuron. It is from the synoptic connection that dendrites, the brain's road map of knowledge are grown. "NKPM" is designed to enable students make meaningful connections and consolidate the gaps between the prior knowledge and new information. Copies of the "Needful Knowledge Package in Mathematics" for the current topic or mathematical concept are distributed to the learners to glance through within a few minutes.

2) "SKACM": (Students' Knowledge Acquisition Card in Mathematics) is designed to capture and retain students' attention to a greater extent throughout the learning episode. It is given to the students before the commencement of the lesson. The students are instructed to write the "summary" of important facts they are able to acquire from the lesson. This is done twice before the end of the lesson: The teacher instructs the students to complete part of the "SKACM" during the "brain-downshifting" period of the whole learning episode. The latter part is completed at the end of the lesson.

3) "WLTM": (Weekly Learning Terrain in Mathematics) is designed to engage the students in active processing. The teacher engages the learner in active processing by guiding the learner to gain insight into the problem. The learner needs to use three skills—order, structure and relate to the new information (at his own pace) to process new information and create mental pattern as favoured by the structure and functions of the brain. The learner needs to order, structure and relate to the new information. Copies of the "Weekly Learning Terrain" in Mathematics are displayed at strategic places in the classroom and on the Mathematics Bulletin Board for students to interact with.

4) "ICSPM": (Index Card Study Profile in Mathematics) is designed to cater for all the categories of learners, viz. fast learners, slow learners and other prominent individual differences that may exist among the students. Copies of "Index Card Study Profile in Mathematics" that are relevant to the present or current topic which is about to be taught should be made available in a shelf in the classroom. These cards contain key facts, mathematical concepts and definition of terms relating to the current topic. Students will be instructed to go at will to the shelf and explore from the enriched learning environments created within the four walls of the classroom.

5) "SEC"/"Q & S": (Self-Evaluation Card/Questions & Solution Card). This is designed for spot assessment. The teacher is expected to release the feedback before the commencement of the subsequent lesson. The outcome of the "Q/S" or Students' performance determines whether the teacher needs to maintain the status quo in the use of his strategies or mandatory to improve upon his strategies towards the actualization of an improved learning outcomes in the subsequent lesson. "SEC" cards containing questions and solution space are expected to be given to the students at the appropriate time. All cards in "Q" portray questions that are drawn from Mathematics concepts or topic (s) to be taught. All Cards in "S" portray detail (step-by-step) solution (s) to the questions in "QS".

2.4.5. Validation and Reliability of Brain-Compatible Instructional Materials (BCIM)

The BCIM were given to two Mathematics experts and one Educational Technology expert in the Department of Science, Mathematics and Technology, University of Ibadan, Ibadan Nigeria for face and content validation in terms of language clarity to the target audience, content coverage, and relevance to the stated objectives.

2.4.6. Primacy-Recency-Effect: Was also Taken into Consideration in This Study

The teacher does his teaching with optimum utilization of the "Prime Times" in mind. The brain learns best at the beginning and at the end of a learning episode—"Primary-Recency Effect" or focused, diffused and focused times in a learning episode. In a 40-minute period, students' attention is strongest for the first 20 minutes, then the brain needs "down time" for approximately 10 minutes (Brain's downshifting is like a camera that has a reduced focus). The next ten minutes is the next best teaching time (closure).

2.4.7. Data Analysis

Data collected were analyzed using Descriptive Statistics of means scores, standard deviation and Analysis of Covariance (ANCOVA) with the pre-test scores as covariates. Initially, students in both the experimental and control groups were pre-tested on the Achievement Test in Mathematics. Statistical analyses showed no significant difference in pre-test scores of the students.

Results of Findings

Table 2. Comparing the effects of brain-based learning strategy (bbls) and the conventional method.

Strategy	N	$\overline{X}$	S.D	Df	t-cal	t-table	Decision
Brain-Based Learning Strategy	120	2.51	0.86	236	2.27	1.940	Significant
Conventional Method	120	2.23	0.49				

Table 2 shows that the mean value (2.51) of students taught using Brain-based Learning Strategy is higher than that of the students taught with conventional method (2.23). This implies that students taught with Brain-based learning strategy performed better than those taught with Conventional Method. This shows that there is significant difference in the academic performance of the two groups. Therefore, the null hypothesis is rejected.

Table 3 showed that the experimental group had a mean value of 4.38 in the pre-test attitude and a mean value of 23.47 in the post-test attitude making a pre-test and post-test mean gain in the experimental group to be 19.97 but the control group had a mean value of 3.27 in the pre-test attitude and posttest of 19.33 with a pre-test and post-test mean gain of 16.07. This result showed that the disposition of students in the experimental group towards Mathematics was higher than the control group. This may be attributed partly to the effect of the treatment.

Table 3. Comparing the attitudes of students in the brain-based learning strategy and conventional method.

Group	N	Pre-test	Post-test	Mean gain
Brain-based learning strategy (Experimental)	120	4.38	23.47	19.97
Conventional Method	120	3.27	19.33	16.09

Table 4. Analysis of covariance (ANCOVA) of students' achievement scores by treatment and cognitive style levels.

Source of Variance			Experimental Method				
			Sum of squares	df	Mean square	F	Sig.
Post-test score	Covariates	Pre-test score	26563.472	1	26563.472	304.984	0.000*
	Main Effects	(Combined) Treatment Cognitive Style	66918.527	2	33459.264	384.157	0.000*
	2-Way Interactions	Treatment * Cognitive Style	579.539	1	579.539	6.654	0.010*
	Model Residual		94061.638 45116.745	4 518	23515.385 87.098	269.988	0.000
	Total		139178.3	240	266.625		

*Significant at P < 0.05.

Hypothesis 1: There is no significant main effect of treatment on students' achievement in Mathematics.

The result in Table 4 shows a significant main effect of treatment on students' achievements in Mathematics ($F_{(1:510)} = 760.93$: $P < 0.05$). This clearly indicates that there was a significant difference in the post-test achievement mean scores of students exposed to the treatment and those exposed to the CTS. In line with this result, Ho_1 was rejected.

The table shows that both the treatment and cognitive style had significant main effect on students' achievements in Mathematics (000*).

To find out the magnitude of the difference between the experimental and control groups, Multiple Classification Analysis was computed and the results are presented in Table 5 below.

This table shows that students exposed to the BBLS obtained the higher adjusted post-test achievement mean score ($\bar{x}$ = 29.44) than those taught using the CTS. The table also indicates that 67.2% of the variation in students' achievements in Mathematics was accounted for by taking the independent variable (treatment) and the moderator variable (cognitive style) together.

Table 5. Multiple classification analysis on pre-test achievement scores by treatment and cognitive style.

Variable and Category				Predicted Mean		Deviation		Eta	Beta
			N	Unadjusted	Adjusted for Factors And Covariates	Unadjusted	Covariates	Beta	
Post Test	Treatment	Experimental control	118 122	30.08 5.68	29.44 6.43	11.29 −13.11	10.64 −12.36	0.746 0.143	0.703 0.132
Score		analytical non-analytical	124 116	21.85 17.02	21.61 17.15	3.06 −1.77	2.82 −1.64		

Multiple regression 0.820 Multiple r. squared 0.672.

Hypothesis 2: There is no significant main effect of cognitive style on students' achievements in Mathematics.

The results in Table 5 shows a significant main effect of cognitive style on students' achievement in Mathematics ($F_{(1:510)} = 26.69$; $P < 0.05$). Thus, students with varying cognitive style levels differed significantly in Mathematics achievement. Therefore, the Ho_2 was rejected.

To find out the magnitude of the difference in mean scores between the analytic and the non-analytic groups, Multiple Classification Analysis was computed.

The table shows that analytic cognitive style group obtained higher achievement mean score ($\bar{x} = 21.61$) than the non-analytic cognitive style group ($\bar{x} = 17.15$).

The effect size or eta squared for each factor is an indicator of the strength of these effects. Table 5 indicates that treatment contributed 74.6% (or eta squared) to the variance observed in students' achievements in Mathematics. Beta-weights or standardized coefficients are calculated to "wash out" the effect of the units of measurement. We can see that (0.703) has a slightly stronger "pull" on experimental group than the control group (0.132).

Hypothesis 3: There is no significant interaction effect of treatment and cognitive style on students' achievements in Mathematics.

Figure 1 reveals a significant interaction effect of treatment and cognitive style on students' achievements in Mathematics ($F_{(1:510)} = 6.65$; $P < 0.50$). Therefore, Ho_3 was rejected.

Figure 1 shows the graphical illustration of the nature of this significant interaction.

Findings showed that there was significant interaction effect of treatment and cognitive style on students' achievement in Mathematics. This result confirms the assertion of researchers (Awofala, 2002; Olajengbesi, 2006) that the personal variable of cognitive style interacts with instruction to produce results. This implies that the treatment is sensitive to students' cognitive style on achievement in Mathematics. In other words, understanding and utilizing the core principles of brain-based instructional strategy to teach students of different cognitive styles in order to achieve the desired learning outcomes becomes inevitable. Also, analytic cognitive style students are very critical in their reasoning more than non-analytic students and are able to distinguish figures as discrete from their background and this may have enhanced their achievements in Mathematics.

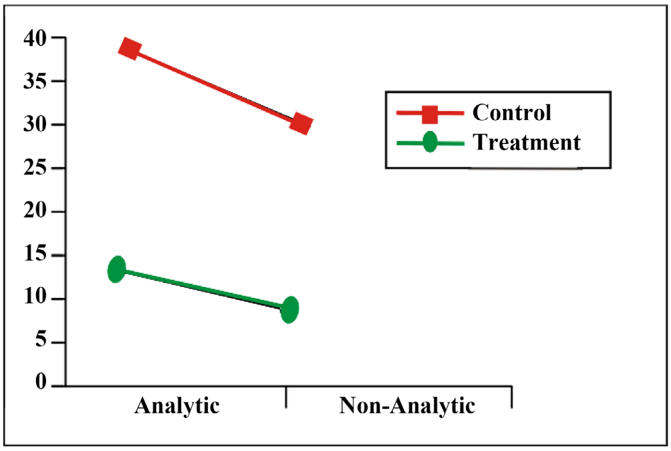

Figure 1. Interaction effect of treatment and cognitive style on students' achievements in mathematics.

3. Discussion

The results of this study obviously exhibited significant main effect of treatment ($F_{(1;510)} = 760.93$; $P < 0.05$); Cognitive Style ($F_{(1;510)} = 26.69$; $P < 0.05$), and interaction effect of treatment and Cognitive Style ($F_{(1;510)} = 6.65$; $P < 0.05$) on students' achievements in Mathematics.

These results showed that brain-based instructional strategy enhanced students' achievements in Mathematics better than the conventional method. The relative effectiveness of the brain-based learning strategy over the conventional method could be due to the fact that brain-based learning strategy is a learner-centered instructional strategy which provides learners with the opportunity for orchestrated immersion-creating learning environments that fully immersed learners in an educational experience.

The learners were immersed in complex, multiple interactive and authentic experiences that were both real and rich.

4. Conclusion

- The effectiveness of brain-based instructional strategy in this study lies in the fact that, it is based on the principles of relaxed alertness, orchestrated immersion and active processing.

- The implication of the findings of this study to educational practice is that brain-based instructional strategy as part of the Mathematics curriculum reform is likely to make learning more contextual and engage learner in decision-making, forming cooperative groups, locating resources and applying the knowledge.
- Providing students with an enriched learning environment will not only close the window of learning disabilities but also enhance students' retentive memory because they will acquire an appreciation of scientific and key mathematical concepts from the beginning.
- Students will no longer be passive recipients of knowledge but acquire it through collaborative efforts.
- Students' unhindered interaction with varied brain-compatible instructional materials in the classroom would ameliorate their disposition of being passive recipients while opening windows of opportunities for them to acquire mathematical knowledge.
- Furthermore, since the Cognitive Style level of the students was found to be crucial at determining their achievements in Mathematics, teachers of Mathematics should endeavour to design lesson plans capable of enhancing the performance(s) of students with varied Cognitive Style levels. The results of the study showed that Mathematics achievement gain resulting from brain-based instructional strategy was sensitive to students' cognitive style. This is in consonance with the findings of Paas & van Merriënboer (2020) which affirmed that extraneous cognitive load may be affected by instructional design, which is not productive for the learner, but where it does, like the brain-compatible instructional materials the outcome becomes highly productive and lasting.

5. Recommendations

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

- To improve students' achievement in Mathematics and a stable performance of students in West African Senior Secondary School Certificate Examinations and other categories of Certificate Examinations in Mathematics globally, innovative strategies, such as brain-based instructional strategy, should be adopted in secondary schools.
- In the use of this strategy, teachers should not only create learning environments that fully immerse students in an educational experience, but they should also eliminate fear in students while maintaining a highly challenging environment with emphasis on consolidation and internalization of information.

Sequel to the aforementioned facts, the adoption of brain-compatible instructional materials for classroom instruction becomes relevant and inevitable for students' optimal performance in Mathematics.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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