EFFECTIVENESS OF PROJECT BASED-LEARNING IN ENHANCING CRITICAL THINKING SKILLS OF STUDENTS IN ELEMENTARY SCHOOLS

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Abstract

The study carried out is referred to as the effectiveness of project based-learning in enhancing critical thinking skills of students in elementary schools. This study was conducted at a Government Girls Elementary School in Lahore, focusing on Grade VIII Science students during the academic session 2022–2023. The research design was experimental, employing a pre-test and post-test control group design, where experimental and control groups were used. The school selected for the research was a Government Girls Elementary School in Lahore. It comprised 50 Grade VIII students who were enrolled in the 2022-2023session. All 50 students were administered a pre-test, after which they were divided into two equal groups of 25 students each. Ability matching was conducted to ensure that the experimental and control groups were similar in terms of their pre-test performance. Two research tools, namely a pre-test and a post-test, were used to collect data. The two instruments were based on the Grade VIII Science textbook provided by the Punjab Textbook Board. Each test carried 96 marks and was designed to assess four cognitive domains. Mean scores, standard deviations, t-values, and p-values were used as statistical methods. The findings revealed that post-test scores differed significantly between students who learned through Project-Based Learning (PBL) and those who learned through traditional teaching strategies at the elementary science level. The experimental group scored higher than the control group, indicating that the PBL approach was effective. In addition, significant differences were observed across different domains of critical thinking. Students who experienced Project-Based Learning showed significant improvement in the application domain, reflecting an enhanced ability to apply knowledge. It is recommended that science teachers be provided with well-designed science kits containing materials required for classroom activities.

INTRODUCTION

Many students struggle because their critical thinking skills are not well developed. These skills belong to higher-order thinking and go beyond simple memorization. These skills equip students with the ability to analyze concepts, draw useful inferences, and apply their knowledge in practical situations. One such life skill that is used by institutions across the globe is computational thinking, and this skill should be developed in children.

These competencies will ensure that students are competent in handling complex and dynamic issues in contemporary society. Critical thinking allows people to see information critically and connect it to their lives in an effective way; it is a higher-order cognitive skill that is significant in making informed decisions in daily life as well as in the workplace (Chaojing, 2021). Along the same vein, critical thinking is also discussed as a rational and cautious method of thinking that allows reasoning, observation, reaching conclusions, and effective communication, which can help individuals make evidence-based beliefs and actions. It also enhances self-management, accuracy, and good judgment, which help learners make fair decisions without being partial. Moreover, critical thinking should be trained through cognitive and metacognitive exercises. Students who are adept at CT find it easier to examine questions, generate and test hypotheses, and make rational decisions based on facts. It has been suggested that critical thinking is one of the key elements of success in the modern era. It not only enhances academic learning but also develops students by providing them with work-related skills and personal qualities that they should possess to be successful in a career (Cottrell, 2021).

Although there is a plethora of literature discussing the need to encourage adolescents and young adults to develop critical thinking, several teachers face problems in implementing it in their curriculum. Current learners are required to improve their learning capacities to address contemporary demands in the global landscape. To do so, there is a need to develop strategies that contribute to the integration of relevant skills into the learning process.

One of such strategies is Project-Based Learning (PBL), which has been particularly useful in expanding the knowledge base of students and building different forms of cognition (Williamson, 2021). This is because PBL is a student-centered and evidence-based learning model which engages learners in practical real-life projects, enabling them to gain knowledge and develop CT. However, in reality, not all practices can be implemented in the conventional classroom context because of many challenges, including project design and project management issues, and the absence of institutional, financial, and pedagogical support. Consequently, the introduction of PBL is either not implemented or implemented in a non-optimal way, and this limits the potential value of the tool as an instrument of educating students (Rizal, 2021).

PBL has become one of the most widespread approaches to teaching, which does not lead to the replication of the traditional education system, which is typically built on a monotonous routine that does not allow students to be creative or exchange ideas with each other. In the conventional classroom, students are passive attendees of lectures, making notes, completing homework, and preparing for exams and tests, and they interact less or not at all. Such a way of teaching deters motivation and competition among students and results in a boring learning environment. Therefore, PBL implementation becomes an important aspect to ensure that students are motivated, curious, inquiring, independent, and positively disposed toward learning. Since it is a constructivist model of instruction, PBL is already a proven effective way of teaching science. It is also one of the reasons why it is believed that students should construct and shape new knowledge through participation, and not memorization (Meng, 2021).

These measures will eliminate myths and assist in efficient learning, as highlighted by researchers. PBL is one of the most widespread strategies that are adopted in science classes. PBL has a positive aspect, as collaboration implies that learners are divided into groups and they brainstorm on issues, share ideas, and reflect on the learning process. Such a model will encourage students to work collectively on their projects and, therefore, use critical thinking skills, problem-solving skills, and collaboration skills in addition to reflecting on their own learning (Moustafa, 2020).

In PBL, students can use what they have learned in real life, hence simplifying the learning process and also acquiring the necessary skills that are necessary in the current world. This is founded on the constructivist philosophy of learning, in which individuals learn well when they are involved in experiences and activities. One of the strengths that PBL also possesses is the fact that it develops critical thinking among students.

Critical thinking refers to a set of skills that relates to the study of information, evidence analysis, and conclusion-making based on sound reasoning. PBL exposes students to open and complex problems whereby they must think deeply about the content and processes. These projects require learners to demonstrate assumptions, think differently, and develop new ideas that could solve issues. The connection between PBL and critical thinking is also validated by the fact that its approach is grounded in inquiry-based learning. In PBL, students are active as they get to formulate questions, investigate alternative answers, and test solutions to actual problems. This approach is closely linked to the principles of critical thinking that require close attention to information, its interpretation, and evaluation. This means that the inquiry process can enable students to acquire more knowledge and increase their critical thinking ability in the long term (Cottrell, 2021).

PBL is a sound teaching and learning process which engages students in real-world problems and challenges. It is a series of complicated and disorganized roles that include investigational, decision-making, and problem-solving actions with critical interaction and innovativeness. Students, through such projects, are able to design problem-solving solutions and assess their progress. PBL enables learners to acquire skills that may enable them to succeed in the globalized world. Academic knowledge becomes better, and readiness in the field of study, employment, and life in general is enhanced through active participation in project-based activities (Naseer, 2022).

The primary purpose of this study is to assess the impact of PBL on the critical thinking skills of young learners. PBL plays an important role in this process, as it enhances students' ability to analyze situations and solve problems effectively. Such a mode of learning provides students with real-life issues which are usually complex and do not have straightforward solutions. In dealing with such problems, students have to grapple with uncertainty, seek useful information, and devise effective solutions. The PBL model allows students to test their ideas, encounter issues, and develop solutions, making them more persistent and flexible, which are good qualities of a critical thinker. Another significant element of PBL is collaboration (Orhan, 2021).

Students also work in groups, allowing them to share their ideas, discuss different viewpoints, and solve problems together. Students are required to justify their thoughts, contrast different opinions, and discuss issues effectively through group work. This type of cooperation shows that critical thinking is not something done individually, but it is also developed through interaction with other people. Generally speaking, the use of PBL in education is an efficient approach to developing students' critical thinking skills. PBL encourages the utilization of learned information, its analysis, and correlation as compared to memorization. The proposal will help the educator to achieve the desired goals as they coincide with the major purposes of developing critical thinking, namely to think independently and critically. Students' critical thinking skills can be developed because of their active participation in the learning process and creating new knowledge.

At the same time, the use of PBL techniques contributes to developing critical thinking due to evaluation techniques. Indeed, the methods of PBL promote the ability of learners to implement acquired knowledge, interpret facts, and offer solutions to problems as opposed to traditional evaluation techniques, which require memorization of knowledge (Fisher, 2011). Real-world assessment activities simulate real-life situations and not only test critical thinking ability but also make learning relevant and practical. Although PBL has strong potential in enhancing critical thinking, its implementation should be presented in detail and supported adequately for teachers and students. The success of PBL depends on continuous improvement of skills, availability of relevant resources, and a positive institutional culture. It should be supported by a learning environment that is conducive to critical thinking through PBL, along with continuous reflection, adaptation, and commitment to student-centered and inquiry-based teaching approaches (Baser, 2017).

To conclude, it would be appropriate to note that PBL is quite a promising method that can help students acquire critical thinking skills. As PBL relies on posing questions, answering them, solving problems, collaborating, and conducting evaluation in real life, it provides opportunities for implementing all the concepts of critical thinking.

PBL will be implemented in the classroom to help students study their subjects in an effective manner, not to mention providing them with the mental capabilities to cope with the demands of modern society.

Recent studies show clear differences in how well high school students develop critical thinking skills. Many learners do not reach the expected level, and this concern continues across the education system. Such an observation proves that it is necessary to develop more effective strategies that could ensure the development of critical thinking among high school students.

One such method that has attracted significant attention from researchers as well as teachers is PBL. PBL is seen as an effective way of attaining educational goals. It is an approach in which students are involved in real-life projects where they are expected to research intricate issues, collaborate, and apply what they have learned in practice. PBL enables students to understand the information provided at schools not only due to solving problems in connection with their real lives but also by acquiring various desirable qualities including critical thinking, creativity, communication, and problem-solving. Though PBL has gained considerable attention, very few studies are currently available about how far this methodology can help students obtain critical thinking skills in high schools. Even though the advantages of PBL have been identified before, most researches cannot provide sufficient proof of the significance of PBL in developing critical thinking skills in high schools. Furthermore, although there are some studies concerning the roles that PBL plays in fostering or hindering the development of critical thinking among this age category, they do not cover enough aspects to give a complete picture. Therefore, this study will probably help to understand the roles that PBL plays in fostering critical thinking skills among students. Even though some studies have analyzed the theory behind project-based learning (PBL) and its possible benefits, there is insufficient empirical evidence about its contribution to improving critical thinking skills among students. To overcome this gap, the current research entitled "Effectiveness of PBL in Enhancing Critical Thinking Skills of Students in Elementary Schools" was carried out.

This study seeks to assess the impact of Project-Based Learning (PBL) on students' science learning results at the elementary level. It also investigates how PBL facilitates the development of critical thinking skills among students at elementary schools.

Research Hypothesis

H0: There is no significant difference in the performance of students taught through Project-Based Learning (PBL) and those taught through traditional teaching methods with regard to critical thinking at the elementary level.

Research Design

A research design gives the procedures that are followed in data collection, the tools that are employed, and the data analysis procedures. This is done by providing a clear definition of these aspects, which ensures that an adequate research design leads to a minimal amount of redundant information being gathered, reduces the likelihood of extraneous errors, and ensures that the research is conducted in an efficient and systematic fashion. The research design implemented in the study was an experimental research design, specifically a pre-test and post-test design with a control group and an experimental group.

Sampling

A sample is a smaller section that is used in studying the entire population. This group is selected in such a way that it portrays the same features as the population. It is simply a part of the whole group, which is researched in detail (Sekaran, 2003). To choose the sample, 50 Grade 8 students of the Government Girls Elementary School, Lahore, were given a test. The test results identified 50 students who were selected as the sample. These students were divided into two groups of 25 students each. One group was the control group, and the other was the experimental group. The matching of students was done based on their test scores to ensure that the two groups were homogeneous.

Investigation Subject Matter

The data collection tools used for meeting the objectives of the study were developed in the form of the pre-test and post-test. The development of both these tests was based on the Science textbook of Grade 8 according to the Punjab Textbook Board.

Pre-test

The Punjab Textbook Board Grade 8 Science textbook was adopted to develop a pre-test, which had 96 marks. The test was a multiple-choice question (MCQ) test that included 96 questions.

Post-test

The same textbook was used to develop a post-test of 96 marks, which consisted of 96 MCQs.

Research Instruments

The research instruments had to undergo validation procedures. The validation process for the research instruments, i.e., pre-test and post-test, was done by asking 10 science teachers about their opinions on these instruments. Improvements were made whenever necessary on the basis of their opinions. This piloting process was done on 10 non-sample students. These instruments were modified based on the results obtained from this pilot study, especially on the difficulty level of items.

Variables of the Study

Independent Variable: Teaching instruction (applicability of project-based teaching)

Dependent Variable: Scores of the post-test

Controlled Variables: Teacher, time taught, gender of students, classroom, content of course, and grade, including:

Section 1.1 through to 1.4 and revision exercise: Ecology

Human nervous system (Sections 2.1 to 2.2 and revision exercise)

Force and pressure (Sections 8.1 to 8.6 and revision exercise)

Technology in everyday life (Sections 11.1 to 11.6 and revision exercise)

Uncontrollable Variables: The intelligence level of the students, their past academic performance, interests, as well as their attitudes.

Data Collection Process

The pre-test and post-test were developed based on certain sections of the Grade VII science curriculum, such as ecology (Sections 1.1 to 1.4 and revision exercises), the human nervous system (Sections 2.1 to 2.2 and revision exercises), force and pressure (Sections 8.1 to 8.6 and revision exercises), and technology in everyday life (Sections 11.1 to 11.6). The test consisted of 96 marks and covered four cognitive areas, namely application, analysis, evaluation, and creativity. Both pre-test and post-test comprised the same type of questions from similar subject areas, in an attempt to measure the efficiency of using PBL. Both tests consisted of 96 multiple choice questions. The two tests were similar in terms of the number of questions posed for each cognitive skill. The questions progressed from simple to complex and concrete forms to facilitate student learning. Students were ranked based on their pre-test scores from highest to lowest and then separated into two groups, one experimental and the other control group.

The process of learning started with the pre-test that was administered before instruction was started. The experiment involved studying similar science topics for two months for both groups, whereby they were taught in class for 40 minutes each day. The method used in the experimental group was the PBL method whereas traditional teaching was used in the control group. The activities employed included brainstorming, drawing visual charts, mind maps, tracing, exploration, analysis, evaluation, application, and creativity activities. Additional activities included physical demonstrations, group contests, worksheets, and paper-based activities. Students were also provided with opportunities for group work, whereby they read real-life problems, created solutions, and presented their results in the form of projects, models, experiments, or reports.

Students studying the ecology chapter visited places such as parks, school gardens, or open spaces to distinguish between producers, consumers, and decomposers. They drew charts, recycled materials, and conducted experiments to observe environmental changes, thereby creating mini ecosystem models and enhancing critical thinking by analyzing relationships and predicting outcomes.

In the chapter on the human nervous system, students were required to complete a project named “How the Brain Controls Our World.” They created models of the brain and spinal cord using clay or cardboard, analyzed case studies of nervous system issues, and developed logical thinking by connecting structure and function.

In the chapter on force and pressure, the project titled “Forces at Work Around Us” and “How Do Force and Pressure Affect Motion and Daily Life?” was conducted. Pulleys and levers, balloons, syringes, and sponges were used in experiments. Students explored pressure concepts, such as why sharp knives cut with less effort and why camels have large feet, and created posters to explain the relationship between force, pressure, and daily life.

In the “Technology in Everyday Life” chapter, the project titled “How Does Technology Affect Our Daily Life, Health, and Environment?” was conducted. Students discussed daily technology use, created timelines of technological development, debated whether technology makes people smarter or more dependent, and proposed green solutions to real-life problems, thereby enhancing critical thinking.

In conclusion of the two months' teaching activity, a post test was administered. The effectiveness of the teaching activity was assessed using the post test, where the questions were set according to four levels of cognition.

Table 1 Table of Specification for 96 items Pre-test

Units	Application	Analysis	Evaluation	Creativity	Total
Ecology	6	6	6	6	24
Human nervous system	6	6	6	6	24
Force and pressure	6	6	6	6	24
Technology in everyday life	6	6	6	6	24
Total	24	24	24	24	96
Total %	25	25	25	25	100

Table 2 Table of Specification for 96 items Post-test

Units	Application	Analysis	Evaluation	Creativity	Total
Ecology	6	6	6	6	24
Human nervous system	6	6	6	6	24
Force and Pressure	6	6	6	6	24

Technology in everyday life	6	6	6	6	24
Total	24	24	24	24	96
Total %	25	25	25	25	100

Data Analysis

The major idea that formed the essence of the above-mentioned research was the comparison and contrast between PBL in relation to the cultivation of critical thinking skills among students of elementary schools.In order to fulfill this task, a schedule of learning activities based on the material of Grade 8 Science was developed and implemented in the school. The pre-test among the students who formed part of the study was conducted to assess their level of critical thinking at the stage where they had already acquired some knowledge. Based on the above-mentioned assumption, the subjects were subdivided into an experimental and control group, where the experimental group received instruction via PBL, while the latter group received teacher-centered instruction. Both groups were administered a post-test in order to measure the effectiveness of the instructions applied, along with assessing their learning achievements. The results were analyzed based on the application of descriptive statistics. Moreover, paired sample t-tests were performed as well. Statistical tests were carried out based on the calculation of means, standard deviations, t-values, and p-values. Furthermore, the research data were segmented into various domains of critical thinking to provide a detailed analysis of students' performance in relation to specific cognitive skills. The chapter presents the statistical procedures and reports the results in table format.

Comparison of Performance of Pre-Test of Both Groups

Table 3 Comparison of Students' Performance of Pre-Test of Both Groups

Area/Domains	Group	N	Mean	SD	df	t-value	p-value (0.05)
Application	Control	25	9.24	2.403	48	-.457	.650 < 2.00
	Experimental	25	9.56	2.551			
Analysis	Control	25	9.40	2.398	48	.691	.493 < 2.00
	Experimental	25	8.96	2.091			
Evaluation	Control	25	9.44	2.501	48	-.238	.813 < 2.00
	Experimental	25	9.60	2.236			
Creativity	Control	25	7.52	1.358	48	-1.148	.253 < 2.00
	Experimental	25	8.04	1.814			
Pre-test total	Control	25	35.80	4.282	48	-1.490	.143 < 2.00
Critical Thinking	Experimental	25	37.40	3.240			

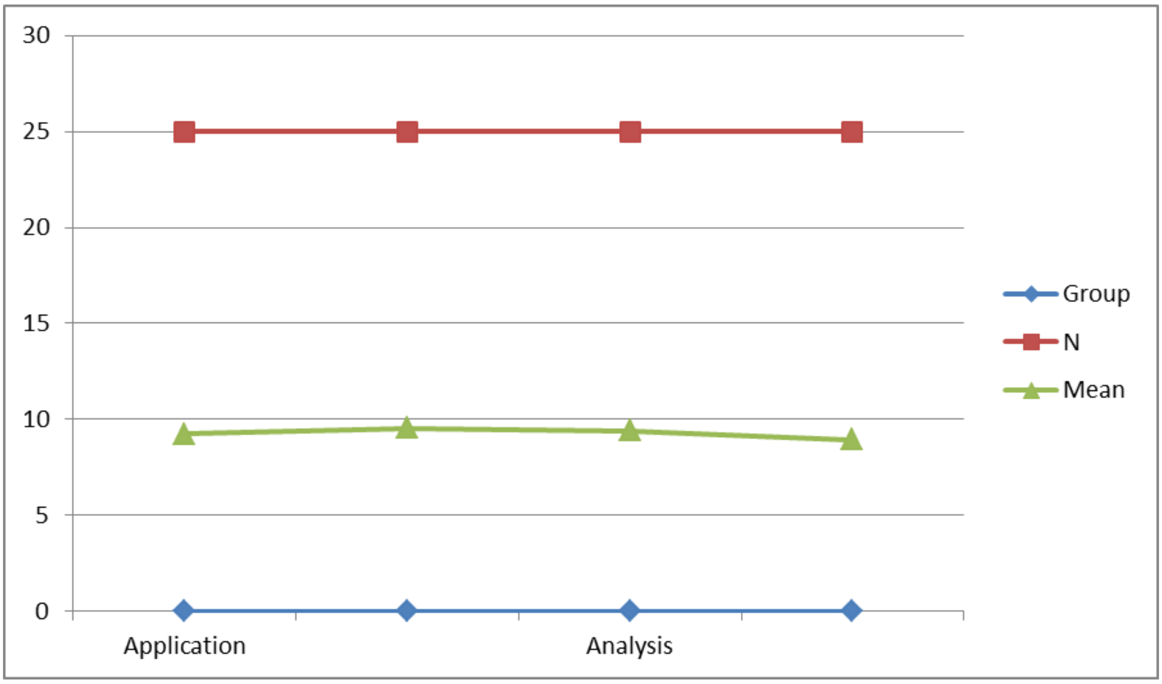
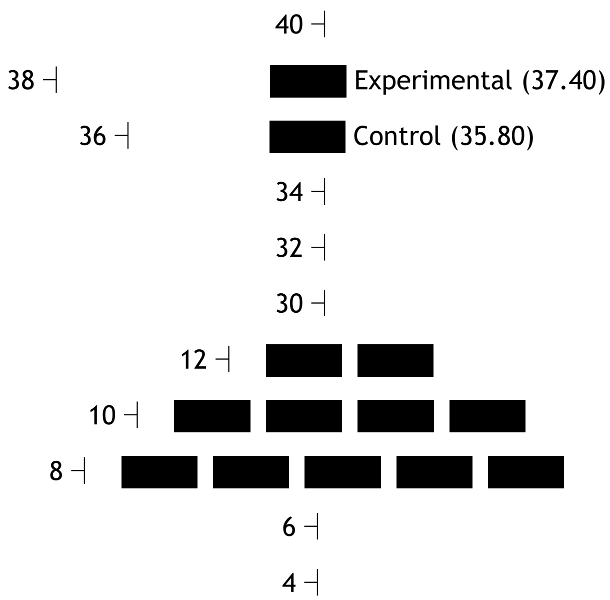


Table 3 shows the comparison between the critical thinking ability levels of the research participants in the experimental and control groups prior to treatment. The comparison was made using a degree of freedom of 48. At a level of significance of 0.05, it was found that the calculated t-values for all critical thinking areas were below the critical value of 2.00. To be more precise, the t-value (domain of application) was -0.457, and the t-value (domain of analysis) was 0.691. Similarly, the t-values for the domains of evaluation and creativity were -0.238 and -1.148, respectively. The outcome achieved provided a t-value of -1.490 in the case of overall critical analysis abilities, which was also insignificant. These results imply that no significant differences were found at the stage of the pre-test. Therefore, it was concluded that the level of critical thinking among the two groups was similar and relatively low prior to the intervention, and this provided an appropriate baseline from which the effects of the instructional treatment could be measured.

Figure: Pre-Test Mean Scores of Controls and Experimental Groups

Mean Score



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App. Ana. Eval. Creat. Total

Control Group
Application = 9.24
Analysis = 9.40
Evaluation = 9.44
Creativity = 7.52
Total CT = 35.80

Experimental Group
Application = 9.56
Analysis = 8.96
Evaluation = 9.60
Creativity = 8.04
Total CT = 37.40

Legend
█ Control Group
█ Experimental Group

The figure illustrates the comparison of pre-test mean scores of the control and experimental groups across different domains of critical thinking, including application, analysis, evaluation, creativity, and overall critical thinking. The results indicate that the mean scores of both groups are relatively similar across all domains. This suggests that both groups possessed nearly the same level of critical thinking skills before the experimental treatment. The independent samples t-test also confirmed that the differences between the groups were not statistically significant ($p > 0.05$), indicating that the groups were equivalent at the pre-test stage.

Comparison of Students' Performance on post-test of control and experimental group on Critical thinking skills

Table 4 Comparison of Students' Performance on post-test of control and experimental group on Critical thinking skills

Groups	**N**	**Mean**	**SD**	**df**	**t-value**	**Sig/p-value**
Control	25	45.24	2.619	48	22.670	**.000**
Experimental	25	71.76	5.230			

Level of significance $\geq$ 0.05

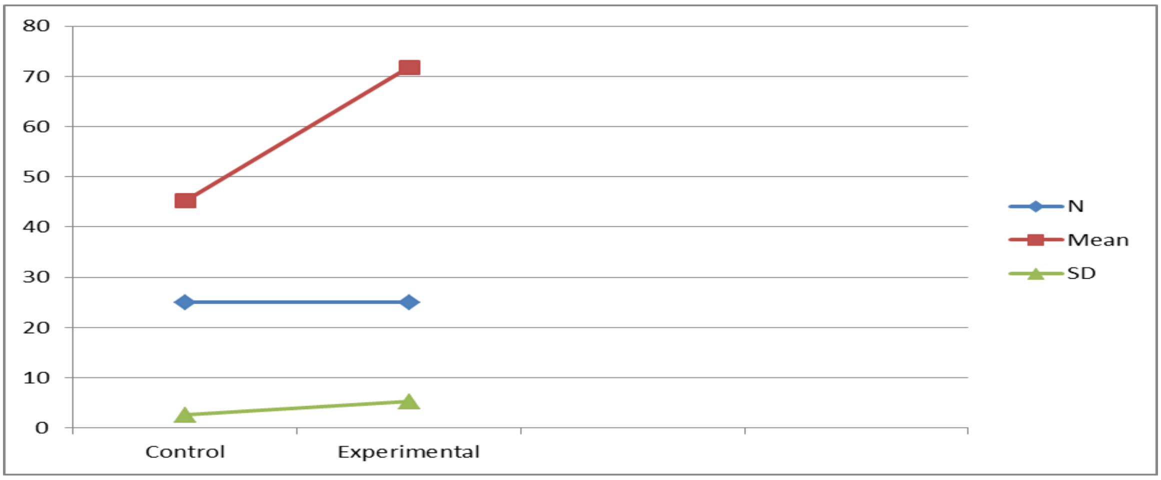


Table 4 compares the post-test results of general critical-analysis abilities of both the experimental and the control groups. The experimental group (M = 71.76, SD = 5.230) performed better in comparison to the control group (M = 45.24, SD = 2.619). The presence of this wide gap shows that students who had undergone learning through PjBL excelled in tasks that required critical thinking, compared to students who had undergone traditional instruction. These results indicated that the null hypothesis ($H0_1$), which stated that no significant difference exists in the performance of critical thinking between elementary students taught through the PBL strategy and those taught through the traditional approach, was rejected. As the results showed, it was evident that PBL has strong potential to foster students' capacity to think critically, thereby making it an effective teaching approach at the elementary level.

Comparison of Students' Performance on pre-test and post-test of the experimental group

Table 5 Comparison of Students' Performance on pre-test and post-test of the experimental group

Groups	N	Mean	SD	df	t-value	Sig/p-value
Pre-test Experimental	25	37.40	3.240	48	22.670	.000
Post-test Experimental	25	71.70	5.230			

Level of significance $\geq$ 0.05

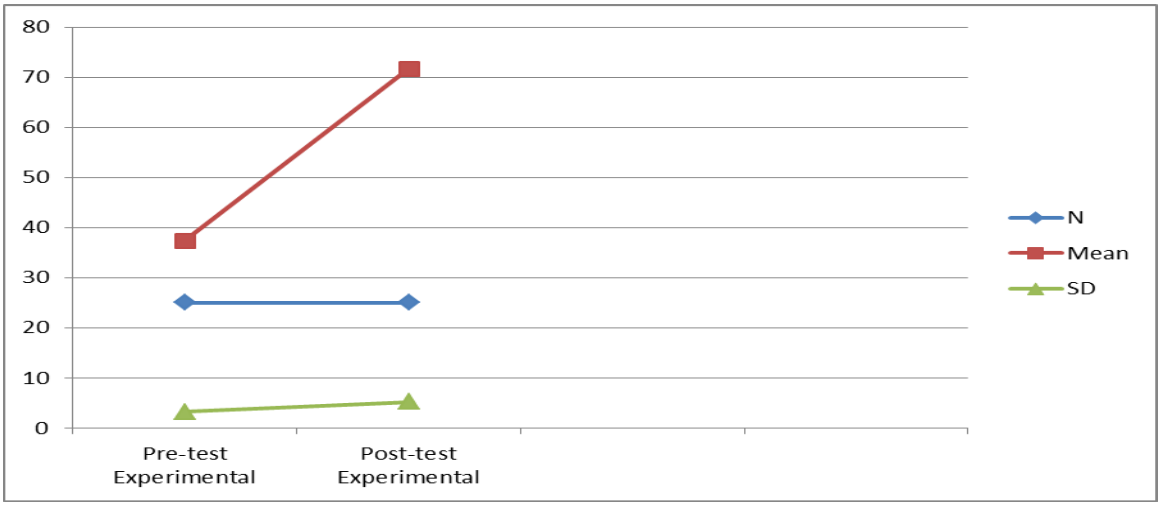


Table 5 demonstrates how the degree of scores of the schoolchildren in the experimental group varied both prior to the test and following the test. In comparison, the post-test mean score was 71.70 (SD = 5.230), while the pre-test mean score was significantly lower at 37.40 (SD = 3.240). The specified improvement is noteworthy, as the group of learners to which the PBL training was applied demonstrated a significantly greater level of critical thinking by the end of the intervention. This difference was shown to be statistically significant, with a t-value of 22.670 and 48 degrees of freedom, and a p-value of 0.000 ($p < .05$). This discredited the sixth null hypothesis (H_{06}), which stated that there was no meaningful difference in the overall critical thinking exhibited by students taught through PBL. These findings indicate that PBL procedures are effective methods for developing critical thinking at the elementary level.

Graph (Post-Test Mean Comparison)

Y-Axis: Mean Scores
X-Axis: Groups (Control, Experimental)

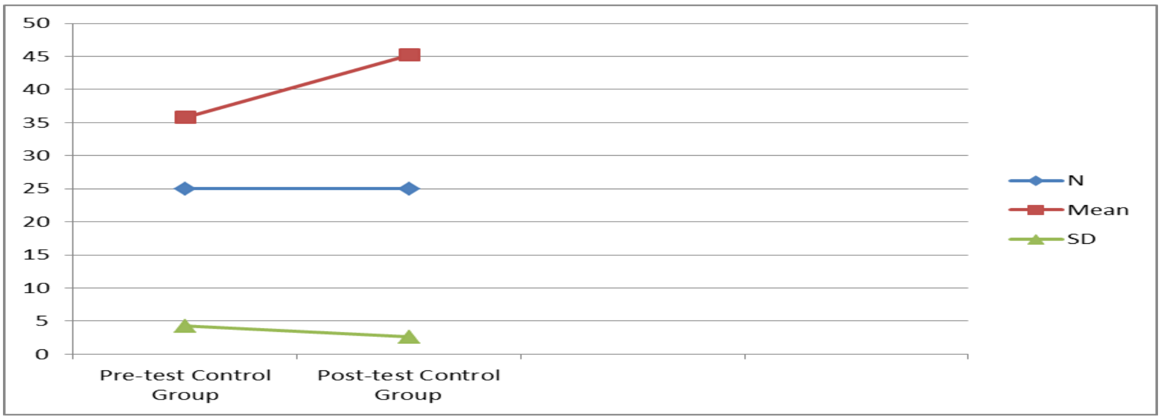
The figure shows the comparison of post-test mean scores of the control and experimental groups on critical thinking skills. The mean score of the experimental group (M = 71.76, SD = 5.230) is substantially higher than that of the control group (M = 45.24, SD = 2.619). The independent samples t-test result (t = 22.670, df = 48, p = .000) indicates a statistically significant difference between the two groups at the 0.05 level of significance. This finding suggests that the instructional treatment given to the experimental group had a significant positive effect on students' critical thinking skills compared to the traditional instruction used with the control group.

Comparison of Students' Performance on pre-test and post-test of control group

Table 6 Comparison of Students' Performance on pre-test and post-test of control group

Groups	N	Mean	SD	Df	t-value	Sig/p-value
Pre-test Control Group	25	35.80	4.282	48	1.490	.143
Post-test Control Group	25	45.24	2.619			

Level of significance ≥ 0.05



The following table, 6 indicates the comparison between two scores: pre-test and post-test performance of the control group. The post-test and pre-test mean scores were 45.24 (SD = 2.619) and 35.40 (SD = 4.282), respectively. The t-value of the test statistic was 1.490, the degrees of freedom were 48, and the p-value was .143 ($p > .05$), indicating a non-significant difference.

Thus, the H_{07} null hypothesis, according to which the performance of critical thinking did not differ significantly among the students trained in accordance with the traditional instructional approach, was accepted. These results showed that the conventional approach to teaching did not lead to a meaningful rise in learners' capacity to think critically, thereby illustrating the low effectiveness of conventional teaching at the elementary level.

Control Group Pre-Test vs Post-Test

Mean Score
50
48
46 Post-Test (45.24)
44
42
40
38 Pre-Test (35.80)
36
34
32
30

Pre-Test Post-Test
Control Group

X-Axis: Test Type (Pre-test, Post-test)
Y-Axis: Mean Score

The figure presents the comparison between the pre-test and post-test mean scores of the control group on critical thinking skills. The mean score of the control group increased from 35.80 (SD = 4.282) in the pre-test to 45.24 (SD = 2.619) in the post-test. However, the independent samples t-test results ($t = 1.490$, $df = 48$, $p = .143$) indicate that the difference between the pre-test and post-test scores is not statistically significant at the 0.05 level of significance. This suggests that the traditional teaching method used with the control group did not produce a significant improvement in students' critical thinking skills.

Findings

At the beginning of the experimental work, the effectiveness of school children in the experimental and control groups as regard to CT was determined prior to the intervention teaching session. Independent samples t-tests were performed to process the obtained results in the pre-test. In this case, degrees of freedom equaled forty-eight. As regards the level of significance of 0.05, the t-values for critical thinking in all areas were less than the critical value of 2.00. More specifically, the obtained t-values amounted to -0.457, 0.691, -0.238, -1.148, and -1.490 in the application domain, analysis, evaluation, creativity, and overall CT abilities, respectively. This means that the two groups were rather similar as regards CT skills prior to the intervention teaching session, so they can be considered a reliable sample for a comparative analysis of PBL (Table 3).

The post-intervention performance of the two groups was significantly different compared to the pre-intervention performance. The experimental group, compared with the control group (M = 45.24, SD = 2.62), performed better (M = 71.76, SD = 5.23), indicating that the cohort taught with PBL scored higher than the one taught without PBL. The t-value of 22.670 was statistically significant with forty-eight degrees of freedom and a p-value of less than .001, indicating a significant difference. Therefore, the null hypothesis (H_{01}), which stated that there would be no significant difference in the performance of students taught through PBL and those taught through the traditional model of teaching in terms of critical thinking, was rejected. According to the findings of the post-test analysis, it can be noted that PBL exposure had a positive effect on the overall critical thinking abilities of the students, thereby proving the effectiveness of the instructional method (Table 4).

The other illustration of the impact of the PBL approach is the comparison of the results of the pre-test and post-test conducted among the participants of the experimental group. The mean score of the experimental group on the post-test was equal to 71.70 (SD = 5.230), whereas the results of the pre-test were much lower and amounted to 37.40 (SD = 3.240). This information clearly shows that PBL enhanced critical thinking skills among learners at the end of the experiment.

In the present scenario, the t-value was calculated as 22.670 at 48 degrees of freedom, and the probability value was found to be below 0.001. Thus, the results were considered statistically significant. As a result, the sixth null hypothesis (H_{06}), which claimed that there would not be any significant difference in the performance of critical thinking skills among learners who were taught using PBL and those taught using the conventional approach, was rejected. The above discussion clearly shows that there was a substantial improvement in outcomes in the context of critical thinking skills among students when the project-based teaching approach was used. This emphasizes the need to adopt the project-based instruction model in primary education (Table 5).

But in contrast, the control group did not demonstrate any improvement from pre-test to post-test. The final scores of the post-test and pre-test of the control group were 45.24 (SD = 2.619) and 35.40 (SD = 4.282), correspondingly. But this difference was not great enough, since t = 1.490, df = 48, and p = .143, which exceeds the level of significance of 0.05. Thus, the difference between the test results of the control group was insignificant.

In this case, by applying such techniques, the seventh null hypothesis (H_{07}), stating that no statistically significant differences in critical thinking would occur for the students taught by traditional methods, is accepted. These results suggest that traditional methods of instruction did not produce any significant improvement in the ability to influence critical thinking skills among learners. Therefore, it may be noted that this reflects the ineffectiveness of traditional teaching methods in developing critical thinking ability among elementary-level science learners (see Table 6).

CONCLUSIONS

The first research question focused on the extent of critical thinking of students from the experimental group and the control group before the implementation of the intervention. As can be seen from the results of the pre-test, there were no statistically significant differences between these two groups; thus, they could be considered comparable and had a similar extent of critical thinking prior to the experiment. The initial research question was focused on the extent of critical thinking of students from the experimental group and the control group before the implementation of the intervention. In turn, the results of the pre-test indicated that there were no statistically significant differences between the two groups under consideration; therefore, they were comparable.

These characteristics of the two groups were needed in order to make the basis for further investigation valid. Moreover, the extent of critical thinking skills of both groups was relatively low before conducting the research, which was an important condition for the validity of the intervention. From the findings of the post-intervention, it becomes evident that the students in the experimental group, who were exposed to the PBL teaching system performed better in comparison with the students who were subjected to the traditional system of instruction. In particular, the post-test results indicate that students in the experiment performed extremely well, thus proving empirically the efficiency of PBL as a tool that can help students develop critical thinking skill set. The post-test results indicate that students in the experiment performed significantly better in comparison with their peers in the domain of application. Specifically, the statistical significance of the difference in post-test scores shows that the improvement in skills of the subjects in the area of application is due to PBL.

As one may deduce, this fact proves that the utilization of the project-based strategy allows for the development of better skills when it comes to using scientific concepts. The substantial difference in the post-test means of the two groups is another indicator of the superiority of PBL teaching method in helping students apply the knowledge gained during classes. Therefore, the results of post-test analysis also reveal the high efficiency of PBL as a teaching technique at the elementary educational stage. Apart from this, students' performance also demonstrated high efficiency in the domain of analysis. According to the post-test results, the differences between the two groups of students were highly significant, meaning that students in the experiment performed much better at the analytical level of skills. This fact suggests that the utilization of PBL allowed for an efficient development of students' analytical thinking skills. Consequently, the significant increase in the post-test mean score of students in the experiment indicates the efficiency of PBL in helping students analyze the concepts provided during classes.

Moreover, it is necessary to note that the post-test analysis showed that students in the experimental group also outperformed their peers in the domain of evaluation of the content provided during lessons. According to the findings of post-test, the differences between students in the two groups turned out to be highly significant. This fact suggests that PBL is an efficient tool for teaching students to assess and justify scientific concepts. In other words, PBL allows students to learn higher order skills efficiently, including the ability to critically think about the things discussed in classes. Another factor indicating high effectiveness of the PBL approach to teaching students is that post-test findings suggest that PBL students performed significantly better in the area of creativity, suggesting that PBL is highly efficient.

Overall, the post-test results showed that students in the experimental group outperformed those in the control group across all areas of critical thinking. The clear difference in scores indicates that project-based learning is more effective than traditional teaching methods, particularly for developing critical thinking in elementary science education. In addition, the comparison of pre-test and post-test results within the experimental group revealed a significant improvement, confirming the positive impact of PBL on students' learning outcomes.

On the contrary, the findings from the control group indicated no significant enhancement in the critical thinking abilities of the learners during the period between pre- and post-tests. This could imply that conventional classroom instructions have little influence on learners' educational outcomes. The lack of a significant difference in mean scores indicates that these methods were not effective in enhancing critical thinking among elementary students. Overall, these findings highlight the greater effectiveness of project-based learning compared to conventional teaching approaches in improving critical thinking skills.

RECOMMENDATIONS

1. It has been suggested that science teachers should be provided with properly prepared laboratory kits that include all the materials needed to perform tasks in the classroom. Every institution ought to have a specific science laboratory or a designated space where science is taught; that space should be well equipped with facilities that are favourable for project-based pedagogies.
2. At the primary, elementary, and secondary levels, textbooks should include unit-based tasks accompanied by images, illustrations, maps, diagrams, clear instructions on how to complete activities, and current information and data to develop critical thinking.
3. Teachers ought to undergo systematic training to be able to apply project-based strategies in different subjects.

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