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Development of Critical Thinking Skills among Secondary Level Students through Constructivist Approach

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Abstract

The purpose of the research was to find out the impact of 7E instructional model of constructivist approach on ability of secondary level students to think critically in the subject of physics. The research design was quasi experimental. The current study's population included both male and female participants of 10th grade science students' studying physics in public secondary schools in Sargodha district. Multistage random sampling procedure was adopted in selection of two sections of science students from each of two public secondary schools, of Sargodha and randomly assigned as control and experimental groups. A critical thinking test in physics with reliability coefficient 0.85 was used as pre and post-test; t-test and ANOVA was used for data analysis. Results were that 7E instructional model had significant effects on students' ability to think critically in Physics. Performance of male and female students of experimental groups in critical thinking test in physics was better than male and female students of control groups. It is suggested that pre-service and in-service teachers' training academy like QAED may include 7E teaching style into teachers' training with practical steps.

Keywords: *7E* Instructional Approach, Physics, Critical Thinking Skills, Secondary Level Students

Introduction

Science education at secondary level prepare pupils to build all three bloom taxonomy domains i.e., cognitive, affective and psychomotor to grasp the natural phenomenon in their physical environment in a conceptual way. Science study at secondary level is further divided into its branches i.e., physics, chemistry, biology, geology etc. among them physics is the most near to everyday life especially in the modern age. As physics addresses energy and matter and studies mutual relationship of energy and matter and its properties in the field of mechanics, quantum mechanics, plasma, electrostatic, electricity and nuclear physics. Physics education is considered to be very fundamental in understanding the world around us, it concerns both macroscopic and microscopic state of matter (Ince, 2018; Watins & Mazur, 2013).

The National curriculum for Physics of secondary classes included standards and leaning outcomes. The standards of National curriculum offer high order thinking, deep knowledge and conceptual understanding for the students' progress and growth along with instructional learning outcomes for knowledge, comprehension, application and scientific skills etc. Hence, the National curriculum for Physics for grade 9th & 10th set standards that can develop problem solving skills and critical thinking (Ministry of Education, 2006). Critical thinking skills play a pivotal role at secondary level education and enable students to resolve their learning difficulties and problems in their daily life (Mahanal et al., 2019). Critical approach performs great role in learning process and enhance higher order thinking layer of cognitive domain i.e., analysis, synthesis and evaluation (Haghparast et al., 2014; Heong et al., 2012). Critical thinking demands both imagination and logic. It involves analysis, deductive & inductive reasoning, and problem-solving, moreover creative, inventive, and complex procedures of problem-solving (Zubaidah et al., 2018). According to Ennis (2013), Critical thinking reflects and makes sense and focuses on what to do or what to believe. As critical thinking skills play an important role in science education, engineering, medical field and business. That's way

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critical thinking may include in teaching of science subjects at secondary level to resolve students learning difficulties about understanding of scientific phenomenon and make them able to resolve real-life problems.

In Pakistan, prevailing curriculum demands new teaching approaches and methods, those must be implemented to fulfill all targets in secondary school physics. Therefore, physics learning at secondary level through 7E instructional model of constructivist approach may be studied for the enhancement of critical thinking, logical reasoning, conceptual understanding, and problem-solving skills among science students.

Literature Review

The aim of secondary school Physics teaching is to allow students to systematically understand the basic knowledge of Physics required for further study of modern science. Furthermore, the main purpose of Physics education to promote conceptual understanding about the modern computer technology and its uses to resolve real life problem. It encourages them to learn experimental abilities, enhance the capacity to think logically and to solve the difficult concept of physics in everyday life (Mekonnen, 2014; Reif et al., 2013).

Traditional teaching methods are not providing embedded learning of students in science subjects whereas modern teaching methods provide embedded learning in realistic context and focus on logical thinking and meaningful understanding instead of rote memorization (Ihejiamaizu et al., 2018; Shaheen & Kayani, 2015). For the holistic growth of our students, effective teaching methods or approaches are designed. However, a significant difference still exists in the classrooms between theoretical awareness and practical teaching. So, in educational practices, new teaching approaches must be applied (Hedden et al., 2017). The comprehensive and appropriate teaching methods in the classroom significantly impact on learning process. In this regard, constructivist teaching approach have significant impact on classroom environment and develop conducive learning environment in science class (Hedden et al., 2017; Tondeur et al., 2017). The constructivist approach helps students for comprehending meaning and constructing their own knowledge and give them conceptual understanding in science subjects (Ihejiamaizu et al., 2018; Roblyer & Doering, 2012). The constructivist approach helps students, to make their knowledge meaningful and give them conceptual understanding in science subjects. The comprehensive and appropriate teaching method in the classroom significantly improve learning process. Therefore, constructivist paradigm have significant impact in generating conducive learning environment in science classes and improve learning (Hedden et al., 2017; Suardana et al., 2018).

Various models of constructivist approach were developed and adopted for school use such as the social interaction model, problem-based inquiry model, information construction model, three stage learning approach "Explore, Explain, evaluate", 4E model "Engage, Explore, Explain, Evaluate", whereas, In the model of 5E phases are "Engage, Explore, Explain, Elaborate, Evaluate". According to Eisenkraft (2003), with an introducing two new components i.e., elicits and extend by add 'Elicit' phase before 'Engage' and Extend phase before Evaluation is the modification form of Bybee's model of 5E. The components of 7E model presented by Eisenkraft (2003) are "Elicit, Engage, Explore, Explain, Elaborate, Evaluate and Extend". This learning model accentuates logical reason through the seven stages of 7E among the students' (Balta & Sarac, 2016; Naade at al., 2018). Science teachers may implement this model in classroom to develop conducive learning environment and improves students' performance.

Researches by Hedden et al. (2017) and Wanbugu et al. (2013) concluded that the 7E instructional model has large impact on better achievement level of science students as students are involved in identification of problem, designing and conducting experiment, and communicating with fellow students for improved achievements in comparison with conventional teaching approach.

However, abilities of secondary school science students to think critically learnt from the 7E model were high achievers than those, who were taught through the discovery method. The scores of average achiever science students about critical thinking skills who learnt through the 7E model were 64.5 and average scores of discovery learning model were 55.3 of secondary level student in science subjects. The 7E model increased the interest and intrinsic motivation among the students towards science subjects (Suardana et al., 2018).

Similarly, Balim et al. (2012), described that use of mind mapping according to 7E instructional learning model qualifies students to solve daily life problems. Further findings were that

the mind maps technique educated through 7E learning model increased students' analytical thinking ability. On the other hand, Gonen and Kocakaya (2010) explored that, 7E learning model promotes thinking abilities and scientific understanding between the learners. The teacher is key agent in the constructivist teaching learning place who allows students to transfer new ideas and information in a more effective way by introducing a computer in lesson plan. These lessons also make it more productive for students to understand. Researchers have combined 7E leaning approach with computer known as use of instructional technology. The use of 7E model in science curriculum significantly effects on students' conceptual understanding and academic achievement. This model promotes students to explore new concepts or ideas. Moreover, the phases of this model have clear effective impact on learning (Şadoğlu & Akdeniz, 2015).

According to Trilling and Fadel (2009) analytical thought is recognized for the capacity to interpret, understand, assess and produce new knowledge. On the other hand Facione (2011) described six cores of critical thinking, i. e. "interpretation, analysis, inference, evaluation, explanation, and self-regulation". However, Ennis (2013) classifies that intellectual activity stresses on the point that what to believe and what to do. So, critical approach consists or includes "interpretation, analysis, summarizing, evaluating information, accuracy, precision, relevance, depth, wideness, logic significance and fairness". As a result, critical thoughts emphasize evaluating, organizing, clarifying, developing, prioritizing, or sorting out points of view. Critical approach helps students concerned decision making process. Critical approach makes a student intellectual and ready for the solution of problems in practical filed.

So, critical thinking is a basic skill that triggers prior research activity and various operations in learning activities. So, critical idea is the foundation stone of accomplishment upgrading, analyzing differences and comparison. This is used as inculcating likeness and contrasts, noticing and labeling causal nexus combination, abstracting views from early examples and judgment on the base of validity of truth (Florea & Hurjui, 2015; Ikman & Rezky, 2016; Setyowati et al., 2018). Critical thinking makes a student intellectual and ready for the solution of problem in practical filed (Birgili, 2015;Facione, 2011;Saputra et al., 2019).

Statement of the Problem

In science subjects, to enhance conceptual and meaningful understanding and development of attitude towards science. In Pakistan National curriculum for Physics (2006) proposed paradigm shift from behaviourism to constructivism in Pakistan (Ministry of Education, 2006). Traditional teaching methods are not effective for conceptual understanding in science subjects. As constructivist approach provide critical thinking and meaningful understanding in science subjects; Eisenkraft (2003) introduced 7E model of Constructivist approach which is more comprehensive and appropriate. It may develop meaningful and conceptual understanding among students of science subjects at secondary level. So, the study is opted to assess the improvement of critical thinking skills among secondary level students through 7E model of constructivist approach.

Theoretical Framework

On the base of constructivist approach, Eisenkraft (2003) developed 7E instructional model is a work plan of this approach for science subjects. 7E Model has been included in the literature when Eisenkraft (2003) expanded 5E model, which is a widely preferred and recognized instructional models of today, by introducing two new phases on the first and final phases. The first phase in 5E model, which is the engage phase, has been preceded by an elicit phase in which students elicit prior information, and the final phase in the same model, which is the evaluation phase followed by an extend phase while the phases in between remained the same. However, Yardley (2013) carried out his study with the purpose of researching the effect of 7E instructional approach, which has been improved in epistemological and metacognitive terms, on the success in physics lesson and epistemological understanding of high school students as compared to the traditional method, whereas 7E instructional approach which has been improved in metacognitive terms may prove more useful to in other areas of learning. Therefore, 7E instructional model which is student centered model may be helpful in developing higher order thinking and in improving academic achievement.

Objective

The objective of research was to find out the effect of 7E model of constructivist approach on secondary school students' ability to think critically in Physics.

Hypotheses

The following were the hypotheses of study:

H_{01}: There is no significant difference between the mean gain scores of students of both the control and experimental groups on critical thinking test in physics.

H_{02}: There is no significant difference between the mean gain scores of male students of both the control and experimental groups on critical thinking test in physics.

H_{03}: There is no significant difference between the mean gain scores of female students of both the control and experimental groups on critical thinking test in physics.

Research Design

In this study about the development of critical thinking skills among secondary level students through 7E model of constructivist approach, an experimental study was conducted; due to administrative problems in schools, equivalent groups were not possible so, Qausi experimental research and pre-test, post-test control design was opted for the study. (Cheema & Mirza, 2013).

Population

This study was delimited to 10th class Physics students studying in secondary schools of district Sargodha. So, Population details are as follows.

1. All the 10^{th} grade male and female science students studying in public schools in Sargodha district were the target population.
2. All 10^{th} grade science students' who study in Government Boys' Comprehensive High School Sargodha and Government Girls' Higher Secondary School Hyderabad Town, Sargodha were the accessible population for this study.

Sampling

Multistage sampling procedure was adopted. In male school the two sections out of six sections of science students were randomly selected and randomly assigned as control and experimental groups each had 46 and 42 students, respectively. On the other hand, two sections of science students out of four in female school were randomly selected as control and experimental groups each had 41 and 40 students respectively.

Research Instrument

Research instrument; critical thinking test in physics was developed, to measure the effect of 7E instructional Model (independent variable) on Critical thinking skills (dependent variables). A test of critical thinking in Physics for 10^{th} grade, relevant to practical life, was developed in English Language with Urdu Translation for better understanding of students on levels recommended by Facione (2011) i.e., "interpretation, analysis, evaluation, inference, explanation and self-regulation". Test items were developed according to topics from textbook of Physics (2020) for grade 10^{th} published by Punjab Textbook Board, Lahore Pakistan which was being taught at secondary level in all Government Schools of School Education Department, Government of the Punjab, Pakistan. Test items were taken according to two-way table of specification pertaining the concepts simple Harmonic Motion (SHM), Sound, Geometrical optics, Electrostatics, Current electricity, Electromagnetism, Information and communication technology and Atomic and Nuclear Physics.

This test was discussed with five (5) peers with M.Sc. Physics qualification for accuracy of content and vocabulary. Further, thirteen (13) experts (7 local and 6 international) were requested to check the content and face validity of test and also share their expertise about rubrics. Incorporating the suggestions of the peer and experts, instrument was improved. Then, a pilot study was done and item-analysis in terms of item difficulty, discrimination index was carried out and also the value of reliability coefficient Cronbach's Alpha (α), was calculated which was 0.85, range item difficulty of test was from 0.39 to 0.70 and the range of discrimination index of test was from 0.39 to 0.94. Hence the instrument was deemed reliable and valid.

Procedure of experiment

In the beginning of the experiment, both control and experimental groups were administered pre-test the test of critical thinking skills. Results of pre-test was not disclosed to students to avoid extra competition among the students. Then control group was taught by the assigned teachers, who had equivalent qualification and experience as researchers has, through routine teaching and the experimental group was taught by the researcher through 7 E model of constructivist approach and. The format of lesson plans were prepared according to 7E learning model of constructivist approach were discussed with five experts having Physics Education background, is given below;

1. Heading of the lesson plan
2. Course
3. Level of the class i.e. 10^{th} grade
4. Objectives in terms of three domains of Bloom Taxonomy i.e., cognitive, affective and psychomotor domains.
5. Resources/ Material
6. Approaches and Technique of 'teaching and learning process'
   a. Group discussion, Question & Answer technique, Demonstration and Experiment.
7. Phases of 7E instructional model
   i. Elicit Phase **(**In this phase, students' prior understandings are prompted). (05 minutes)
   ii. Engage Phase **(**Student perform an experiment/activity to capture students' attention and engage them). (10 minutes)
   iii. Explore Phase **(**Students work with one another to explore ideas through hands-on activities). (10 minutes)
   iv. Explain Phase (The teacher will invite pupils to articulate the subject in their own perspective). (15 minutes)
   v. Elaborate Phase (Students will get deeper understanding of the concepts by performing additional open-ended and different kinds of activities. Their practical skills will be enhanced and refined through this phase). (15 minutes)
   vi. Evaluate Phase (The teacher in this stage evaluates his students' learning and provides them with the suitable feedback). (10 minutes)
   vii. Extend Phase (In this phase, after studying, the instructor prepares pupils for the practice of information and skills in their everyday lives).

After teaching the specified topics, post-test was administered to both the experimental and control groups.

Analysis of Data and Findings

Gain scores were calculated by subtracting pre-test scores from post-test scores. Data was analyzed using t-test for independent samples and ANOVA.

Before analysis, assumptions of tests i.e., t-test and ANOVA, normality and homogeneity of data were to be checked. For this purpose, Kolmogorov-Smirnov and Shapiro-Wilk test were applied and results are given in the following tables.

Table 1

Result of Kolmogorov-Smirnov and Shapiro-Wilk test for normality

Dependent Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CTTP	.114	169	.057	.955	169	.059

Table 1 shows the result of Kolmogorov-Smirnov and Shapiro-Wilk test for normality. The result of Kolmogorov-Smirnov test represents that, as p-value is large than alpha value for critical thinking test in physics (*p= 0.057 greater than 0.05 & p = 0.059 greater than 0.05*), which means that, data came from normal distribution. So, the assumption was not violated.

However, Levene's test for checking the homogeneity of variance as assumption of ANOVA, was applied. Results are presented as follow:

Table 2

Summary of Levene's test

Dependent Variable	F	df_1	df_2	Sig.
CTTP	15.96	1	167	.267

Table 2 depicts the outcomes of Levene's test for homogeneity of variance that, p-value for critical thinking test in physics is larger than alpha value ((F = 15.96, p = 0.267 > 0.05). Hence, the variance are equal the assumption was not violated for ANOVA.

To analyze the critical thinking test score of the students of control and experimental groups' hypotheses were tested and results are presented in the tables below.

H_{01}: There is no significant difference between the mean gain scores of students of both the control groups and experimental groups on critical thinking test in physics

Table 3

Comparison of mean gain scores in critical thinking test in the subject of physics of control groups and experiment groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	87	8.83	4.41	4.63	167	0.000	1.01
Control	82	5.76	2.54				

**p<0.05*

Table 3 reflects that the mean gain scores of students included in control and experimental groups on critical thinking test in physics was significantly different such that t (167) = 4.63, df =167 & p-value 0.000 less than 0.05 and the null hypothesis "There is no significant difference between the mean gain scores of students of both the control groups and experimental groups on critical thinking test in physics" was not accepted. Hence, the greater mean gain score (M=8.83 & SD=4.41) with the larger effect size of Cohen's d value=1.01 > 0.8 shows that students of experimental groups treated with 7E instructional model obtained greater scores in critical thinking test in physics performed better as compared to students (M=5.76 & SD= 2.54) of control groups taught through routine teaching methods.

Gender-based analysis of mean gain scores in critical thinking test of students included in control groups and treatment groups is being presented as follows.

H_{02}: There is no significant difference between the mean gain scores of male students of both the control and experimental groups on critical thinking test in physics.

Table 4

Comparing mean gain scores in critical thinking test between male students of experimental and control groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	46	11.28	3.81	6.92	84	0.000	2.06
Control	40	6.47	2.33				

**p<0.05*

Table 4 depicts that difference in mean gain scores of critical thinking test in physics between the male students of treatment groups and male students of control groups was significant as indicated by t (84) = 6.92, df =84 & p = 0.00 and the null hypothesis "There is no significant difference between the mean gain scores of male students of both the control and experimental groups on critical thinking test in physics" was rejected. Hence, the greater mean score (M=11.28 & SD=3.81) with the larger effect size of Cohen's d=2.06 > 0.8 shows that, male students treated with through 7E instructional model obtained greater scores in critical thinking test in physics showed better performance as compared to male students (M=6.47 & SD= 2.33) taught through routine teaching taught methods in the subject of physics.

H_{03}: There is no significant difference between the mean gain scores of female students of both the control and experimental groups on critical thinking test in physics.

Table 5

Comparing mean gain scores in critical thinking test in physics between female students placed in control groups and experimental groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	41	6.21	2.98	4.43	81	0.000	1.24
Control	42	3.80	1.93				

**p<0.05*

Table 5 reflects that the difference of mean gain scores in critical thinking test in physics between female students of control groups and treatment groups was significant, as indicated by t (81) = 4.43, df =81 & p-value equal to 0.000 and the null hypothesis "There is no significant difference between the mean gain scores of female students of both the control and experimental groups on

critical thinking test in physics" was rejected. Hence, the greater mean gain score (M=6.21 & SD=2.98) with the larger effect size of Cohen's d value=1.24 > 0.8 reflects that performance of female students of treatment groups treated with 7E instructional model gained better scores in critical thinking test in physics was better as compared to female students of control groups (M=3.80 & SD=1.93) taught through traditional teaching methods.

Achievement level wise Analysis of Critical Thinking Scores

After analyzing the gender-based analysis, now the achievement levels wise i.e. (low, average and high) analysis between the control and experimental groups students is being presented as follows.

Table 6

Comparing mean gain scores in critical thinking test between the students of high achiever students included in experimental groups and control groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	19	7.44	2.63	3.77	35	0.000	0.86
Control	18	4.38	2.19				

**p<0.05*

Table 6 depicts that the difference appeared in mean gain scores of critical thinking test in physics between high achiever students of control groups and treatment groups was significant such that t (35) = 3.77, df =35 & p-value equal to 0.000. Hence, the greater mean score (M = 7.44 & SD =2.63) with the effect size of Cohen's d value= 0.86 > 0.8 shows that high achiever students of treatment groups taught through 7E instructional model gained better scores in critical thinking test in physics was better as compared to high achievers of control groups (M =4.38 & SD=2.19) taught through traditional methods.

Table 7

Comparing mean gain scores in critical thinking test between average achiever students of control groups and experimental groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	27	10.44	2.29	5.11	51	0.01	1.37
Control	26	7.15	2.39				

**p<0.05*

Table 7 reveals that mean gain scores in critical thinking test in physics between average achiever students of control groups and treatment groups was significantly different as indicated by t (51) = 5.11, df =51 & p-value equal to 0.01. Hence, the greater mean gain score (M=10.44 & SD=2.29) with larger effect size Cohen's d = 1.37 > 0.8 reveals that average achiever students of treatment groups treated with 7E instructional model, gained better scores in critical thinking test in physics as compared to average achievers of control (M=7.153 & SD= 2.39) groups students taught through routine teaching methods.

Table 8

Comparing mean gain scores in critical thinking test between low achiever students of control groups and experimental groups

Groups	N	Mean Scores	SD	t	df	p-value	Effect Size
Experimental	41	10.36	4.53	5.93	77	0.001	2.05
Control	38	5.47	2.37				

**p<0.05*

Table 8 reflects that the difference appeared in mean gain scores in critical thinking test in physics between low achiever students of control groups and experimental groups was significant, as indicates by t (77) = 5.93, df = 77 & p-value equal to 0.000. Hence, greater mean score (M=10.36 & SD=4.53) with the huge effect size of Cohen's d value= 2.05 > 0.8 shows that low achiever students of treatment groups gained better scores in critical thinking test in physics as compared to the control group's low achievers (M=5.47 & SD= 2.37) taught through routine teaching methods.

Table 9

ANOVA results for various levels of academic achievement

Source	SS	df	MS	F	Sig.	Effect Size Eta squared (η^2)
Between Groups	597.521	2	289.760	95.527*	0.000	0.70
Within Group	262.709	84	3.127			0.305
Total	860.230	86				

**p<0.05*

Table 9 shows that the difference appeared in mean gain scores in critical thinking test in physics among the students having different achievement levels was significant as revealed by F = 95.527, p-value equal to 0.000 less than 0.05 with moderate effect size η^2= 0.70 and 0.305.

For the examination of further differences between the groups, post hoc test (*LSD*) was used. The following table shows just the significant results.

Table 10

Results of Post hoc (LSD) Test

Achievement level (I)	Achievement level (J)	Mean Difference (I-J)	Std. Error	Sig.
High Achiever	Average Achiever	5.25	.52	.000*
Average Achiever	Low Achiever	6.73	.49	.000*
	Low Achiever	1.48	.43	.001*

** p<0.05*

Table 10 reveals that a positive mean difference (5.25) with p-value 0.000 < 0.05 indicates that high achiever students within experimental groups performed better than average achievers. Similarly positive mean difference (6.73) with p-value 0.000<0.05 depicts that high achiever students performed better than low achievers. Likewise, positive mean difference (1.48) with p-value equal to 0.000 less than 0.05, exhibits that performance of averages is also significantly better as compare to students of low achievers within experimental groups.

Analysis through two way ANOVA with respect to achievement levels and groups

Results of Analysis through two way ANOVA with respect to achievement levels and groups are given the given below tables

Table 11

Number of students' w.r.t. achievement levels placed in experimental groups and control groups

		Label of Value	N
Group	1	Control	82
	2	Experimental	87
Achievement Levels	1	High Achiever	37
	2	Average Achiever	53
	3	Low Achiever	79

Table 11 shows that there were 82 and 87 students placed in control and experimental group and 37, 53 and 79 in all three categories were high, average and low achievements correspondingly.

Table 12

Analysis through two way ANOVA with respect to achievement levels and groups

Source	Type III Sum of Squares	df	Mean Square	Partial Eta Squared (η2)	F	Sig.
Group	531.576	1	531.576	.260	57.165	.000
Level	190.067	2	95.033	.111	10.220	.000
level * Group	31.953	2	15.976	.021	1.718	.013
Error	1515.736	163	9.299			
Total	12714.000	169				
Corrected Total	2403.941	168				

R Squared = .369 (Adjusted R Squared = .350)

Table 12 represents that there exist an interaction effect of achievement level and teaching learning methodology as indicated by F value =1.71, df = 2 at p-value 0.000 less than 0.05 with respect to critical thinking skill. Hence, high achievers (mean=13.2) performed better than average achievers (mean = 9.4) and low achievers (mean = 6.3).

Gender Based Analysis of scores in critical thinking within Experimental Group

After analyzing the achievement wise analysis, now the gender based analysis with respect to achievement levels (i.e. low, moderate, and higher achievers) with the experimental groups is being presented as follows.

Table 13

Gender based comparison of mean gain scores in critical thinking test within experimental groups

Gender	N	Mean Scores	SD	t	df	p-value	Effect Size
Male	47	11.89	2.79	6.95	85	0.000	1.39
Female	40	7.37	3.23				

**p<0.05*

Table 13 represents that the difference in mean gain scores in critical thinking test in physics between male and female students of experimental groups was significant, as indicated by t (85) = 6.95, df =85 & p-value equal to 0.000. Hence, greater mean gain score (M=11.89 & SD=2.79) with the larger effect size of Cohen's d value = 1.39 > 0.8 reveals that male students had greater mean gain scores in critical thinking test in physics as compared to female students (M=7.37 & SD= 3.23) within experimental groups treated with 7E instructional model.

Table 14

Comparing mean gain scores in critical thinking test between high achiever female and male students within experimental groups

Gender	N	Mean Scores	SD	t	df	p-value	Effect Size
Male	13	9.69	1.70	6.06	18	0.000	1.59
Female	07	5.42	1.37				

**p<0.05*

Table 14 depicts that the difference of mean gain scores in critical thinking test in physics between high achiever male and female students of experimental groups was significant as indicated by t (18) = 6.06, df =18 & p-value equal to 0.00. Hence, the greater mean gain score (M=9.69 & SD=1.70) with the larger effect size of Cohen's d value= 1.59 > 0.8 reveals that high achiever male students gained better scores as compared to high achiever female students (M=5.4 & SD= 1.37) within experimental groups treated with 7E instructional model.

Table 15

Comparing mean gain scores in critical thinking test between average achiever female and male students within experimental groups

Gender	N	Mean Scores	SD	t	df	p-value	Effect Size
Male	10	12.0	1.95	3.76	24	0.000	0.69
Female	16	9.41	1.76				

**p<0.05*

Table 15 reflects that the difference appeared in mean gain scores in critical thinking test in physics between average achiever male and female students within experimental groups was significant as indicated by t (24) = 3.76, df =24 & p-value equal to 0.000. Hence, the greater mean gain score (M=12.00 & SD=1.95) with effect size of Cohen's d value = 0.69 reveals that average achiever male students had greater scores than the average achiever female students (M=9.41 & SD= 1.76) within experimental groups treated with 7E instructional model.

Table 16

Comparing mean gain scores in critical thinking test between low achiever female and male students within experimental groups

Gender	N	Mean Scores	SD	t	df	p-value	Effect Size
Male	24	13.45	1.35	3.84	39	0.000	1.45
Female	17	6.00	3.77				

**p<0.05*

Table 16 shows that the difference of mean gain scores in critical thinking test in physics between low achiever female and male students of experimental groups was significant as indicated by t (39) = 3.84, df =39 & p-value equal to 0.000. Hence, the greater mean gain score (M=13.45 &

SD=1.35) with the larger effect size of Cohen's d value= 1.45 > 0.8 reveals that low achiever male students had greater scores than the low achiever female students within experimental groups (M=6.00 & SD= 3.77) treated with 7E instructional model.

Conclusion and Discussion

Teaching learning using the constructivist 7E instructional paradigm was more effective than traditional teaching techniques in improving the critical thinking skills of 10th grade male and female physics students. It was found that the performance of male and female students in the experimental group in the critical thinking test in physics was outstanding than their respective counterpart male and female students in the control group. Furthermore, the performance of low average and high achiever students included in experimental groups in test of physics about think critically was better than the high, low and average achiever students placed in control groups. Moreover, it was also the concluded that, within experimental group the critical thinking test scores of male students was better than female students' taught through 7E instructional model.

The ability to think critically of students' was improved by 7E Eisenkraft instructional model; This finding was also supported by Suardana et al. (2018) and Parno et al. (2019) who explored that, secondary school students taught through 7E instructional strategy had high scores in critical thinking ability test in chemistry subject as compared to students taught through traditional teaching methods. The average scores of secondary school students on ability to think critically test in chemistry subject taught through 7E model was better than the students who received instruction through traditional teaching methods. Furthermore, critically thinking skills of male students was better than female students within experimental group. The similarly findings was of Bulbul (2010), Shaheen and Kayani (2017) were that on critical thinking test in biology, male students belong to treatment group obtained comparatively greater mean gain scores than the female students' placed in the group treated with traditional methods of teaching. Finding of their study showed that, 7E instructional paradigm enables students to communicate in a variety of ways so that they may think critically and scientifically about biological phenomena.

In nut shell, activity-based learning technique i.e., 7E instructional strategy moves students from passive-learning to active-learning environment and enhances students thinking style. It is also evident that the constructivist 7E instructional model has a substantial impact on learning outcomes since multiple phases of this model increase students' thinking ability so that learning becomes meaningful and students learn to create their own knowledge via the various phases (Marfilinda et al., 2020). It is evident from present findings that 7E instructional model of constructivist approach enables students to think critically and acquire meaningful knowledge of physics concepts. Findings of Suardana et al. (2018) and Parno et al. (2019) are also strengthen current finding who found that, secondary school students taught through 7E instructional strategy had high scores in critical thinking ability test in chemistry subject.

Recommendation

It is expected that 7E instructional model may be adapted to achieve the objectives and outcomes of science education and prepare the scientists of tomorrow. This study contributes to the research in physics education overall in science education through generalizing the performance of secondary school student in physics taught with 7E instructional model of constructivist approach enhanced their ability to think critically. So, it is suggested that pre-service and in-service teachers' training academy like *QAED (Quaid-e-Azam Academy for Educational Development)* may include 7E teaching style into their training session and they may take practical steps to train the prospective teachers in using 7E instructional model with emphasis on development of students' critical thinking abilities.

Suggestions for further research

The study was conducted on students' critical thinking skills in physics at secondary level. Therefore, study may be conducted on the specific branch of science like on Chemistry, Biology and Mathematics at secondary level and also non science subjects required to be studied.

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