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RESEARCH PAPER

Development of Reasoning Skills among Prospective Teachers through Cognitive Acceleration Approach

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ABSTRACT

The main objectives of this study were to; investigate the effects of the Cognitive Acceleration approach on the reasoning skills of the prospective teachers at the university level and compare the effects of the Cognitive Acceleration approach and traditional approach concerning reasoning skills of prospective teachers' at the university level. The study was experimental and followed a pre-test post-test control group experimental design. The sample of the study included the experimental group and control group from the BS Education program in the Department of Education at International Islamic University Islamabad. A simple random sampling technique was used to select the sample after pre-test and pairing of prospective teachers. CTSR (classroom test for scientific reasoning) developed by A.E. Lawson (2000) was used to collect the data through pre-tests and post-tests. The experimental group's perception about different activities of the experiment was taken through a self-made rating scale. Collected data were analyzed by calculating mean scores and t-test for hypothesis testing by using SPSS. The main findings of the study revealed that the Cognitive Acceleration teaching approach has a significant positive effect on the reasoning skills development of prospective teachers at the university level. Findings also showed that participants found this teaching approach effective and learned many new concepts and skills with the help of thinking activities. Based on findings it has been concluded that the Cognitive Acceleration teaching approach might be encouraged for training prospective teachers at the university level and training sessions about the use of the Cognitive Acceleration approach must be arranged by teacher education programs and institutions.

Introduction

Teaching and learning are becoming a more important component of educational policy and curriculum nowadays in many countries (Gallagher et al., 2012). It is recognized by the OECD's DeSeCo Project (OECD, 2005) that in today's world, individuals need to learn much more than the basic reproduction of theoretical knowledge and it is only possible with Cognitive and practical skills and creative abilities (Mceetya, 2008).

Cognitive Acceleration is known as an approach that is based on the Piaget (1970) and Vygotsky (1978) theory which aims to develop the general abilities of students for information processing. Most commonly, the Cognitive Acceleration approach consists of three main pillars that are called (1) Cognitive conflict, (2) social construction, and (3) Metacognition. Cognitive conflict is introducing the problem by challenging the student to think about it, social construction is the process of making knowledge together as a group and metacognition involves the process of reflection on students' thinking and also group thinking (McCormack, 2009).

Initially, research on Cognitive Acceleration (CA) was started in 1992 at Chelsea College London University and the main focus of this research was junior secondary science students and the development of their thinking skills with CASE lessons. After this research, many other Cognitive Acceleration programmes CATE, Let's Think, Let's Think through science, and ARTS were also developed at King's College London. Each of these programmes has established its learning material for students focusing on the main pillars of the Cognitive Acceleration approach for developing intellectual skills among students (Adey, 1999).

The purpose of Cognitive Acceleration is to increase the ratio of semi-abstract and abstract thinking which becomes possible, according to Piaget, between 14-15 years old (Adey & Shayer, 2002). The first Cognitive Acceleration program was developed by Michael Shayer, Philip Adey, and Carolyn Yates in 1981, and relied in its original version on Piaget's theory of Cognitive development. The outcome of this program was a package of 30 lessons entitled "Cognitive Acceleration through Science Education" (Serret, 2004). The origins of this model go back to the work carried out in Chelsea College, which showed that many concepts in science require demands that exceed students' current mental abilities. According to the thinking styles described by Piaget, a team of researchers developed a tool to analyze the Cognitive requirements and a group of Cognitive development tests which were used in a wide survey study to identify the level of students' thinking at different ages. The result revealed differences between students' thinking styles and curricula requirements (Adey, 1999). Shayer & Adey (2002) state that there are three basic assumptions on the interventions of Cognitive Accelerations, summarized as; (1) the programmes used in these interventions are appropriate, based on some general mental functions through an independent context or within a specified study content (2) These functions develop during the transition from one stage to another, and (3) The development of these functions is affected by environment and maturation.

Reasoning skills

Thinking is one of the main devices people use to comprehend and control their general surroundings (Baker et al., 2001). Thinking shows itself especially in people's efforts to illuminate or take care of an issue or to clarify new circumstances (Bowell, & Kemp, 2015). Along these lines, thinking doesn't just contain the abilities we need to prevail in our working or academic lives yet, in addition, include the essential abilities we need to survive.

Many studies have proposed thinking as an important component in science and math education (Kanari & Millar, 2004; Lawson, 1995; Park and Han, 2002; Türkmen, 2006;

Oehrtman and Lawson, 2008). It is observed that thinking helps students to enhance their understanding abilities and skills to assess the problem logically in an innovative way. So it is recommended that thinking is a powerful tool for students in the learning process to find out new ways to analyze the problem from all perspectives, making suitable assumptions, arriving at suitable solutions, and most importantly defending their decisions. But at the same time it is also proposed by specialists and instructors that it becomes difficult to evaluate the critical thinking activities and further characterizing it for building up students' thinking abilities (Hall et al., 2007; Hudspeth & Pribram, 1990; Murawski, 2012; Hugerat et al., n.d.; Endler & Bond, 2014).

Critical Thinking

Critical thinking is the most common phrase of the teaching-learning process of school and college settings. Commonly, the concept of critical thinking has a history of 2500 years back and has its roots in the mid-late 20th century. Critical thinking helps students to create and apply new thoughts to make their thinking more improved. Generally, an individual is a scholar to the extent he improves his thinking abilities consistently. Critical thinking is also known as a process of intellectually conceptualizing, applying, analyzing, synthesizing, and evaluating the information that is generated from observation, discussion, reflection, or reasoning (Güner & Erbay, 2021; Warburton & Torff, 2005; Kavenuke et al., 2020).

Foundations of critical thinking are also led by Socrates, Thomas Aquinas, Francis Bacon, Rene Descartes, John Locke, and Sir Issac Newton. These foundations are also developed by John Dewey, Ludwig Wittgenstein, and Jean Piaget. Robert Ennis in one of his studies conducted in the 1960s proposed to encourage the use of reasoning abilities in the teaching-learning process according to the learning environment and thinking capabilities of students. It is to be considered that an ideal critical thinker always makes the right decision and logically presents information by showing good behavior (Haug & Mork, 2021; Limbach & Waugh, 2010).

Higher Order Thinking Skills and their Importance in Teaching-Learning Process

The quality of education is not only judged by policy makers, curriculum, or plans but teachers also play a major role in the execution of educational plans and policies. A good education system demands qualified and trained teachers with all necessary skills required to make an educational system successful (Purnomo, 2017). Many of the researchers proposed that teachers have a great commitment towards quality education (Gil-Flores et al., 2017; Hu et al., 2017; Stylianides & Stylianides, 2007). Quality of education can be maintained by incorporating 21st-century skills in teachers. Three main 21st century skills known as 1) learning and innovation skills, 2) life and profession skills, and 3) information, media, and innovation skills (Scott, 2017) with higher-order thinking skills (HOTS) (Barak et al., 2007) for the development of reasoning and critical skills among students.

In the updated Blooms' Taxonomy, Higher-order thinking skills (HOTS) are characterized as analyzing, evaluating, and creating (Anderson and Krathwohl, 2001; Thompson, 2008). HOTS are associated with the utilization of tasks to make investigation, assessing, and making reasoning for theoretical information. So to equip students with

HOTS it is important to guide them about handling issues, making interpretations, and making decisions.

In the teaching-learning process, HOTS can be easily taught to young students by giving them more and more practice exercises of HOTS (Zehra & Garisson, 2011; Limbach & Waugh, 2010). Active learning and student-centered learning including problem-solving learning (Mokhtar et al., 2013), project-based learning (Orlich et al., 2010), discovery learning, and inquiry-based learning (Orlich et al., 2010) are those learning styles that can best prepare the young students with HOTS. These learning styles demand more trained and skilled teachers as compared to traditional teachers, so before students, it is essential to train teachers with HOTS skills for an effective teaching-learning process. Five major HOTS have been recognized in the Syllabus. They are problem-solving skills, inquiring skills, reasoning skills, communicating skills, and conceptualizing skills (Mumcu, 2017).

Hypotheses

H_{01}: There is no significant difference between the mean scores on reasoning skills pre- test between the experimental group and control group.

H_{02}: There is no significant difference between the mean scores on reasoning skills post-test between the experimental group and control group.

Material and Methods

Research Design

The research design of the study was a true-experimental pre-test post-test control group design. The study was experimental and quantitative in nature. Two groups control group and the experimental group were formed for the experiment. Pre-test and post-test was used to check the effect of the Cognitive Acceleration approach on the reasoning skills of prospective teachers. Symbolic representation of the research design is as;

RO_1 X_1 O_2

RO_3 X_2 O_4

Where O_1 and O_3= pre-test and O_2 and O_4 =post-test

Population

The population of the study included all prospective teachers enrolled in the BS Education program in the Department of Education at International Islamic University Islamabad. The population consisted of only female enrolled prospective teachers. The total population of the study was 250.

Sample and Sampling Technique

The sample of the study consisted of prospective teachers from the BS Education program studying the "Teaching of General Science" subject during Fall 2019. Total numbers of 64 prospective teachers were treated as a sample of the study and a simple random sampling technique was used to select the sample for the control and experimental group after the pre-test. The sample of the study was selected keeping in view the nature and research design of the study i.e. true experimental pre-test post-test design.

Instrumentation

To collect the data from the experimental and control group following instruments were used in the study.

CTSR (Classroom Test of Scientific Reasoning)

CTSR (classroom test of scientific reasoning) was used to measure the reasoning skills of prospective teachers. The Classroom Test of Scientific Reasoning (CTSR) 2000, developed by A. E. Lawson, is designed to assess students' scientific literacy and thinking skills. The test measures students' ability to apply aspects of scientific and mathematical reasoning, including analyzing situations, making predictions, and solving problems. The CTSR consists of 24 items that are suitable to measure the reasoning abilities of prospective teachers at the university level. As this instrument has open access on the internet, no permission was required to use it for the present study.

http://www.public.asu.edu/~anton1/AssessArticles/Assessments/Mathematics%20Assessments/Scientific%20Reasoning%20Test.pdf

Perception Scale

A self-made perception scale to explore the experimental group's perception about the experiment was used as an instrument of the study. The perception scale was consisting of statements related to activities and materials used during the experiment.

Data Collection

The effect of the Cognitive Acceleration teaching approach was checked by;

1. Applying the CTSR before and after the completion of the experiment.

2. Self-reported sheets filled by the students about their experiences, impressions, and attitudes towards the different aspects of the experiment.

Results and Discussion

Data collected through pretest, posttest and perception scale, were analyzed using SPSS software. To compare the effect of the Cognitive Acceleration approach between the control group and experimental group *t*-test was applied. The effect size was also calculated to measure the effect of the Cognitive Acceleration approach on the experimental group. Prospective teachers' perception about different aspects of the experiment was calculated through the mean.

Table 1
Mean scores analysis of CTSR pre-test post-test of Experimental group

	Pre-test	**Post-test**
Type of Test	CTSR	CTSR
Total number of participants	32	32
Mean score	12.15	16.00

Table 1 shows the analysis of the mean scores of the Classroom test of scientific reasoning (CTSR) for pre-test and post-test of the experimental group. The mean value (12.15) for the CTSR pre-test and (16.00) for the post-test shows that the Cognitive development of the experimental group was enhanced during the Cognitive intervention and they were able to perform better in the CTSR post-test. The difference in mean scores also depicts that there is a difference between Cognitive developments of the experimental group between pre-test and post-test of CTSR.

Table 2
Mean scores analysis of CTSR pre-test post-test of Control group

	Pre-test	**Post-test**
Type of Test	CTSR	CTSR
Total number of participants	32	32
Mean score	10.50	10.50

Table 2 presents the analysis of the mean scores of CTSR of pre-test post-test for the control group. The mean value for pre-test (10.50) and post-test (10.50) shows that participants of the control group were on the same level of Cognitive development before pre-test and after post-test. They were at the same level of Cognitive abilities as no Cognitive development treat was given to the control group. They were taught with the traditional method of teaching following lectures, activities, and presentations.

Table 3
Analysis of CTSR pre-test of the control group and experimental group

Type of test	**Group**	**N**	**Mean**	**df**	**t-value**	**p-value**
CTSR pre-test	Experimental	32	12.16	62	.594	.323
	Control	32	10.50			

P = 0.05

Table 3 shows the comparative analysis of the Classroom Test of Scientific Reasoning (CTSR) pre-test for the control group and experimental group. P-value (.323) and t-value (.594) analyzed that there is no significant difference between the CTSR pre-test mean scores of the experimental group and control group. Analysis shows that both the control group and experimental group were at the same level of understanding in the performance of the CTSR pre-test so the null hypothesis for the CTSR pre-test was failed to reject. Mean scores analysis for the CTSR pre-test depicts that prospective teachers from the experimental group (12.16) were able to perform better as compared to prospective teachers from the control group (10.50).

Table 4
Analysis of CTSR post-test of the control group and experimental group

Type of test	Group	N	Mean	df	t-value	p-value
CTSR post-test	Experimental	32	16.00	62	8.534	.000
	Control	32	10.50			

P = 0.05

Table 4.6 highlights the comparative analysis of the Classroom Test of Scientific Reasoning (CTSR) of post-test for the control group and experimental group. According to the p-value (.000) and t-value (8.534), it has been analyzed that there is a significant difference between the post-test performance of the control group and the experimental group. According to the analysis experimental group was much better in CTSR post-test performance than the control group. As the p-value (.000) is less than the level of significance (0.05) so null hypothesis for the CTSR post-test is rejected and a significant difference is found between both groups. Mean scores analysis of CTSR post-test shows that prospective teachers from the control group (10.50) were are at the same level of understanding as they were in the pre-test whereas prospective teachers from the experimental group (16.00) were at the higher level of understanding in CTSR post-test.

Table 5
Analysis of effect size of intervention on the experimental group

Type of test	Cohen's d value
CTSR	2.13

Table 5 presents the analysis for the effect size of intervention (experiment) on the reasoning abilities and pedagogical skills of the experimental group. Effect size value for CTSR (2.13) shows that there was a larger effect of the Cognitive Acceleration approach on the reasoning abilities of prospective teachers who participated in the intervention of the present study. Effect size is decided larger as CTSR value (2.13) is greater than (0.8) which is considered the larger effect size value of Cohen's d formula.

Table 6
Analysis of prospective teachers' perception about the experiment

S. No.	Statement	Mean value	Decision
1	I got motivation from this teaching style	4.28	Agreed at a high level
2	The course content was according to learning needs	4.75	Agreed at a high level
3	The course content was according to my expectations	4.12	Agreed at a high level
4	I have understood all the concepts from this teaching style	4.15	Agreed at a high level
5	A.V.Aids needed for this teaching style were available during the class	3.53	Agreed at a high level

6	I enjoyed all the learning activities during the class	4.18	Agreed at a high level
7	Learning activities were in accordance with the subject	4.75	Agreed at a high level
8	I had enough opportunities during the discussion to interact with my peers	4.12	Agreed at a high level
9	Proper guidance and support was provided during the assigned activities	4.68	Agreed at a high level
10	I got continuous feedback on each activity	3.84	Agreed at a moderate level
11	Enough opportunities were provided to ask the questions during the discussion	4.31	Agreed at a high level
12	I can apply the basic concepts of the subject in my daily life	4.09	Agreed at a high level
13	I had to work harder for this course as compared to other courses	3.96	Agreed at a moderate level
14	The teacher's guidelines for every activity and discussion were clear and understandable	4.71	Agreed at a high level
15	I got encouragement after studying this course	4.31	Agreed at a high level
16	I had support from my peers during the group activity	4.03	Agreed at a high level
17	The material provided for this course was up-to-date and understandable	4.71	Agreed at a high level
18	The support provided by the teacher was enough to understand the material of this course	4.53	Agreed at a high level
19	I preferred to work in group activity rather than individual activity	4.06	Agreed at a high level
20	Activities performed during this course enhanced my reasoning abilities	4.50	Agreed at a high level
21	When a topic was boring, the teacher made it interesting with examples and activities	4.25	Agreed at a high level
22	I had access to my teacher during the course whenever I needed	4.18	Agreed at a high level
23	Objectives, of course, were achieved during the course allocated time	4.12	Agreed at a high level

24	Assessment criteria for every task were communicated at the start of the course	4.43	Agreed at a high level
25	Assessment criteria were fair for every student	4.37	Agreed at a high level
26	I enjoyed every activity during the course	4.31	Agreed at a high level
27	I have learned a lot of new skills including reasoning skills	4.65	Agreed at a high level
28	I would prefer the Cognitive Acceleration teaching method for other courses as well	4.31	Agreed at a high level
29	I would like to use this teaching method during my teaching-learning process	4.46	Agreed at a high level
30	I have understood all the materials from this teaching style	4.54	Agreed at a high level

Table 4.11 presents the analysis of the mean scores of the experimental groups' perceptions about different activities of intervention (experiment). The decision for responses was taken according to three decision values decided by the researcher according to rating scale values.

1. 4.00 to 5.00 (Agreed at a high level)
2. 3.99 to 2.00 (Agreed at moderated level)
3. 1.99 and below (Agreed at the lower level)

Means scores analysis for perception statements shows that for the majority of the activities prospective teachers from the experimental group were agreed at the higher level as they were motivated by the Cognitive Acceleration teaching approach. The majority of the prospective teachers were able to understand all the concepts taught from the Cognitive Acceleration teaching approach and they were of the view that all necessary A.V.Aids needed for this teaching approach were available during the experiment. For statement 10 prospective teachers were of the view at a moderate level (3.84) that they get regular feedback about every activity performed during the experiment and for statement 13 they were also agreed at the moderate level (3.96) that it was not difficult for them to prepare this course with extra time or difficulty. For the rest of all statements prospective teachers were agreed at the high level which predicts that they were much satisfied with the Cognitive Acceleration teaching approach, all the activities performed during experiments, teaching method, A.V. Aids used during the experiment, and feedback provided on the activities performed during the experiment.

Discussion

The results of the present study indicate that the Cognitive Acceleration approach has a significant effect on the reasoning ability of students which are in line with the results of (Warburton & Torff, 2005; Magno, 2010; Martinez, 2006; Mousa, 2002; Mbano, 2003; Saleh, 2005; Gallagher, 2008; Mustafa; 2012). The present study also found significant means scores difference between post-test scores of the control group and experimental group for reasoning abilities which are supported by (Warburton & Torff, 2005; Magno, 2010; Martinez, 2006; Mousa, 2002; Mbano, 2003; Saleh, 2005; Gallagher, 2008; Mustafa; 2012).

Results of the present study inferred that prospective teachers from the experimental group have improved their thinking skills through Cognitive Acceleration lessons and rate Cognitive Acceleration approach as a mode of thinking critically within the classroom which are in line with the results of (Paul & Elder, 2005; Moon, 2008 and Paul, Elder & Bartell, 1997).

Findings of the study revealed that effective use of critical thinking activities has a significant effect on the Cognitive functioning of prospective teachers which are in agreement with (Okpala & Ellis, 2005; Amusan, 2014). So as a result of the present study higher education institutions can adopt the Cognitive Acceleration approach in their maximum classroom with effective critical thinking activities. Teachers' training or workshop sessions can be arranged to guide the teachers about effective use of critical thinking activities with good time-management skills.

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