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Effect of 5e Instructional Model On Students Learning Outcomes in The Subject of Chemistry

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Abstract
This study evaluated the effectiveness of the 5E Instructional Model in enhancing the cognitive and creative thinking abilities of higher secondary school students in Peshawar, Pakistan. Specifically, it compared the impact of the 5E model and the traditional Lecture Method on students' academic performance. The research used an experimental design, involving two groups of 19 students each, with one group taught using the 5E model and the other using the Lecture Method. Over 15 hours of instruction, students were assessed through a written assignment. The study employed a pre-test and post-test control group design, with 88 students randomly assigned to either the experimental group (5E model) or control group (Lecture Method). Data were analyzed using both descriptive and inferential statistical methods, with an independent samples t-test to test the null hypotheses. The results revealed that students in the experimental group, taught using the 5E model, significantly outperformed those in the control group, showing improved understanding of chemistry concepts. The uniformity in performance across different topics suggested that the 5E model could be effectively implemented in various areas of chemistry education. The study concludes that the 5E Instructional Model is a highly effective pedagogical approach for teaching science subjects at the secondary and higher education levels. It is recommended that the Government of Khyber Pakhtunkhwa adopt this model in its education policies and develop technology-driven resources aligned with the 5E framework to enhance the quality of teaching and learning.

Keyword: 5E Instructional, Effective padagocal approach, Descriptive and inferential statistical methods, Academic performance, Lecture Method, Exprimentl Group, Control Group

Introduction
The continuous search for effective teaching strategies that enhance student academic performance remains a fundamental objective in education. One such strategy, the 5E Instructional Model, has gained recognition for its structured, student-centered approach to learning. Developed by Bybee (1997) as part of the Biological Science Curriculum Studies (BSCS), this model incorporates five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Each phase

facilitates active learning by encouraging students to construct their knowledge through inquiry-based activities. The 5E model aligns with constructivist principles, which emphasize hands-on experiences and critical thinking, making it particularly effective for teaching science subjects, including chemistry (Newby, 2004).

Chemistry presents unique learning challenges for students, as it integrates theoretical knowledge with practical applications and abstract conceptual frameworks. Traditional teacher-led instruction, often reliant on memorization, does not foster deep learning or long-term retention of chemical principles. Consequently, educators seek alternative pedagogical approaches that actively involve students in the learning process. The 5E Instructional Model provides a viable alternative by engaging students in inquiry-driven activities, fostering collaborative discussions, and promoting reflective learning—elements that align with the investigative nature of scientific inquiry (Akar, 2005).

This study aims to assess the impact of the 5E Instructional Model on students' academic performance in chemistry. Specifically, it compares student achievement, conceptual understanding, and attitudinal development between traditional and 5E-based instruction. The research also explores how the 5E model enhances students' problem-solving abilities, scientific reasoning, and interest in chemistry. Findings from this study will contribute valuable insights for educators and policymakers regarding the benefits of student-centered instructional methods, ultimately improving science education.

Teaching and learning are interconnected processes that significantly influence educational outcomes. While teaching has traditionally been perceived as the transmission of knowledge from teacher to student, research over the past century has expanded this perspective, emphasizing the importance of instructional methods in fostering meaningful learning experiences (Gloria, 2014). In science education, conceptual understanding is prioritized over rote memorization, as scientific literacy is crucial for students' ability to contribute to societal and technological advancements (Oliver, 2007).

Constructivist learning theories, advocated by scholars such as Jean Piaget, Howard Gardner, George Hein, and Eleanor Duckworth, emphasize that students actively construct knowledge through interaction with ideas and experiences. In a constructivist classroom, students are not passive recipients of information; rather, they engage in discovery-based learning, integrating new concepts with their prior knowledge (Bybee, 1997). The 5E Instructional Model embodies this approach by structuring lessons around active participation, critical thinking, and real-world application.

Each phase of the 5E model serves a specific role in the learning process. The Engagement phase captures students' interest and connects prior knowledge to new concepts. Exploration encourages hands-on investigation, allowing students to test and refine their understanding. The Explanation phase facilitates discussion and teacher guidance to clarify concepts. Elaboration deepens learning through application to novel situations, reinforcing comprehension. Finally, the Evaluation phase assesses students' mastery and ability to apply their knowledge in meaningful ways (Wilder & Shuttleworth, 2004). By integrating these phases, the 5E model creates an engaging and effective learning environment that enhances students' understanding and retention of scientific principles.

This study seeks to validate the effectiveness of the 5E Instructional Model in chemistry education, providing empirical evidence of its impact on student learning. Through comparative analysis, the research will demonstrate how this instructional approach improves student outcomes and fosters a deeper, more meaningful engagement with scientific concepts. The findings will be instrumental in guiding educational leaders and policymakers in adopting innovative teaching strategies that enhance the overall quality of science education.

Problem Statement

Traditional chemistry teaching methods, which rely on memorization and teacher-led instruction, often fail to foster deep understanding and critical problem-solving skills among students. These approaches hinder students' ability to apply theoretical knowledge to practical situations, limiting their participation in scientific inquiry. The 5E Instructional Model (Bybee et al., 2006) offers an alternative, student-centered learning framework that promotes active engagement across five phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation.

Despite its potential benefits for science education, limited research exists on the effectiveness of the 5E model specifically in chemistry instruction. This study examines how the 5E model impacts student achievement, knowledge retention, and application compared to traditional teaching methods. Additionally, it explores the model's influence on students' scientific reasoning, problem-solving skills, and attitudes toward chemistry. By providing empirical evidence on the efficacy of the 5E model, this research aims to support the implementation of student-centered instructional approaches in chemistry education.

Research objectives

The main objectives of the study are;

1. To investigate the effect of the 5E model on the student's learning outcomes.
2. To evaluate the impact of the Lecture Method on students' comprehension and learning outcomes.
3. To compare and contrast the expected outcome based on Lecture Method and 5E instructional Model.

Research Hypotheses

Ho1: There is no significant effect of 5-E's model on the students' learning outcomes.

Ho2: There is no significant effect of the lecture method on students' learning outcomes

Ho3: there is no significant effect of the teaching method on the outcome of students.

Importance of the Study

This study is significant as it evaluates the 5E Instructional Model's effectiveness in enhancing conceptual understanding, problem-solving skills, and student engagement in chemistry education. By promoting active, inquiry-based learning, the research highlights the need to move beyond traditional teacher-led instruction. It addresses gaps in existing research by providing empirical evidence of the model's impact on chemistry learning outcomes. Additionally, the study contributes to global educational goals by supporting innovative teaching methods that develop critical thinking and scientific reasoning, ultimately preparing students for success in STEM fields.

Nature and Design of the Study

The present study was quantitative in nature and the design for the study was experimental, where two groups, i.e., the control group and the experimental group, went through a series of classes. In the present study, an experimental study where two different sets of students underwent two different instructional models: The Lecture Method and the 5E based teaching model. One set of students was taught using the conventional method, i.e., the lecture method, while the other was exposed to a controlled classroom environment based on the 5E model. In the first set, a total of 19 students were taught through the lecture method. In the second set, another total of 19 students were taught through the 5E model, for which teachers were properly trained first. After 15 hours (23 classes) of teaching, students were assessed in the form of a written assignment. The outcomes of the students were evaluated out of 50 marks. Comparison and contrast were made as per the stated objectives.

Population of the study

All the students enrolled during the 2022-23 session were the population of the study there are a total of 38 higher secondary schools in District Peshawar, Khyber Pakhtunkhwa. Target population were 550 students in GHSS Urmar Bala Peshawar, thirty-eight (38) students were selected as a sample population from this school. Students were selected through random sampling techniques, subject to the approval of the principal.

Sr. No	Population of the School	Total No of Students taken in our survey (9^{th} class Chemistry)	Control Group	Experimental Group
01	550	38	19	19

Selection of text

In selecting the text for the experiment, the following factors were taken into account. The study scheme was developed according to the National Curriculum 2006 guidelines. The researcher selected Chapters 1, 2, and 3 from the ninth-grade chemistry textbook published by the Khyber Pakhtunkhwa Textbook Board, Peshawar.

Classroom layout and grouping of the students.

Experimental and Control Groups

The enrollment of the responding students included an experimental group and a control group, which contained 19 students each, making a total of 38 students in the study. Teaching was done using a whiteboard, and all students were placed in laboratory environments to improve the learning experience of the students. Students in the experimental group were taught through the use of the 5E Model in the classroom, which focuses on engaged and exploratory learning, while the control group received focus in direct teaching in their lessons.

Tools of the Study

To evaluate student outcomes, a test comprising 50 marks was employed as the primary assessment tool. The test was designed with a variety of question types to gauge different aspects of student understanding:

Multiple Choice Questions (MCQs): Worth 14 marks, these questions assessed students' recall and recognition of key concepts.

Restricted Response Questions (RRQs): Worth 18 marks, these questions required students to provide brief written responses, allowing for the evaluation of their understanding of specific topics.

Constructed Response Questions (CRQs) and Extended Response Questions (ERQs): Also worth 18 marks, these questions encouraged students to articulate their thoughts and demonstrate their ability to apply concepts in more complex scenarios.

The test varied in terms of content, application, and conceptual depth to ensure a comprehensive assessment of the students' learning.

Homogeneity

Both groups had an equal number of students, all within the same age group, ranging from 14 to 15 years. The students spoke the same language and came from similar socioeconomic backgrounds.

Status of the group

Only male students were selected and divided into two groups: the control group and the experimental group

Level of Study (Secondary School Level)

This investigation was carried out on the public secondary school level students of Peshawar district, Khyber Pakhtunkhwa province of Pakistan.

1. Class (Grade) level of students

Only class 9th students were selected, for this study. No other level or class was considered.

2. **Subject**

Learning outcomes of class 9th students in the subject of chemistry was evaluated based on 5E's model.

Contents Allocation-grade chemistry students were chosen for both the control group and the experimental group. The control group learned content through the Lecture Method while the experimental group was taught using the 5E-based instructional model. The chapters of the study were the first, second and the third disintegration which contained both narrative and descriptive materials as well as precisional and evaluative materials. Both groups went through a teaching span of seven weeks.

Pre and Post Testing First a test of both the groups was conducted in order to know their existing level. After seven (7) weeks of teaching a second test was conducted to know the learning outcomes of both the group. Post-test included the content already taught over the course of previous seven weeks. Post-test was given to both the groups i.e. experimental and control group.

In these seven weeks, variety of topics taken from chapter no 1st, 2nd and 3rd were taught to the students. No other chapter was discussed.

Testing Mode (pre and post)

In the beginning of study, a pretest score was analyzed and in the post test two groups that is control group and experimental will be observed. Data or test taken before that is pretest and posttest was correlated

Experimental Duration

After conducting the initial pretest, the experimental teaching phase lasted for seven weeks. Following this period, a post-experiment assessment was administered, and the results were correlated for further analysis.

Control of Study Variables

The experiment was conducted within the same school to control extraneous variables. The following measures were taken to minimize their impact.

History and Maturation

Both groups experienced similar maturation processes, ensuring that internal validity was not compromised by historical influences.

Testing

To mitigate the testing threat, post-test items were shuffled.

Post-test Administration

As a means of measuring student accomplishment, a posttest procedure in the form of a certain test which includes a comparison between pretest and posttest scores was conducted for both the experimental and control groups.

Mortality

]The experiment was limited to a seven-week duration to control for attrition. Parents and students agreed to maintain consistent attendance throughout the experiment.

Specificity of Variables

The sampling procedures for both experimental and control groups were identical. The pretest and posttest assessments were also the same for both groups.

Experimenter Effects

The same teacher instructed both the experimental and control groups, using different teaching methods for each.

Data Analyses

This section focuses on the presentation, analysis, and interpretation of information gathered. Data were collected as pretest and posttest scores for the case study groups, which were analyzed and presented in the form of tables and interpreted. The pretest was conducted among 19 students of class nine at Government Higher Secondary School Umar Bala in Peshawar. A total of 19 students were in both the control group and the experimental group. Analyses were done based on their scores.

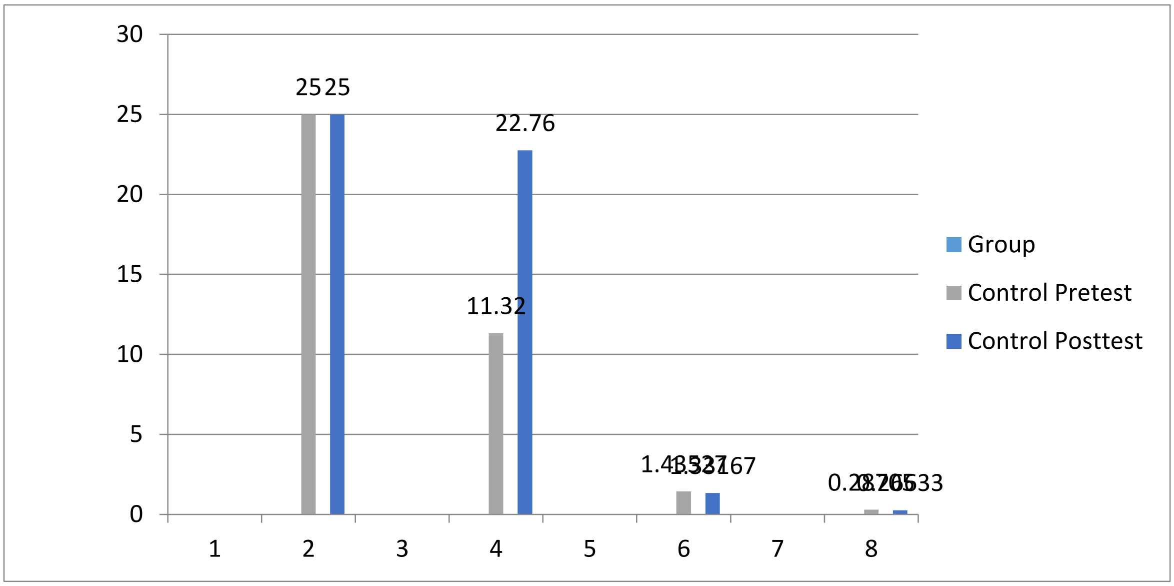
Ho1 There is no significant effect of 5E model on the students' learning outcomes.

Table: 4.1 A. Comparison of pre-test and post-test score of control group

Group	N	Mean	S.D	$S.E_M$
Control pre-test	19	12.21	4.224	.969
Control post-test	19	18.68	7.048	1.617

Table: 4.1 B. Paired samples t- test of control group on bases of pre-test and post-test

Group	M	S.D	$S.E_M$	t	df	P-Value
Control pre-test Control post-test	6.56	6.834	.2361	-.973	18	.142



To compare the two groups, a paired sample t-test was used. Mean score for the control group pretest is equal to 12.21 with standard deviation value of 4.224, where mean score for the control group posttest is equal to 10.68 with standard deviation value of 7.048. In Table 4.1 B, we see an average for the difference in scores which is equal to 6.56 ($t = -0.973$, $df = 18$, $p = 0.142$) which is not statistically significant. This finding means that the average control group overall posttest score did not differ a lot from the mean pretest score, which implies no apparent change in performance has occurred.

Thus, the hypothesis H01 which states that "there is no significant effect of the 5E model on mean pre-test scores and average post-test scores in chemistry among students" is accepted.

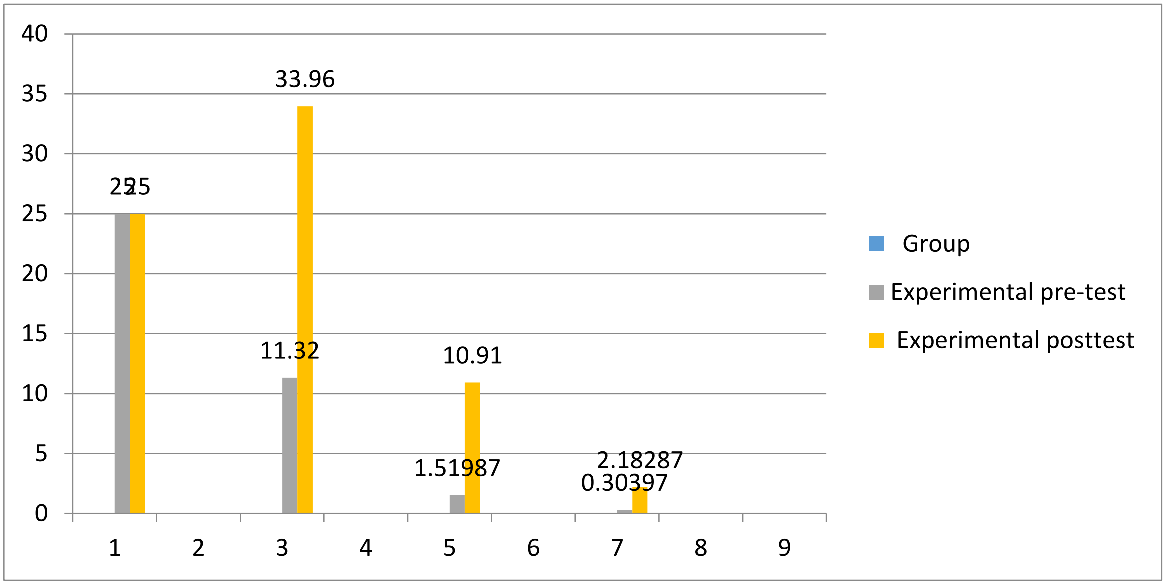
H_{02}: There is no significant effect of lecture method on students' learning outcomes.

Table: 4.2 A. Comparison of pre-test and post-test score of experimental group.

Group	N	Mean	S.D	$S.E_M$
Experimental pre-test	19	11.32	1.51987	.30397
Experimental post-test	19	33.96	10.91	2.18287

Table:4.2 B. Paired samples t- test experimental group on basses of pre-test and post-test score.

Group	Mean	S.D	$S.E_M$	t	df	p-value
Experimental pre-test						
Experimental post-test	-22.6	9.8102	1.9620	-11.5	24	.0001



According to Table 4.2 A, a pre-test was given to the experimental group which had an average of 11.32 with a SD of 1.51, while the average marks for the post test was 33.96 with a SD of 10.91. In this case, Table 4.2B describes the paired-sample t-test with the results of a mean difference of -22.64, t = – 11.53, df = 24, p = .0001. So as a direct relationship of this t-value, which is -11.53 & is much lower than 1.96, it therefore indicates that the mean average score of the experimental group post-test is greater than the pre-test. It is concluded that the students performed better due to the effectiveness of the experimental treatment. Therefore, the second null hypothesis (H02), which states "There is no significant difference between the pre-test and post-test mean scores of students taught chemistry using" is rejected.

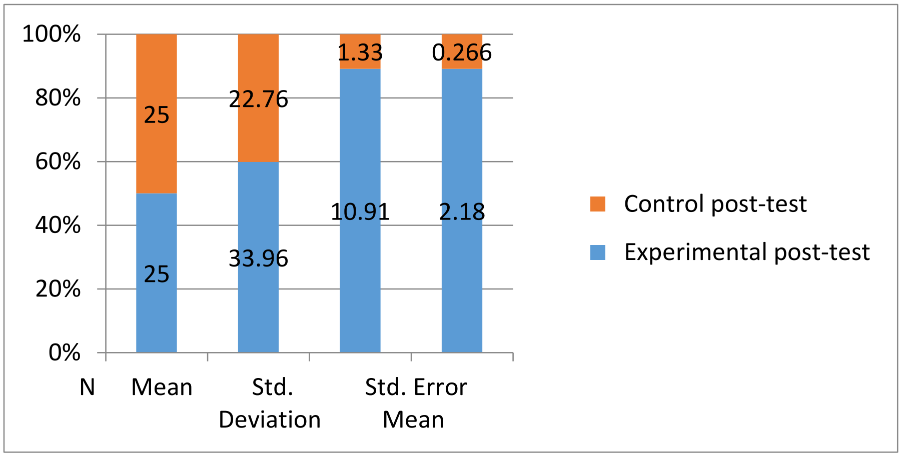
H_{03}: there is no significant effect of the teaching method on the outcome of students.

Table 4.3A: Comparison of experimental and control groups on post-test.

Group	N	Mean	Std. Deviation	Std. Error Mean
Experimental post-test	19	33.96	10.91	2.18
Control post-test	19	22.76	1.33	.266

Table4.3B. Paired samples t- test of experimental and control groups on basses of post- test

Group	Mean	S.D	$S.E_M$	T	df	p-value
Experimental post-test Control post-test	11.20	11.20	2.2181	5.05	18	.000



From the examination of Table 4.3A , it is evident that the mean score on the post test of the experimental group is 33.96 (SD = 10.91) compared to the mean score of 22.76 (SD = 1.33) obtained by the control group. In Table 4.3B, the paired samples t-test shows the mean difference to be 11.2, t value being 5.04 at df = 24 and the level of significance being .00001.

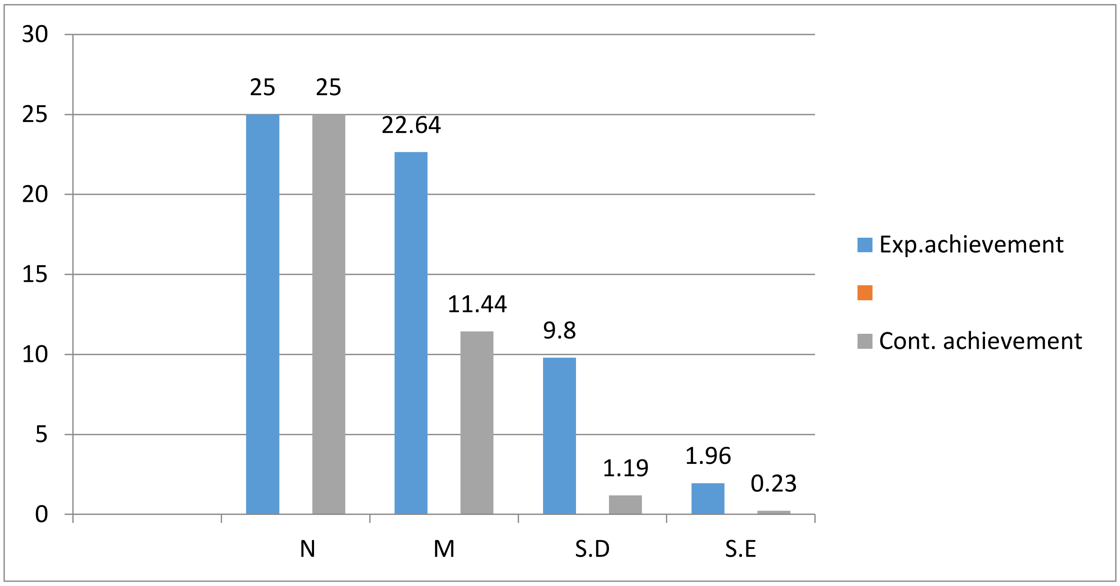
These results show that the two groups differed significantly in their post-test scores where the mean post-test score of the experimental group was much higher than the score of the control group. This also means that the achievement of the students in the experimental group in Chemistry was higher than that of the students in the control group. **Hence hypothesis $H_0$3 "there is no significant effect of the teaching method on the outcome of students" is rejected.**

Table: 4.4 A. Comparison of achievement scores of experimental and control groups.

Group	N	Mean	Standard deviation	Standard error mean
Experimental	19	22.64	9.80595	1.96119
Control	19	11.44	1.19304	.23861

Table: 4.4 B. Paired samples t- test of experimental and control groups on bases of achievement scores.

Group	Mean	S.D	S.E	T	Df	P-value
Experimental Control	11.20	10.44	2.088	5.364	18	.0001

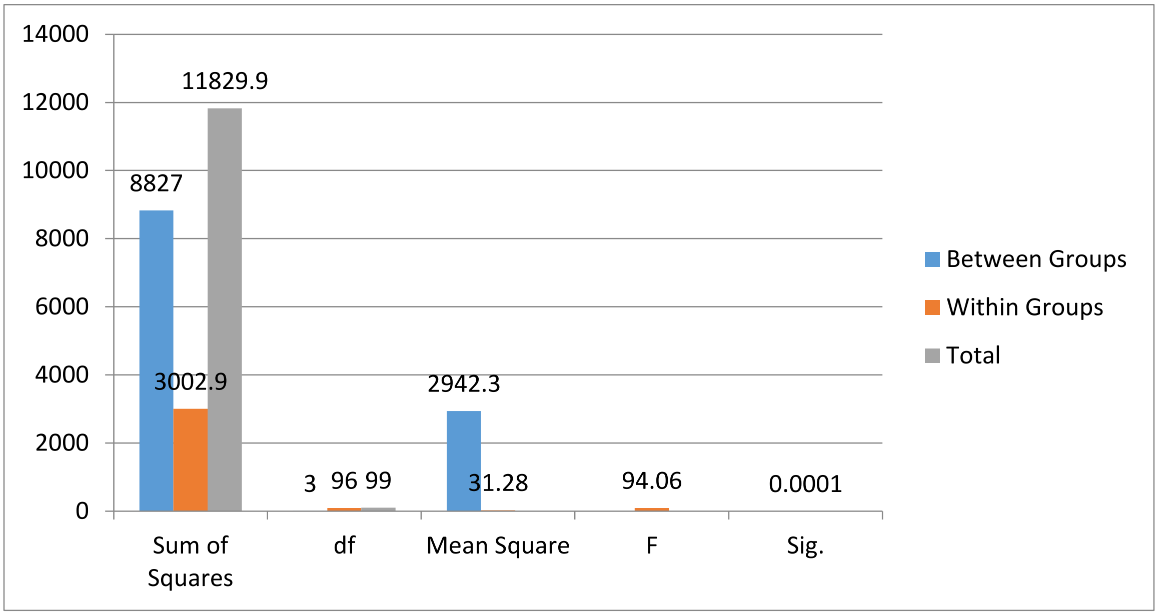


The difference between the two groups was measured through a t test for paired samples. It can be seen in table 4.5A that in the control group, the average achievement score was 11.44 (SD = 1.19) while in the experimental group the mean score was 22.64 (SD = 9.80). For table 4.5B, the average difference is stated as 11.20, there is a t-test value of -5.36 (df = 24) with p statistics of 0.0001 which are all significant statistically.

This argument can be interpreted to mean that on average, achievement scores of the trainees in the experimental group were significantly higher than those of the trainees in the control group; this validates the existence of statistically significant differences between these two groups in favour of the computer-based integrated learning system over the traditional method. Consequently, the hypothesis H05 which says, "There are no differences in the mean gain scores of students in chemistry," is not accepted.

Table 4.5 ANOVA for all pre-test post-test scores

Source of variation	**Sum of squares**	**Df**	**Mean square**	**F**	**p-value**
Between Groups	8827	3	2942.3	94.06	.0001
Within Groups	3002.9	72	31.28		



The overall averages from all groups were statistically tested using the F-test which obtained a value of 94.06 and a p value of 0.0001 thus suggesting that average scores obtained from the different groups were not the same. There are four groups and the sum of squares between the groups is 8827 with a mean square of 2942.3 and degrees of freedom df of three. The sum of squares in the within groups is 72. In total sum of squares it is estimated there is a total of 11829.9 with total df of 99 as illustrated in Table 4.6. This analysis confirms that are differences in achievement levels across the groups.

Table 4.6 Post hoc test for all groups.

Category	N	M	Difference of mean	df	t	p-value
Experimental pretest Control pretest	19 19	11.32 11.32	0	36	.0001	.0001
Experimental post-test Control post-test	19 19	33.96 22.76	-11.2	36	-5.09	P<.0001
Exp. achievement test Cont. achievement test	19 19	22.64 11.44	-11.2	36	-5.66	P<.0001

A post hoc test was used to evaluate outcomes between a control group and an experimental group. The pre-test results of of the two group showed that their means were the same since 11.32 was the average score for both groups. The differences in means = 0, degree of freedom (df) = 36, t-value = 0.000, p-value = 0.0001. It implies that there existed mere differences between the groups even before any intervention was carried out.

On the other hand, the final test scores highlighted a better performance for one group as compared to the other group. The post-test means of the experimental group stood at 33.96 while that of the control group sunk down to 22.76. The mean difference proved to be -11.20, with df = 36, t-value = -5.09, this limit is +0.0001. This is to mean that once the intervention was done, the containment group did a relatively better job when compared to the experimental group.

In addition, the achievement test results confirmed these as well as the experimental group's aim score of 22.64 was higher than that of the control group which achieved a score of 11.44 on average. The difference in means was yet again -11.20, with df = 36, t = -5.66, and p < 0.0001. These results further support the position that the participants in the experimental group had a greater degree of achievement in learning than those in the control group.

The performance of the test subjects in the experimental achievement test is better than all the group's mentioned which suggests that 5Es based integrated learning system is a better form of teaching than the conventional method.

Conclusion

The study, conducted at a higher secondary school, examined the effectiveness of the 5E instructional model in teaching chemistry by randomly assigning students to either an experimental or control group. The experimental group received instruction through the 5E model, while the control group followed conventional methods. Over seven weeks, both groups were assessed using a chemistry achievement test. Pre-test results showed no significant differences, and post-test results for the control group remained statistically unchanged, confirming that traditional methods had little impact. However, the experimental group showed significantly higher post-test scores, demonstrating the effectiveness of the 5E model in improving conceptual understanding and academic performance. Statistical analyses, including paired samples t-tests and F-tests, reinforced these findings. The study highlights the 5E model's role in enhancing chemistry learning and emphasizes the need for more interactive, student-centered teaching methods to improve educational outcomes.

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