Impact of Using PhET Simulation for Teaching Science Concepts to the Standard VIII Students in Pudukkottai District, Tamil Nadu, India

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Abstract *: Simulations represent computational replicas of actual or hypothesized scenarios or natural occurrences. These virtual models enable users to investigate the consequences of altering parameters within them. PhET Interactive Simulations, often referred to as "PhET," constitute a series of free online interactive simulations developed by the University of Colorado Boulder. These simulations are purposefully crafted to facilitate improved comprehension and learning of various scientific and mathematical concepts for both students and educators. This study endeavours to evaluate the current grasp of science concepts among eighth-grade students and aims to enhance these concepts through the utilization of PhET simulations. Five pivotal science concepts were selected from the eighth-grade science textbook in Tamilnadu as the focus of this study. The research employed a two-fold approach, consisting of an experimental group and a control group. An assessment tool comprising opinion-based questions and achievement-based tests (questionnaire) was employed. The study commenced with a pre-test for the control group, followed by a post-test after delivering suitable teaching-learning experiences to the experimental group. Based on statistical data, there was a significant difference between the control and experimental groups. It concludes that the conventional lecture-based approach in teaching science concepts proved inadequate in achieving desired learning outcomes. In addressing these shortcomings, PhET interactive simulations are shown to be engaging, effective, and valuable learning tools for diverse students and the application of innovative and interactive techniques, such as PhET simulations, notably improved learners' comprehension and academic achievement. These simulations are recommended as effective instructional aids for comprehending science concepts and enhancing the academic achievements of eighth-grade students in classroom settings.*

Key words**:** Interactive simulations, PhET, Science Concept, Simulation, 8th grade students

Introduction

Education is the systematic development and cultivation of natural abilities. It encompasses all processes that enhance human capabilities and behaviour. Education is organized, sustained instruction designed to impart a combination of knowledge, skills, and understanding for all aspects of life. On the other hand, education is a dynamic force in the life of every individual, influencing physical, mental, emotional, social, and ethical development. Dr. S. Radhakrishnan emphasized that a child's education should not be limited to the acquisition of information or the development of skills alone. It must also foster creative imagination and introduce the child to the supreme values of life: love, truth, beauty, and goodness.

Today, education is conceptualized as a crucial factor that promotes economic growth, making it an essential area for investment (Besime et al. 2022). Many nations are recognizing their responsibility in the field of education. In numerous countries, investment in education is increasingly viewed as a means to foster economic growth and to improve and generate new knowledge, technologies, and environmental management practices. To meet the demands of the 21st century, it has been rightly pointed out that 'Education must become more than what it is today; it should be both the reflection and the active agent of change, pushing and promoting essential and desirable changes.

Simulations represent computational replicas of actual or hypothesized scenarios or natural occurrences (Clark et al. 2009). These virtual models enable users to investigate the consequences of altering parameters within them (Plass et al. 2009; Linn et al. 2010). PhET Interactive Simulations, often referred to as 'PhET,' constitute a series of free online interactive simulations developed by the University of Colorado Boulder. These simulations are purposefully crafted to facilitate improved comprehension and learning of various scientific and mathematical concepts for both students and educators (Sokolowski and Rackley, 2011). This study endeavours to evaluate the current grasp of science concepts among eighth-grade students and aims to enhance pivotal science concepts through the utilization of PhET simulations. The concepts were selected from the eighth-grade science textbook in Tamil Nadu as the focus of this study.

Research objectives

1. Assess the existing comprehension of science concepts among eighth-grade students.
2. Introduce PhET interactive simulations to eighth-grade students.
3. Implement science concepts through PhET simulation activities for students.
4. Ascertain the impact of the treatment on eighth-grade students.

Methodology

The research employed a two-fold approach, consisting of an experimental group and a control group. Totally 60 student samples were collected from Government Higher Secondary Schools in Thiruvarankulam Block, Tamil Nadu. Out of the 60, 30 male student samples were selected from the Government Boys Higher Secondary School, Alangudi for the control group and the remaining 30 female student samples were selected from Government Girls Higher Secondary School, Alangudi for the experimental group in Thiruvarankulam Block, Pudukkottai District, Tamil Nadu (Plate 1).

Plate.1. Photographs depicted (A) Govt. Boys Higher Secondary School Alangudi (Control group) and (B) Govt. Girls Higher Secondary School Alangudi (Experimental group).

As intervention of this study, five science concepts (Global Warming and Green House (Term I and II), Chemical equations and balancing (Term II), Atom (Term II), Acid, Base and pH (Term III) and Sound (Term I).) have been chosen from the standard VIII Tamilnadu science text book and were taught with normal traditional lecture approach to control groups' students and same science concepts were taught with suitable teaching learning experience of PhET interactive simulations to the experimental groups' students.

Pre and Post-test were conducted to know the achievements. An assessment tool comprising opinion-based questions and achievement-based tests (questionnaire) was employed. The tool (questionnaire) consists of 50 MCQs with a single best response (each question have 1 score) for above five science concepts. The study commenced with a pre-test for the control group, followed by a post-test after delivering suitable teaching-learning experiences to the experimental group (Plate 2 and 3). The following statistical techniques are used in the study. Descriptive and inferential analysis mean, standard deviation and t – test, correlation coefficient, box plot and effect size.

Plate 2. Photographs depicted (A) The pre and post-tests were conducted in Control group and (B) Experimental group students.

Plate 3. (A & B) Investigator executed the PhET science simulation activities with Experimental group students.

Results and Discussion

i) Control Group`s date analysis

ii) After giving the activities mentioned to the control group the pre and post-test was conducted to assess the achievement. The comparative pre and post-test marks are tabulated in Table 1 and the comparative graph is presented in Figure 1

Table. 1. The pre and post-test score are obtained from the Control Group.

Science concept		I		II		III		IV		V	
Sl. No	Student name	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	SB1	8	9	8	8	1	8	7	6	8	8
2	SB2	4	8	7	6	1	8	7	6	3	8
3	SB3	7	8	7	8	5	8	4	6	6	9
4	SB4	3	9	8	8	2	8	6	6	6	5
5	SB5	6	8	8	8	3	8	4	5	6	6
6	SB6	6	8	8	8	2	3	5	5	3	8
7	SB7	6	8	8	8	1	5	7	4	7	4
8	SB8	7	9	7	8	1	8	5	6	8	8
9	SB9	6	6	7	5	3	5	4	5	3	3
10	SB10	4	5	7	3	1	8	4	4	9	10
11	SB11	3	9	4	8	2	4	5	7	4	6
12	SB12	5	7	7	7	1	5	6	5	4	6
13	SB13	6	7	8	8	1	8	6	5	8	8
14	SB14	3	9	8	8	0	8	4	8	9	8
15	SB15	3	9	9	8	2	3	6	7	2	3
16	SB16	5	10	7	6	2	5	6	6	4	6
17	SB17	7	7	6	6	2	8	4	5	9	6
18	SB18	1	6	2	6	4	3	5	6	1	5
19	SB19	5	2	4	7	3	2	5	7	3	3
20	SB20	8	7	4	8	4	4	6	6	5	7
21	SB21	4	8	7	6	1	8	4	1	2	4
22	SB22	2	3	1	2	2	2	3	3	3	4
23	SB23	6	8	8	8	3	8	4	5	8	9
24	SB24	2	7	8	8	2	3	5	5	6	9
25	SB25	4	10	2	8	1	0	3	5	5	6
26	SB26	2	9	3	6	2	3	5	4	6	9
27	SB27	7	6	4	7	2	4	2	3	6	8
28	SB28	5	6	1	7	1	1	4	3	5	6
29	SB29	6	8	5	5	3	3	4	3	3	5
30	SB30	2	9	4	2	3	0	6	4	5	8
Total		**143**	**225**	**180**	**201**	**61**	**151**	**146**	**151**	**157**	**195**

I- Global Warming and Green House; **II-** Chemical equations and balancing; **III-** Atom; **IV-** Acid, Base and pH; **V-** Sound.

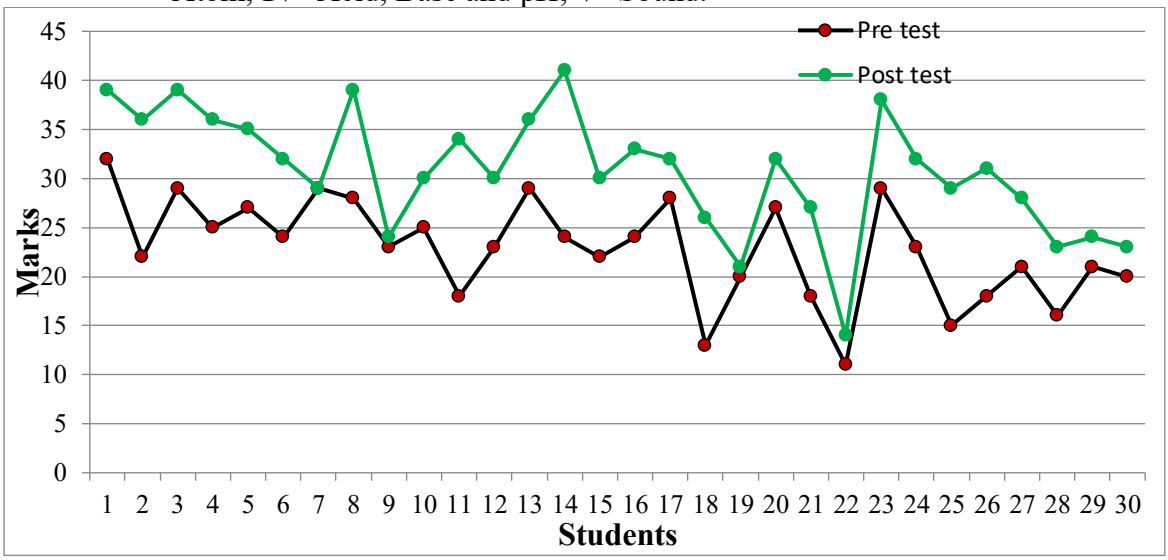

Figure. 1. The pre and post-test score obtained from Control Group.

In control group, students' achievements were analysed and the mean and SD values are obtained. The pre-test means score is 22.8 and the standard deviation is 5.2. The post-test means score is 30.8 and the standard deviation is 6.2. The pre-test marks sum is 684 and post-test marks sum is 923. The post-test average score is at a maximum level (61.6%), while compared with pre-test scores (45.6 %). The difference of the average percentage between the pre and post-test is 16. All the data was obtained from 30 number of VIII students. It is inferred that the post-test average percentage achievement is greater than the pre-test average percentage achievements.

Two sample assuming equal variances T-test was conducted to compare the pre and post-test of the control group. There was a significant difference in the score for pre-test (M=22.8, SD= 5.175) and post-test (M=30.8, SD= 6.223) conditions; the obtained calculated 't' value 1.342 is less than the critical table value 2.045 corresponding to the 0.05 level of significance. The results suggest that the difference is not significant. Hence, as per the null hypothesis is accepted and by conventional criteria, this difference is considered to be extremely statistically accepted in their achievement. It has concluded there is no significant difference between the pre and post-test mean scores of the control group achievements. This shows that the teaching of science concepts with normal traditional lecture approach has no significant difference between the pre and post-test mean scores.

ii) Experimental groups` date analysis

After giving, the activities mentioned to the experimental group the pre and post-test was conducted to assess the achievement. The comparative pre and post-test marks are tabulated in Table 2 and the comparative also graph depicted in Figure 2.

Table. 2. The pre and post-test score are obtained from the Experimental Group.

Science concept		I		II		III		IV		V	
Sl. No	**Student name**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
1	**SG1**	6	9	7	10	4	9	5	10	6	9
2	**SG2**	4	6	2	10	5	9	3	9	3	10
3	**SG3**	6	9	4	10	5	10	2	10	6	10
4	**SG4**	6	7	4	9	2	8	3	9	7	10
5	**SG5**	4	8	5	9	4	8	3	9	8	9
6	**SG6**	4	7	3	9	3	9	3	9	4	8
7	**SG7**	4	9	4	10	3	9	1	8	7	8
8	**SG8**	4	7	6	10	2	9	4	9	8	9
9	**SG9**	3	6	1	9	3	9	3	9	3	9
10	**SG10**	6	8	4	10	3	8	3	10	5	10
11	**SG11**	4	9	5	9	5	7	4	8	4	7
12	**SG12**	6	7	5	9	3	7	3	8	6	9
13	**SG13**	4	8	5	8	2	8	2	7	6	9
14	**SG14**	3	7	6	10	5	8	6	8	4	10
15	**SG15**	4	8	3	9	3	9	3	9	4	9
16	**SG16**	5	8	3	9	3	9	3	10	7	9
17	**SG17**	3	9	5	7	5	8	3	7	3	8
18	**SG18**	5	5	4	9	2	8	4	9	7	7
19	**SG19**	6	10	6	10	3	9	6	9	4	8
20	**SG20**	5	6	5	9	2	8	1	8	3	8
21	**SG21**	4	6	5	10	4	8	3	9	6	8
22	**SG22**	5	7	3	10	1	9	7	9	6	8
23	**SG23**	6	7	3	9	5	9	2	8	7	8
24	**SG24**	6	6	4	9	3	8	4	8	5	6
25	**SG25**	6	9	7	9	1	7	2	7	6	9
26	**SG26**	5	8	4	10	6	9	2	9	5	9
27	**SG27**	7	7	6	9	2	9	5	9	4	8
28	**SG28**	6	10	3	10	4	10	1	6	4	9
29	**SG29**	7	9	5	10	4	10	6	10	5	9
30	**SG30**	7	9	5	10	4	10	5	8	6	10
Total		151	231	132	281	101	258	102	258	159	260

I- Global Warming and Green House; **II-** Chemical equations and balancing; **III-** Atom; **IV-** Acid, Base and pH; **V-** Sound.

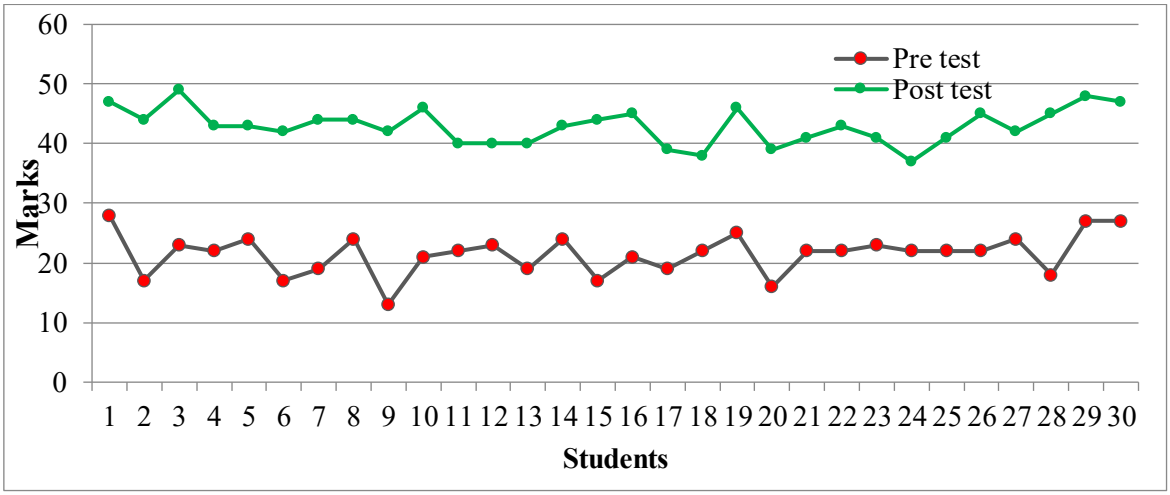

Figure. 2. The pre and post-test score are obtained from the Experimental Group.

In experimental group, students' achievements were analyzed and the mean and SD values are obtained. The pre-test means score is 21.5 and the standard deviation is 3.441. The post-test means score is 42.9 and the standard deviation is 3.004. The pre-test marks sum is 645 and post-test marks sum is 1288. The post-test average score is at a maximum level (85.9%), while compared with pre-test scores (43%). The difference of the average percentage between the pre and post-test is 42.9.

Two sample assuming Equal Variances T-test was conducted to compare the pre and post-test of the experiment group. There was a significant difference in the score for pre-test (M=21.5, SD= 3.441) and post-test (M=42.9, SD= 3.004) conditions; the obtained calculated 't' value 2.208 is greater than the critical table value 2.045 corresponding to the 0.05 level of significance. The results suggest that the difference is significant and it is considered to be extremely statistically accepted in their achievement. It is concluded that there is significant difference between pre and post-test mean scores of the experimental group. This shows that the teaching of science concepts with suitable teaching learning experience of PhET interactive simulations approach has significant difference between pre and post-test mean scores of the experimental group.

A Pearson product-moment correlation coefficient was computed to assess the relationship between the pre and post-test scores of experimental groups. There was a positive correlation between the two variables, r = 0.3701, n = 30, p = 0.05. A scatter plot summarizes the results (Figure 3) Overall, there was a strong, positive correlation between pre and post-test scores of experimental groups. Increases in teaching learning experience of PhET interactive simulations approach were correlated with increases in post-test scores.

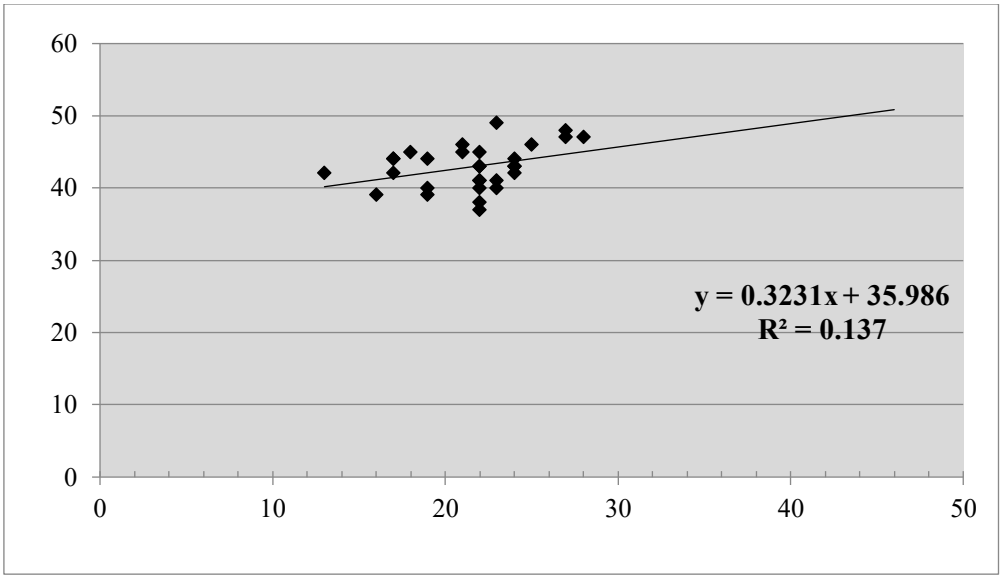

Figure 3. Results of correlation coefficient relationship between the pre and post-test scores of experimental groups.

Box plots are used to show overall patterns of response for a group. They provide a useful way to visualize the range and other characteristics of responses for a large group. They enable us to study the distributional characteristics of a group of scores as well as the level of the scores. To begin with, scores are sorted. Then four equal-sized groups are made from the ordered scores. Usually, these groups labelled 1 to 4 starting at the bottom. In post-test box plot shows comparatively short than the pre-test box plot, which means, the mid quartile of the post-test mean score range 41 to 45 marks. While pre-test box plots the mid quartile mean score range 19 to 24 marks (Figure 4). Therefore, this suggests that overall students were performed high level in post-test than the pre-test.

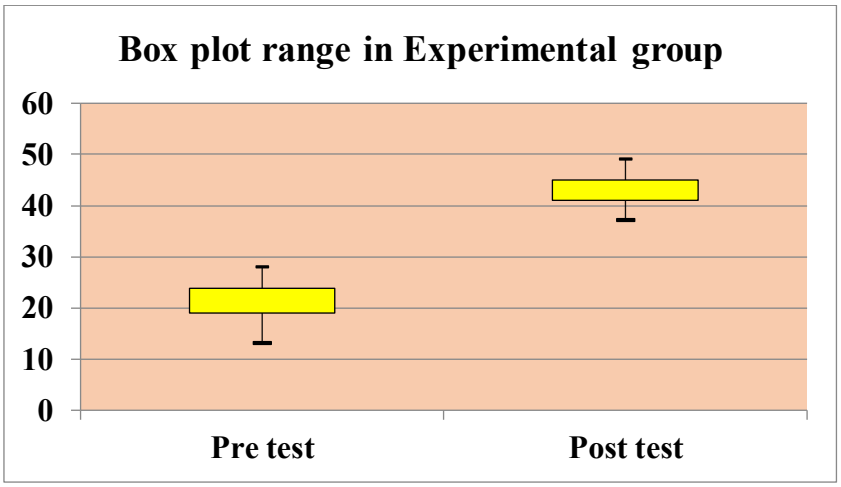

Figure 4. The pre and post-test score obtained from experimental group.

iii) Effect size between experimental and control group

Effect size is simply a way of quantifying the size of the difference between two groups. It is easy to calculate, readily understood and can be applied to any measured outcome in Education. It can be used to accompany the reporting of t-test results. In this study effect size was computed to assess the between the control and experimental group. In experimental group, average Mean= 322, average SD= 3.222 are values interpreted with the control group average Mean= 26.8, average SD= 5.699. Result is Cohen's *d* value *(d)* found to be 1.1665. As per Cohen`s **rule of thumb** guidelines (1988), which is considered as a large effect size (< 92%) between the control and experimental group (Table. 3).

Table. 3 Cohen's value score obtained from the control and experimental Groups.

Group	Mean			SD		Cohen's value *(d)*	Effect size
Control group	Pre-test	22.8	26.8	5.175	5.699	1.1665	Larger (< 92%)
	Post-test	30.8		6.223			
Experimental group	Pre-test	21.5	32.2	3.441	3.222		
	Post-test	42.9		3.004			

While facing challenges in implementing inquiry-based instruction, an increasing body of evidence suggests that inquiry-based learning has the potential to create a constructivist environment. In such a setting, students can actively participate in processes that lead to the construction of knowledge (Xinxin et. 2018). Previous research indicates that within simulation-supported settings, inquiry-based learning offers students more impactful learning opportunities, leading to superior performance compared to those engaged in traditional instructional methods (Xinxin et. al 2018). In this study, we focused on enhancing five pivotal science concepts through the utilization of PhET simulations. Krobthong (2015) revealed that teaching physics using Interactive Science Simulations methods aligns with the PhET concept, claiming that the application of Interactive Science Simulations may contribute to students' better achievement when used in conjunction with lectures, class activities in the laboratory, and homework.

Adams (2010) studied student engagement and learning with PhET interactive simulations, summarizing that there is considerable evidence that PhET interactive simulations can be powerful tools for achieving student learning in science. Similarly, our present study, along with statistical data, explored that in the control group, results show that teaching science concepts with the normal traditional lecture approach yielded no significant difference between the pre and post-test data. In the experimental group, results show that increases in the teaching-learning experience of the PhET interactive simulations approach were correlated with increases in post-test scores. Additionally, following Cohen's rule of thumb guidelines, which

consider a large effect size as greater than 0.92, there was a significant difference between the control and experimental groups.

Conclusion

From the present investigation, it can be concluded that the learners understanding ability and level of academic achievement have been improved and enhanced by applying the innovative and interactive techniques, such as PhET simulations, notably improved learners' comprehension and academic achievement. The conventional lecture-based approach in teaching science concepts proved inadequate in achieving desired learning outcomes. In addressing these shortcomings, PhET interactive simulations are shown to be engaging, effective, and valuable learning tools for diverse students. These simulations are recommended as effective instructional aids for comprehending science concepts and enhancing the academic achievements of eighth-grade students in classroom settings.

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