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USE OF E-LEARNING STRATEGIES AND STUDENTS' RETENTION OF KNOWLEDGE IN BASIC SCIENCE AND TECHNOLOGY

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ABSTRACT: *The study focused on enhancing students' retention of knowledge using two e-learning strategies in Basic Science and Technology in Benue, Nigeria. A non-randomised control group, pretest-posttest quasi-experimental design was employed. The study population comprised 27367 Upper Basic II students where a sample of 202 was drawn using multistage sampling technique. Developed Machine-Assisted Learning (MAL) and Virtual Science Laboratory (VSL) apps by the researchers were used as pedagogical strategies. The instrument used for data collection was Basic Science and Performance Test (BSTPT) which was transformed to Basic Science and Technology Retention Test (BSTRT) through reshuffling. This was validated, trial-tested and subjected to reliability analysis using Kuder Richardson (KR)-21 which gave 0.94. Four research questions were stated and analysed using mean and standard deviation, and graphs while four hypotheses were stated and tested using Analysis of Covariance (ANCOVA) at 0.050 level of significance. The findings revealed that, there were significant differences in the mean retention* scores [F2, 195 = 199.689, p = 0.000 < 0.050] *among MAL, VSL and Expository groups. A follow up pair wise comparisons confirmed the hypothesis in all the three combinations: MAL and VSL (p = 0.000 < 0.05); MAL and Expository (p = 0.00 0< 0.05) and VSL and Expository (p = 0.000 < 0.05). The findings also revealed that, there was no significant gender disparity in the mean retention scores of the students in MAL [F1, 57 = 0.817, p = 0.370 > 0.050] and VSL [F1, 72 = 0.226, p = 0.636 > 0.050]. It was further found that, there was no significant interaction effect of strategies and gender on the students' mean retention score [F2, 195 = 0.191, p =0.826 > 0.050]. The study concluded that the use of MAL and VSL apps have enhanced students' knowledge retention in BST than expository strategy. Based on the findings, it was recommended among other things that, the government and teachers-trainees' institutions should train teachers on the development and implementation of the MAL and VSL since they have greater effects on students' durable memory.*

KEY WORDS*:* e-learning, machine-assisted learning, virtual science laboratory, retention of knowledge, gender, and basic science and technology

INTRODUCTION

The development of a nation hinges on the level of scientific and technological advancement where education remains a veritable tool for inculcation of resilience, skills and scientific literacy needed for inclusive participation in socio-scientific issues. This could be why the Federal

Republic of Nigeria (FRN, 2013), in release of her educational objectives for secondary schools, emphasises on the need to equip students with skills to live effectively in the modern age of science and technology. This is pertinent because, this era is characterised by rapid development in science and technology where innovations such as Artificial Intelligence (AI), Internet generations, virtual reality, social media, robotic apps and several smarttechs are emerging; and the children of the era cannot afford to lag behind. Combining with the students' abject retention and general unsatisfactory performance, the world is undeniably witnessing catastrophic issues like Coronavirus-19 (COVID-19) pandemic, climate change, insecurity among others that are threatening the world's education and economy. Consequently, a systematic rethink of education along critical dimensions by devising resilient means against the current and future challenges through the use of innovative strategies for Basic Science and Technology (BST) instruction becomes pertinent for national development.

According to Nigerian Educational Research and Development Council (NERDC) (2012), BST is the product of restructuring and integration of four Primary and Junior Secondary School science curricula namely Basic Science, Basic Technology, Physical and Health Education, and Information and Communication Technology (ICT) which a child encounters at the Upper Basic level under the current 9-3-4 system of education. Among other things, the integration of these curricula became necessary because of the need to encourage innovative teaching that can promote quality interactions, engaged and experiential learning, creativity, critical thinking and development of science process skills (NERDC, 2012). Besides, the goals of BST are to develop students' interest in science and technology; acquire and apply basic scientific and technological knowledge and skills to meet the contemporary societal needs; take advantage of numerous career opportunities provided by science and technology; be safety and security conscious; and become prepared for further studies in science and technology.

Despite these objectives, abject retention and general underperformance in science and technology among male and female students were reported (Ode, Ayua, & Alagwu, 2019; Aneke, & Ezugwu, 2018). These could be attributed to the use of conventional teaching strategies like expository and lecture methods which usually assign one teacher to many students in an overcrowded classroom mostly for the purpose of examination and certification. Expository strategy is a conventional method where the teacher explains a subject matter to the students (Teddy, 2015). The teacher completely dominates the classroom discussions and sometimes permits a few questions and answers. In the opinion of Brooks and Brooks (2014), this type of classroom suffers large class-size, lack of time to practice science experiments, denies students of active and meaningful learning. Consequently, a shift from the old system to technology-driven strategy like electronic learning (abridged as e-learning) for BST teaching and learning is suggested.

The word e-learning is synonymously used with virtual knowledge, online education, computer-based teaching and learning, electronic instruction, web-based knowledge and networked education. Whatever may be the meaning of e-learning, the idea is to revamp the traditional styles of instruction using AI and ICT resources. E-learning can be considered as pedagogical platforms driven by ICT where apps are developed to mimic teacher's intelligent processes in

terms of instructional delivery, displaying experiments, test administration, taking attendance, giving prompt feedbacks on virtual format among others (Vedantu, 2020). Though, AI and ICT, and human resources that can facilitate the integration of e-learning are insufficient in Nigerian schools but the introduction of technology-driven methods gives students the opportunities to access information of interest and interact with electronic tools, and peers and experts (Achor, & Ityobee, 2020). E-learning helps students to learn meaningfully to gain knowledge autonomy as it is reported to be learner-centered, activity-based, resource-based, interactive, flexible, accessible, integrative and collaborative capable of getting all students fully involved in the learning process (Brooks, & Brook, 2014). This may help them to develop exploration based on scientific assumptions and processes and share knowledge via the Internet anywhere and anytime.

The study focused on Machine-Assisted Learning (MAL) and Virtual Science Laboratory (VSL) strategies. Machine-Assisted Learning is predicted to offer a distinct learning advantage over traditional forms of lecture or mere exposition of students to science content. It is a student-centered mode of electronic science exposition or lecture where students receive learning experience with the aid of multimedia resources (Utermohlen, 2019). The objectives are to replace the traditional exposition of science content and help students learn and share learning experience on instructional domain in order to think creatively; and actively participate in the teaching process and acquire ICT skills. This strategy is envisaged to facilitate learning, improve course navigation, simplify learning process, analyse answers and give prompt feedback to students' responses. It is an ordinary application programme running on desktops, tablets, laptops and smartphones that can teach students on a one-on-one basis. It involves the use of short video lessons, audio, PowerPoint slides, screen shares, Portable Document Formats (PDFs) or other electronic versions of lesson which can be available for both students and teachers on web pages of a dedicated educational app. For a student to learn, he/she could login and click on domain links and move from one section of the lesson to another. If a student could not understand the facts in a specific topic or subject area as often happens in the conventional classrooms, machine-assisted learning may provide students with unlimited access to learning materials, test series, web links, chatbots, search options or even interact with peers and experts via live chat integrated into the learning platform for further information (Kumar, & Singh, 2019).

Virtual science laboratory strategy on the other hand could be seen as laboratory activities without real laboratory walls and doors usually packaged in software format but situated in an electronic environment. In the opinion of Esam (2016), it enables students to link between the theoretical and practical aspects of learning without papers and pens. The design relies on realistic experimentation and representation of analogy to construct better understanding of scientific concepts; and this considers the workability of the tools in a variety of learning settings and how the tools run on different browsers, operating systems and devices including touch-enabled ones. Virtual laboratories allow various experiments to be conducted at convenience and affordable cost; and it is electronically programmed in order to simulate the practice of real experiments inside the real laboratories (Murugan, & Kamisah, 2018). It displays experiments which are difficult to be performed in a conventional laboratory due to its danger, high cost or shortage of equipment and automatically evaluates students' learning outcomes (Olugbade,

Adekomi, & Sofoworo, 2016). The challenges of abstract teaching and rote learning could be accommodated by the application of virtual science laboratory which may lead to enhanced students' durable learning and academic retention.

Retention is the term used to denote a demonstration that meaningful learning has taken place, maintained and sustained over time which can be proved through recall, recognition, recitation or practice (Abu, & Flowers, 2019). In the opinion of Atomatofa (2013) retention is the ability of a student to hold factual knowledge, skills, images and figures in memory and at the same time retrieve for use when the need arises. However, abject retention was reported which has been ascribed to the use of old teaching strategies like expository and lecture methods that are usually teacher-centered, inflexible and restrictive for students' meaningful learning (Ameh, 2014). When students at the Upper Basic level of education are provided with e-learning system incorporated with audio-visual activities, it is likely that, they will get motivated and become autonomy of their learning and may consequently lead to durable learning. It is against this background that, the researchers have been spurred to investigate the effects of e-learning strategies on students' retention to see if this variable could be improved with the use of machine-assisted learning and virtual science laboratory strategies.

Statement of the Problem

Educators do not find satisfaction in students' retention of knowledge despite enormous investments in science and technology education (Shikaan, 2012). This worrisome situation has been ascribed to persistent use of old system like expository and other methods characterised by teacher-centredness, theoretical abstraction, note copying and passive learning. The problem is compounded by acute shortage of scientific and technological equipments coupled with limited time the teacher has for learning activities making it difficult for students to exhibit how concepts are covered and applied in a real life situation. This suggests that the current educational system is defective coupled with the challenges of COVID-19 pandemic, global climate change and insecurity. If these problems are not given urgent attention, they will not only impede students' meaningful and durable learning but would also lead to setback in scientific and technological advancement of the nation. These necessitated the quest for innovative apps like MAL and VSL. Thus, the problem of this study is therefore, what is the effect of the use of e-learning strategies (machine-assisted learning and virtual science laboratory) on students' retention of knowledge in BST in Benue, Nigeria?

Research Questions

The following research questions guided the study:

1. What is the difference in the mean retention scores of the students taught BST using MAL, VSL and expository strategies?
2. What is the difference between the mean retention scores of male and female students taught BST concepts using MAL?
3. What is the difference between the mean retention scores of male and female students taught BST concepts using VSL?
4. What is the mean interaction effect of strategies and gender on the students retention scores in BST?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

1. There is no significant difference in the mean retention scores of the students taught BST concepts using MAL, VSL and expository strategies.
2. There is no significant difference between the mean retention scores of male and female students taught BST concepts using MAL.
3. There is no significant difference between the mean retention scores of male and female students taught BST concepts using VSL.
4. There is no significant mean interaction effect of strategies and gender on students' retention scores in BST.

RESEARCH METHOD

The study adopted a non-randomised control group, pretest-posttest quasi-experimental design. A sample of 202 was drawn from a population of 2767 students in 213 approved Upper Basic schools in Benue Education Zone C, Nigeria using multistage sampling technique. Four out of 6 sampled schools considered ICT compliant were purposively selected and assigned to MAL and VSL; while two schools were also assigned to expository strategy. The researchers developed two e-learning instructional packages (MAL and VSL apps) using the concepts of work, energy, power and kinetic theory drawn from the BST curriculum of the Universal Basic Education. The developed apps were used as treatments for experimental group I and II while the expository strategy was used for control group. The MAL and VSL with Universal Resource Locator (URL), https://bstelearningtutors.com was a dynamic domain majorly composed of subsystems such as user profile, enrolment, lessons, presentation, assignment, evaluation, quizzes, forum, chatbot, live chat, feedbacks, complaints, PDFs, audio, animations, hyperlinks, announcement, attendance, user guide. Each works in unity and diversity to provide the required data flows in order to do their jobs and generate reports. A student could login to the lesson domains, MAL (https://bstelearningtutors.com/mal) or VSL (https://bstelearningtutors.com/vsl) using a unique username and password and then learn, watch and listen, and interact with the apps, peers and teachers. The role of the teachers is majorly 'a guide on the side' while the students remain connected to the instructional apps.

The researchers recruited and conducted a week training exercise for 6 BST teachers who served as research assistants. The training involved orientation on how to implement MAL, VSL and expository strategies. The researcher ensured that, only regular class teachers were involved in the treatment and data collection. The rationale for doing this was to equip them with the fundamental knowledge, competencies and skills on the use of the strategies as well as test administration in order to ensure a normal presentation of classroom situation as well as prevention of extraneous variables such as nervousness from occurring.

Basic Science and Technology Performance Test (BSTPT) which was developed by the researchers and then transformed to Basic Science and Technology Retention Test (BSTRT) through reshuffling after posttest was the instrument used for data collection. The test was made

up of 30 multiple choice items with four options where the students were expected to choose answers considered appropriate either by clicking A, B, C, or D on their answer sheet. Each question attracted 1 mark; and time allotted for it was 60 minutes. A table of specification was drawn to ensure content spread and coverage of the lessons' objectives. The instrument was subjected to validation by science education experts; and trial-tested and its reliability analysis using KR-21 yielded 0.94. Forty five (45) students were trial-tested and these were not formed sample for the main study.

The students in all the three groups wrote BSTPT and BSTRT using a paper and pencil test. A total of eight weeks was used for the study. Week one, before the treatment, BSTPT was administered as pretest. With the help of research assistants, the topics were taught for a period of five weeks and at the end, the same BSTPT was administered again as posttest; and after an interval of two weeks, the test was reshuffled and re-administered as retention test (BSTRT). The students' scores were converted to 100% for further analysis. The data collected through the administration of the instrument were analysed using mean and standard deviation, and graphs to answer the research questions while ANCOVA was used to test the hypotheses at 0.05 level of significance. Bonferroni effect size and pair wise comparisons were established to determine the magnitude of the difference between and among the groups.

RESULTS

Research Question One

What is the difference between the mean retention scores of the BST students taught using MAL, VSL and expository strategies?

Table 1: Mean and Standard Deviation of Students' Retention Scores in MAL, VSL and Conventional Strategies

Strategies		Pretest	BSTRT	Mean Gain
Machine-Assisted Learning	Mean	26.02	67.05	41.04
	N	60	60	
	Std. Deviation	8.26	9.03	
Virtual Science Laboratory	Mean	26.92	74.11	47.19
	N	75	75	
	Std. Deviation	10.85	9.19	
Expository Strategy	Mean	27.61	44.61	17.00
	N	67	67	
	Std. Deviation	11.07	8.58	

The analysis of data on Table 1 shows the mean and standard deviation of students' knowledge retention in the BST taught the concepts of work, energy, power and kinetic theory using MAL, VSL and expository strategies. The table reveals that, during pretest, the mean score of the students taught using MAL is 26.02 with a standard deviation of 8.26; and 67.05 with a standard deviation of 9.03 in retention test. During pretest, the mean score of the students taught using

VSL is 26.92 with a standard deviation of 10.85; and 74.11 with a standard deviation of 9.19 in retention test. The mean score of the students taught using expository strategy is 27.61 with a standard deviation of 11.07 during pretest and 44.61 with a standard deviation of 8.58 in retention test. The mean gain in retention scores of the students taught using MAL is 41.04, those taught with VSL is 47.19 while those taught with expository strategy is 17.00. From the results, VSL students performed significantly better followed by those in MAL group than their counterparts in expository group.

Research Question Two

What is the difference between the mean retention scores of male and female students taught BST concepts using MAL?

Table 2: Mean and Standard Deviation of Male and Female Students' Retention Scores When Taught BST Using MAL

Gender		Pretest	BSTRT	Mean Gain
Male	Mean	25.56	67.94	42.38
	N	34	34	
	Std. Deviation	7.42	8.71	
Female	Mean	26.62	65.88	39.26
	N	26	26	
	Std. Deviation	9.36	9.46	
Mean Difference				3.12

Table 2 shows the mean and standard deviation of male and female students' retention scores in BST taught using MAL. The result shows that the pretest mean scores of 34 male students in the MAL is 25.56 with a standard deviation of 7.42 while the mean retention scores of their 26 female counterparts who took the same test is 26.62 with a standard deviation of 9.36. The result on Table 2 further reveals that, the mean retention score of male students taught using MAL strategy is 67.94 with a standard deviation of 8.71 while their female counterparts had a mean retention score of 65.88 with a standard deviation of 9.46. Also, the mean gain of the male students is 42.38 and that of the female is 39.26 and the difference is 3.12 in favour of male students. Since, the difference in their mean gains is considered small, it implies that female and male students had close retention scores in the retention test.

Research Question Three

What is the difference between the mean retention scores of male and female students taught BST concepts using VSL strategy?

Table 3: Mean and Standard Deviation of Male and Female Students' Retention Scores When Taught BST Using VSL.

Gender		Pretest	BSTRT	Mean Gain
Male	Mean	27.24	73.44	46.20
	N	45	45	
	Std. Deviation	10.62	8.36	
Female	Mean	26.43	69.47	43.04
	N	30	30	
	Std. Deviation	11.34	7.97	
Mean Difference				3.16

Table 3 shows the mean and standard deviation of male and female students' retention scores who took BSTRT at the end of VSL treatment. The result shows that, the pretest mean score of 45 male students in the VSL group is 27.24 with a standard deviation of 10.62 while the mean score of their 30 female counterparts who received the same treatment and test is 26.43 with a standard deviation of 11.34. The result on Table 3 further reveals that, in BSTRT, the mean retention score of the male students taught using VSL strategy is 73.44 with a standard deviation of 8.37 while their female counterparts had a mean retention score of 69.47 with a standard deviation of 7.97. The mean gain of the male students is 46.20 and that of the female is 43.04 and the difference between their mean gains is 3.16 in favour of male students. This shows that male and female students had almost the same mean retention score.

Research Question Four

What is the mean interaction effect of strategies and gender on the students' academic retention scores in BST?

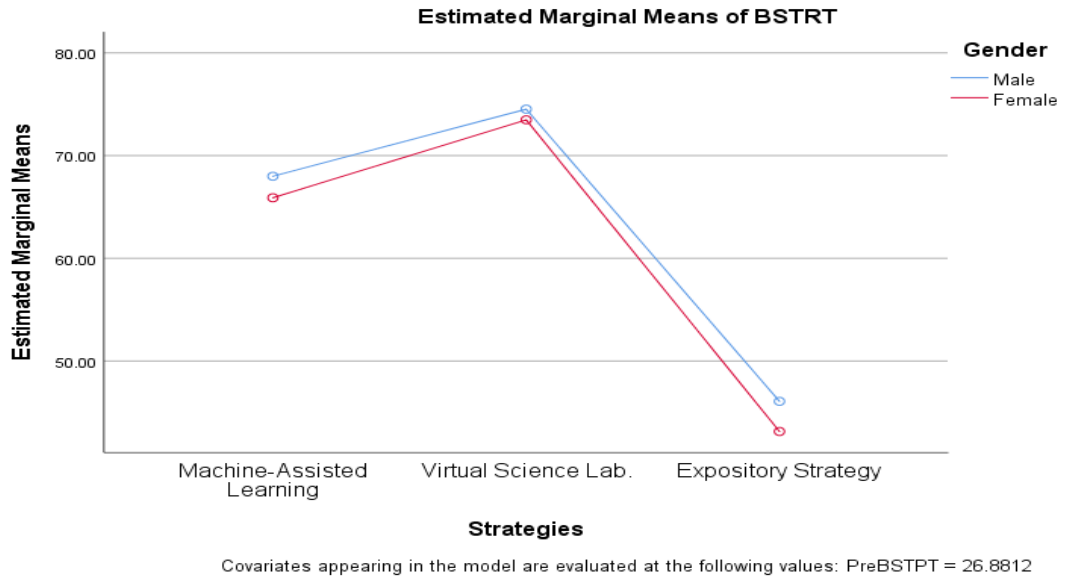

Figure 1: Graphical Representation of Interaction Effect of Strategies and Gender on Students' Knowledge Retention

Figure 1 shows the graphical representation of interaction effects of strategies and gender on students' mean retention scores in Basic Science and Technology when taught the concepts of work, power, energy and kinetic theory using MAL, VSL and expository strategies. The graph shows that, the interaction patterns for male and female students in the methods did not cross, meaning interaction did not occur on the graph. Since, the lines did not intersect, it therefore means that strategies and gender has no interaction effect on students' retention scores in Basic Science and Technology.

Hypothesis One

There is no significant difference between the mean retention scores of the students taught BST concepts using MAL, VSL and expository strategies.

Table 4: ANCOVA Test for Mean Retention Scores of Students Taught BST Concepts Using MAL, VSL and Expository Strategies

Dependent Variable: BSTRT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	33056.555[a]	6	5509.426	68.767	.000	.679
Intercept	87227.486	1	87227.486	1088.740	.000	.848
Pretest	24.778	1	24.778	.309	.579	.002
Strategies	**31997.245**	**2**	**15998.623**	**199.689**	**.000**	**.672**
Gender	196.308	1	196.308	2.450	.119	.012
Strategies * Gender	**30.574**	**2**	**15.287**	**.191**	**.826**	**.002**
Error	15622.970	195	80.118			
Total	830882.000	202				
Corrected Total	48679.525	201				

a. R Squared = .679 (Adjusted R Squared = .669) * denotes F is significant at 0.05 alpha level

Table 4 reveals that [F2, 195 = 199.689, p = 0.000 < 0.050]. Since the p-value is less than the significance level of 0.05, the null hypothesis is therefore rejected. This implies that, there is significant difference in the mean retention scores of the BST students taught using MAL, VSL and expository strategies. The partial n^2 of 0.672 obtained for the strategies means that, 67.20% of the students' retention scores could be attributed to the strategies employed in the teaching and learning of BST concepts. This indicates a high significant difference among MAL, VSL and expository strategies. A follow up pair wise comparisons test was conducted to locate where the magnitude of difference among the three groups as indicated on Table 5.

Table 5: Pair Wise Comparisons of Mean Retention Scores of Students Taught BST Concepts Using MAL, VSL and Expository Strategies

(I) Strategies	(J) Strategies	Mean Difference (I-J)	Std. Error	Sig.
Machine Assisted Learning	Virtual Science Laboratory	-7.060*	1.573	.000
	Expository Strategy	22.334*	1.602	.000
Virtual Science Lab	Expository Strategy	29.394*	1.520	.000

Based on estimated marginal means. *. The mean difference is significant at the .05 level.

Table 5 shows the summary of the bivariate comparisons of the strategies of teaching and learning of BST concepts and their effect on students' mean retention of knowledge. It shows that, the comparison of the mean retention scores for MAL and VSL strategies yielded a mean difference (I-J) of -7.060* with a standard error of 1.573 in favour of VSL group. The comparison of MAL and expository yielded a mean difference of 22.334* with a standard error of 1.602 in favour of MAL while the comparison of VSL and expository yielded a mean difference of 29.394* with a standard error of 1.520 in favour of VSL group respectively. Since 0.000 is less than the p-value of 0.050 in all the comparisons, the null hypothesis is therefore rejected. This implies that, there is significant difference in the mean retention scores of students taught BST concepts using MAL, VSL and expository strategies.

Hypothesis Two

There is no significant difference between the mean retention scores of the male and female students taught BST concepts using machine-assisted learning.

Table 6: ANCOVA Results on Mean Retention Scores of Male and Female Students Taught Using MAL

Dependent Variable: BSTRT

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	139.891[a]	2	69.945	.854	.431	.029
Intercept	26754.248	1	26754.248	326.764	.000	.851
Pretest	77.577	1	77.577	.947	.334	.016
MALGender	**66.857**	**1**	**66.857**	**.817**	**.370**	**.014**
Error	4666.959	57	81.876			
Total	274549.000	60				
Corrected Total	4806.850	59				

a. R Squared = .029 (Adjusted R Squared = -.005) * denotes F is significant at 0.05 alpha level.

Table 6 shows the summary of ANCOVA test results of male and female students' mean retention scores in the MAL strategy. The result shows that [F1, 57 = 0.817, p = 0.370 > 0.050]. Since the significant p-value is greater than the set significant value of the study ($p > 0.05$), the null hypothesis is therefore not rejected. This indicates that, there is no significant difference in the mean retention scores of male and female students taught BST using MAL strategy. Since the partial n^2 obtained for gender is 0.014, it means that, 1.40% could be accounted for gender when BST students were taught using MAL. It could therefore be concluded that, there is no significant effect of gender on students' retention scores when MAL strategy was used in teaching and learning of concepts of work, power, energy and kinetic theory.

Hypothesis Three

There is no significant difference between the mean retention scores of male and female students taught BST concepts using virtual science laboratory strategy.

Table 7: ANCOVA Results on Mean Retention Scores of Male and Female Students Taught Using VSL

Dependent Variable: BSTRT

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	28.024[a]	2	14.012	.162	.850	.004
Intercept	55388.233	1	55388.233	641.653	.000	.899
Pretest	7.544	1	7.544	.087	.768	.001
VSLGender	**19.546**	**1**	**19.546**	**.226**	**.636**	**.003**
Error	6215.123	72	86.321			
Total	418128.000	75				
Corrected Total	6243.147	74				

a. R Squared = .004 (Adjusted R Squared = -.023)

* denotes F is significant at 0.05 alpha level.

Table 7 shows the summary of ANCOVA test results for male and female students' mean retention scores in BST taught using VSL. The result indicates that, [F1, 72 = 0.226, p = 0.636 > 0.050]. Since the significant p-value is greater than 0.05 level of significance, the null hypothesis is therefore not rejected. This indicates that, there is no significant difference in the mean retention scores of the male and female students taught BST concepts using VSL. Since the partial n^2 obtained for gender is 0.03, it means that only 3.00% of the students' retention score could be attributed to gender difference when VSL strategy was employed in teaching BST. This showed that, the use of VSL is gender-friendly since the obtained n^2 is considerably small.

Hypothesis Four

There is no significant interaction effect of strategies and gender on the students' academic retention scores in BST.

The results of data analysis for hypothesis four can be found on Table 4. In addition to the test of the students' mean retention scores, table 4 also contained the analysis of Two-Way ANCOVA test which determines the interaction effect of the three strategies and gender on mean academic

retention scores of the Upper Basic II students. The results of the analysis yielded [F2, 195 = 0.191, p = 0.826 > 0.050]. The null hypothesis is therefore not rejected since the p-value is greater than 0.050 level of significance. This means that, there is no significant interaction effect of MAL , VSL and expository strategies and gender on retention scores when taught BST students the concept of work, power, energy and kinetic theory. The effect size is 0.002 as indicated by the corresponding partial n^2 value which was considered small. This means that, only 0.20 % of the interaction in the retention of knowledge among the strategies was explained by treatments and gender. Hence, the interaction of the treatments and gender on students' academic retention scores has no significant statistical effect size. From the profile plot for strategies and gender (Figure), the marginal lines did not intersect; meaning there is no significant interaction effect of strategies and gender on the students' retention scores.

DISCUSSION OF FINDINGS

The findings revealed that, BST students in the experimental groups taught using Machine-Assisted Learning (MAL) and Virtual Science Laboratory (VSL) demonstrated durable knowledge of learning experiences and therefore scored better than their control group counterparts taught using expository strategy. This was confirmed in the rejected null hypothesis 1 in the bivariate comparisons of the strategies of teaching BST and their effects on the mean retention scores. Thus, the students taught using MAL and VSL retained learning experience better than their peers taught using expository strategy. However, the students taught using VSL significantly retained learning experience better than their counterparts in MAL group. This finding is in agreement with Atomomatofa (2013) who found significant difference in the retention scores of Physics students when taught with e-learning and conventional lecture method. Similarly, Ameh (2013) investigated the effects of adapted Intelligent Tutoring System in the teaching of Introductory Physics and found that, the strategy enhanced academic retention better than the talk-and-chalk method.

Better retention could be attributed to the fact that, teaching and learning process was practically based on audio-visual learning where students were given ample opportunities to engage in concrete multimedia activities rather than been taught facts or theoretical abstraction in one-short-lesson as experienced in traditional classroom. Improved students' retention supports the chant by McLeod (2018): *What I see ... I forget; What I hear ... I remember; What I do ... I understand.* This chant means that, when it comes to learning, hearing is not as good as seeing, seeing is not as good as experience; and true learning is only evident when experience produces an action. The MAL and VSL apps had incorporated functionalities that made it possible for students to see, hear and practice science activities in real life situations. This could mean that, instruction that utilises the principles of explanation and seeing on the screen encouraged the students to learn better which promoted retention and deeper learning in Basic Science and Technology.

This confirmed the chant that, there might be retention of learning experience only when and where students gain proper understanding of the learnt concepts when they are given opportunity to see, hear and do. MAL and VSL resources such as videos, virtual tutorials, animations, fora,

live chat, BSTbots, web pages and social media were available to the students in 24 hours and helped deepened learning retention. With the apps, the information was broken down to its most basic components in order to make it memorable. The human brain remembers images and videos more effectively than just text, because visual summaries help to boost knowledge retention and active recall. During the experiment, visuals help students to connect the information to existing mental schemas. For example, when a student recognises videos and images, he/she may immediately see the relationship between the new concepts and the previously learned ideas. The use of these cognitive tools to support teaching and learning of BST might have provided appropriate coding of incoming information which in turn provided the index that might be consulted and retrieved without elaborate search in the memory lane. Since the ultimate target of educational efforts is permanent and meaningful learning, innovative strategies like MAL and VSL found to have helped the learners to retain learning experience and consequently remember them after a period of time should be employed in teaching and learning of science education.

Findings on the effects of gender on students' retention of knowledge reveals that, there is no significant disparity in the mean academic retention scores of male and female students taught BST either by using MAL or VSL. This implies that, based on the statistical evidence from the mean retention scores of the BST students, the use of MAL and VSL are gender-friendly. The likely explanation for this gender-inclusive retention ability could be that, the strategy was characteristically opened and involved all students regardless of gender. These findings are in agreement with Esam (2016) who revealed that, irrespective of gender, e-learning enabled students to focus their energies and had more accurate idea of what is expected of them to achieve at the end of the lesson as a result of accessibility and availability of multimedia resources in 24 hours.

The finding from the hypothesis 4 revealed that the interaction among strategies and gender has no significant effect on students' knowledge retention of the BST students. Both male and female students had similar mean scores when compared the interaction effects of strategies and gender on their retention of knowledge. Two independent variables (strategies and gender) were crossed with one another in order to observe their levels of interaction; however, retention scores of the male and female did not intersect (figure 1***)*** and this indicates that, there is no interaction effect of strategies and gender on students' retention of knowledge in BST. Studies on the interaction effects of the strategies and gender on retention of knowledge were found to be scanty**.** On the basis of the finding of the hypothesis 4, whether MAL, VSL or expository strategies can be maximally employed regardless of gender in enhancing durable knowledge retention in Basic Science and Technology.

CONCLUSION AND RECOMMENDATIONS

It is evident from the findings of the study that, the use of MAL and VSL strategies as pedagogical strategies had fostered students' knowledge retention better than the use of conventional strategy in Basic Science and Technology. However, the application of VSL showed better effectiveness as reflected in the students' mean retention scores than the use of

MAL. Findings also showed that, there was no significant gender disparity in the mean retention scores of the students taught using MAL and VSL. There was no significant effect of strategies and gender on students' mean retention scores; and hence the three strategies can be maximally employed in BST instruction without the need for division on gender basis. It is concluded that, the implementation of the MAL and VSL in school system will continue to advance durable knowledge regardless of gender; build academic resilience against the current and future global catastrophes like COVID-19, climate change and insecurity; and also provide teachers and students with reliable assistance to fulfil their responsibilities with improved efficiency. It is therefore recommended that:

1. The government and teachers-trainees' institutions should train science teachers on the development and implementation of the MAL and VSL since they have greater effects on students' durable knowledge retention.
2. Government, Non-Governmental Organisation (NGOs) and Ministries of Education should fund the development of adequate instructional apps as well as procurement of relevant multimedia resources to enable schools integrated MAL and VSL strategies.
3. Basic Science and Technology teachers should endeavour to sponsor themselves on workshops and seminars on the use of MAL and VSL so as to keep themselves abreast with the requisite competencies and skills on the development and application of the strategies.
4. Students who are the central figure in the curriculum implementation process should cooperate with their teachers in terms of their curiosity, persistent, knowledge, skills, ideas, attitudes, tolerance of uncertainty and adaptation to changes in order to encourage effective integration and implementation of the MAL and VSL strategies in the school system.

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