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Effect of Real Engagement in Active Problem Solving (REAPS) Model on academic achievements of secondary school students in the subject of Physics

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Abstract

National Curriculum of Physics for grades IX and X (2006) has recommended creating a sense of curiosity and wonder in students by demonstrating an increased awareness about the natural world, creativity, and problem-solving skills. It is also the demand for 21st-century skills. Moreover, by developing this ability in the school years' students, they may be successful in the coming academic years and in their professional life also. For this reason, many of the models have been used. Hence, the research was conducted to find the effect of Real Engagement in the Active Problem-Solving model on secondary-level students' academic achievements in Physics. Using a Quasi-experimental design, two sections from two public schools were selected. One section from each school was randomly allocated to a traditional and one to a treatment group. Traditional groups were taught by their respective teachers and the experimental groups were treated by the researcher. A test of academic achievement was developed on the concept of mechanics and electrostatics in the 10th-class Physics book published by Punjab Text Book Board Lahore (2020) and administered a pre-test and post-test. Data were analyzed by using a t-test, one-way ANOVA, and MANOVA. It was found that 10th-class students treated with the REAPS model performed better in the academic achievement test in physics as compared to the students taught through traditional methods. So, it is recommended that QAED academy conduct training on the REAPS model may be conducted as it is feasible not only for these topics but also for the other concepts and other branches of science. Moreover for Education, may include assessment items for the subject of Physics in SSC examinations so that, these exams may discriminate the students on the basis of higher-order skills.

Keywords: Real Engagement in Active Problem-solving Model, academic achievements, Physics, Secondary Level

Introduction

The twenty-first century is the era of innovative technology, humans have to solve their daily life problems in a systematic way, by organizing the problems, analyzing them, and then solving them through divergent and convergent thinking. This is the responsibility of the formal education system to change the approach of previously memorizing knowledge by the students to bring new concepts by developing divergent and convergent thinking. This change will help in coping with the technological world (Gibbs, 2018).

Among all the branches of science, physics includes the study of the largest galaxies of the universe to the smallest subatomic particles. It is taken as the basis for other sciences which includes chemistry, biology astronomy, oceanology, seismology, etc. That is why physics is taken as the study of the natural sciences in the universe (Heck et al., 2017). Similarly, Gibbs et al., (2017) stated that the study of Physics is the basis for understanding the concept of the world

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which is present not only in our surroundings but also inside and outside us. Physics' laws are considered universal because it is the fundamental branch of science and they are proved in many ways. The aim of studying physics is to determine the connection between matter and energy. Moreover studying physics helps in developing critical thinking skills.

Zimmerman and Maker (2020) stated that people have to face a lot of problems in their daily lives. So, it is necessary for people to have critical thinking skills that lead to problem-solving and ultimately which improves academic achievements, for making decisions about these problems. For this sake, Dino (2017) suggested that innovators of STEM (Science, Technology, Engineering, and Mathematics) were needed to bring some advances in engineering and technology. To enhance people's critical thinking skills, it is necessary to motivate, encourage, and support them to find effective solutions to the problems they face in their daily lives (Pease et al., 2020).

There are many teaching strategies and methods for enhancing academic achievements in science subjects but incorporating different strategies, a model called Real Engagement in Active Problem Solving (REAPS) model was created. It is the combined efforts of Schiever and Zimmerman in 2004, in association with Ph.D. scholars from many countries like Egypt, Russia, Turkey, Taiwan, and Saudi Arabia 2004. It is a student-centered approach and is used for solving real-world problems. REAPS model is an appropriate experience for a problem solver, it could be a kind of creation for the old experiences and considered an effective instructional strategy for learners, who are learning in any context, belonging to every age group, and working under any institutional curriculum. The REAPS model is considered an ideal approach for the motivation of gifted students (Maker et al., 2015). So, the REAPS model may be more helpful/beneficial for the students of physics to create a new solution for the old problems and answer the questions of what? Why? And how? Henceforth measuring the effectiveness of the REAPS model in Critical Thinking skills in physics is necessary. This study was intended to find out the effectiveness of the REAPS model on the academic achievement of 10^{th}-class physics students.

Objectives of Study

The objectives were to:

1. Find the effectiveness of the REAPS model on the academic achievements of 10^{th}-class students studying physics.
2. Study the differential effect of gender on REAPS model implementation for the academic achievements of 10th-grade students.
3. Find out the simultaneous effect of the REAPS model on different types of items (knowledge, comprehension, and application level of the cognitive domain) of the academic achievement test.

Hypotheses of study

Hypotheses are as follows

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Ho1: There is no statistically significant difference between the mean gain scores of students of the control group taught through the traditional method and the experimental group taught through the REAPS model in the academic achievement test of physics.

Ho2: There is no significant difference between the mean gain scores of students taught through the REAPS Model and the traditional method in knowledge, comprehension, and application level items of cognitive domain simultaneously.

Ho3: There is no gender-based significant difference in the mean academic achievement scores of 10th-class students taught through the REAPS Model within treatment groups.

Ho4: There is no significant simultaneous difference in mean gain scores of the students in knowledge, comprehension, and application level items within the treatment group.

The study may be an attempt to assess teaching and learning practices in an actual classroom in order to develop critical thinking skills about how problems are solved by innovative methods. The findings of this study may highlight the practices in physics classrooms and how high school students perceive this subject in Pakistan. The findings may also facilitate the teachers to enhance physics learning for innovations in physics teaching, which may in turn. The study may serve as a resource material and can be helpful for future researchers.

Methodology

This investigation examines the effectiveness of the independent variable i.e., method of teaching and gender with two levels of each variable with the dependent variable i.e., academic achievements. Due to administrative issues in the schools, it was not possible to take equivalent groups in the schools so, a non-equivalent Quasi-experimental design was followed because providing the treatment of the REAPS Model researcher has to keep the existing classroom as an intact class. According to Kuuk & Arsalan (2020), the groups are considered to be nonequivalent when there is no possibility of creating groups through random assignment. In this study, four similar groups were selected, out of which, two groups (male = 45 and female = 40) were given treatment through REAPS Model, and traditional methods were used to teach the other two groups (male= 45, female = 40), taught by their perspective teachers.

The population of the study

In district Sargodha, there were 162 male high schools for boys and 182 female high schools in the public sector that were the population. There is a bilingual medium of instruction in all the secondary schools i.e., English and Urdu mixed. Schools in district Sargodha are similar to each other for the reason that the students studying there have almost the same residential and socio-economic status.

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Sampling and sample of the study

Multistage sampling was used for the selection of a representative sample for this study according to the steps as follows:

1. At first, all such schools having the availability of science students, science laboratories, permission of head teachers, and two or more sections, were selected from Sargodha city.
2. From these schools, two schools; one Boys and one Girls Secondary School were randomly selected.
3. Two sections were selected randomly from the five science sections of 10^{th}-class in Government Girls' Secondary School and two from six science sections of 10^{th}-class in Government Boys' Secondary School. Randomly one section was taken as traditional and the other as a treatment group out of the selected sections in each school.

Research Tool

An academic achievement test for 10^{th}-class students covering the text relevant to practical life was developed according to the contents of Physics Textbook (2020) published by Punjab Text Book Board Lahore. The test consisted of sixty (60) items. After validation and experts' opinions, 32 items were selected for the final test.

the items distribution and scores as per selected topics and there were categorized as 22% (7 scores) from Simple Harmonic Motion, 15% (5 scores) from motion of a simple pendulum and damped oscillation, 9% (3 scores) from wave motion, 6% (2 score) from types of mechanical waves, 12% (4 scores) from ripple tank, 3% (1 score) from electric current, 3% (1 score) from potential difference, 3% (1 score) from the electromotive force, 3% (1 score) from Ohm's Law, 3% (1 score) from characteristics of Ohmic and non Ohmic conductors, 6% (2 scores) from conductors, 6% (2 scores) from combination of resistors, 3% (1 score) Electrical energy and Joule's Law and 3% (1 score) from Electrical power. These topics were given in the grade 10 Physics Textbook published by PTBB Lahore (2020). Moreover, the test items categorization was according to three levels of cognitive domain i.e., knowledge (10) items, comprehension, and application. The categorization of 32 items according to these levels was as follows:

- Knowledge level items developed were 10 (31%).
- Comprehension level items developed were 12 (38%) and
- Application-level items developed were 10 (31%)

Procedure of Experiment

1. Six lesson plans following the REAPS model of the constructivist approach were developed for selected topics (Mechanics and electro-statistics) before starting the experiment.
2. Before the commencement of the experiment, an academic achievement test for pre-testing was conducted from experimental and control groups of students in both schools.

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3. The pre-tests were marked and scores were kept confidential to avoid carry-over effects and such that students may use memory and may not feel any complexity or competition.
4. The treatment, teaching through the REAPS model of the constructivist approach was carried out for a period of nine weeks. While in the control groups; traditional teaching methods were used for giving instructions. Both groups were taught for 40-minute sessions a day.
5. The researcher and a male teacher taught in public school for years so no one was new to the students. In this way, teachers' effects were minimized.
6. According to the recommendations of Alhusaini (2016) treatment was carried out for nine weeks, making it the usual practice and minimizing the novelty effect.
7. Control groups were taught through traditional methods by their assigned teachers. They disclosed that usually, they keep the following points in lesson plans while teaching the subject of physics.
    i. Prior knowledge questions about the topic.
    ii. To communicate and illustrate the subject using the writing board by means of a lecture form.
    iii. Formative assessment questions were asked during the lesson to make students attentive and evaluate their comprehension of the subject.
    iv. Performing activities according to the lesson plans.
    v. Allowing the students to ask; if they have any questions in their minds related to the topic.
    vi. At the final phase assign the students some homework which is our tradition. So that the students may write the explanation of the topic in their notebooks on their own.
8. At the end of the experiment, post-tests were administered to both the treatment and control groups to evaluate the performance of students in academic achievement tests in physics.

Finding and Results

Table 1

Analysis of Scores of Academic Achievement Test in Experimental and Control Groups

Group	N	Mean	SD	t	df	p-value	Effect Size
Students learn with a traditional method	80	3.16	4.25	4.62	145	0.000	0.99

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Students to learn with the REAPS method	67	7.40	6.75

Table 1 depicts that the mean gain achievement scores of participants of treatment groups and traditional groups in the subject of Physics were significantly different, as indicated by t = 4.62, where df =145 and p = 0.000 < 0.05. So, the null hypothesis was not accepted. Henceforth, the higher mean gain score (M = 7.40 & SD = 6.75) with greater effect size Cohen's d = 0.99 > 0.8 shows that participants of treatment groups instructed through the REAPS model gained better achievement scores than the participants of traditional groups (*M* = 3.16 & *SD* = 4.25) instructed through traditional methods.

Table 2

Gender-based Analysis of academic achievement test scores in control and Experimental groups

Group	N	Mean	SD	t	df	p-value	Effect Size
Female Students learn with a traditional method	35	3.37	3.83				
Female students to learn with the REAPS Model	31	6.16	4.32	2.7	64	0.007	0.64
Male students learn with a traditional method	45	3.00	4.5				
Male students to learn with the REAPS Model	36	10.52	6.9	5.85	79	0.000	1.67

Table 2 shows the analysis of the scores having t = 0.40, p = 0.007 < 0.05 which indicates that the difference of mean gain scores on achievement test between female participants of treatment groups and the female participants of traditional groups was significant. Hence the null hypothesis was not accepted. It is evident that female participants instructed through REAPS model having higher mean gain scores (*M* = 6.16 and *SD* = 4.32) with greater Cohen's d effect 1.67 > 0.8 on achievement test, acquired better scores than the female participants (*M* = 3.37mml and *SD* = 3.83) instructed through traditional method. Whereas, from the analysis of male students the scores having t = 5.85, p = 0.000 < 0.05 which reflects that the mean gain scores on achievement test of male participants of treatment groups and the male participants of traditional groups were significantly different. Hence the null hypothesis was not accepted. It is evident that male participants instructed through REAPS model having higher mean gain scores (*M* =10.52 and *SD* = 6.9) on achievement test with greater Cohen's d effect 1.67 > 0.8, acquired better scores than the male participants (*M* = 3.00 and *SD* = 4.5) instructed through traditional method.

The study is comprised of the comparison of two nonequivalent groups (traditional and treatment) with respect to multiple continuous variables are levels of test items (application level,

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comprehension level, and knowledge level items). To compare these groups multivariate analysis was used.

Table 3

Multivariate and Univariate Analysis for the Effectiveness of Treatment on knowledge, comprehension and application level items of academic achievement test

Test		Multivariate Results	
	Hypothesis df	F	Sig
Wilks' Lambda	3	18.02	.000
Univariate results			
Variables	df	F	Sig.
Knowledge	1	51.56	.000
Comprehension	1	9.19	.003
Application	1	15.59	.000

Multivariate analysis results show that the difference among mean gain scores of treatment group and traditional groups' participants ($F = 18.02$, $p = 0.000 < 0.05$) on knowledge, comprehension, and application level of items was significant. So null hypothesis was not accepted. Univariate Analysis of Variance explained that the difference in gain scores of knowledge items was significant as indicated by ($F = 51.56$, $p = 0.000 < 0.05$), comprehension ($F= 91.9$, $p = 0.003< 0.05$) and Application ($F = 15.59$, $p = 0.000 < 0.05$)

Table 4

Comparison of mean gain scores in academic achievement test of physics within treatment groups

Gender	N	Mean	SD	t	df	p-value	Effect Size
Male students to learn with the REAPS model	36	10.5	6.93				
				4.68	65	0.000	1.55
Female students to learn with REAPS model	31	3.77	4.34				

Table 4 shows the analysis of the scores having $t = 4.68$, $p = 0.000 < 0.05$ which reflects that the mean gain scores in achievement test of physics of male and female participants within treatment group were significantly different. Hence the null hypothesis was not accepted. It is

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reflected/revealed that male participants instructed through REAPS model having higher mean gain scores (M = 10.5 and SD = 6.39) on achievement test on items measuring academic achievements, acquired better with greater Cohen's d effect 1.55 > 0.8, than the female participants instructed through REAPS model (M = 3.29, & SD = 4.69).

The study is comprised of the comparison of two non-equivalent groups (males and females) with respect to multiple continuous variables such as levels of test items (application level, comprehension level, and knowledge level items). To compare these groups multivariate analysis was used.

Table 5

Multivariate and Univariate Analysis for the Effectiveness of Treatment on knowledge, comprehension and application level items within the treatment group

Test	Multivariate Results		
	Hypothesis df	F	Sig
Wilks' Lamda	3	13.55	.000
	Univariate results		
Variables	df	F	Sig.
Knowledge	1	35.44	.000
Comprehension	1	1.12	.003
Application	1	2.28	.136

Multivariate analysis results reflect that the difference in mean gain marks on knowledge, comprehension and application between male and female participants within treatment group was significant (F = 13.55, p = 0.000 < 0.05). So, null hypothesis Ho9 was not accepted. Univariate Analysis of Variance explained that the difference in gain scores of knowledge level items was also significant (F = 35.44 and p = 0.000 < 0.05) and comprehension level items (F = 1.12 and p = 0.000 < 0.05) but was not significant for application-level items (F = 2.28 and p = 0.136 > 0.05) cognitive domain between male and female participants within treatment group.

Conclusion

1. REAPS model of problem-solving is more appropriate for teaching-learning physics as compared to the traditional method, both for male and female students at the secondary level.
2. REAPS model of teaching-learning problem solving is more appropriate for knowledge, comprehension, application, and higher-level items of cognitive domain academic performance achievement in physics at the secondary level.

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3. REAPS model of problem-solving was more effective for 10th-grade male students in learning physics concepts as compared to female 10th-grade students.
4. In the domain-specific achievement test, the performance of male students was better in knowledge level items and comprehension level items than female students whereas, in application and higher level, both performed equivalently.

Discussion

It was concluded that students performed better in their academic achievements as compared to control groups' students at the secondary level. These findings were supported by Alfaiz (2019) who concluded that after the implementation of PBL (Problem-Based Learning) in the treatment group of Physics, students' academic achievement scores were significantly higher than the scores of students in control group. It may be due to the fact that the students developed interests through engaging them by giving the concept of physics according to real-life problems. The students were more active while solving physics problems, their logical and reasoning skills were provoked, and that helped them a lot in achieving good scores in achievement test. In the field, while practicing the REAPS model it is evident that teachers can use these steps easily and they don't have to face the problem of much time in syllabus covering. It can be used as an alternative approach that provides the practice questions to both participants i.e., teacher and students, as both participants are dealing with a number of Physics problems related to real life (Bahar et al., 2021). This model also specifies the level of difficulty of questions that are actually going to be solved. Timely completion of questions provides teachers with elongated opportunities to take feedback, on the basis of which teachers can improve the learning process (Pease et al., 2020)

Recommendations

1. It was concluded that male students performed better in academic achievement as compared to female students. Therefore, it is recommended that further research be conducted to explore the reasons behind gender differences in academic performance in the teaching-learning atmosphere of Problem-solving.
2. It is found in the study that students performed better in knowledge and comprehension level items; so it is recommended that assessment agencies, for example, Boards of Intermediate and Secondary Education, may include problem-solving and Critical Thinking skills' assessment items for the subject of Physics in SSC examinations so that, these exams may discriminate the students on the basis of higher order skills.

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