

Enhancing Critical Thinking in Physics through Real Engagement in Active Problem

Solving (REAPS) Model

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Abstract



The research was conducted to find the effect of Real Engagement in the Active Problem-Solving model on the critical thinking skills of secondary-level students in physics. All the 10th-class students of one girls and boys public school of Sargodha city were the population. Using Quasi-experimental design, two sections from each school were selected. One section from each school was randomly allocated to as traditional and one as treatment group. Traditional groups were taught by their respective teachers and the experimental groups were treated by the researcher. A test of critical thinking skills was developed from nineteen (19) topics from 10th-class Physics published by Punjab Text Book Board Lahore (2020) and administered as a pre-test and post-test. Data were analysed by t-test, one-way ANOVA, and MANOVA. It was found that 10th-class students treated with REAPS model performed better in the critical thinking skills test in physics as compared to the students taught through traditional methods. It is recommended that the Directorate of Staff Development may arrange training workshops for in-service teachers to use REAPS model in their daily teaching.

Keywords: Real Engagement in Active Problem-solving Model, Critical Thinking Skills, Physics, Secondary Level, Gender

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).

Critical Thinking Skills may not be developed randomly or without any effort. It has to pass from organized, thoughtful, and repetitive practices in students for developing perceptive thinking (Sun, 2021). Because generally in a test, verbal and quantitative reasoning, critical and analytical thinking skills may have been attained with lots of effort and it needs a base of the students from the secondary level and had a great impact upon the academic achievements of the students (Dwyer & Walsh, 2020). Moreover, in schools for teaching students, there may be some efforts in changing the ways through which the students have to escalate from lower-order skills to higher-order thinking skills in cognition.

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 (Heller, 2017). Similarly, Gibbs (2017) stated that the study of Physics is the basis for understanding the concept of the world 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 it is 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.

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Zimmerman and Maker (2020) stated that people have to face a lot of problems in their daily life. So, it is necessary for people to have critical thinking skills 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. For enhancing 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 life (Maker, 2020).

There are many teaching strategies and methods for developing the skills of critical thinking 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 (2004), in association with PhD 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. 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 REAPS model in Critical Thinking skills in physics is necessary. This study was intended to find out the effectiveness of REAPS model on the critical thinking skills of 10th-class physics students.

Objectives of Study

The objectives were to:

1. Find effectiveness of REAPS model on the critical thinking of 10th-class students studying physics.
2. Study the differential effect of REAPS model on the critical thinking skills of 10th-class students on the basis of gender.
3. Find out the simultaneous effect of REAPS model on different types of items (open-ended, close-ended, and semi-open-ended) of the critical thinking skills test.

Hypotheses of study

Hypotheses are as follows

- Ho1: There is no statistically significant difference between mean gain scores of students of control group taught through the traditional method and the experimental group taught through REAPS model in the critical thinking skills test of physics.
- Ho2: There is no significant difference between mean gain scores of students taught through REAPS Model and the traditional method in open-ended, semi-open-ended, and close-ended items simultaneously.
- Ho3: There is no gender-based significant difference in the mean critical thinking skills scores of 10th-class students taught through REAPS Model within treatment groups.
- Ho4: There is no significant difference in mean gain scores of the students in open-ended, semi-open ended, and close-ended items simultaneously within treatment group.

Significance of Study

This research will be significant according to the following factors;

- i. The study will be helpful in finding new methods for the improvement of teaching and learning of physics. It also provides some recommendations to teacher education programs in Pakistan about the new challenges for policies of the future.
- ii. The study will 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 will highlight the practices in physics classrooms and how high school students perceive this subject in Pakistan. The findings will facilitate the teachers to enhance physics learning for innovations in physics teaching, which may in turn.
- iii. The findings will help as a basis for contributing in giving useful suggestions to all stakeholders in science education i.e., students, teachers, head teachers, curriculum developers, and policymakers, etc. That will also be beneficial in discussions about the professional development of high school physics teachers. Furthermore, the study will contribute best to the teaching and learning of physics.

- iv. The findings of the study will provide guidelines for curriculum developers and textbook writers to adopt a better learning approach to strengthen and focus on the ability to solve problems, Critical Thinking Skills, logical reasoning, creativity, laboratory work, and application of physics principles among secondary level students.
- v. The study will serve as a resource material and would 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 variables i.e., academic achievements, critical thinking, and ability of problem-solving. 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 REAPS Model researcher has to keep the existing classroom as an intact class. According to (Kuuk, 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, from those two groups were given treatment through REAPS Model, and traditional methods were used to teach the other two groups. The detail of the groups is that from the four groups included in the study, two were treatment groups (male = 45 and female = 40) and taught through REAPS model, and two were control groups (male= 45, female = 40) taught by the traditional method 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 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.

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 10th-class in Government Girls' Secondary School and two from six science sections of 10th-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

A critical thinking skills test for 10th-class students covering the text and 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 Eleven (11) items. After validation through expert's opinion, 10 items were selected for the final test.

The distribution of items and scores according to the selected topics were as 10% (3 scores) from Simple Harmonic Motion, 30% (9 scores) from the motion of a simple pendulum and damped oscillation, 10% (3 scores) from wave motion, 10% (3 scores) from types of mechanical waves, 10% (3 scores) from electric current, 10% (3 scores) from Ohm's Law, 10% (3 scores) from factors affecting resistance, 10% (3 scores) from a combination of resistors and 10% (3 scores) from safe use of electricity in homes.

Test items were categorized according to three higher-order levels of cognitive domain i.e., Analysis, synthesis, and evaluation. The categorization of 10 items according to these levels was as follows:

- Analysis level items developed were 5 (50%)
- Synthesis level items developed were One (10%), and
- Evaluation level items developed were 4 (40%)

Maximum items were selected from the comprehension level on the basis of item difficulty and discrimination power.

Procedure of Experiment

1. Lesson plans following REAPS model of the constructivist approach were developed for thirteen selected topics before starting the experiment.
2. Before the commencement of the experiment, a critical thinking skills test for pre-testing was conducted from experimental and control groups of students in both schools.
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 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 minutes 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 given to both the treatment and control groups to evaluate the performance of students in the critical thinking skills test in physics.

Finding and Results

Table 1

Analysis of Scores of critical thinking test in Experimental and Control Groups

Groups	N	Mean	SD	t	df	p-value	Effect Size
Students learn with the traditional method.	67	3.10	3.5	12.6	138	0.000	1.63
Students to learn REAPS method	73	13.68	5.8				

Table 1 shows the analysis of the scores such as $t = 12.6$, $p = 0.000 < 0.05$ which shows that the difference between mean gain scores of students of traditional groups and the treatment groups in the critical thinking skills test of physics was significant. Hence the null hypothesis was not accepted. It is evident that participants of the treatment group instructed through REAPS model having higher mean gain scores ($M = 13.68$ and $SD = 5.8$) with greater Cohen’s d effect $1.63 > 0.8$, on the critical thinking skills test, gained better scores than the participants of traditional groups ($M = 3.10$ and $SD = 3.5$) instructed through traditional method.

Table 2

Gender-based Analysis of critical thinking test scores in control and Experimental groups

Group	N	Mean	SD	t	df	p-value	Effect Size
Male students learn with the traditional method	32	1.12	2.04	12.6	66	0.000	2.49
Male students learn with the REAPS model	36	15.5	5.73				
Female students learn with the traditional method	35	4.9	3.4	6.14	78	0.000	2.05
Female students learn with the REAPS Model	37	11.9	5.95				

Table 2 shows the analysis of the scores having $t = 12.6$, $p = 0.000 < 0.05$ which reflects that the difference between mean gain scores in the critical thinking skills test of Physics of male participants of the traditional group and male participants of the treatment group was significant. Hence the null hypothesis was not accepted. It is reflected that participants of the treatment group instructed through REAPS model having higher mean gain scores ($M = 15.5$ and $SD = 5.7$) with greater Cohen's d effect $2.49 > 0.8$ on the critical thinking skills test, acquired better scores than the participants of traditional group instructed through traditional method ($M = 1.12$ and $SD = 2.04$). On the other hand, the analysis of the scores having $t = 6.14$, $p = 0.000 < 0.05$ indicates that the difference between mean gain scores in the critical thinking skills test of Physics of female participants of the traditional group and female participants of the treatment group was significant. So, the null hypothesis was not accepted. It is reflected that female participants of the treatment group instructed through REAPS model had higher mean gain scores ($M = 11.9$ and $SD = 5.95$) with greater Cohen's d effect $2.05 > 0.8$ on Critical Thinking skills' test items gained better scores than the female participants of traditional group instructed through traditional method ($M = 4.9$ and $SD = 3.4$).

Table 3

Multivariate and Univariate Analysis for the Effectiveness of Treatment on Close-ended, semi open-ended, and open-ended items

Test	Multivariate Results		
	Hypothesis df	F	Sig
Wilks' Lamda	3	49.48	.000
Univariate results			
Variables	Df	F	Sig.
Close Ended	1	49.59	.000
Semi Open-ended	1	20.43	.000
Open Ended	1	90.23	.000

Multivariate analysis results reflect that the difference of gain scores on application, comprehension, and knowledge level items of treatment and traditional groups was significant ($F = 49.48$, $p = 0.000 < 0.05$). So, the null hypothesis was rejected. It depicted that the difference in gain scores of items on close-ended items was also significant ($F = 49.59$ and $p = 0.000 < 0.05$), for semi-open-ended items ($F = 20.43$ and $p = 0.000 < 0.05$) and open-ended items ($F = 90.23$, $p = 0.000 < 0.05$) of CT skills test between treatment and traditional groups.

Table 4

Overall gender-based comparison of mean gain scores in CT skills' test of physics within treatment groups

Gender	N	Mean	SD	t	df	p-value	Effect Size
Male Students taught through the traditional method	36	15.5	5.73	2.61	71	0.011	0.51
Female Students treated with REAPS model	37	11.9	5.95				

Table 4 shows the analysis of the scores having $t = 2.61$, $p = 0.011 < 0.05$ which reflects the significant difference of mean gain scores in the CT critical thinking skills test of physics between male and female participants within the treatment group instructed through REAPS model. Hence the null hypothesis was rejected. It is evident that male participants of the treatment group instructed through REAPS model had higher mean gain scores ($M = 15.5$ and $SD = 5.73$), with moderate Cohen's d effect $0.51 > 0.5$, gained better scores than the female participants of the treatment group instructed through REAPS model ($M = 11.9$ and $SD = 5.95$).

Table 5

Multivariate and Univariate Analysis for the Effectiveness of Treatment on Close-ended, semi open-ended, and open-ended items within the treatment group

Test	Multivariate Results		
	Hypothesis df	F	Sig
Wilks' Lamda	3	49.49	.001
Univariate results			
Variables	df	F	Sig.
Close Ended	1	1.42	.236
Semi Open-ended	1	6.31	.014

Open Ended	1	11.06	.001
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Multivariate analysis results reflect that the difference between gain scores on close-ended, open-ended, and semi-open-ended of male and female groups was significant ($F = 49.48$, $p < 0.01$) within the treatment group. So, the hypothesis of no difference was not accepted. Univariate Analysis explained that the difference in gain scores of items on open-ended items was significant ($F = 11.06$, $p = 0.001$) and also for semi-open-ended ($F = 6.31$, $p = 0.014$) but not significant for close-ended items ($F = 1.42$, $p = 0.236$) of Critical Thinking skills' test between male and female participants within the treatment group.

Conclusion

1. The REAPS model of problem-solving was more appropriate for developing critical thinking skills in secondary-level students of physics as compared to the traditional method. Similarly, comparing male and female students included in the treatment group taught through REAPS method performed better in the test of critical thinking skills in physics at the secondary level as compared to male and female students included in the control group taught through the traditional method.
2. REAPS model was more appropriate for learning physics as the students of treatment groups taught through REAPS model had better performance in close-ended, semi close-ended and open-ended items of critical thinking skills test of physics at the secondary level as compared to control groups taught through traditional method.
3. It was concluded that within the experimental group, REAPS model was more effective in developing critical thinking skills in male students of 10th-class Physics than in female students.
4. In different types of test items i.e., close-ended, semi-open-ended, and open-ended items, within an experimental group simultaneously, male students performed better in semi-open-ended items and open-ended items than that of female students of 10th class physics. But in close-ended items of critical thinking skills test both male and female students had equivalent scores.

Discussion

It is concluded that the performance in the test of critical thinking skills of Physics students of the treatment groups was better than the students included in the control group. This was supported by Alfaiz (2019) who concluded that Problem-based learning (PBL) was an effective method to teach physics and students' problem-solving and critical thinking abilities in the treatment group were developed more than that of students of the control group. He also concluded that students' critical thinking skills had increased in his experiment were increased after implementing PBL (a component of REAPS Model) in science class. A possible reason may be that students were ready to take responsibility for their own learning which seems to enhance their self-directed learning.

In the field, while practicing 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 that teachers can improve the learning process (Pease et al, 2020)

Recommendations

1. It was reflected that REAPS model is suitable for enhancing critical thinking skills. So, it is recommended that QAED (Quaid E Azam Academy for Educational Development) may organize special training workshops for in-service teachers to familiarize them with this model and enable them to use it in their daily teaching-learning process.
2. Assessment agencies, for example, Boards of Intermediate and Secondary Education, are assessing the lower-order thinking skills like knowledge and comprehension of the students nowadays. But it is the need of the hour to evaluate the problem-solving and critical thinking skills of the students. Hence, it is recommended that Examination Boards may include assessment items for problem-solving and Critical Thinking skills in SSC examinations so that, these exams may discriminate the students on the basis of higher-order skills like problem-solving and critical thinking.

3. Pre- Service teachers' training programs (B.Ed., ADE and BS Education, etc.) may emphasize introducing REAPS models that are beneficial in enhancing critical thinking skills and problem-solving abilities in the students at the secondary level.

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