THE EFFECTIVENESS OF SIMULATIONS IN SUPPLEMENTING TRADITIONAL PHYSICS LABORATORY EXPERIMENTS, STUDENTS' PERFORMANCE AND ATTITUDES TOWARDS SIMULATIONS

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Abstract

This research focuses on measuring how the use of simulation can effectively influence the performance of learners and the attitude of learners towards the use of simulation technology. The research employed: quasi-experiments where the participants were divided into control and experimental groups to measure the effects of simulation technology in supplementing traditional laboratory experiments, and questionnaires to investigate the state of physics laboratories and the attitudes of both learners and teachers towards the use of simulation technology. Results gathered from these investigations will contribute to science education in Dutsin-Ma Local Government of Katsina State, Nigeria by emphasizing the application of computer-simulated technology in the area of physics laboratory experiments when facilitated by the teacher and used independently by the students to proffer an alternative to traditional laboratories and physics experiments. It will also encourage the use of computer technology and improve digital literacy among both teachers and students. This will open more room for scientific experiments in physics which would not be limited only to the laboratory but anywhere so far as the required software is readily available. The review of the literature also reported different effects of simulations on different types of knowledge. Some studies showed that simulations had a significant impact on factual knowledge and others on procedural knowledge (Bello, et al., 2016).

Keywords: Simulation, Questionnaire, ANOVA, Experiment, VSO

Introduction

Science education in Nigeria has dated as far back as when the Christian missionaries brought western education into Nigeria, starting with the Church Missionary School in Lagos Nigeria in 1859 (Ogunleye, 1999). Science education foundations were implemented in subjects like arithmetic, algebra, geometry, and physiology. Over the years, Nigeria has experienced significant development in science education starting from the educational reforms that took place from 1932 – 1960. Among those reforms are the introduction of Higher School Certificate courses in some existing schools in 1951, the establishment of West African Examination Council (WAEC) in 1952, the establishment of the Science Teachers Association of Nigeria (STAN) in 1957, and the establishment of Federal Colleges of Arts, Science and Technology at Ibadan in 1950, Zaria in 1952, and Enugu in 1954.

Physics is one of the fundamental science subjects according to the newly improved curriculum by Nigerian Educational Research and Development Council (NERDC) as approved by the Federal Government of Nigeria in 2011. Physics is the natural science that studies matter, its motion and behavior through space, time and the related entities of energy and force. Physics is a compulsory prerequisite subject for most science and technology courses in tertiary institutions around the world. This has made the study of physics a core part of sciences and made the need for students to perform well in the subject important. For students to perform well in physics, educators have designed the physics curriculum in such a way that students are taught using lecture method together with laboratory activities aimed at verifying concepts taught in the lesson and students who perform in active learning with hands-on experiments learn through self-discovery.

For students to learn through self-discovery, they must be equipped with adequate facilities required to facilitate learning, such as a conducive and learner-friendly classroom, a qualified teacher and a well-equipped laboratory where the student will perform independent experiments. But due to the state of our educational system in Nigeria, students do not have that opportunity/luxury due to overpopulated classrooms, teacher-student ratio, and ill-equipped laboratories. Due to these challenges, the need to apply technology-related teaching and learning strategies has become relatively important, and can be implemented through the use of smartphones when a personal computer is not readily available. This proposed technology is the Physics Education Technology (PhET), a simulation technology compatible with both smartphones and personal computers.

It is understood in research that simulation technology is vital in influencing learners' performance. However, certain factors determine whether simulation technology can be effectively implemented in secondary schools across Northern Nigeria. Simulation technology is defined as a program that models an existing or proposed system to identify and understand those factors that control the system and predict the system's behaviour (Samuel, 2018). Simulation technology is designed to mimic the real system and its behaviour, which offers students the opportunity to perform experiments independently and get similar results as the traditional procedure (Vlachopoulos & Makri, 2017). Simulation technology is also designed to serve as a substitute for students that are new to the whole system, so they get familiar with the system and for a system that is too risky to the learners. That is why various fields use simulations as a training strategy before the learners are introduced into the main fields (Rokooei *et al.,* 2017).

Due to inadequate funding from individual state governments, the quality of graduates from state owned Schools does not possess the capability to compete efficiently with their counterparts from other institutions in science and technology. To bridge the gap between state-owned schools and federal owned institutions in Katsina State, the Katsina State Government Partnered with the Voluntary Service Organization (VSO) where they launched the mobile science lab programme 'lab on the wheels' in 2017. This mobile science laboratory comprises a 'van and a qualified teacher trainer to rotate between 15 schools and reach around 7,500 pupils and 60 teachers'. The initiative by the VSO in improving science education is a very good improvement in science education, but it is limited in its reach. To reach a large number of students even without a physical laboratory, various researchers have recommended using simulation technology.

Science and technical education in Nigeria have been plagued with numerous challenges despite the instructional strategies recommended by researchers (Odo, C.R. & Odo, A. I., 2016), these challenges still persist. Researchers have identified the challenges facing science education: lack of proper funding, teacher-student ratio, poorly equipped laboratories, unavailability of instructional materials (text-books), lack of qualified teachers, inappropriate teaching methodologies, and gender factors (Mckagan, *et al.,* 2018). Physics being a science subject is not exempted from these challenges as it also requires the use of scientific methods in order to arouse curiosity and interest in the learner. The laboratory is considered essential in carrying out scientific methods as it serves as a tool for the teacher and student to perform empirical procedures called an experiment. These laboratories been ill-equipped serve as a challenge in the proper delivery of the physics curriculum hence students are not familiar with experimental apparatus, the scientific method and methods of data analysis. Due to these factors, the students cannot make careful experimental observations and cannot think or draw conclusions from data.

Simulation technology can supplement ill-equipped laboratory and may help increase student exposure, reduce costs, and eliminate hazardous waste and safety concerns. Therefore, this study aims at examining the contribution of simulation technology in practical physics in Dutsin-Ma Local Government Area of Katsina State, by applying simulation technology in practical physics to identify the perceptions of teachers and students towards simulation technology. A 3D simulation entitled "Simple Circular Motion Rides" (Open Source Physics, 2013) was used. It featured a person standing on a merry-go-round, and students were able to control the magnitudes of the angular speed and the radius of the circular trajectory. The 3D simulation was not only to investigating the impact of the angular speed (ω) and the radius (r) on the force (F) exerted on the person riding the merry- go- round, but also to observe the interaction between ω, r and F from different viewpoints and angles (Spodniakova pfefferova, M., 2015). The research also focused on investigating the effectiveness of computer simulations in supplementing physics laboratory experiments on concepts related to "Hookes' Law". It also compares the finding of the research with the ones presented from previous research studies as reported in literature.

The functions of laboratory facilities in physics

Laboratories are venues for teaching and learning science as they offer students the opportunities to think about, discuss, and solve real life problems (Trumper, 2003). In Physics, laboratory activities include many varied activities such as taking measurements and studying physical and chemical properties of objects and samples. In laboratory activities, materials, instruments and equipment are required. For example, practical work on the measurement of resistance of a wire requires that materials such as ammeter, voltmeter, key and source of electric current such as battery/cell must be available and used. The role of the laboratory is central in high school physics courses since students must construct their understanding of physics ideas. This knowledge cannot simply be transmitted by the teacher, but must be developed by students in interactions with nature and the teacher. The separation of laboratory activities from a lecture is artificial and not desirable in high school physics (Adegoke, 2017).

A well-designed science laboratory can provide the sorts of experiences necessary to correct misconceptions and to develop useful physical insight. It is one of the few places where students can involve themselves in the processes of science: students gain a first-hand understanding of physical phenomena, construct for themselves the theories needed to comprehend the physical world and express their own questions, further engaging them in the learning process (Trumper, 2003).

The state of physics laboratory facilities in secondary schools

The laboratory consists of various tools and equipment used by scientist's/science students either for the finding of new knowledge or to ascertain previous findings. Laboratories have been the scientist workshops where practical activities are conducted to enhance a meaningful learning of science concepts and theories (Olwasegun, *et al.,* 2015). The laboratory has helped increase students' performance in learning and understanding the subject physics.

The lack of equipment seemed to be one of the important factors hindering teachers and students from doing a practical activity both in theoretical and practical classes in Nigeria (Adegoke, 2017). Therefore, one can conclude that students are not properly exposed to practical activities may be due to ill-equipped laboratories in most public schools or lack of interest on the path of the teachers or students.

Contributions of simulation technology to physics

Many physics concepts taught at secondary School are very abstract and teachers do not normally present them to the learners in a concrete way. Simulations are tools that facilitate learning through representation and practice in a repeatable, focused environment. It helps students identify and understand factors that control the system and predict the future behaviour of a system (Samuel, 2018). It can bring into the classroom, aspects of the world or universe that are too expensive, dangerous, abstract, difficult or too slow or too fast in occurrence to be comprehended.

Computer simulations have become increasingly powerful and available to teachers in the past three decades. At earlier times, laboratory classes were utilized to prove and learn the theoretical aspects where the students were given full freedom to experiment, discover and deeply rationalize about their hesitation. But nowadays, insufficient laboratory equipment and limited time allocated for practical forced teachers to perform laboratory activities in crowded groups, were the students have no opportunities to truly explore the experimental setup and the theory that are trying to prove. Currently, science teachers can select from a wide range of computer simulations available, through the internet. The computer simulations are designed to facilitate teaching and learning through visualization and interaction with dynamic models of natural phenomena (Sarabando, *et al.,* 2014).

Computer simulations offer idealized, dynamic and visual representations of physical phenomena and experiments which would be dangerous, costly or otherwise not feasible in a school laboratory (Mckagan, *et al.,* 2008). Computer simulations may allow students to visualize objects and processes normally beyond the user's control in the natural world. Compared to textbooks and lectures, a learning environment with a computer simulation has the advantages of systematically exploring hypothetical situations, interacting with a simplified version of a process or system, changing the time-scale of events, and practising tasks and solving problems in a realistic environment without stress.

Effective computer simulations are built upon "mathematical models" to depict the phenomena or process to be studied accurately, and a well-designed computer simulation can engage the learner in interaction by helping the learner to predict the course and results of certain actions, understand why observed events occur, explore the effects of modifying preliminary conclusions, evaluate ideas, gain insight, and stimulate critical thinking (Sarabando, *et al.,* 2014).

Results

The statistical analysis of the data collected from the questionnaire for this study is shown below.

S/n	Question	Yes	No	Total
1.	Do you have a physics laboratory in your School?	83.5% 167	16.5% 33	200
2.	Do you have a qualified Physics teacher/laboratory attendant in your School?	28% 56	72% 144	200
3.	Is your Physics laboratory well equipped?	17.5% 35	82.5% 165	200
4.	Does your Physics Laboratory have the capacity to accommodate all physics students in a class?	29.5% 59	70.5% 141	200
5.	Do you Perform physics experiments for all practical topics?	14.5% 29	85.5% 171	200

Table 1: Descriptive Statistic on the State of Physics Laboratories in Nigeria

From the table 1 above, results shows that majority (83.5%) of the respondents reported to have a physics laboratory in their School, these respondents (72%) also acknowledged to not having a qualified physics teacher in their schools, another 82.5% of the respondents stated that their physics laboratory was not well equipped, 70.5% of the respondents reported that their physics laboratory cannot accommodate all the physics students in their class and 85.5% of the respondents did not perform physics experiments for all practical topics in their schools.

Table 2: Descriptive Statistic on the Contribution of Simulation to Physics

S/N	Statement	SA	A	N	D	SD	Mean	S.D
1.	Simulation has made the understanding of physics concepts easier	57	37	78	17	11	3.56	3.20
2.	Simulation has made it easier to get good grades in physics	8	10	162	16	4	3.01	2.53
3.	Simulation has made physics experiments easier to perform	57	63	48	29	12	3.76	3.35
4.	Simulation has increased interests in learning physics	23	17	158	2	0	3.31	2.56

Note. SA= strongly agree, A= agree, N= neutrals, D= disagree, SD= strongly disagree.

In the first statement, the mean is 3.08; hence, it means that majority of respondents are neutral as to whether simulation has made the understanding of physics concepts easier. The mean of the second statement is 3.01, which indicates that the majority of the respondents are neutral as to whether simulation has made it easier to get good grades in physics.

Table 3: Descriptive Statistic of the Perceptions of Teachers and Students on Simulation

S/N	Statement	SA	A	N	D	SD	Mean	S.D
1.	Physics simulations can make up for laboratory experiments	100	80	10	10	0	4.75	3.85
2.	Physics simulation experiments will improve grades	50	120	20	7	3	4.04	3.59
3.	Physics simulations will make understanding physics concepts better.	16	16	130	38	0	3.05	2.61
4.	Physics simulations will motivate learners	18	63	70	40	9	3.21	2.84

In the first statement, the mean is 4.75, hence, it means that majority of respondents agree strongly that physics simulations can make up for laboratory experiments. The mean of the second statement (4.04) indicates that most of the respondents agree that physics simulation experiments will improve learners' grades. The third statement indicates that the majority of the respondents reported to be neutral with a mean of 3.05 and 3.21 as to whether simulation technology in physics will motivate learners to learn physics.

Comparison of student performance in the pre-test

All participants from the experimental and the control groups were subjected to a pre-test in order to check their background knowledge about "Hookes' Law". Data from the pre-test is divided into two (2) parts: Descriptive Statistics and One-way ANOVA. In this part, a one-way analysis of variance (one-way ANOVA) is used to compare the experimental and control groups' mean in the pre-test

	N	Mean	Standard Deviation	Standard Error
Experimental Group	10	2.47	1.65	0.24
Control Group	10	2.39	1.96	0.29
Total	20	2.43	1.80	0.19

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Table 4: Descriptive Statistics of the Pre-test Total Score

Table 4 above shows the descriptive statistics of the experimental group versus the control group in terms of their performance in the pretest. The experimental group has a higher mean score (*M* = 2.47) than the control group (*M* = 2.39). In addition, the distribution of scores around the mean is slightly higher in the control group (*SD* = 1.96 and *SE* = 0.29) compared to the experimental group (*SD* = 1.65 and *SE* = 0.24).

Table 5: One-Way ANOVA of the Pre-test Total Score

	Sum of the Square	df	Mean Square	F	Sig.
Between Groups	0.14	1	0.14	0.042	0.839
Within Group	298.66	91	3.28		
Total	298.8	92			

Table 5 above features a one- way ANOVA to determine whether there is any significant difference between the groups regarding their performance in the pre-test. Results collected from the 2 groups show that there is no significant difference between them F (1, 91) = .042, p = .839.

Comparing post-test total score of the experimental group to the post-test total score of the control group

In order to compare the performance of the experimental group to that of the control group in the post-test, a one- way analysis of variance (one-way ANOVA) is used.

Table 6: Descriptive Statistics for the Post-test Total Score

	N	Mean	Standard Deviation	Standard Error
Experimental Group	10	21.21	4.08	0.59
Control Group	10	18.70	5.21	0.77
Total	20	19.97	4.82	0.50

Table 6 features the descriptive statistics that compare the experimental group to the control group in terms of their performance in the post-test. The experimental group has a higher mean score (M = 21.21) than the control group (M = 18.70). In addition, the distribution of scores around the mean is slightly higher in the control group (SD = 5.21 and SE = 0.77) compared to the experimental group (SD = 4.08 and SE = 0.59).

Table 7: One-Way ANOVA for Post-test Total Score

	Sum of the Square	Df	Mean Square	f	Sig.
Between Groups	147.29	1	147.29	6.74	0.011
Within Group	1987.61	91	21.84		
Total	2134.90	92			

Results from a one-way ANOVA presented in table 7 show that the difference between the mean score of the experimental group and that of the control group is statistically significant, F (1, 91) = 6.74, p = .011.

Discussion

The development of simulated laboratory environments has been met with wide acceptance in science education (Bello, *et al.,* 2016). Simulation-based learning has the advantage of exposing students to realistic experiment scenarios which provide comparable learning experiences across student populations, enabling all learners to meet the course objectives (State, et al., 2020). High fidelity technology, computerized laboratory simulators add a sense of realism to the simulated activity and provide context to the learning activities (Spodniakova pfefferova, M., 2015).

Understanding the effect of perceived self-efficacy and the impact on performance in a simulated environment can assist educators to support student learning. The literature suggests that researchers need to examine the nature of self-efficacy and other motivational and cognitive variables within the self-regulated learner framework including learner characteristics (Bello, *et al.,* 2016). Results from the survey showed that the physics laboratory in their schools is in a poor state, the respondents accepted to have a physics laboratory but majority did not have a qualified physics teacher and laboratory attendant, they also denied having a well-equipped laboratory, their laboratory also cannot accommodate a class and that they do not carry out experiments for every practical topic (Adegoke, 2017).

In the second section of the questionnaire, most of the respondents were neutral about whether simulations have contributed to physics experiments. The majority of the respondents also suggested how simulations can be used to supplement laboratory experiments in secondary schools, by giving assignments, classroom activities, homework, practice tool etc. In the fourth section of the questionnaire, the respondents (teachers and students) have a good perception and believe that simulations can improve interests in physics, motivate learners and improve physics grades (Samuel, 2018).

The data presented from the quasi-experiment were based on students' performance on a 7 item content test administered twice, first as a pre-test and then after the implementation of the intervention as a post-test. Results from the pre-test showed no statistically significant difference between the performance of the experimental group and that of the control group in terms of the total score on the test (p = .839). This shows that both groups were homogenous in terms of understanding of the tested content prior to the intervention. Data related to the post-test, which took place after the implementation of the intervention with the experimental group was then presented. The comparison between the experimental and the control groups' performances on the post-test showed that the experimental group achieved a higher mean score than the control group on the test total score. A one- way analysis of variance analysis was found to be statistically significant (p = .011). It can be depicted from these results that the intervention of computer simulation had a positive impact on students' performance in physics practical, specifically in the topic of "Hookes' Law". This positive impact may be due to the high interactivity of computer simulations. In fact, even though the method that was used with the control group provided students with physics concepts and processes that could help students understand abstract ideas related to physics topics, they were still passive resources. The interaction level of students with the simulations was limited to observing the events presented. On the other hand, a computer simulation allows students to control the initial conditions of the physics phenomena presented in the simulation. As a result, the student is not limited to only observing a ready-made simulation, but he can expand his interaction with this technology to investigating different outcomes that result from different settings that he/she have control.

Based on review, many studies reported similar impacts for simulations on students' learning of physics, (Podolefsky, Perkins and Adams, 2010). In this study, the success of simulations in enhancing students' learning was attributed to the "engaged exploration" offered by the simulation, as students were able to use the simulations to explore the topic of "Hookes' law" in ways that were similar to how scientists explore physics phenomena. Another factor contributing to the success of simulations in this study was the high level of interactivity with dynamic and immediate feedback to the students.

Conclusion

This study showed that physics laboratories across Nigeria were not in a good state and schools neither had qualified physics teachers nor a well-equipped physics laboratory. Physics experiments were something the schools were not familiar with. The respondents of the survey also showed a wide acceptance towards the use of simulation technology as they believed it can improve performance, interests and motivation in learning physics concepts. The study showed that students of the experimental group scored significantly higher than their respective peers from the control groups, showing that computer simulations impacted students' performance. These findings were discussed in the context of previous research findings such as those reported by Podolefsky, Perkins and Adams (2010), Adegoke & Chukwunenye (2013). Results of this study showed that computer simulations did help students perform better, they did show an advantage over other conventional methods used with the control group.

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