The Effect of Cognitive Acceleration Programme on Critical Thinking of Science Students at Secondary Level

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Abstract

This study was conducted to determine the effect of Cognitive Acceleration Programme on the critical thinking skills of 9th graders. The posttest only non-equivalent control group design was used. Two sections of class 9th were selected conveniently for experimentation. There were 80 participants (girls) in the experiment. There were 30 intervention lessons in the experimental classrooms. The posttest was designed based on Cornell Critical thinking test. Test was validated by experts from the Faculty of Education, Allama Iqbal Open University Islamabad. The data were analyzed by the SPSS. The independent sample t-statistics were applied for control and experimental groups separately. The t-value for the comparison of performance of experimental and control group in sub-skills of critical thinking i.e., inference, deduction, assumption, interpretation, and argumentation showed significant difference. The results showed that critical thinking skills can be developed significantly through cognitive acceleration programme. So, the thinking science activities were recommended to science educators to incorporate into the classroom to accelerate critical thinking of students.

Keywords: *Cognitive Acceleration, Critical Thinking, Inference, Deduction, Assumption, Interpretation, Argumentation*

1. Introduction

Thinking is the ability related with cognition and it is the distinguishing feature between animals and human beings. Creation in any field is the result of using thinking in a good way. Critical thinking is the base of any new composition work. Thinking is helpful in creation of new ideas and arrangement of new ideas arises in human mind. Every human being in this world has different thinking capacity and this is a universal phenomenon. Thinking is the most prominent part of learning and, so, forms special part of the work ahead for students and their teachers. Thinking acceleration is

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neither the result of the maturation of the organism, nor of the influence of environment alone, but because of the interaction of the two. Interaction refers to the active relationship an organism has with the environment.

Critical thinking is integral to logical reasoning in a discipline and required to get advance knowledge. Although, critical thinking is not depended on context (Winch, 2006) and it a life-long learning skill. Halpern (2001) argued, "Critical thinking has been elaborated in political term, the ability necessary in response to the economic needs of students, national governments, and other stakeholders who argue with educational institute to develop such individuals who are helpful in developing the country economy successful". The purpose of critical thinking is to improve the thinking quality by developing the ability to evaluate one's own thinking in listening, reading, speaking, and writing (Paul & Elder, 2006). Meanwhile it is observed that critical thinking requires certain attributes such as fairness, humility, empathy, and integrity. These attributes make the critical thinker to apply suitable criteria (Pithers & Soden, 2000). Vygotsky argued that social interaction not only facilitates development but it also shapes and transforms the thinking of an individual and this work anticipated that a social construction of critical thinking (Shayer, 2003). The goal of science education is to foster critical thinking in students for example, the development of assumption skill in students, students can use logical and critical thinking and students can explain more than one alternative explanation of a problem. Students can test the reliability of knowledge they generate by research and critical abilities to analyze an argument by reviewing scientific understanding. Critical thinking is necessary element for learning of science. So, teacher can fulfill the demands of national standards through his/her teaching by achieving the high rate (Messenheimer & Packwood, 2002).

Cognitive Acceleration Programme is highly-researched intervention programme started in UK by Philip Adey and Micheal Shayer, funded by British Social Science Research Council (CASE I) and (CASE II) designed to check the working of this programme. The main aim of the Cognitive acceleration programme is the development of formal operational thinking of secondary level students. In a number of countries, the teaching of thinking is becoming an important part of curriculum documents and educational policy (Gallagher, Hipkins, & Zohar, 2012). This research and observations will be helpful to the present situation in Pakistan where, there is requirement of excellent practice with reference to the teaching of critical thinking because

most of the classrooms rarely implement activities designed to increase cognition in different ways that will enhance the students' critical thinking.

1.1 Statement of the Problem

Thinking is a process in which people are engaged when they are able to solve a problem or a challenging task. Quality learning produced when challenging problems are given to students, intrinsic motivation developed by curiosity and students give different solutions of a problem by experimentation and logical reasoning. A person's intellectual power increases as a result of critical thinking. In 21st century, educators want to see critical thinking in students as a result of their educational outcome. This study was focused to determine the effect of Cognitive acceleration programme on critical thinking of students' studying in District Sheikhupura, Pakistan.

1.2 Objective of the Study

The study was focused on the following objective;

1. To determine the effect of Cognitive Acceleration Programme on Critical Thinking of science students at 9th grade in Biology.

1.3 Research Hypotheses

H_{o1}: There is no significant difference in the level of Critical Thinking of experimental group taught through thinking science lessons and control group taught through usual classroom curriculum.

The relevant sub-hypotheses emerged from the main hypothesis are:

(a) Cognitive Acceleration Programme has no significant effect in enhancing students' skill to infer.

(b) Cognitive Acceleration Programme has no significant effect in enhancing students' skill to deduce from given information.

(c) Cognitive Acceleration Programme has no significant effect in enhancing students' skill to assume.

(d) Cognitive Acceleration Programme has no significant effect in enhancing students' skill to interpret information.

(e) Cognitive Acceleration Programme has no significant effect in enhancing students' skill of argumentation.

1.4 Significance of the Study

In today's modern age of information and technology, critical thinking skill is crucial for educated person to meet the challenges of rapidly progressing world. Traditional classroom instruction does not motivate and develop critical thinking skills in students. This study will add significant knowledge in the field of education. If the opportunity will be given to students of low socio-economic background, then Cognitive Acceleration

Programme can enhance their thinking abilities. Educators must implement this programme for development of critical thinking in students. The teachers will consider thinking as an important skill rather than any traditional skill. This study will be helpful for the students to produce critical thinking among them. The results of the study will help them to retain their interests and resulted in "better understanding" of concepts. The study will help encourage the students to make new inventions/ innovations in result of critical thinking. The results of the study will be beneficial to the high school science students who can think critically and can deal with difficult problems to find new solutions and ideas. The findings of the study will be utilized to guide the teachers to improve their methodology. The results of the study will be beneficial for training institutes of science teachers.

1.5 Delimitations

The study was delimited to 9th grade students in the subject of Biology in District Sheikhupura, Punjab, Pakistan.

2. Literature Review

Adey and Shayer (1990) conducted a study in UK to accelerate the development of formal thinking of students and find out that Cognitive Acceleration Programme develop the logical operational thinking of secondary level students. Similarly Adey, Roberston and Venville (2002) found out that Cognitive Acceleration Programme increased the thinking level of students. Iqbal and Shayer (2000) concluded that instructional interventions improve students' critical thinking skills and positively beneficial for learning. Hu et al (2011) did an experimental study in China and findings of the study indicate that Problem based learning promote critical thinking in students. Mbano (2003) in a study in secondary school in Malawi identifies that Cognitive Acceleration Programme give beneficial results in fostering the thinking of students. Gallagher (2009) conducted a study of Cognitive Acceleration Programme at primary level in an Irish school and the results showed that CASE programme increase the rate of cognitive development of primary level students. Shayer and Adey (2002) recommended to explore thinking skills through cognitive acceleration.

Many critical thinking researchers describe that critical thinking skills and abilities are teachable. Halpern (2001) gave evidence of two important instructional programs those have fostered the critical thinking skills of students at college level. In one research study, students were taught through general problem-solving skills improved on Piagetian-inspired measures of cognitive development. In another study, college students have been taught by a specific problem-solving strategy which produced in math

representation that is mostly liked by experts than new students. It has been found that instructional methods which are used to develop critical thinking of students have positive effect. In a meta-analysis of 117 practical studies, which are conducted to check the effect of instructional interventions on the development of critical thinking skills and dispositions of students, Gellin (2003) concluded that these interventions, generally, show positive impact, with a mean effect size of 0.34. However, effect sizes have homogenous impact, but it varies dramatically by changing the type of intervention and in change of sample and its characteristics. For example, the values of effect size for K-12 level students were higher than undergraduate students.

The work on Cognitive Acceleration Programme was first conducted by Adey and Shayer (1990) in UK to develop the logical operational thinking in students. Later on Adey, Roberston & Venville (2002) also conducted a research on this programme to enhance the thinking abilities of students. Mbano (2003) in his research study on Cognitive Acceleration Programme at secondary level students in Malawi conclude that this programme is beneficial in fostering thinking of students. Similarly, another study conducted in an Irish school at primary level by Gallagher (2009) and the result showed that CASE programme is very helpful cognitive development of students. The research on Cognitive Acceleration Programme was also conducted in Pakistan by Iqbal and Shayer (2000). The result of study indicate that this programme promote thinking and increase achievement level of students at secondary level.

Gallagher (2009) negatively pointed out that such kind of thinking projects never changes the teaching and learning process. As concluded by Ku (2009) in China shows that Problem based learning foster the critical thinking of students in medical discipline. In view of Kang, Scharmann, and Noh (2004) the cognitive conflict significantly affect the logical thinking abilities of students. Magno (2010) pointed out that meta-cognitive skills and strategies positively influence the critical thinking skills of students. Hu et al. (2011) argue in their study that learn to think programme positively impact the thinking abilities of students and level of achievement. In a study conducted by Belluigi and Cundill (2017) in South Africa, reported that students' involvement in spiraling activities which is base for development of diversity in the classroom, students draw different solutions of a problem according to their personality, background knowledge and discipline. Such types of activities develop competencies in students that are required for fostering the critical thinking in students. These competencies cannot be developed through traditional teaching methods and models. Another study

conducted by Whiley et al. (2017) concluded that the use of threshold concepts and well-organized collaborative learning activities in the class is a key factor in enhancing the critical thinking of students. The pedagogical approaches use for these activities must be given by trained teachers than these will give beneficial results.

Hu et al (2011) pointed out that critical thinking is a set of measureable, tangibles, and transferrable skills. In his paper he explores that how students question answer by practicing the complex knowledge in which critical thinking are included. Critical thinking is a complex phenomenon of affective practices and socio-material. Dominguez et al. (2015) argued that online peer review activities enhance the students' critical thinking skills if delivered by professionally trained teachers. This methodology works if teachers constantly monitor the activity and students give proper feedback. According to FitzPatrick and Schulz (2015) the critical thinking of students increases if the outcomes of daily routine are strongly aligned with classroom assessment. The assessment is designed on the base of higher-level thinking skills which give opportunity to students to think critically and learn effectively.

Two studies which in opponent view of this programme were, one study conducted by Gallagher et al. (2002) pointed out that such kind of thinking projects like Cognitive Acceleration Programme never change the teaching and learning process. Iqbal and Shayer (2000) pointed out in their study that in several circumstances teacher's knowledge and expression are not reflected in their teaching practice so cannot initiate thinking among students.

There is no significant study conducted in Pakistan regarding the Cognitive Acceleration Programme and no study in literature to find the effect of Cognitive Acceleration Programme on Critical Thinking of students. So, this study was designed to investigate the effect of Cognitive Acceleration Programme on the Critical Thinking of students at secondary level.

3. Research Methodology

3.1 Research Design

The Quasi Experimental, post-test only Non Equivalent Control Group design was used. Two sections were selected conveniently from the school mentioned ahead. They were not randomized on the basis of their previous class results or abilities. It was assumed that Pakistani students are critical thinkers of same ability. They were selected from Govt. M. C Model Girls High School Akbar Bazar Sheikhupura. Experimental group was taught

by principal researcher by delivering Thinking science lessons while the control group was taught by the concerned teacher. These lessons were adopted from an organization in UK namely "Let's Think" and were implemented as an intervention to Pakistani students in a high school of District Sheikhupura. Threats to internal and external validity were undertaken properly.

3.2 Population of Study

The population of the study was the students of 9th class of the Govt. schools of Punjab on which the results of the study are generalizable. Due to applying inferential statistics, the results drawn from sample might be generalized on population.

3.3 Sample of Study

The total number of the participants involved in the experiment were 80 girls. Two sections were selected from Govt. M.C Model Girls High School Akbar Bazar Sheikhupura. 40 Participants were in experimental group and 40 in control group. The technique used for the selection of the sample was "convenient sampling". The groups were selected as they were made by the school. The criteria of convenience had been thus:

(a) Permission of the school principal for experimentation.
(b) Willingness of the class teachers.
(c) Willingness of the students for participation in experiment.

3.4 Instrument

The instrument used for data collection was the Critical Thinking Test which was designed on the basis of standardized Cornel Critical Thinking Test. It was developed by the researchers, validated from the experts in Faculty of Education in Allama Iqbal Open University Islamabad. The experts suggested minor amendments. After the incorporation of these minor amendments, the Critical Thinking Test was pilot tested on a similar group of 9th graders. The data obtained were analysed by using SPSS. Reliability analysis had been done. The value of Cronbach's Alpha was 0.695. Then it was used as posttest after the intervention.

4. Data Analysis and Interpretation

The data were analyzed through SPSS software by using t-statistics.

The comparison of difference in mean scores of control and experimental groups is shown in Table 4.1

Table 4.1
Overall Comparison of Post-test Scores of Control and Experimental Groups of Critical Thinking Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	Df	t-value	Sig. (2-tailed)
Experimental	40	33.325	10.3	5.73513	78	8.666	0.000***
Control	40	23.025		4.85950			

$p<0.05$

The overall results show that the average scores in the post-test of experimental group was 33.325 and for control group was 23.025. So, the difference between average scores of experimental and control group was 10.3 as generated by SPSS. The t-value was calculated as 8.666 significant at ($p<0.005$) 0.000 significance level.

Table 4.2
Overall Comparison of Post-test scores of Control and Experimental Groups of Inference Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	df	t-value	Sig. (2-tailed)
Experimental	40	6.025	2.6	1.04973	78	9.05	0.000
Control	40	3.425		1.48302			

$p<0.05$

The table 4.2 shows that the control group secured an average score of 3.425 in the Inference skills (item# 7, 11, 17, 18, 30, 34, 35, 41, 42) in the posttest and for experimental group it was 6.025 in the same. The difference in mean scores was 2.6 in the average scores of experimental and control groups. The t-value was calculated as 9.050 significant at ($p<0.05$) significance level 0.000.

Table 4.3
Overall Comparison of Post-test scores of Control and Experimental Groups of Deduction Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	df	t-value	Sig. (2-tailed)
Experimental	40	8.550	2.625	2.58149	78	5.259	0.000
Control	40	5.925		1.81712			

$p<0.05$

The table 4.3 shows that the control group secured an average score of 5.925 in the Deduction skills (item# 3, 4, 8, 12, 19, 22, 23, 28, 29, 31, 37, 48) in the posttest and for experimental group it was 8.550 in the same. The difference in mean scores was 2.625 in the average scores of experimental and control groups. The t-value was calculated as 5.259 significant at ($p<0.05$) significance level 0.000.

Table 4.4
Overall Comparison of Post-test scores of Control and Experimental Groups of Assumption Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	df	t-value	Sig. (2-tailed)
Experimental	40	10.700	3.675	2.22111	78	7.902	0.000
Control	40	7.025		1.92803			

$p<0.05$

The table 4.4 shows that the control group secured an average score of 7.025 in the Assumption skills (item# 1, 9, 10, 13, 14, 16, 21, 25, 32, 39, 40, 45, 46, 47) in the posttest and for experimental group it was 10.700 in the same. The difference in mean scores was 3.675 in the average scores of experimental and control groups. The t-value was calculated as 7.902 significant at ($p<0.05$) significance level 0.000.

Table 4.5
Overall Comparison of Post-test scores of Control and Experimental Groups of Interpretation Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	df	t-value	Sig. (2-tailed)
Experimental	40	3.80	0.45	1.28502	78	1.484	0.142
Control	40	3.35		1.42415			

$p<0.05$

The table 4.5 shows that the control group secured an average score of 3.35 in the Interpretation skills (item# 2, 5, 6, 15, 24, 36, 38, 50) in the posttest and for experimental group it was 3.80 in the same. The difference in mean scores was 0.45 in the average scores of experimental and control groups. The t-value was calculated as 1.484 significant at ($p<0.05$) significance level 0.142.

Table 4.6
Overall Comparison of Post-test scores of Control and Experimental Groups of Argumentation Skills

Group	N	Post-test Mean	Mean Difference	St. Dev. (post-test)	df	t-value	Sig. (2-tailed)
Experimental	40	4.90	1.25	1.41058	78	3.335	0.000
Control	40	3.65		1.57789			

$p<0.05$

The table 4.6 shows that the control group secured an average score of 3.65 in the Argumentation skills (item# 20, 26, 27, 33, 43, 44, 49) in the posttest and for experimental group it was 4.90 in the same. The difference in mean scores was 1.25 in the average scores of experimental and control groups. The t-value was calculated as 3.335 significant at ($p<0.05$) significance level 0.000.

The findings of the study are summarized as:

1. Experimental group show overall significant difference is the critical thinking skills than control group.
2. Experimental group has mean difference of 2.6 than control group in Inference skill. This value shows that there is statistically significant difference in the level of Inference skill of experimental group.

3. Experimental group has mean difference of 2.625 in Deduction skill than control group. This value shows that there is statistically significant difference in the Deduction skill of experimental group than control group.
4. The mean difference in posttest for Assumption skill was 3.675. This value shows that there is significant difference in Assumption skill of experimental group.
5. The difference in mean of both groups in posttest was 0.45. This value shows that there is minor difference in the Interpretation skill of experimental group than control group.
6. The difference in mean score value was 1.25. This value shows that there is significant difference in Argumentation skill of experimental group.

5. Discussion and Conclusion

The study was designed to investigate the effect of Cognitive Acceleration Programme on the Critical Thinking of students at secondary level. The results of the study showed that Cognitive Acceleration Programme has a significant effect in increasing the Higher-Order thinking abilities of students. The results of the post test of both groups show that there is a significant difference in mean score of experimental group. The gain in mean score of experimental group in Inference, Deduction, Assumption, Interpretation, and Argumentation skill was 6.02, 8.55, 10.70, 3.80, and 4.90 respectively. The overall gain in mean score of experimental group is 10.3 than control group. The experimental group improved significantly in different critical thinking skills like Inference, Deduction, Assumption, Interpretation, and Argumentation after the implementation of intervention Thinking Science lessons. The results of the study are similar to the findings, conclusions, and overall results of the researches quoted in the references' list as well. The results are similar like Halpern (2001), Gellin (2003), Adey and Shayer (1990), Adey, Roberston and Venville (2002), Kennedy, Fisher and Ennis (1991), and Hu et al (2011) found in their researches. Mbano (2003) and Gallagher (2009) got the similar findings on cognitive development of school level students.

The following conclusions were made from the findings;

1. The overall critical thinking skill of the girls can be improved significantly through Cognitive Acceleration Programme, studying at Pakistani public sector secondary schools.
2. The Inference skill can be developed significantly through the thinking science lessons as compared to the traditional methodology.
3. The Deduction skill can be developed significantly though the thinking science lessons as compared to the traditional methodology.

4. The Assumption skill can be developed significantly through the thinking science lessons as compared to the traditional methodology.
5. The Interpretation skill can be developed significantly through the thinking science lessons as compared to the traditional methodology.
6. The Argumentation skill can be developed significantly through the thinking science lessons as compared to the traditional methodology.

6. Recommendations

On the basis of the findings and conclusions of the study, the following recommendations are suggested:

1. Cognitive Acceleration Programme effectiveness may be investigated regarding critical thinking in the subject of Chemistry Practical at secondary level and other science subjects as well as their practicals at various levels.
2. Cognitive Acceleration Programme effectiveness may be researched regarding interest, motivation and other psychological attributes related to critical thinking of the high school Chemistry students.
3. Cognitive Acceleration Programme is effective in enhancing the cognitive skills of students so it is recommended to be included in the middle, secondary, and higher secondary level curriculum to foster the thinking skills of students which has lifelong learning effect on them.

References

Adey, P., Robertson, A., & Venville, G. (2002). Effects of a Cognitive Acceleration Programme on Year I pupils. *British Journal of Educational Psychology*, *72*(1), 1-25.

Adey, P., & Shayer, M. (1990).Accelerating the development of formal thinking in middle and high school students. *Journal of Research in Science Teaching, 27*(3), 267–285.

Belluigi, D. Z., & Cundill, G. (2017). Establishing enabling conditions to develop critical Thinking skills: a case of innovative curriculum design in Environmental Science. *Environmental Education Research*, *23*(7), 950-971.

Dominguez, C., Nascimento, M. M., Payan-Carreira, R., Cruz, G., Silva, H., Lopes, J., & Morais, E. (2015). Adding value to the learning process by online peer review activities: towards the elaboration of a methodology to promote critical thinking in future

engineers. *European Journal of Engineering Education*, *40*(5), 573-591.

FitzPatrick, B., & Schulz, H. (2015). Do curriculum outcomes and assessment activities in science encourage higher order thinking? *Canadian Journal of Science, Mathematics and Technology Education*, *15*(2), 136-154.

Gallagher, C., Hipkins, R., & Zohar, A. (2012). Positioning thinking within national curriculum and assessment systems: Perspectives from Israel, New Zealand and Northern Ireland. *Thinking Skills and Creativity, 7*(2), 134–143.

Gellin, A. (2003). The effect of undergraduate student involvement on critical thinking: A meta-analysis of the literature 1991–2000. *Journal of College Student Development, 44*(6), 746–762.

Hu, W., Adey, P., Jia, X., Liu, J., Zhang, L., Li, J. & Dong, X. (2011). Effects of a 'Learn to Think' intervention programme on primary school students. *British Journal of Educational Psychology, 81*(4), 531–557.

Halpern, D. F. (2001) Assessing the effectiveness of critical thinking instruction. *The Journal of General Education, 50*(4), 270–286.

Iqbal, H. M., & Shayer, M. (2000). Accelerating the development of formal thinking in Pakistan secondary school students: Achievement effects and professional development issues. *Journal of research in science teaching*, *37*(3), 259-274.

Kang, S., Scharmann, L. C., & Noh, T. (2004). Reexamining the role of cognitive conflict in science concept learning. *Research in Science Education*, *34(1)*, 71–96.

Ku, K. Y. (2009). Assessing students' critical thinking performance: Urging for measurements using multi-response format. *Thinking Skills and Creativity, 4*(1), 70–76.

Magno, C. (2010). The role of metacognitive skills in developing critical thinking. *Metacognition and Learning*, *5*(2), 137-156.

Mbano, N. (2003). The effects of a cognitive acceleration intervention programme on the Performance of secondary school pupils in Malawi. *International Journal of Science Education*, *25*(1), 71-87.

Messenheimer, T., & Packwood, A. (2002). Writing: the state of the state vs. the state of the art in English and American schools. *Literacy*, *36*(1), 11-15.

Paul, R. W., & Elder, L. (2006). Critical thinking: The nature of critical and creative thought. *Journal of Developmental Education, 30*(2), 34–35.

Pithers, R. T., & Soden, R. (2000). Critical thinking in education: A review. *Educational Research, 42*(3-4), 237–249.

Shayer, M.(2003). Not just Piaget, not just Vygotsky, and certainly not Vygotsky as an alternative to Piaget. *Learning and Instruction, 13*(5), 465–485.

Shayer, M., & Adey, P. (2002). *Learning intelligence: Cognitive acceleration across the curriculum from 5 to 15 years*. Buckingham, UK: Open University Press.

Whiley, D., Witt, B., Colvin, R. M., Sapiains Arrue, R., & Kotir, J. (2017). Enhancing critical thinking skills in first year environmental management students: a tale of curriculum design, application and reflection. *Journal of Geography in Higher Education*, *41*(2), 166-181.

Winch, C. (2006). *Education, Autonomy and Critical Thinking.* Abingdon, Oxford: Routledge.

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