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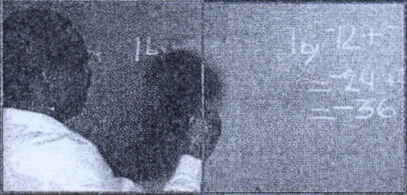
Review of EDUCATION

INSTITUTE OF EDUCATION JOURNAL, University Of Nigeria, Nsukka

Volume 22, No. 1 February 2011



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INSTITUTE OF EDUCATION JOURNAL, University Of Nigeria, Nsukka

Volume 22, No. 1 Feb. 2011

Printed in the
Federal Republic of Nigeria at
TIMEX: 29 Ogui Rd. Enugu
Tel: 08062885765

ISSN: 978-2585-10-6

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REDUCING SENIOR SECONDARY SCHOOL STUDENTS' MATHEMATICS ANXIETY THROUGH BRAIN-BASED INSTRUCTIONAL STRATEGY: A STUDY IN SCHOOL EFFECTIVENESS

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Abstract

One of the indicators of school effectiveness is the state of learning environment. Learning environment could be physical or psychological (anxiety). This study focuses on the later. If the learning environment is not conducive, students are not likely to learn well, thus failure rate may be high. One of the psychological learning environments which is potent in causing high failure rate in mathematics is students' anxiety. The students' anxiety in mathematics is likely to have its root from how the subject is taught. This study, therefore, examines ways of reducing Senior secondary school students' anxiety in mathematics using brain-based instructional strategy. The study adopted a quasi experimental design with pre test – post test control groups. Two instruments: response (mathematics anxiety scale) and stimulus (experimental package) were used to collect data. The result shows that students exposed to brain-based instructional strategy had their anxiety level in mathematics reduced than those in the control group. It is, therefore, recommended that teachers should use brain-based instructional strategy in teaching. Moreover, because brain-based instructional strategy is relatively new, teachers should be taught to use it in teaching mathematics in schools since it has the potential to reduce students' mathematics anxiety.

Key words: **Brain-based instructional strategy, student mathematics anxiety, school effectiveness, senior secondary school mathematics**

Introduction

Anxiety is an ailment of the central nervous system (Awolola, 2009). Levine, (1995) believes that anxiety is a very common symptom and a certain amount is useful to the individual as it acts as stimulant and increases efficiency, however, too much anxiety have reverse effect and interfere negatively to individual life. Anxiety is seen as an ailment that manifests in consciousness of the action of the heart (palpitation or high heart rates), tremors and diarrhoea which are associated with increased activity of the sympathetic autonomic system. Anybody with high level of anxiety will probably be nervous or disorganized under stress, inducing fears in any situation that he perceives as a potential threat. This means that anxiety of any form is likely to relate negatively with academic performance (Umoinyang, 1999).

Anxiety in general is used in response to a perceived threat to an individual (Barnes, 1984). The threat may be real or imagined and for those who are unable to avoid the threat, feelings of distress, confusion and fear are experienced (Barnes 1984). Mathematics anxiety has been defined as the feeling of tension, helplessness, mental disorganization and dread one has when required to manipulate numbers and shapes and the solving of mathematical problems (Ashcraft & Faust, 1994). The special characteristics of Mathematics anxiety can be described as 'the feelings of uncertainty and helplessness in the face of danger.

Mathematics anxiety has been related to teachers and the classroom setting. Mathematics anxious students often show signs of nervousness when the teacher comes near, freezing and stopping work or covering it up to hide it (Barnes, 1984). Researchers report a negative correlation between the level of achievement and the level of test anxiety and after controlling for intelligence found differences in the learning rate between high anxious and low anxious groups (Richardson and Suinn, 1972).

The anxious student thinks more of failure and its consequences upon his life and therefore responds with deep emotional reaction and negative centred thoughts. On the other hand, the less anxious students is relaxed and tackles his assignment, questions or tests more carefully and with a high concentration. In view of the students' exhibition of fear towards the subject, it suffices to say that the high test anxiety level in students should be checked in order to make them relax and learn more in mathematics class. There are different ways of reducing mathematics anxiety; one of them is test-wise as suggested by Yinyinola (2008).

Despite the previous efforts in reducing mathematics anxiety, not much desired results have been achieved. Therefore, this study was designed to reduce senior secondary school students' mathematics anxiety through brain-based instructional strategy. Brain-based instructional strategy sometimes called Brain-Compatible instructional strategy is an educational approach based on how current research in neuroscience suggests the ways our brains naturally learn best (Lucas, 2004). This instructional strategy can easily be integrated into any learning environment, from a kindergarten classroom to a seminar for adult. To many, the term "brain-based" learning sounds redundant, they ask, is not 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 prevent learning (Sousa, 2004 & 2008).

Hart (1983) argues that 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 pushed 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, p. 33).*

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

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

(i) **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.

(ii) **Orchestrated Immersion:** This is a technique of trying to eliminate fear in learners, while maintaining a highly challenging environment.

(iii) **Active Processing:** This technique allows the learners to consolidate and internalize information by actively processing it.

The nervous system is made up, predominantly, of tissue that has the special property of being able to conduct impulses rapidly from one part of the body to another. The specialized cells that constitute the functional units of the nervous system are called neurons. Within the brain and spinal cord, neurons are supported by a special kind of connective tissue that is called neuralgia. Neurons are cells that specialized for the reception, integration, interpretation and transmission of information (Singh, 1999). Nerve cells can convert information obtained from the environment into codes that can be transmitted along the axons. By such coding the same neuron can transmit different kinds of information.

It is assumed that brain-based instructional strategy will reduce the level of anxiety since the central nervous system that controls the students' level of anxiety is also controlled by the brain. So if the brain is considered while teaching mathematics, students who are anxious are likely to feel relaxed and assimilate more. Therefore, this study examined how to reduce senior secondary school students' mathematics anxiety through brain-based instructional strategy and to determine the size of the effect of the brain-based instructional strategy in the reduction of mathematics anxiety.

The effect of a treatment could be measured along two dimensions. The first one is using the statistically significant effect and the second is using the effect size. In this study, the two approaches are considered. Statistical significance of brain-based instructional strategy was obtained using Analysis of Covariance (ANCOVA) and effect size was obtained using the correlation approach. Normally, one would have used a t-test analysis to compare the experimental and control groups but the researcher is interested in removing the initial differences between the students in the experimental and control groups and that is why ANCOVA was used in this study.

In general, effect size can be measured in two ways: a) the standardized difference between two means, or b) the correlation between the independent variable classifications and the individual scores on the dependent variable. Effect size is a name given to a family of indices that measure the magnitude of a treatment effect. Unlike significance tests, these indices are independent of sample size. Pearson's r correlation can be used when the data are continuous or binary; thus the Pearson r is arguably the most versatile effect size. This was the first important effect size to be developed in statistics. Pearson's *r* can vary in magnitude from -1 to 1, with -1 indicating a perfect negative linear relation, 1 indicating a perfect positive linear relation, and 0 indicating no linear relation between two variables. Another often-used measure of the strength of the relationship between two variables (effect size) is the Cohen's *d* which is most commonly used to refer to standardized measures of effect. Cohen's measure of effect size "d" is defined as the difference in the means of two groups divided by the pooled standard deviation. The first approach (correlation) was used in this study. This correlation is called the "effect size correlation" (Rosnow & Rosenthal, 1996). Measures of effect size in ANOVA are measures of the degree of association between and effect (e.g., a main effect, an interaction, a linear contrast) and the dependent variable. They can be thought of as the correlation between an effect and the dependent variable. If the value of the measure of association is squared it can be interpreted as the proportion of variance in the dependent variable that is attributable to each effect.

Research Questions

Two research questions were asked to guide this study. The questions are:

1. Is there a significant main effect of treatment (brain-based instructional strategy) on students' anxiety in mathematics?
2. What is the effect size of treatment on students' anxiety in mathematics?

Methodology

The study adopted quasi experimental design with pre test – post test control group. Two treatment groups were used (the experimental group and the control group). The dependent variable was the students' anxiety in Mathematics. This design was preferred because the experimental and control groups were naturally assembled groups as intact classes with similar characteristics. Since intact classes were used, it was not possible to administer treatment to equal number of subjects in the two experimental groups.

The advantage of this design over others is that it controls the threats to selection of sample, interaction and maturation. In this study, the threat to selection, maturation and interaction was controlled by randomly assigning schools to the control (C) and experimental (E) groups.

The research design is symbolically illustrated below:

Observation before treatment	Treatments	Observation after treatment	
O_1	X_1	O_2	→ Experiment (BBIS[i])
O_1	X_2	O_2	→ Control (CTS[ii])

Fig. 1 Pre-test – Post-test control group research design

Where X_1 represents BBIS treatment.
X_2 represents CTS treatment

O_1 = Pre-test measures
O_2 = Post-test measures

The variables of the study include: An independent variable – Teaching method and a dependent variable – student mathematics anxiety.

Sample and Sampling Techniques

The sample consists of three hundred and twenty-five (325) Senior Secondary School II mathematics students drawn from six intact classes randomly sampled from six secondary schools in three local government areas in Ibadan municipal[i] in Oyo State, Nigeria. Simple random sampling technique was employed in drawing the participating schools as well as assigning the schools to experimental and control groups. The students in experimental schools were taught topics in geometry using the BBIS while the control schools were taught the same topics using the CTS. These topics were chosen because evidence suggests that a vast majority of students often skip questions on these mathematical concepts during external examinations like in Senior School Certificate Examination (WAEC Examiners' report, May/June, 2005).

Instrumentation

Two instruments namely: Mathematics Anxiety Rating Scale (MARS) and Brain-Based Instructional materials (BBIM) were used for the study. MARS is an instrument designed to determine the participants' mathematics anxiety. Mathematics anxiety was measured through the use of an adapted version of Mathematics Anxiety Rating Scale (MARS) developed and used by Beaslye, Mark, Jeffrey and Natali (2001). The MARS has two sections, A and B.

Section A is designed to elicit responses in relation to participants' age, gender and name of school. Section B consists of twenty (24) items based on five point scale ranging from 1 = not at all to 5 = very much.

Not at all ← 1 2 .... 5 → Very much

For each of the items, student is expected to indicate how much each of the items frightens him/her. Some of the items in MARS are, cringing in terror about mathematics, uneasiness in mathematics class, short-time retention of mathematics concepts, zoning out in mathematics class, mathematics phobia, studying for mathematics test/exam, inferiority complex.

The Brain-Based Instructional Materials (BBIM) in mathematics was developed based on the findings of Jensen (2000) and Nunley (2004). Their findings showed greatest gain in achievement and attitude with the manipulative materials (left hemispheric). These materials are:

(a) NKPM (Needful Knowledge Package in Mathematics). This was designed to enable students make meaningful connections and consolidate the gap between the prior knowledge and new information. Copies of the NKPM for the topics selected for the study were distributed to the students to glance through within some minutes.

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

(c) WLTM (Weekly Learning Terrain in Mathematics). This was designed to engage the students in active processing. The teacher engaged the learners in active processing by guiding them to gain insight into the problem. The learners were allowed to order, structure and relate to the new information at their own pace. Copies of the WLTM were displayed at strategic corners in the classroom and on the mathematics bulletin board for students to interact with.

(d) ICSPM (Index Card Study Profile in Mathematics). This was 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 the ICSPM relevant to the topics chosen for the study were made available in a shelf in the classroom. These cards contained key facts on mathematics concepts and definition of term relating to the current topics. Students were instructed to go at will to the shelf and explore from the enriched learning environments created within the four wall of the classroom.

(e) SEC and Q&S (Self – Evaluation Card): This was designed for spot assessment. The teacher is expected to release the feedback before the commencement of the subsequent lesson. The outcome of the sport assessment determines whether the teacher needs to maintain the status quo in the use of the strategy or it is mandatory to improve upon the strategy towards the actualization of an improved learning outcomes in the subsequent lesson. SEC containing questions and solution space were given to the students at the appropriate time. All cards in Q portrayed questions that were drawn from mathematics concepts or topics to be taught. All cards in S portrayed detailed (step-by-step solutions) to the question(s).

The BBIM were given to two mathematics experts and one instructional technology expert in the field of Teacher Education and Educational Evaluation from the University of Ibadan in Nigeria for face and content validation in terms of language clarity to the target audience (b) content coverage (c) relevance to the stated objectives and (d) design.

Procedure

The regular mathematics teachers in the selected schools, who were trained by the researcher, were used for the study. Each teacher was given a copy of validated lesson plan as well as copies of the three instruments used for the study. The MARS was administered as pre-test and the scores were recorded before the commencement of the treatment.

The main treatment for the study was teaching using the BBIS and the CTS and it lasted for seven weeks. The experimental group was taught mathematics using the BBIS. This involved the following presentation steps:

(a) Link new information to existing knowledge
(b) Identify 'prime times'
(c) Optimizing learning through different media (music) – composed by Jim Revees was used as a carrier, an arousal, and as a primer
(d) Use of brain-based instructional material to guide and support students' attention, encoding and retrieval process
(e) Peer teaching during the "down time" – fast learners identified using pretest scores and were allowed to teach others, the materials they were learning
(f) Evaluation of student achievement using SKAC and SEC

The control group was taught the same concepts in mathematics using the CTS. In using this strategy, the regular mathematics teacher delivered the pre-planned lesson to the students without the use of instructional aids. The teacher proceeded to the task of solving the problem without giving the student the opportunity to discover methods of finding solution or principles behind the solution. Interaction between the students and the teacher was minimal and the students listened and assimilated principles and procedures for the correct solution to the problem. Immediately after the treatment, the MARS was again administered as post test measure to the students.

Data Analysis

Data collected were analyzed using analysis of covariance (ANCOVA) with the pre-test scores as covariates. The use of ANCOVA enabled the researcher to partial out the initial differences from the two groups.

Results and Discussion

The findings of this study are presented in the following tables.

Research Question 1

Is there a significant main effect of treatment on students' anxiety in mathematics?

Table 1: Summary of Analysis of Covariance (ANCOVA) on Students' Anxiety in Mathematics.

Source of variation	Sum of Squares	Df	Mean Square	F	Sig
Covariate (Pre Test)	233.344	1	233.344	2.680	.106
Treatment	2070.852	1	2070.852	23.782	.000*
Residual	27515.700	323	87.075		
Total	34408.339	324	106.199		

The F-ratio for the pre test (covariate) is not significant $F_{(1, 323)} = 2.680$; $P > 0.05$. This implies that there was no significant difference between the pre scores in the mathematics anxiety test of students in the two groups before the introduction of treatments (brain-based learning strategy and control) as shown in Table 2.

Table 2 Mean score of the pre and post tests

Treatment	Pretest		Posttest	
	Mean	SD	Mean	SD
Experimental	89.49	10.34	26.42	4.56
Control	90.12	9.99	79.45	9.23

So, the two group can be assumed to be homogenous statistically (there is no evidence that the two groups are homogenous in all respect because of age, family background, gender, etc). The result shows that there is a significant difference between the post test scores in the mathematics anxiety test of students exposed to brain-based learning strategy and those exposed to conventional methods $F_{(1, 324)} = 23.782$; $P < 0.05$. The source of variation, therefore, could be traced to the treatment.

Table 3: Multiple Classification Analysis on Students' Anxiety in Mathematics.

Variables + Categories	N	Unadjusted Mean	Eta	Adjusted Mean	Beta
Treatment					
Brain-based	158	30.08	.846	26.42	0.82
Control	167	85.71		79.45	
Multiple Regression	.820				
Multiple R Squared	.672				

From Table 3, the students exposed to brain-based learning strategy had adjusted mean score which is better (26.42) than those exposed to conventional strategy (79.45). Note that the lower the anxiety scores the better. The implication is that the anxiety level of students exposed to the brain based instruction is lowered, but the anxiety level of the students exposed to the control is three times higher than that of the students exposed to the brain based instruction.

Research Question 2

What is the effect size of treatment on students' anxiety in mathematics?

The correlation r (effect size) between the treatment (BBIS and control) and students' scores in the anxiety scale is 0.82. This means that 0.672 is the coefficient of determination in the relationship between the treatment (brain-based instructional strategy and control). It also means that 67.2% of the variance in the reduction of students' anxiety in mathematics is accounted for by the treatment.

Discussion

Students exposed to brain-based instructional strategy had their anxiety in mathematics reduced than those in the control group. Although it cannot be guaranteed that the two set of students were the same in all respect, the advantage of the design used is that it controls the threats to internal validity except those linked with interaction and history, maturation and instrumentation (Kerlinger and Lee 2000). The threat that could be noticed in the study due to interaction and history, maturation and instrumentation was adequately taken care by the method of analysis used – ANCOVA.

This study is not focused on the use of brain-based instruction on the students' achievement. However, its use has revealed that brain-based instruction has reduced such statements from students as cringing in terror about mathematics, uneasiness in mathematics class, short-time retention of mathematics concepts, zoning out in mathematics class, mathematics phobia, studying for mathematics test/exam, inferiority complex. Mathematics anxiety observed as the feeling of tension, helplessness, mental disorganization and dread one has when required to manipulate numbers and shapes and the solving of mathematical problems (Ashcraft and Faust, 1994) could be reduced using brain-based instruction. This is because brain-based instruction consists of low threat and high challenge, it brings the brain to a state of optimal learning (Sousa, 2004; Ryan & Abbot, 1999; Caine & Caine, 1998; Jensen, 1998), students can now see that the fear, cringing and anxiety exercise by them during mathematics classes are uncalled for because brain-based instruction is a technique which eliminates fear in learners. It also allows the learners to consolidate and internalize information.

The cognitive theory of test anxiety has three common elements. The first is that high levels of test anxiety are believed to adversely influence students' self appraisals and appraisals of evaluative situations. Second, test anxious students are hypothesized to engage in more negative thoughts (negative internal dialogue, during evaluative task). Third, students' performance attributions are believed to be influenced by high level of test anxiety. The result shows that the higher the mathematics anxiety score, the more anxious the students are. If the mathematics anxiety score is low, the students are assumed to have adjusted favourably. This result implies that students in the experimental group had their anxiety level reduced after they were exposed to the treatment.

Coefficient of determination (the square of *r*, referred to as "*r*-squared") is used in determining the strength of correlation as shown in Table 2 (coefficient of determination 0.715). This is a measure of the proportion of variance shared by the two variables (in this case, treatment and students' anxiety in mathematics) and varies from 0 to 1. Pearson's r correlation, introduced by Karl Pearson, is one of the most widely used effect sizes. The effect size of 71.6% obtained in Table 2 is considered large using the Cohen's yardstick. Cohen (1988) gives the following guidelines for the social sciences with respect to the relative size of effect sizes: small effect size, *d* = 0.1; medium, *d* = 0.3; large, d = 0.5 and above. This implies that the effect of brain-based learning strategy on students' anxiety in mathematics in this study is large.

Conclusion and Recommendations

Considering the statistical and the effect size of brain-based learning strategy on students' achievement in mathematics, we can conclude that brain-based learning strategy is a potent interactive instructional strategy that can be used to reduce students' anxiety in mathematics. Therefore, for developing strong attitude towards mathematics, the use of brain-based learning strategy is being recommended for the mathematics teachers and students of all grades.

The preliminary results (before the intervention) leading to this study shows that teachers of students used for this study were not familiar with this method, hence, it is recommended that mathematics educators should organize workshops and seminars to educate teachers on brain-based learning strategy and they should also be given established guidelines which they can use as immediate tools in their own classrooms for effective teaching learning process to improve students' achievement in mathematics.

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[i] Brain-Based Instructional Strategy
[ii] Convectional Teaching Strategy
[i] Ibadan municipal is made of five local government areas, these are: Ibadan North, Ibadan North East, Ibadan North West Ibadan South East and Ibadan South West.