



Effects of a Locally Constructed Brain Model on Academic Achievement and Retention of Senior Secondary School Biology Students in Minna, Niger State, Nigeria

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ABSTRACT

The human brain is considered to be one of the most abstract concepts in senior secondary school biology, and in Nigeria there are no cost-effective 3D teaching models available in public secondary schools. This study determined if a locally. This experiment used a quasi-experimental design involving a pretest–posttest control group with delayed retention test. Two intact classes of Senior Secondary II biology in two public schools in Minna were randomly assigned to groups (N = 256; experimental n = 119, control n = 137). Experimental group was taught using locally constructed brain model while the control group was taught through conventional method. Data was collected using 30-item Locally Constructed Brain Model Achievement Test (LCBMAT; $r = 0.86$) and analyzed using means, standard deviation and one-way ANOVA at $p < 0.05$. The groups were found to be equivalent at pretest ($F(1, 254) = 0.66, p = .417$). Posttest results showed that the experimental group had higher mean score ($M = 17.80, SD = 5.55$) compared to control group ($M = 10.72, SD = 4.65$), $F(1, 254) = 123.31, p < .001, \eta^2 = 0.33, d = 1.39$. The retention scores of the experimental group (14.03 vs 10.42), $F(1, 254) = 47.56, p < .001, \eta^2 = 0.16, d = 0.86$, though showed high score than the control group, the group lost more posttest score than the control group during the retention period. In the experimental group there were no sex differences in achievement ($p = .075$) and retention ($p = .629$). A locally constructed brain model was more effective than conventional method in terms of achievement and retention, and it benefited both males and females equally.

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INTRODUCTION

Biology is an important course in the Nigerian senior secondary school syllabus and a key requirement for studies in medicine, pharmacy, agriculture, and other life sciences (Federal Ministry of Education [FME], 2014). Nevertheless, students' achievement in the subject in internal and external examinations poses a challenge, and the more complex concepts constitute the most challenging ones. The human brain is a case in point. It is impossible to view the various parts of the brain and understand their position in relation to each other,

and it is not possible to view and interact with the object by means of a textbook illustration or blackboard drawing. Teacher-centered instruction may promote memorization of names of various parts rather than their understanding and interconnection, and a recent large meta-analysis demonstrated that active learning promotes better examination performance in comparison with traditional lectures in undergraduate science, technology, engineering, and mathematics (STEM) courses (Freeman et al., 2014).

Physical models are widely used to represent structures that are too small, too

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complex or too inaccessible to be handled directly. A three-dimensional brain model lets learners see, touch and manipulate the parts of the brain, and so connects the teacher's verbal description to a concrete image (Mayer, 2009). Commercial anatomical models, however, are costly and are rarely available in under-resourced public schools. Models built from locally available materials such as clay, cardboard, fabric and recycled plastic are a low-cost alternative that teachers and students can make, repair and adapt, and that draws on materials familiar to learners (Usman, 2014).

There are two theoretical approaches that can help justify the application of such models. The first one is by Bruner (1966), who identified three ways of representation of knowledge, enactive (via action), iconic (via images), and symbolic (via language). The author claims that the process of teaching becomes most efficient when students get an opportunity to progress from enactive and iconic representation of knowledge to the symbolic one. With the help of the hand-held model of brain, learners will have both enactive and iconic experiences before they become familiar with the symbolic terms of lobes and their functions.

The use of locally made or improvised materials is widely used in Nigerian education studies. It was found by Odo and Nworgu (2014) that senior secondary students who studied the nervous system using locally made anatomical models achieved better results compared to those studying it through lectures on achievement and retention tests. Similar findings were obtained by Adeyemi and Olaleye (2010), Aina and Olanipekun (2015) regarding locally produced biology models, and Ezeudu and Eze (2013) for three-dimensional models. Research conducted in other subjects shows the same tendency (Nwoke & Nwaneri, 2020; Obikezie et al., 2022). According to Ibrahim (2012) and Olorundare and Abdu-Raheem (2017), improvised materials proved to be no less effective than regular ones, which confirms the use of the cheaper alternative

instead of arguing against its use. Not many of such studies cover the issue of the human brain, especially the retention and sex difference issues. The present study thus focused on examining the impact of the construction of a local brain model on Senior Secondary II (SS II) students' performance and retention of the functions of the human brain, and how the gender of the students influenced the impact. The following null hypotheses were tested using a 0.05 level of significance:

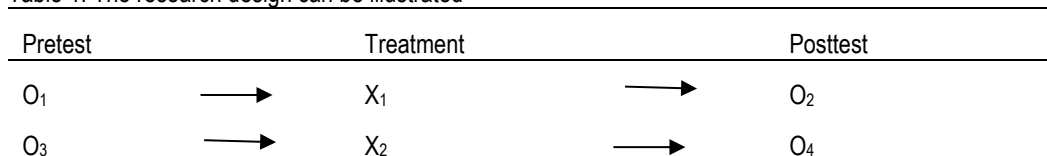
- HO₁:** There is no significant difference between the means of achievement scores of students exposed to the functions of the brain using the locally developed brain model and those using the traditional method of teaching.
- HO₂:** There is no significant difference between the means of achievement scores of male and female students using the locally developed brain model.
- HO₃:** There is no significant difference between the means of retention scores of students exposed to the functions of the brain using the locally developed brain model and those using the traditional method of teaching.
- HO₄:** There is no significant difference between the means of retention scores of male and female students using the locally developed brain model.

METHODOLOGY

The experimental research design that was employed here is a quasi-experimental pretest/posttest control group design where there is a delayed retention test in both groups. The intact classes were selected. Experimental group (X_1) was taught using the brain model locally constructed and the control group (X_2) using the traditional method. Pretest (O_1 , O_3), posttest (O_2 , O_4) and retention test were conducted in both groups. The design can be illustrated as follows:



Table 1. The research design can be illustrated



Source: Gravatter et al. (2010)

The study was carried out in Minna, the capital of Niger State, north-central part of Nigeria. The study population consisted of 12,433 SS II students enrolled in senior secondary schools owned by the government in Minna (Niger State Ministry of Education). The target population was students enrolled for biology during the 2024/2025 academic year. Two secondary schools were chosen using simple random sampling technique,

while one intact SS II biology class was selected from each of the schools using the simple random sampling technique. The two classes were randomly allocated to the experimental and control groups. The sample size was 256 students (154 males, 102 females), with 119 being allocated to the experimental group (Bosso Secondary School), and 137 in the control group (Government Day Secondary School, Minna).

Table 2. Distribution of participants by school, group and sex

School	Group	Male	Female	Total
Bosso Secondary School	Experimental	78	41	119
Government Day Secondary School, Minna	Control	76	61	137
Total		154	102	256

Test of achievement and retention was carried out using Locally Constructed Brain Model Achievement Test (LCBMAT). It was made up of thirty items which had four options (A to D) and maximum score of thirty. The questions were from the content of senior secondary school biology on functions of the brain and also the objectives of the lesson. They were from WAEC and NECO past question papers and standard textbooks so as to reflect the standard of the Senior Secondary School Certificate Examination.

The 30 test questions were validated by face validation of three lecturers from the Federal University of Technology, Minna and analyzed using item analysis on the basis of difficulty, discrimination, and distractors. Reliability was checked using a pilot study involving 20 randomly selected students from a senior secondary school in Minna, with the result that the reliability coefficient was found to be $r = 0.86$. The model is handmade and three-dimensional in nature, depicting the human brain using affordable local materials. It highlights the major structures of the brain such as cerebrum, its lobes, cerebellum and

medulla oblongata. The objective of the model is to allow easy identification and touch of each structure together with its functions.

Approval was gotten from the principals of the two schools, and the biology teachers helped in the selection of the classes. They both took the LCBMAT as a pre-test in order to get the knowledge level before taking up the experiment. The experimental group then learned about the functions of the brain for two weeks with the help of a research assistant, who followed lesson plans prepared in consultation with the researcher, with the model showing and indicating the different parts of the brain and their respective functions. The control group was also taught on the same topic by the researcher using the lecture method without the model. After learning, the items in the LCBMAT were shuffled and used for the post-test.

The data analysis was performed by means of SPSS software package, version 21. Performance was described with the help of means and standard deviations, whereas null hypotheses were tested by one-way ANOVA at the 0.05 level of significance. First of all, pretest

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results were compared to find out whether the groups can be considered equivalent. The values of effect sizes ($\eta^2 = SS \text{ between}/SS \text{ total}$ and Cohen's d by means of pooled within-groups standard deviation) and 95% confidence intervals for mean differences were estimated based on ANOVA output and descriptive statistics.

Groups' equivalence before the pretest

The descriptive statistics for both groups in the three test sessions are presented in Table 3. Pretest averages were nearly equal (experimental 7.45, control 7.74), and no statistical significance was found with the help of ANOVA, $F(1, 254) = 0.66$, $p = .417$, $\eta^2 = 0.003$ (Table 4). Thus, the groups had comparable knowledge prior to the experiment.

Table 3. Means and standard deviations of LCBMAT scores of the experimental and control groups

Group	n	Pretest		Posttest		Retention	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Experimental (model)	119	7.45	2.94	17.80	5.55	14.03	4.38
Control (conventional)	137	7.74	2.78	10.72	4.65	10.42	3.99

HO₁ Achievement levels of experimental and control groups

The average score for the experimental group increased by 10.35 points from pre-test to post-test compared to 2.98 points for the control group. Post-test scores of the experimental group were 7.08 points higher (95% CI [5.82, 8.34]) than those of the control group, which was statistically significant ($F(1, 254) = 123.31$, $p < .001$), with a large effect size ($\eta^2 = 0.33$, $d = 1.39$).

HO₂ Achievement by gender in the experimental group

Females ($n = 41$) scored higher on average in the post-test (19.05, $SD = 5.60$) compared to males ($n = 78$) who scored 17.14 ($SD = 5.45$); however, the 1.91-point difference was statistically non-significant, $F(1, 117) = 3.23$, $p = .075$, $\eta^2 = 0.03$, $d = 0.35$ (Tables 4 and 5). The second null hypothesis is accepted.

Table 4. Posttest and retention scores of male and female students taught with the locally constructed brain model

Sex	N	Posttest		Retention	
		$\bar{x}$	SD	$\bar{x}$	SD
Male	78	17.14	5.45	14.17	4.29
Female	41	19.05	5.60	13.76	4.57

HO₃ Retention of experimental and control groups

The experimental group performed better than the control group in the retention test (14.03; 10.42; difference of 3.61 points, 95% CI [2.58, 4.64]), $F(1, 254) = 47.56$, $p < .001$, $\eta^2 = 0.16$, $d = 0.86$. The third null hypothesis was therefore rejected. The two groups decreased from the post-test to the retention test: the experimental group decreased by 3.77 points while the control group decreased by 0.30 points (see Figure 1). Nevertheless, the retention mean score of the experimental group was still 6.58 points higher

than their pre-test mean score, while that of the control group was 2.68 points.

HO₄ Retentions of male and female students in the experimental group

There were no significant differences between the mean retentions for male (14.17, $SD = 4.29$) and female students (13.76, $SD = 4.57$), $F(1, 117) = 0.24$, $p = .629$, $\eta^2 = 0.002$, $d = -0.09$. The fourth null hypothesis was supported. Scores of females were reduced by 5.29 points in comparison to those of males (reduced by 2.97 points).

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Table 5. Summary of one-way ANOVA tests and effect sizes

Comparison	df	F	p	η^2	d	Mean difference [95% CI]
Pretest: experimental – control	1, 254	0.66	.417	0.003	-0.10	-0.29 [-0.99, 0.41]
Posttest: experimental – control	1, 254	123.31	< .005	0.33	1.39	7.08 [5.82, 8.34]
Retention: experimental – control	1, 254	47.56	< .005	0.16	0.86	3.61 [2.58, 4.64]
Posttest: female – male	1, 117	3.23	.075	0.03	0.35	1.91 [-0.19, 4.01]
Retention: female – male	1, 117	0.24	.629	0.002	-0.09	-0.41 [-2.09, 1.27]

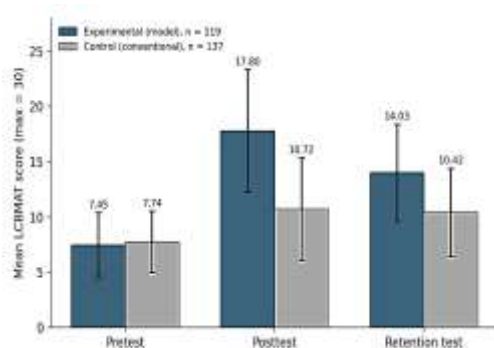


Figure 1. Mean LCBMAT scores of the experimental and control groups at pretest, posttest and retention test. Error bars show ± 1 SD.

DISCUSSION OF FINDINGS

The students who were taught the functions of the brain using the locally made model scored significantly higher in post-test as compared to those who were taught in a conventional way. This is because there was no difference in the pretest scores of the two groups; hence, the finding could be attributed to an effect of the method of instruction employed. The effect size ($\eta^2 = 0.33$, $d = 1.39$) is high considering that it is above the threshold of 0.14 for effect size. This finding corroborates previous results from Nigeria that local or improvised models enhance biology learning (Adeyemi & Olaleye, 2010; Aina & Olanipekun, 2015; Ezeudu & Eze, 2013; Odo & Nworgu, 2014). The reason behind this could be the theories on which the experiment was based. Manipulation and identification of the parts of the model enabled the learners to have enactive and iconic experiences of the brain before they

encountered the symbolic representations of its parts and functions (Bruner, 1966), making it move closer to the concrete side of the experience continuum proposed by Dale (1969).

The experimental group scored higher on the retention test as well, but the difference was still large ($d = 0.86$). This result requires special consideration, as the experimental group lost 3.77 points when comparing the post-test and retention test, while the control group showed little changes (-0.30), thus the difference became smaller (from 7.08 to 3.61). It is normal to have greater reduction of the initial score if the initial score was higher, but in this case the control group did not show significant gain to lose. It is impossible for this study to isolate the effect of forgetting from other factors, thus the only thing that can be said for sure – the model helped to achieve better performance after delay.

Sex differences have not been revealed in the experimental group in either achievement or retention, which indicates that the model was effective for both boys and girls. This statement must be viewed with great care. The posttest mean score of female students was 1.91 points higher ($p = .075$, $d = 0.35$); the size of the female subgroup was also relatively small ($n = 41$). It must be emphasized that an insignificant result does not mean that there is no difference. More participants are required to prove the presence or absence of the observed female superiority in learning. It may be stated that the conducted research shows the possibility of using a teacher-made brain model as an alternative to commercially produced models when school budgets do not provide sufficient funds.

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CONCLUSION AND RECOMMENDATIONS

In SS II biology students of Minna, teaching the functions of the human brain using a locally made model proved to be much more successful than conventional teaching in terms of achievement and retention, and there was no significant difference between males and females. Under the constraints of the research design, the model can be used as an effective and cheap means for teaching an abstract biology concept. On this note, the study recommends that:

1. Biology teachers should create and use locally made brain models when explaining the human brain to their students, using them equally with male and female students.
2. Those responsible for the planning of teacher training programmes should ensure that making affordable teaching models is included in the curricula of such programs.
3. Curriculum planners should promote the use of locally improvised teaching models in schools which do not have any laboratory or anatomical materials.
4. Future research should involve more schools and the use of randomisation within classes or schools, use of analysis of covariance or multilevel models in analysis of results, testing of teaching models of different subjects and other educational levels, use of various intervals of retention tests, and students' interest and attitudes to biology.

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