REDUCING COGNITIVE LOAD THROUGH COMPUTER BASED MULTIMEDIA INSTRUCTIONS.

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Abstract

This study investigated the impact of multimedia presentations in the reduction of cognitive load imposed on students working memory in the process of learning. Two multimedia instructional packages were designed for the purpose of the study. The moderating effect of gender was investigated. The study adopted the pretest – posttest, control group, quasi experimental research design. 80 randomly selected secondary school I Biology students from three government secondary schools in Ibadan, Oyo state of Nigeria were the participants. The findings revealed that multimedia instructional packages help reduce the level of cognitive load imposed on students memory when learning. Also, it was found that when cognitive load is high, then academic performance will be poor. Based on the findings, it was recommended that multimedia instructional packages be used in secondary schools for effective and efficient teaching and learning of Biology.

Key words: multimedia, multimedia Instructional packages, cognitive load, learning, student, academic achievement, Biology.

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Introduction

Science and technology education has become important for the sustenance of the nation. Every day, there are innovations in these fields. To be able to keep up with these advancements, it becomes imperative that young minds be exposed to science. The federal government, knowing this, included science in the school curriculum at both the primary and secondary school levels. Biology is one of the science subjects offered in the secondary schools. Biology is the study of living things. Living things form a very important part of our environment which we depend solely on and without which we cannot exist. Biology occupies a unique position in the school curriculum. With the advent of internet and World Wide Web today, knowledge has exploded and several disciplines such as Physiology, Genetics, Molecular Biology, etc. have made Biology their central focus. As a result, Biology literacy has become relevant to everyone. Therefore, as Sanlibio (2014) puts it, Biology is tied with our lives, our very existence as humans. However, over the years, the performance of students in the subject has been appalling (WAEC 2012, 2013).

Many reasons have been attributed to this problem of poor performance of students in Biology ranging from teachers to students to the subject itself. Some identified causes are: nature of science itself and its teaching methods, biological level of organization and abstract level of concepts, difficulties with textbooks, overloaded Biology curricula, students' learning and studying habits, students' negative feelings and attitudes towards the topic and a lack of resources, cognitive capability of the students (Chiapetta and Fillman, 1998, Tekkaya C., Ozkan O., Sunur, S., 2001, Cimer, A. 2011, 2012). However, poor teaching methods adopted by teachers at senior secondary school level have been identified as one of the major factors contributing to poor performance of students' in Biology (Adegoke 2011,Ahmed and Abimbola, 2011; Umar, 2011, Cimer, 2012).

The method of teaching in most Nigeria schools is the "chalk and talk" method. The persistent use of this method has been found to makes students' passive rather than active learners and does not promote insightful learning and long–term retention of some abstract concepts in Biology (Ahmed, 2008; Ahmed and Abimbola, 2011; Kareem, 2003; Umar, 2011). This method makes teachers the repertoire of knowledge with students making little or no contribution during class session. Sometimes, concepts are too vague for students to understand within the time frame. As a result, a high level of cognitive load which is the total amount of mental activity imposed on working memory per time is imposed on the students'

memory therefore making topics too difficult to learn and so result in a poor academic achievement. Therefore, educators see the pressing need to reconsider the techniques and methods of instruction at senior secondary school level, and an instructional system that is supported by technology for meaningful learning was suggested (Adegoke, 2011, Nweke, Dirisu, Umesi, 2012, Gambari, Yaki, Gana, Ughovwa, 2014). It is in this vein that Information and Communication Technology (ICT) has been proved to be of great help. However, of the different forms of ICTs, computer technologies have changed the way teaching and learning is done with its use of software that allow for the integration of sound, video, graphics, texts into a multisensory whole in a form of multimedia and thereby saving time and energy and bringing about effective and efficient learning. However, observations has shown that the use of computer in developing countries such as Nigeria as teaching and learning aid is restricted to privately owned institutions and public schools where children of the affluent attend (Kuti, 2006, Adegoke, 2011). Hence, in an attempt to find solutions to this problem of poor academic performance in Biology, this study considered a change from the conventional method of teaching to a computer based one, finding out the impact of multimedia presentations on cognitive load.

Literature Review

The theoretical framework of the study is the cognitive load theory (CLT) and cognitive theory of multimedia learning (CTML).

The cognitive load theory was developed by John Sweller from the University of New South Wales in Australia in the 1980s. The theory was known as the cognitive load theory because the central focus is not on how learning occurred but instead on how efficient the process can become. Cognitive Load Theory suggested that for instruction to be effective, care must be taken to design instruction in a way as to not overload the mind's capacity for processing information. The theory explains that there are three types of cognitive load imposed on students working memory in the course of learning: Intrinsic load, Extraneous load and Germane load.

The intrinsic load imposed upon working memory is a static amount of effort required by the learner which cannot be altered. It represents the actual content, that is, the desired focus of the learning process and the level of difficulty that it imposes upon the learner (DeLeeuw and Mayer, 2008). Extraneous load is the working memory load experienced by learners as they interact with instructional materials. It includes everything that is involved in the learning

environment. Extraneous load should be eliminated from the learner's working memory because it distracts the learner from paying attention to the desired content (Merrienboer and Ayres, 2005). Germane cognitive load is defined by Sweller (2006) as the load devoted to the processing, construction, and automation of schemas. Germane load is an essential part of learning, and it is required in order for a person to process because it is the thinking that is required to make sense of new content and to help organize it and connect it with already existing schemas that a person has in his or her long-term memory.

The cognitive theory of multimedia learning (CTML) was designed by Richard E. Mayer in the 1990s. CTML falls under the larger framework of cognitive science and information processing model of cognition (Sorden, 2005). The theory centers on the idea that attempt to build meaningful connections between words and pictures and that students learn more deeply with words and pictures than they could have with either words alone or pictures alone (Mayer, 2009). The theory explained that multimedia brings about meaningful learning and that meaningful learning is demonstrated when the learner can apply what is presented in new situations.

Gender issues have been found to have an effect on the perception and academic achievement of students. Some studies revealed that male students perform better than female students in the sciences such as Physics, Chemistry and Biology (Danmole, 1998), some revealed that female students performed better than male students and some did not find any influence of gender on academic achievement (Yusuf and Afolabi, 2010). Some researchers however concluded that male and female students would perform equally the same if they are exposed to the same type of instructions. Gender therefore, may be a very important moderating factor in this research, especially since it involves the use of computers and a science subject, two areas that usually are labeled as male domains.

Research Question

R.Q 1: which type of cognitive load is commonly exhibited by the students after been exposed to the treatment?

Research Hypotheses

The following null hypothesis are generated and tested at 0.05 level of significance:

H_{o1}: there is no significant main effect of treatment on students' academic achievement in Biology

H_{o2}: there is no significant main effect of gender on students' academic achievement in Biology

H_{o3}: there is no significant interaction effect of treatment and gender on students' academic achievement in Biology

H_{o4}: there is no significant difference among the three treatment groups in the level of cognitive load exhibited

H_{o5}: there is no significant main effect of gender on the level of cognitive load exhibited by the students' in the treatment groups

Methodology

This study adopted a pre-test posttest control group quasi-experimental design. Biology content pre-test was used as a covariate. The design is structurally shown as follows

Experimental Group 1: A1 Q1 A2

Experimental group 2: A1 Q2 A2

Control Group: A1 Q3 A2

Where

A1 = Pre-test Assessment for experimental and control groups (covariate)

Q1= Treatment: multimedia instructional package 1

Q2 = treatment: multimedia instructional package 2

Q3 = Conventional teaching method

A2 = Post-test assessment for experimental and control groups

Two multimedia instructional packages were designed for the purpose of the study. The first, MIP 1 was designed with pictures, narrations and onscreen texts. The second, MIP 2 was designed with animations, narrations, onscreen texts and video clips. Topics on cell division: mitosis and meiosis were divided into the duration of six weeks in each package. The packages were validated by three Educational technologists and three Biologists. The experimental group 1 used MIP 1 and experimental group II used MIP 2. (Pictures were downloaded from www.google.com and videos from *https://www.youtube.com/watch?v=FykU6Oe5JE8*). The teacher was a facilitator, clarifying concepts, answering questions from students. The control group went through the same content during this period. They were exposed to the content through conventional teaching

methods i.e. “the chalk and talk method”. Screen shots from packages are found in Appendix A.

Study Participants

A total of 80 senior secondary schools II Biology students from three secondary schools in Ibadan, Oyo state of Nigeria were the participants of the study.

Grouping

Gender	Control group	Experimental I	Experimental II
Male female	23 17	8 13	13 6
Total	40	21	19

Instruments

The Biology Achievement Test (BAT): The instrument was developed based on the biology syllabus of the senior secondary school year II (SS II) and from past questions on SSCE (WAEC and NECO). It consists of 30 multiple-choice items with four possible answers for each question (A-D). To ensure the validity of the test items, a table of specifications, which showed the various levels of learning against the topics, was prepared. Based on the learning objectives, test items were developed in all categories. The BAT was trial tested on 20 SS II students from two schools not participating in the research. From the students’ responses, a reliability coefficient of 0.72 was established using the Kuder-Richardson (KR 20) formula. The BAT was used as the pre-test as well as the post-test.

The cognitive load measurement questionnaire: The cognitive load measurement questionnaire was adapted from Leppink, J., Paas, F., Van der Vleuten, C.P.M. et al. (2013) and used by the researcher to measure the cognitive load imposed on the students during the study. The questionnaire consists of 10 items with a scale ranging from 0 to 10, 0 meaning not at all the case and 10 meaning completely the case. Before the instrument was used in the main study, it was give validity after which it was used on a representative sample to test for its reliability. Cronbach’s Alpha was used to get a reliability value of 0.72

Data Analysis

Data collected through the instruments were analyzed through ANOVA, ANCOVA and MANOVA. T-test was used for comparison of gender results and Estimated Marginal Means (EMM) was used to determine the magnitude and direction of differences among groups.

Answers to Research Question

R.Q 1: which type of cognitive load is commonly exhibited by the students after been exposed to the treatment?

Table 4.0a: Types of Cognitive Load exhibited by the Students

Types of cognitive load	Frequency	Percentage (%)
Extraneous	22	27.5
Intrinsic	41	51.3
Germane	54	67.5

Table 4.0a reveals that largest proportion (67.5%) of the students exhibited germane load. This is followed by those that exhibited intrinsic load (51.3%) and those that exhibited extraneous load (27.5%). Table 4.0b further presents the cognitive loads exhibited by students based on treatment groups and figure 4.1 shows the graphical representations of cognitive load exhibited in treatment groups.

Table 4.0b: Types of Cognitive Load exhibited in the Treatment Groups

cognitive load	Control	Experimental 1	Experimental II
Extraneous	19 (47.5)	3 (14.3)	0 (0.0)
Intrinsic	26 (65.0)	9 (42.9)	6 (31.6)
Germane	18 (45.0)	17 (81.0)	19 (100)

Figure 4.1: Graphical Representation of Cognitive Load exhibited in the Treatment Groups

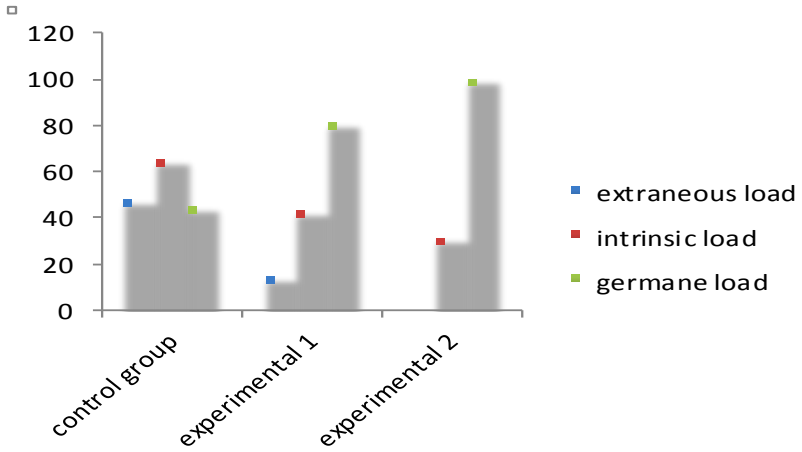

Table 4.0a and figure 4.1 reveals that many (47.5%) of the students in control group exhibited extraneous cognitive load, few (14.3%) of those in experimental group I exhibited extraneous cognitive load and none (0.0%) of students in experimental group II exhibited the load. Also, majority (65.0%) of the students in control group exhibited intrinsic cognitive load, some (42.9%) of students in experimental group I exhibited intrinsic cognitive load and few (31.6%) of the students in experimental group II exhibited intrinsic cognitive load. Of germane load, few (45.0%) of the students in control group exhibited germane load, majority (81.0%) of the students in experimental group I exhibited germane load and all (100.0%) of the students in experimental group II exhibited germane load.

This implies that conventional method of teaching imposes more extraneous and intrinsic cognitive load on students than germane load and that teaching with multimedia instructional packages imposes more germane load than intrinsic and extraneous load. Also, of multimedia instructional packages, packages with more of videos will cause more germane load, reducing intrinsic and extraneous loads to the barest minimum level than packages designed without videos.

Testing the Null Hypothesis

H_{o1}: there is no significant main effect of treatment on students' achievement in Biology

Table 4.1: Tests of Between-Subjects Effects

Dependent Variable: postscore

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	942.247[a]	18	52.347	7.016	.000	.685
Intercept	1387.667	1	1387.667	185.988	.000	.762
prescore	27.249	1	27.249	3.652	.061	.059
trtmt	405.633	2	202.816	27.183	.000	.484
gender	29.591	1	29.591	3.966	.051	.064
trtmt * gender	74.212	2	37.106	4.973	.010	.146
Error	432.740	58	7.461			
Total	22487.000	77				
Corrected Total	1374.987	76				

a. R Squared = .685 (Adjusted R Squared = .588)

Table 4.1 shows that there is a significant main effect of treatment on students achievement in Biology ($F_{(2, 58)} = 27.18$; $P < 0.05$; partial eta square = 0.48). Therefore, H_{o1} is rejected across the three groups.

Table 4.2: Estimated Marginal Means Table

Variable	Mean	Standard error
Intercept		
Pre score	9.08	-
Post score	17.25	.37
Treatment		
Control	13.14	.55
Experimental I	16.68	.65
Experimental II	21.94	.93
Gender		
Male	16.53	.50
Female	17.98	.54

Table 4.2 reveals that students' exposed to multimedia instructional package II had the highest mean score (21.94), followed by those exposed to multimedia instructional package I (16.68) while those exposed to conventional strategy scored lowest (13.14). Table 4.3 shows the source of the significance.

Table 4.3: Pair wise Comparison of the Groups using Scheffe's Post Hoc Test.

Treatment	Control	Experimental I	Experimental II
Control		*	*
Experimental I	*		*
Experimental II	*	*	

Table 4.3 shows that the significance difference exposed by table 4.1 was as a result of the significant difference between:

i. Experimental II and experimental I
ii. Experimental II and control
iii. Experimental I and control

The implication of this is that MIP II is significantly better than MIP I and both packages are significantly better than conventional teaching in enhancing students' achievement in Biology.

H_{o2}: there is no significant main effect of gender on students' achievement in Biology.

According to Table 4.1, gender has no significant main effect on students' performance ($F_{(1, 58)} = 3.97$; $P > 0.05$; Partial eta square = 0.06). Therefore, H_{o2} is not rejected.

Ho_3: there is no significant interaction effect of treatment and gender on students' achievement in Biology

According to table 4.1, there is a significant interaction effect of treatment and gender on students' academic performance in Biology ($F_{(2, 58)} = 4.97$; $P < 0.05$; partial eta square = 0.65). Therefore, H_{o3} is rejected. This implies that male and female students in experimental group two performed significantly better than the male and female students in experimental group one who also performed significantly better than those in control group.

H_{o4}: there is no significant difference among the three treatment groups in the level of cognitive load exhibited

Table 4.4: Summary of Analysis of Variance on Cognitive Load among Treatment Groups

Treatment	N	Mean	SD	F	df	Sig	Remark
Control	40	3.18	1.62	8.99	2, 77	.000	Significant
Experimental I	21	2.10	1.34				
Experimental II	19	1.63	.96				

Table 4.4 shows that there is a significant difference among the treatment groups in the level of cognitive load exhibited ($F_{(2, 77)} = 8.99$; $P < 0.05$). Therefore, Ho_4 is rejected. The mean score showed that those exposed to conventional study had the highest cognitive load (3.18), followed by those exposed to MIP I (2.10) while those exposed to MIP II had the least cognitive load (1.63)

H_{o5}: there is no significant main effect of gender on the level of cognitive load exhibited by students in the treatment.

Table 4.5: summary of independent samples test of effect of gender on cognitive load

Gender	N	Mean	SD	F	Sig	T	df	Remark
Male	44	2.75	1.62	0.43	0.51	1.45	78	Not significant
Female	36	2.25	1.44					

Table 4.5 reveals that there is no significant main effect of gender on the level of cognitive load exhibited by the students' in the treatment groups. (t= 1.45; df = 78; P> 0.05). Therefore, H_{O5} is not rejected.

Discussion and Implication of Findings

The findings of this study revealed that there is a significant difference in the academic achievement of students across the three groups. Those exposed to the multimedia instructional packages performed significantly better than those in the control group. This might be as a result of the multimedia elements such as animations, narration, onscreen text, pictures amongst others which were used in the design of the packages. The result of this study is in line with the findings of Adegoke (2011), Aremu and Sangodoyin (2010), that computer based instruction bring about a higher gain in achievement when compared with conventional teaching method. The result is also in line with those Abidoye (2015) and Narzoles (2013). The higher significance of MIP II is in line with the assertion of Ogochukwu (2010) that videos can focus attention through editing, and can manipulate time and space through time – lapse, slow motion amongst others. Therefore, using videos can be more compelling than direct observation.

It was found that conventional method of teaching imposes a high cognitive load composing of more intrinsic and extraneous cognitive load than germane load on the students unlike in the experimental groups where the reverse is the case. This might be as a result of the sitting arrangement and overcrowded classroom causing distractions during learning and making instruction difficult for the learners to process and therefore leading to their poor academic performance. It could also be because topics were not presented in simple ways but rather in vague ways. This could also be because instruction is too direct, students cannot see for themselves how the concept really happened in practical and almost real life experience. So, according to Merrienboer and Ayres, (2005), extraneous load should be eliminated from the learners working memory because it distracts the learner from paying attention to the instruction and more of germane load should be built. Deleeuw and Mayer (2008) explained that germane load is an essential part of learning as it is required in order for a person to process instruction and automate schemas necessary for meaningful learning. Therefore, students' better performance in the experimental groups must be because they were able to automate what they just learnt with previous knowledge because the classes were not too large and the lessons were complimented with pictures, animations, and even video clips,

motivating the students and focusing their attention to the study thereby bringing about meaningful learning.

Gender has no significant main effect on students' academic achievement in Biology and on the level of cognitive load they exhibit at the end of the study. Therefore, the amount of mental activity imposed on the working memory of the male students while learning the topic: cell division in Biology is not significantly different from those of their female counterparts. The male and female students in the different treatment groups perceived the efficiency and easiness to learn the topic the same way based on their treatment groups. This must also be the reason why there was no significant main effect of gender on the academic performance of students in the three treatment group. Therefore, the cognitive capability of male students is not significantly different from their female counterparts. Hence, students (both male and female) will perform the same way if they are exposed to the same type of instruction. The result of the study is in line with the findings of Spencer (2004), Yusuf and Afolabi (2010), Aremu and Sangodoyin (2010) that there is no significant difference in the performance of male and female students exposed to computer assisted instructions in Biology.

Conclusion

Effective and efficient learning have gone beyond depending only on the traditional method of teaching. According to Mayer (2010a), meaningful learning is an active learning where the learner constructs new knowledge and is demonstrated when the learner can apply what is presented in new situations. This implies that the poor performance of students' in our schools is because meaningful learning has not been attained. The findings of this study revealed that multimedia presentations can bring about better academic performance by reducing, if not completely eliminating intrinsic and extraneous cognitive loads and increasing germane load which is a good load, an essential part of learning required in order for a person to process because it is the thinking that is required to make sense of new content and to help organize it and connect it with already existing schemas that a person has in his or her long-term memory. Therefore, the use of computer based multimedia instructional packages should be adopted in our schools if we truly desire better academic achievement of students.

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Appendix A: Screen shots from MIP 1 and MIP 2