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Efficacy of improvised portable electrolysis console on students' academic achievement in physics

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Abstract
The dearth of instructional materials in teaching key concepts in Physics such as Electrolysis in Nigerian schools is rather disparaging to productive and effective teaching and learning. As such, improvising to mitigate this lack of instructional materials becomes an imperative intervention. This study investigated the efficacy of an improvised portable electrolysis console on the academic achievement of physics students in Lagos State senior secondary schools. The Improvised Portable Electrolysis Console, IPEC, is a PCB (Printable Circuit Board) designed semi-automatic electronic instructional material which allows teachers and learners to physically carry out electrolysis experiments, (i.e. Verification of Faraday's laws of electrolysis, electroplating, and de- rusting). The pretest-posttest control group non-randomized quasi-experimental research design was employed in the study. A total of 143 students, (70 male and 73 female) from 4 co-educational public senior secondary schools in Lagos State, Nigeria constituted the sample. A validated research instrument-Electrolysis Students Written Achievement Test (ESWAT), (reliability coefficient; r = 0.75) was used in data collection. Two research questions were answered, and two research hypotheses were both tested at a 0.05 level of significance. The data gathered were analyzed using descriptive statistics, ANCOVA and independent samples t–test. The results showed that the learners' taught using the IPEC intervention had better academic achievement than their counterparts who were not exposed to the use of the IPEC. Also, there was no statistically significant gender disparity in the achievement of students exposed to the use of IPEC, showing that the achievement of both genders of learners was influenced equally, i.e., the IPEC intervention has no gender disparity. The study therefore recommended the use of Improvised Portable Electrolysis Console for the teaching and learning of electrolysis in physics.

INTRODUCTION

Physics is the fundamental branch of science that studies the interaction between matter, space, time, and energy. It is the bedrock of science and its contribution to the technological advancement of the human world cannot be over-emphasized. (Environmental Science, 2024). It is an interdisciplinary body of knowledge which serves as a nexus amongst other branches of science and plays a vital role in their application in solving real-life problems affecting man and his immediate environment. (Perl-Nussbaum, 2023).

The physics subject curriculum at Nigerian Secondary Schools consists of five themes. The themes according to NERDC (2019) comprise the interaction of matter, space, and time; conservation principles; field at rest and in motion; energy quantization and quality of matter; and physics in technology respectively. Daramola and Omosewo (2012) identified the concept of electrolysis as being embodied in the physics in technology theme.

Electrolysis refers to the chemical change or decomposition reaction which occurs when electric current is passed through an electrolyte. (Turner et al., 2023 &Chai et al., 2019). Electrolysis from the many concepts embedded in physics represents an indispensable body of knowledge whose application is massively employed in industrial manufacturing processes and of immense benefit to economic development. It has diverse applications ranging from surgery and medicine, chemical production, battery production, raw material extraction and purification.

However, in the teaching and learning context, electrolysis appear complex, cumbersome to assimilate mostly due to its unrelation to leaners' daily activities and unfamiliar scientific terminologies used in the delivering the lesson content (Taba 1998 & Mbajiorgu et al., 2006). Teaching electrolysis abstractly may lead to shallow comprehension, less retention and most importantly, inability to relate with real-world industrial application of the concept. This ultimately douses learners' interest in making a concrete knowledge content from such an important concept and extinguishes the potentials of future exploitation of electrolysis industrialization for national development.

Understanding electrolysis properly requires that students observe physical changes at the electrodes and the electrolytes such as color changes and bubble formation and be able to identify and predict products at both the cathode and anode. Unfortunately, from meticulous literature search, it could be deduced that the concept of electrolysis still remained largely taught theoretically as no study has hitherto revealed the efficacy and influence of any instructional material or intervention in the teaching and learning of electrolysis experimentally in the Nigerian educational space, hence necessitating this study.

Adeyemo (2010) and Oladejo, Olosunde, Ojebisi and Isola (2011) agreed that to make remarkable progress and consider the conceptual nature of Physics as a subject, there is a need to adopt the usage of instructional materials in enhancing students' learning and academic achievement of Physics. Inadequacy of instructional materials in teaching physics has further aggravated the appearance of physics to students as an abstract and tough subject, provoked students' poor academic achievement and even reduced the enrollment of students into physics-related programs (Abubakar, 2020). Unfortunately, learners have been deprived of the benefit of learning this concept in its experimental form due to it being taught using the traditional discussion method. Instructional materials have been agreed to enhance students' active participation, foster deep-rooted learning and improve academic achievement. Standard and improvised instructional materials both have significant impact in the improvement of academic achievements of students in physics (Onasanya and Omosewo 2011).

Literature searches have shown various models of improvised instructional approaches adopted in the teaching and learning of electrolysis. Nkhululeko (2019) discovered that the use of computer-based simulation in teaching electrolysis enhanced the understanding of both teachers and learners but highlighted concerns about the viability of this approach due to the shortage of computers in schools. Anggraeni et al. (2022) in their study utilized the video-based approach in teaching electrolysis to vocational school students in Indonesia and concluded that there was a significant increase in students' achievement compared to the students who were taught using the conventional approach.

However, not many of these approaches centered the instructional approach on the real-time experimentation of electrolysis which requires direct participation of the students in their learning process and helps students catch a live glimpse of the physical and chemical changes undergone, thereby having a deep-rooted understanding of the concept and longer retention of knowledge which resonates with the Dale's Cone of Experiential Learning.

This formed the basis of this study which investigated the efficacy of the Improvised Portable Electrolysis Console on the achievements of students in electrolysis and the moderating effect of gender on the dependent variable. The choice of gender was based on the inconclusive results of gender and achievement of students in physics. Some researchers are of the view that physics is a male-dominated subject while some obtained that achievement in physics is not based on gender. Therefore, there is a need to further investigate the effect of gender on achievement of students in physics. Udo and Madu (2024) investigated the influence of gender on the effects of demonstration strategy on academic achievement in physics and revealed that gender has no influence in academic achievement of students. Offordile et al (2021) also discovered that gender plays a neutral role in influencing the academic achievement of students learning physics using the peer-tutoring learning strategy.

Theoretical Framework

This study hinges on the Dale's Cone of Experiential Learning. The Experiential Learning Cone Theory was developed by Edgar Dale in 1946. Learners are found to learn, retain and remember 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say and write, and 90% of what they say as they do a thing. (Dale, 1969). This model gives corresponding accounts of how various instructional designs and learning processes yield retention in a hierarchical manner with the more concrete experiences at the base of the cone and then becomes more abstract as it ascends to the peak of the cone (Ebako et. al., 2024). It also suggests that instructional methods involving the students and require hands-on in the process strengthens knowledge and results in up to 90% retention and should be considered (David & Summers 2014).

Statement of the Problem

The role of instructional materials in driving learning practically involving learners' active participation and achieving meaningful learning objectives in physics cannot be over-emphasized. This will create a better stimulating learning environment for the learners igniting the required interest in wanting to experience the learning outcomes in real-time, which will engender a longer retained knowledge, practical skills and improved academic achievement in experimental concepts like electrolysis. However, improvisation remains a viable alternative in the face of the glaring dearth in the availability of instructional materials required to effectively teach electrolysis experimentally.

However, numerous challenges have been identified to bedevil the teaching and learning of electrolysis in Nigerian schools, from these problems, the daring lack of instructional material to teach electrolysis in physics in its observable and appealing form, remains a potential menace in the adequate teaching and learning of electrolysis. As a result of this, mitigating the adverse effects of the inadequacy of instructional materials on the quality of teaching and learning of electrolysis becomes imperative and would require that unavailable instructional materials be improvised. This study therefore examined the effects of the improvised electrolysis console on students' academic achievement in electrolysis.

Purpose of the Study

Specifically, this study was carried out to determine:

1) The effect of the Improvised Portable Electrolysis Console on students' academic achievement in electrolysis in Lagos State Secondary schools.
2) The effect of the Improvised Portable Electrolysis Console on Lagos State Secondary School students' academic achievement in electrolysis based on gender.

Research questions

1) What is the effect of the Improvised Portable Electrolysis Console on students' academic achievement in electrolysis in Lagos State Secondary schools?
2) What is the gender-based effect of the Improvised Portable Electrolysis Console on students' academic achievement in electrolysis in Lagos State Secondary schools?

Research Hypotheses

The following null hypotheses were tested at a 0.05significant level:

H_{01}: There was no significant difference between the academic achievement of students taught with the Improvised Portable Electrolysis Console and those taught with the traditional method in electrolysis.

H_{02}: There was no significant difference in the academic achievement in electrolysis of students taught with the Improvised Portable Electrolysis Console based on gender.

METHODS

This study adopted the pretest, posttest control group non-equivalent quasi-experimental research design.

Experimental group	O_1	X	O_2
Control group	O_3	___	O_4

Where: $O_1$and O_3= Experimental and Control Groups participated in the Pre-test, O_2 and O_4 = Experimental and Control Groups participated in the Post-test, Where X= Treatment and; and ___ = No treatment

Sample and Sampling Technique

A simple random sampling technique was employed in selecting a district out of the six education districts in Lagos state. Education district 4 with a total of 54 government-owned schools was selected. Afterwards, a purposive sampling technique was used to select 4 schools for the study based on the researcher's laid down criteria. The sample consisted of an intact class of 143 students in SS3 drawn from 4 different schools under Education District 4 in Lagos State. 60 of the students were from two of the schools used as the control group, while 83 students were from the remaining two schools used as the experimental group.

Instruments

The research instruments employed in this study were broadly categorized into Stimulus instruments and Response instruments.

1) Stimulus Instruments: The stimulus instruments comprise the following categories of instruments.
   a) Instructional guide on the Improvised Portable Electrolysis Console (IPEC): The instructional guide for the IPEC was developed by the researcher to outline the step-by-step procedure by which the trained research assistant, i.e. the teachers can operate the IPEC seamlessly for use as an instructional material.

b) Instructional guide for teaching Electrolysis using conventional pen and talk method for the control group: This involved the utilization of the conventional diagrams, charts, and images with which the students in the control group will be taught.

2) Response Instruments: The response instruments comprise the following categories of instruments:

An Achievement Test was developed by the researcher and named the Electrolysis Students' Written Achievement Test (ESWAT). The ESWAT is comprisedof20 items, distributed into 14 objective multiple-choice items each with a key and three distractors and 6 theory questions in the form of supply-type items. The items of the ESWAT covered the definition of electrolysis, the characteristics of the electrodes, the application of Faraday's law of electrolysis in solving numerical problems, the electron behavior and as well as industrial application of electrolysis. These items were structured based on the table of specifications as shown in Table 1.

Table 1. Specification on ESWAT

S/N	Content	K	C	App	Ana	S	E	Total
1	Definition of electrolysis	2	-	1	-	-	1	4
2	Characteristics and functions of the electrodes	1	-	1	1	-	1	4
3	Calculations using Faraday's laws of electrolysis	1	-	2	-	-	-	3
4	Behavior of electrons during electrolysis	1		1	2	-	-	4
5	Application of electrolysis	1	1	1	1	1	-	5
	Total	**6**	**1**	**6**	**4**	**1**	**2**	**20**

Validation of the Research Instrument

The research instruments for this study were validated for both face and content validity by two Physics education experts lecturing in a tertiary institution and two Physics teachers in senior secondary schools. Corrections and recommendations were duly effected.

One hundred and forty-three copies of the ESWAT were administered to 143 S.S.S 3 science students. The Split-Half reliability technique was employed to analyze the ESWAT. The SPSS was used to compute the Kuder-Richardson 20, Split-Half, and Spearman-Brown between the ESWAT split-half. The Kuder-Richardson 20, Split-Half, and Spearman-Brown coefficients are 0.75, 0.73 and 0.82 respectively.

Training of Research Assistants: The four participating teachers were trained as research assistants for this study. The two teachers from the experimental groups were trained on the use of the IPEC as instructional material for teaching electrolysis while the two other teachers from the control group schools were trained on the use of other relevant instructional materials. This process lasted for a week.

Pre-Test: The Pre-test was carried out on the 4 schools selected for the study. The ESWAT, which was prepared in line with the provisions of the Lagos State Unified Scheme of Work for physics, was administered to the students. This procedure was completed within the second week.

Control Group Teaching: By the third week, the teachers at the control group schools with intact classes of 31 students and 29 students respectively taught their respective classes using the conventional pen-and-talk method relying on diagrams and pictures as instructional materials for 80 minutes.

Experimental Groups Teaching: Between the fourth week, the already trained teachers at the experimental groups comprising two schools with intact classes of 31 and 52 students respectively deployed the IPEC for use as the instructional material for the lesson. The lesson also lasted for 80 minutes.

Post-Test: The administration of the post-test ESWAT was done at the end of a revision class following the lesson in each of the four schools. The revision class lasted 15 minutes in each case.

Methods of Data Analysis

Data collected were analyzed using descriptive statistics of mean and standard deviation. Also, inferential statistics of Analysis of Covariance (ANCOVA) were employed.

RESULTS AND DISCUSSION

Research question 1: What is the effect of the Improvised Portable Electrolysis Console on students' academic achievement in physics in Lagos State Secondary schools?

Table 2. Analysis of the Mean Differences and Standard Deviations of Students' Pretest and Posttest Scores in ESWAT for Experimental and Control Groups

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Experimental	83	51.70	13.89	78.98	11.48	27.28
Control	60	47.70	13.79	48.60	13.48	0.90

Table 2 shows that the students' achievement in electrolysis at the pretest was marginally higher for the experimental group ($\bar{x}$ = 51.70; Std.Dev. = 13.89) than for the control group ($\bar{x}$= 47.70; Std. Dev. = 13.79). For the post-test, results obtained ($\bar{x}$ = 78.98; Std. Dev. = 11.48) indicated that the experimental group had a significantly higher achievement score compared to the control group's score ($\bar{x}$ = 48.60; Std. Dev. = 13.48). In addition, 27.28 was the mean gain in the experimental group, as against the meager 0.90 mean gain accrued by the control group which could be traced to their pre-test experience. This outcome clearly indicated that the learners responded better to the stimulus instrument and is concordant with the Dale's Cone of Experiential Learning which indicated that learning through concrete experiences yields improved comprehension and retention. This outcome also corroborated those of Nkhululeko (2019) and Anggraeni et al., (2022) who both recorded significant improvement in learners' achievement using their respective instructional interventions in teaching electrolysis.

Table 3. Analysis of Experimental Group's ESWAT's Gender-Based Posttest Results

Gender	N	Percentage (%)	Mean	Standard Deviation
Male	42	50.61	80.19	12.21
Female	41	49.39	77.73	10.67
Total	83	100.00	78.96	11.49

Table 3 shows that the experimental group's male students' achievement in electrolysis at the posttest was slightly higher ($\bar{x}$ = 80.19; Std. Dev. = 12.21) compared to the female students' achievement ($\bar{x}$ = 77.73; Std. Dev. = 10.67).

Analysis of Research Hypothesis

Hypothesis 1: There was no significant difference between the academic achievement of students taught with the improvised portable electrolysis console and those taught with the traditional method.

Table 4. ANCOVA Analysis Showing the Difference in the Academic Achievement of Students in the Experimental Group and Control Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	33,060.191	2	16,530.096	107.985	.000
Intercept	55,296.648	1	55,296.648	361.234	.000
Pretest	3,670.155	1	3,670.155	28.529	.000
Treatment	32,985.152	1	32,985.152	215.481	.000
Error	20,971.551	137	153.077		
Total	668,368.000	140			
Corrected Total	54,031.743	139			

a. R Squared = .612 (Adjusted R Squared = .606)

Table 4 shows the F-calculated value of 215.077 and the p-value of 0.000 is the result of the differences between the performances of the treatment group and the control group. Since the calculated p-value is less than the alpha level of significance of 0.05, the null hypothesis which states that there is no significant difference between the academic achievement of students in the treatment group and those in the control group is rejected.

Therefore, there is a significant difference between the performance of students in the treatment group and those in the control group.

Hypothesis 2: There was no significant difference in the academic achievement of students taught with the improvised portable electrolysis console based on gender.

Table 5. Independent t-test Analysis Showing the Differences in the academic achievement of Students in Treatment Group based on Gender

Gender	N	Mean	Standard Deviation	t-value	df	p-value	95% CI: Lower	Upper
Male	42	80.19	12.21	-0.975	81	.332	-8.074	5.145
Female	41	77.73	10.67					

Table 5 shows the mean score of male and female students as 80.19 and 77.73 respectively. The table revealed that the calculated p-value .332 is greater than 0.05 level of significance. Hence, the null hypothesis which states that there is no significant difference between the academic achievements of students in the treatment group based on gender is accepted.

Therefore, there is no significant difference between the academic achievements of students in the treatment group based on gender.

Implications of the Findings

The implications drawn from the findings of the study are that the results gathered from this study imply that improvisation proffers a sustainable alternative to imported standard instructional materials in the face of scarcity of resources in procuring them. This helps in driving an improvisation-focused workforce in the national educational technology industry, self-reliant instructional process, and local industrialization and by extension, promote the economic development of the country.

The main finding from this study is that the use of the Improvised Portable Electrolysis Console as an instructional material in teaching electrolysis to students proved effective in improving the academic achievement of students in electrolysis in comparison to the conventional instructional materials under the pen and talk strategy. This could be accounted for because the use of IPEC allowed for the active participation of the learners and enlivened their experience of the learning outcomes as the learning process involved hands-on activities and real-time experimentation of electrolysis.

Students from the treatment group were able to outperform their counterparts from the control group following their exposure to the use of the improvised portable electrolysis console as an instructional material to learn electrolysis experimentally. This is an expected outcome as learning has become more interactive, appealing, engaging and real, leading to better learner involvement and higher retention. This finding was corroborated by Onasanya and Omosewo (2011) who in their investigation of the effects of standard and improvised instructional materials on the academic achievements of students in physics concluded that improvised and standard instructional materials both have a significant impact on the improvement of learners' academic performance in physics.

This study also discovered that the academic achievement of students was not gender biased. Both the male and female students exposed to the use of the improvised portable electrolysis console as an instructional material performed equally. This shows that students' academic achievement on electrolysis does not depend on gender.

This finding agrees with the outcome obtained by Yusuf (2020) who in her study on the influence of students improvised instructional materials on senior school physics, found that there was no significant effect of gender on students' academic achievement in physics. In addition, the outcome also mirrored the findings of Udo and Madu (2024) who revealed that gender has no influence in the academic achievement of students in their study of the influence of gender on the efficacy of demonstration strategy on academic achievement in physics.

Limitations of the study

The study has revealed the efficacy of the Improvised Portable Electrolysis Console as an instructional material on the academic achievement of students in physics. However, the following limitations were observed regarding this study:

1) Only schools with functional physics laboratories within education district IV were selected for this study. Therefore, it's not possible to generalize this study to other learners whose schools are without functional physics laboratories.
2) The sample utilized from this study only comprised of students from government owned schools, totally excluding students from private schools.
3) The sample of the study was limited to the learners only, excluding the teachers who utilized the IPEC for teaching electrolysis.

Suggestions for Further Studies

For the benefits of further studies in this area, the following suggestions are made:

1) This study should be replicated with a larger sample which will include the teachers who deploy the IPEC for teaching electrolysis.
2) Further studies should research teachers' perceptions and attitudes, in relation to the use of the IPEC for teaching electrolysis
3) This study should be replicated in other educational districts in Lagos and Nigeria at large in order to justify the findings.
4) This Study should be extended to investigate the effects of the IPEC in academic achievements of students in chemistry and the outcomes be compared with the result of this research work.

CONCLUSION

The study has emphatically revealed that proper learning is better achieved when stimulus-driving interventions such as instructional materials which make physics learning concrete and appealing are deployed leading to better comprehension, longer retention and enhanced academic achievement. In addition to this, the study equally proved that improvised instructional materials can bring about desired learning outcomes in the teaching and learning of electrolysis and other physics concept at large. Based on this, the following recommendations are hereby made:

1. Teachers should understand the necessity attached in trying all feasible means to make their lessons concrete, realistic, practical and appealing, making the learners active participants in the learning process. This in accordance with Dales' Cone of Experiential Learning provides better comprehension and retention for the learners.
2. Teachers should be self-motivated to improvise instructional materials for teaching physics to facilitate teaching and learning and improve learners' understanding and retention of the lesson content.
3. The government should develop a robust curriculum such that suggestions for possible improvisation techniques for developing instructional materials on each topic/content are allowed to feature in the document.
4. Teachers should also involve their learners in improvising instructional materials for teaching to stimulate creativity in them and increase students' active participation in their learning.
5. Government at all levels should invest in the development of at least one educational resource and technology incubation center in all local governments to produce instructional materials.
6. Federal and State Ministries of Education in collaboration with Tech-based organizations should periodically organize training and workshops for teachers and school administrators on leveraging tech-skills in the development of science-based instructional materials.

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