

Analysis and Application of Improvised Free Fall Apparatus and Bomb Calorimeter in Teaching the Concepts of Enthalpy and Entropy in Chemistry Education in Tertiary institutions.

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Abstract-- The research study was on the Analysis and Application of Improvised Freefall Apparatus and Bomb Calorimeter in teaching the concepts of enthalpy and entropy through deployment of materials within the learner's immediate environment. This was undertaken to find a solution to persistent student's poor performance in abstract chemistry concepts. A total of 120 NCE 1 chemistry students were involved in the study. This number was made up of 73 males and 47 females drawn from two colleges of Education in Cross River State of Nigeria. Three research hypotheses and two research questions were formulated to guide the study. A non-randomized pretest- posttest control group design was used for the study and the instruments used in gathering data for the study were Achievement Test in Chemistry (ATC) and Cognitive Ability Test (CAT). Kuder- Richardson formula-21 was used to establish the reliability of achievement- test in chemistry (ATC). The reliability coefficient of ATC and CAT were 0.83 and 0.78 respectively. Data collected were analyzed using Analysis of covariance (ANCOVA) and Scheffe post hoc analysis was used to obtain the direction of significance. Also descriptive statistics were used. All hypotheses were tested at 0.05 level of significance. From the findings, it was observed that improvised freefall apparatus had a significant. Main effect on student performance in the concepts of enthalpy and entropy in chemistry. There was also a significant difference in the performance of male and female students when taught the concepts enthalpy and entropy using freefall apparatus. Cognitive ability level had significant effect on student's performance in the concept of enthalpy and entropy. Conclusion from the findings led to the recommendation that chemistry lecturers should explore and develop improvised materials within their immediate environment in teaching abstract concepts in chemistry.

Keywords-- Bomb Calorimeter, Cognitive ability, Enthalpy, Entropy, Freefall apparatus.

I. INTRODUCTION

The major aim of science teaching is to promote the understanding of concept being taught with a view of applying knowledge of such understanding in real life situation. [15]

The National Policy on Education [10] emphasized that science taught in schools should be such that it will have meaning and relevance to the need of the child and society that provide the child the opportunity to explore, interact with and interpret certain scientific processes going on in his environment.

[2] consider Chemistry as the most important of the physical sciences that directly affect man's everyday life. The chemist work with nature and attempts to unlock natural secret by seeing answers to many questions that affect man's existence [13] Ironically, despite the perceived importance of chemistry in technological development, research reports show that the academic performance of students both in secondary and tertiary institutions has been consistently poor especially in chemistry. [16], [17]).

Evidence from the works of [17] attribute the poor performance in chemistry to inadequate exposure of students to basic chemistry concepts, the abstract nature of chemistry, its conceptual demands, its relatedness to mathematics, student attitudes toward the subject, structural material and incompetent teachers. [15] Contends that science teachers shy away from activities-oriented teaching methods which are known to be effective and rely on the teaching methods that are easy but most inadequate and inappropriate.

Enthalpy and Entropy are concepts in chemistry, it is all about heat changes whether exothermic or endothermic heat release, while entropy is a measure of disorderliness within a system as a result of heat charges. The effective teaching of this concept can be approach in two different ways, teaching with standard laboratory materials (calorimeter) and also with improvised materials (freefall apparatus). using standard laboratory materials to teach science will enable the learner to develop problem solving skills and positive attitude, acquire scientific application and interests as well as developing functional knowledge and manipulative skills [19] But using improvised materials in teaching science concept will enable the learners to acquire more of what is obtained with standard materials. [5]

Suggested that the mastery of chemistry concepts (enthalpy, entropy) cannot be fully achieved without the use of learning instructional materials so as to enable them acquire the cognitive competence and process skills needed for learning the concepts.

Improvisation is described as the act of using standard materials or local materials from the environment or teachers made materials to enhance instruction [5] [3] said that in developing learning and teaching materials, the use of learners environment and locally improvised materials should be used in providing first hand science experience. It is believed that if improvised local materials are effectively used, it will motivate the learners depending on how the learners perceive and pays attention to this local improvised materials used. The use of local materials in science teaching implies the utilization of the scientist environment, which is a practice in improvisation [11] He advocates the use of locally sourced improvised materials in chemistry education. He admitted that we are yet to devise school-based experiments to illustrate, justify or explain the usage of such materials. Studies by [8] showed that improvised materials showed superior effect on students achievements and interest, the more familiar the students are with instructional material or a science class, the more interest they are likely to develop and hence more achievement in the concept.

Freefall apparatus was designed from scrap of metals which are readily available in our local environment. It consists of iron rods, pipes and discarded metal strings. On this ground, the need to use locally improvised freefall apparatus in teaching the concepts of enthalpy and entropy is in support of [7] that the environment provides a situation that helps learners to acquire experience that enhance learning in the affective, psychomotor and cognitive domains.

This research was based on the theory of constructivism. Constructivists view knowledge as being constructed by individuals through their own experience within the world. This approach to learning emphasizes the use of authentic challenging problems where learners make meaning through active participation [12] constructivism emphasizes active learning, the linking of new knowledge to knowledge learners already possess and the application of understanding to authentic situations. Here knowledge construction result, from activity so knowledge is embedded in activity.

A) Statement of the problem

Enthalpy and Entropy are abstract concepts which students persistently perform poorly in chemistry [7].

Enthalpy is a concept in chemistry; it is all about heat changes whether exothermic or endothermic heat releases, while entropy is a measure of order/disorder in a system. Effective and meaningful teaching and learning of abstract scientific concepts like enthalpy and entropy requires active students involvement in the teaching-learning process through meaningful and relevant-hands-on-activities. The harsh economic realities experienced in Nigeria today, coupled with the high cost of standard commercial equipments and chemicals needed for experiments, and also the inappropriate increase in enrolment in our schools have made it virtually impossible for the government at the state and federal levels to provide essential science facilities in schools, thereby leaving our laboratories as mere demonstration and practical examination centers where available.

Studies however have shown that improvisation-sourcing, selection and deployment of relevant instructional elements of the teaching/standard or accredited teaching learning elements can always help in filling the gap especially when the materials are drawn from the learners local environment [6].

There is inadequate utilization of learning resources within the learner's environment by science teachers [11]. This suggests that the mastery of chemistry concepts cannot be fully achieved without the use of learning materials. This normally leads to poor achievement and lack of interest in chemistry. Also science teachers have not been able to utilize teaching resources within their environment to enhance teaching and learning of science (Chemistry).

The problem of this study is how can student's performance in chemistry be enhanced? Will improvised freefall apparatus and Bomb calorimeter also be effective in facilitating students performance in the concepts of enthalpy and entropy in physical chemistry? This research therefore seeks to provide an example of deploying local materials like improvised Freefall apparatus and Bomb calorimeter in teaching the concepts of enthalpy and entropy.

B) Purpose of the study

The purpose of this study was to investigate whether teaching the concepts enthalpy and entropy to chemistry students using improvised Freefall apparatus had advantage on their performance compared to standard Bomb calorimeter.

The study was designed to achieve the following objectives.

- i. To compare the effect of using improvised Freefall apparatus and standard Bomb calorimeter in teaching the concepts of enthalpy and entropy on student's academic performance in chemistry
- ii. To determine the influence of gender on student's academic performance when taught the concept of enthalpy using freefall apparatus.
- iii. To assess the effects of cognitive ability levels (high, average and low) on students performance in the concept of enthalpy and entropy in chemistry when taught with freefall apparatus and standard bomb calorimeter.

C) Research questions

In order to guide the study, the following research questions were raised in the study.

- i. What differences exists among the mean performance scores of chemistry students taught the concept of enthalpy and entropy using freefall apparatus and standard bomb calorimeter.
- ii. What is the difference in the mean performance scores of chemistry students with high, average and low ability levels taught the concept of enthalpy and entropy using freefall apparatus and standard Bomb calorimeter

D) Research hypotheses

The research specifically tested the following null hypotheses at 0.05 level of significance.

HO1. There is no significant difference in the mean performance scores of chemistry students taught the concepts of enthalpy and entropy using improvise freefall apparatus and standard Bomb calorimeter.

HO2. There is no significant difference in the mean performance scores of male and female chemistry students taught the concepts of enthalpy and entropy using improvise freefall apparatus and standard Bomb calorimeter.

HO3. There is no significant difference in the mean performance scores of chemistry students with high, average and low cognitive ability levels taught the concepts of enthalpy and entropy using Freefall apparatus and standard Bomb calorimeter.

II. RESEARCH METHODOLOGY

A) Research Design

The research adopted a non-randomized pretest-posttest control group design.

B) Area of study.

The study was conducted in tertiary institutions offering NCE programmes in cross River State of Nigeria. Specifically the tertiary institutions were Colleges of Education, namely Federal College of Education (FCE) Obudu and Cross River State College of Education, Akamkpa.

C) Population

The population of the study covered all year 1 NCE students offering Chem/Maths, Chem/ISC, Chem/Maths, Chem/Physics combinations. The population was 210 students comprising male female students in the 2025/2026 academic session.

D) Sample and Sampling Technique

The sample of the study was one hundred and twenty (120) students drawn from the population of year 1 NCE chemistry students in the two colleges of Education in Cross River State using intact classes.

Purposive sampling technique was used in selecting the colleges of Education from among other colleges, the criteria were

- i. The college must be co-educational offering chemistry/Education with other options.
- ii. The college must possess well equipped chemistry laboratory.
- iii. The college must have well staffed and experienced chemistry lecturers.

Four (4) colleges met the above criteria and Two (2) colleges among those that met the above criteria were selected by balloting. The two colleges were randomly assigned to treatment and control groups.

E) Instruments and Validation

Two researchers made instruments were used for data collection namely Achievement Test in chemistry (ATC) and cognitive ability test. (CAT). A total of twenty five (25) multiple choice items were constructed on the concepts of Enthalpy and Entropy for the achievement test in chemistry. Also (25) multiple choice items were constructed with four options on ability levels of students, to determine their cognitive ability levels. The result obtained was used to classify students into high, average and low ability levels.

The instrument s were faced and content validated by two lecturers in the department of science Education, University of Cross River State. Reliability of the instruments were determined using Kuder-Richardson Formula-21. A reliability index of 0.76 was obtained.

F) Research Procedure

The following procedure was followed for the administration of the instruments. Relevant permission was obtained from the Heads of department as well as chemistry lecturers in each of the colleges that were used for the study. In order to measure possible pre-existing differences in overall performance abilities of the experimental and control groups, pre-achievement test was administered prior to treatment to all the two groups and the results were used as covariates measures. After the administration of the pre-achievement test, the cognitive ability test was administered to all the groups through the help of the research assistant.

The results obtained were used to classify students into (3) groups of ability levels using inter-quartiles range, (66 and above) were classified as high ability level, (below 48) were classified as low ability level, while those that scored between upper and lower quartiles were classified as having average level.

After one week the concepts enthalpy and entropy using freefall apparatus and bomb calorimeter was taught by the research assistants to the experimental group from a well articulated laboratory activities involving experiments on enthalpy and entropy illustrating energy transfer.

The control group was taught using standard bomb calorimeter. The teaching was done for four weeks. One week later, posttest was administered to the two groups (experimental and control) for one hour using twenty five item test.

G) Methods of Data Analysis

The data collected were analyzed using descriptive statistics and analysis of covariance (ANCOVA) using pretest scores as covariates .

All hypotheses were tested at 0.05 levels of significance.

III. RESULTS AND DISCUSSION

The two research questions were answered using mean and standard deviation.

A) Research Questions

B) Research Question one (1)

What differences exists among the mean of performance scores of chemistry students taught the concepts of enthalpy and entropy using free fall apparatus and standard bomb calorimeter??

Table 1: Mean and Standard Deviation Scores of Experimental and control Group

Group	N	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Gain
Experimental control	62	24.66	7.98	59.24	4.94	34.58
	58	22.95	7.25	48.14	5.85	25.19
Total	120	23.88	7.65	53.87	7.74	30.04

Table 1 showed that the mean gain (34.58) of the experimental group is greater than the mean gain(25.19) of the control group. This indicates that students taught using free fall approved improvised perform better than those using standard Bomb Calorimeter

C) Research Question (2)

What is the difference in the mean performance scores of chemistry students with high, average and low ability levels taught the concept enthalpy and entropy using free fall apparatus and standard Bomb Calorimeter

Table II: Mean and Standard Deviation of Experimental and Control Group Based on Ability Levels

Group	Ability Level	N	Pretest $\bar{X}$	Pretest SD	Post-test $\bar{X}$	Post-test SD	Mean Gain
Experimental	High	25	25.04	7.60	74.00	5.47	48.96
	Average	26	24.73	9.08	67.38	3.19	42.65
	Low	11	23.64	6.50	66.00	4.90	42.36
Control	High	05	21.40	7.13	51.60	2.97	30.20
	Average	32	23.66	7.53	58.25	6.42	34.59
	Low	21	22.24	7.04	50.76	3.06	28.52
Overall	High	30	24.43	7.53	70.27	9.90	45.84
	Average	58	24.14	8.21	62.34	6.92	38.20
	Low	32	22.83	6.79	36.00	8.24	33.17

As shown in table 2, the mean gain (48.96) of students with high ability level in the experimental group was greater than those (42.65) and (42.36) of low ability levels .

Also the mean gain of (34.59) in average ability level was greater than (30.20 and 28.52) respectively, in control group.

D) Research Hypotheses

The following three hypotheses were tested at 0.05 level of significance.

Ho1. There is no significant difference in the mean performance score of chemistry students taught the concepts of enthalpy and entropy using improvise freefall apparatus and standard Bomb calorimeter.

Table (III): covariance Analysis (ANCOVA) of student's pretest performance classified by Resource materials with pretest as covariate.

Source	Sum of Squares	DF	Mean Squares	F	Sign of F	Decision
Corrected model	6625.04	2	3312.52	92.00	.000	*
Intercept	40957.91	1	40957.91	1137.50	.000	*
Pre-test	24.78	1	24.78	0.69	.409	NS
Resource Materials	6426.97	1	6426.97	178.49	.000	*
Error	4212.83	117	36.01			
Total	481590.00	120				
Corrected Total	10837.87	119				

* = Significant at .05 level of significance.

NS= Not significant at .05 level of significance.

As shown in table 3, the calculated probability value (F-value) .000 of the main effect of resource materials is less than the declared probability value (alpha level) .05. Therefore, the null hypothesis is rejected. This implies that there exist a significant difference in the main performance scores of chemistry students taught the concept enthalpy and entropy using freefall apparatus and standard Bomb Calorimeter.

Ho2: There is no significant difference in the mean performance scores of male and female chemistry students taught the concepts of enthalpy and entropy using improve Freefall apparatus and standard Bomb Calorimeter.

Table (IV): Covariance Analysis (ANCOVA) of students posttest scores classified by Gender with pretest scores as covariates.

Source	Sum of Squares	DF	Mean Squares	F	Sign of F	Decision
Corrected Model	6902.543	4	172.64	50.43	.000	*
Interest	40152.18	1	40152.18	1173.35	.000	*
Pretest	34.54	1	34.54	1.01	.317	NS
Resource Materials	6640.76	1	6640.76	.194.06	.000	*
Gender	58.49	1	58.49	1.71	.194	*
Resource material& G	224.96	1	224.96	6.57	.02	*
Error	3935.32	115	34.22			
Total	4811590.00	120				
Corrected total	10837.87	119				

* = Significant at .05 level of significance.

NS=Not significant at .05 level of significance.

As shown in table 4, the calculated probability value (F-value). .194 of gender was less than alpha level .05. Therefore, the null hypothesis was rejected. This implies that there exists a significant difference in the mean performance scores of male and female chemistry students taught the concept of enthalpy and entropy using freefall apparatus and standard Bomb calorimeter.

HO3: There is no significant difference in the mean performance scores of chemistry students with high, average and low cognitive ability levels taught the concepts of enthalpy and entropy using freefall apparatus and standard bomb calorimeter.

Table (V): Covariance Analysis (ANCOVA) of students posttest performance classified by cognitive ability level with pretest as covariates

Source	Sum of Square	DF	Mean Square	F	Sign of F	Decision
Corrected model	8129.01	6	1354.84	56.52	.000	*
Intercept	39664.00	1	39664.00	1654.58	.000	*
Pretest	4.31	1	4.31	180.00	.672	NS
Resource materials	4790.12	1	4790.12	199.82	.000	*
Cognitive Ability	402.05	2	201.02	8.39	.000	*
Resources x cognitive Ability	611.74	2	305.87	12.76	.000	*
Error	2708.86	133	23.97			
Total	481590.00	120				
Corrected Total	10837.87	119				

* =Significant at .05 level of significance

NS= Not Significant at .05 level of significance.

As shown in table 5, the calculated F=Value (.000) of the main effect of cognitive ability level was less than the declared alpha level (.05). Therefore, the null hypothesis was rejected. This implies that there exists a significant difference in the mean performance scores of chemistry students with high, average and low cognitive ability levels taught the concepts of enthalpy and entropy using freefall apparatus and standard bomb calorimeter

IV. RESULTS AND DISCUSSION

The results of the research findings were discussed under the following sub- headings.

- 1) Effect of teaching resource materials (Freefall apparatus, Bomb calorimeter) on students' academic performance on the concepts of enthalpy and entropy.:

- 2) Effect of gender on students' academic performance on the concepts of enthalpy and entropy.:
- 3) Effects of cognitive ability levels on students' Academic performance in the concept of enthalpy and entropy in chemistry.:
- 4) Effect of resources materials on students' academic performance.:

The result of investigation as shown in table 3 implies that a significant difference was found to exist in the performance scores of chemistry students taught the concepts of enthalpy and entropy using improvised freefall apparatus and bomb calorimeter as resources. Finding resulting from the testing of this hypothesis as presented in table 3 showed that the resources (Freefall apparatus) had a significant main effect of $P < .05$. this is because the calculated probability value ($P < .05$) .000 of the main effect was less than the declared probability value (178.49). The above finding appeared consistent with those of [14], [8]. These studies pointed out that improve resources from the environment were effective in enhancing performance and retention in science. Concrete objects provide concrete basis for conceptual thinking and thus facilitate better and proper understanding of basic science concepts. This study is also in line with the works of [2], that the environment is the largest and most complete laboratory ever imagined. Nature man-made fixtures and field activities are available every wherein the environment. The entire environment is a mixture of several substance that can be use in teaching certain concept in science (chemistry).

The research study corroborates with the work of [4] who posited that the concrete concept in science can be learnt using real and instant perspective manipulation of materials. This form of interaction is what is termed as learning science "doing"

5) Effect of gender on students' academic performance on the concept of enthalpy and entropy.:

Another area of concern in this study was to investigate the effect of gender on student's performance on the concepts of enthalpy and entropy in chemistry after being taught with freefall apparatus and bomb calorimeter.

The results of investigation as shown in table 4 indicated a significant difference in the mean performance scores of male and female chemistry students taught the concepts enthalpy and entropy using freefall apparatus and standard bomb calorimeter.

As shown in the table 4, the calculated p-value. .194 was less than the alpha 0.50. The result is consistent with the research finding of [21] that gender had a significant influence on student's academic performance in chemistry, they noted that every learner both male and female must be given the opportunity to display his/her manipulative ability ones they are taught with the same resource material. This is because good performance of students depends on their interest as well as the technique used by the teacher and the types of resource materials involved. This study is also in line with the findings of [18] that a significant difference exists in the performance of male and female students in science and mathematics.

6) Effects of cognitive ability levels on students' Academic performance in the concept of enthalpy and entropy in chemistry:

The result of the investigation as shown in table (5) indicated that a significant difference was found to exist in the mean performance scores of chemistry students with high, average and low cognitive ability levels taught using improvise freefall apparatus and standard bomb calorimeter. As shown in table 5, the calculated F-value (.000) of the main effect of cognitive ability level was less than the declared value (.05).

The result is in agreement with the findings of Inyang and [11], [9] that students ability level was a significant factor in their performance in chemistry units studied and a significant difference exists between the mean posttest and pretest scores among students of different ability levels in the learning and understanding of chemistry concepts. Also the result is in line with the findings of [1] that students ability levels have significant influence on problem solving tasks.

V. CONCLUSION

Based on the results of the study, it can be concluded that improvised freefall also facilitates students' academic performance in the concept of enthalpy and entropy in chemistry. Gender had a significant effect on student's performance in the concepts of enthalpy and entropy using freefall apparatus as resources. Also, cognitive ability level of the students affects academic performance. Also a combination of resource materials, gender and cognitive ability level significantly influence the performance of students.

VI. RECOMMENDATIONS

Based on the results of the study, the following recommendations were made.

1. Lecturers/science teachers should endeavor to be creative and use teaching resources from the environment alongside standard materials in teaching various concepts in chemistry.
2. Seminars/workshops should be organized for chemistry lecturers and teachers to educate them on the utilization of resources like improvised freefall apparatus in the teaching and learning of chemistry

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