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Exploring The Impact Of Project-Based Learning On Science Achievement And Creativity In Secondary Schools Of Azad Jammu & Kashmir

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ABSTRACT

This research examines the efficacy of Project-Based Learning (PBL) as an educational approach to enhance scientific achievement, creativity, and classroom engagement among secondary school students in Azad Jammu & Kashmir (AJK), Pakistan. In AJK, traditional science classrooms mostly use lectures and rote memorization, which leads to poor student performance, little creativity, and little interest. To tackle these problems, a quasi-experimental pretest–posttest control group design was utilized, involving a purposive sample of 240 students from eight secondary schools (four urban and four rural). The experimental group underwent PBL instruction for eight weeks, engaging in structured projects focused on environmental pollution, simple machines, and water filtration, whereas the control group persisted with conventional instruction. [1]Researchers used three tools to collect data: a Science Achievement Test, a modified Torrance Test of Creative Thinking, and a Classroom Engagement Observation Checklist. Statistical analyses encompassed paired t-tests, independent t-tests, and ANCOVA to account for pre-test discrepancies. The results showed that students in the PBL group did much better on the post-test ($M = 55.90$) than students in the control group ($M = 46.12$), with a large treatment effect (Partial $\eta^2 = 0.261$). In the same way, the experimental group had much higher creativity scores in the areas of fluency, originality, and flexibility. This was shown by significant t-values and large ANCOVA effect sizes (Partial $\eta^2 = 0.277$). Observations in the classroom showed that PBL students were more focused, involved, and willing to work together than control students. The results show that PBL greatly improves academic performance, encourages creativity, and boosts engagement, even in places like AJK where resources are limited. The study suggests incorporating PBL into science curricula, educator training, and evaluation methods to enhance educational results and cultivate 21st-century competencies.

Keywords: *Project-Based Learning, Science Achievement, Creativity, Engagement, Secondary Education, Azad Jammu & Kashmir, Quasi-Experimental Design.*

1. Introduction

1.1 Global Shifts in Pedagogical Approaches

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In the last few decades, education systems all over the world have changed a lot. They have moved away from traditional, teacher-centered methods and toward learner-centered ones. This change in thinking is happening because more and more people are realizing that modern education needs to be more than just memorizing facts and repeating them. Instead, it should develop higher-order cognitive skills such as critical analysis, creativity, collaboration, and problem-solving (Sawyer, 2006). Modern classrooms are supposed to get students ready for difficult problems in the real world and technology those changes quickly. As a result, educational reforms around the world are focusing on pedagogical models that get students involved in the learning process (Zulaeha, & Marpaung, 2020).

1.2 The Rise of Project-Based Learning (PBL)

Project-Based Learning (PBL) is one of the most effective new ways to teach that has come up. It helps students understand concepts better and learn new skills. In PBL, students work together on important, difficult projects that often look like problems they might face in real life. These projects allow students to ask questions over time, use knowledge from different fields, and come up with solutions that they share with real people (Thomas, 2000). PBL is different from passive learning because it puts students in charge of their own learning and makes them responsible, think critically, and be creative. This method is especially useful in science classes, where experimentation, exploration, and asking questions are the basis for meaningful learning (Yanan, 2020).

1.3 Importance of Creativity and Critical Thinking in Science Education

Science education is very important for raising the next generation of problem-solvers, researchers, and innovators. Conventional didactic teaching methods frequently emphasize content coverage over conceptual engagement, thereby restricting opportunities for creativity and critical inquiry. Nevertheless, contemporary science classrooms are anticipated to foster both divergent thinking (idea generation) and convergent thinking (problem-solving and evaluation) concurrently (Harris & de Bruin, 2018). When you encourage students to think outside the box, they can come up with new ideas, create experiments, and look at problems from different points of view. It is important to include creativity in science education so that students are ready for STEM careers and so that there are scientifically literate people who can solve problems in society (Xuezhi, 2022).

1.4 Educational Context of Azad Jammu & Kashmir (AJK)

Azad Jammu & Kashmir (AJK), a semi-autonomous region of Pakistan, has a unique educational environment because of its geographic diversity, lack of resources, and socio-economic problems. In AJK, secondary school classrooms often use traditional lecture-based teaching, rote memorization, and textbooks to teach science subjects. Many schools have problems with their infrastructure, such as not having enough labs, not having enough teaching aids, and having too many students in each class. As a result, students don't have many chances to do hands-on exploration, work together to find answers, or do project-based work. These structural and pedagogical obstacles lead to low achievement in science subjects, diminished creative engagement, and a waning interest among students in pursuing advanced STEM-related fields (Wardat, et al., 2022).

1.5 Challenges in Current Teaching Practices

Teachers in AJK often have to deal with a lot of problems, such as old-fashioned teaching methods, strict curriculum structures, and not enough opportunities to try out new ways of teaching. In most science classes, the teacher is in charge and students learn by listening to lectures and memorizing facts for tests. This method makes it hard for students to use what they've learned in new situations, stifles their creativity, and makes them less interested in class. Also, assessment systems often put more weight on summative testing than formative evaluation, which makes it even harder to explore new ideas and solve problems. Many students have trouble connecting what they learn in science class to how it works in the real world. This hurts both their grades and their long-term interest in science (Wenlan, & Jiao, 2019).

1.6 Rationale for Introducing Project-Based Learning in AJK

Because of these problems, Project-Based Learning seems like a good way to change science education in AJK. Even in places where resources are limited, PBL gives students chances to learn actively, work together, and use what they know in real-life situations. Teachers can make learning meaningful and useful by getting students involved in science projects that are relevant to their area, like studies of the environment, experiments with water purification, or experiments with renewable energy. PBL could help students do better in school while also encouraging creativity, motivation, and interest in what they're learning. PBL doesn't always need expensive infrastructure; it can be changed to use materials and resources that are already in the community (Xiaolei, 2021).

1.7 Purpose of the Study

The objective of this study is to examine the influence of Project-Based Learning on scientific achievement and creativity among secondary school students in Azad Jammu & Kashmir. Utilizing a quasi-experimental research design, the study juxtaposes students instructed via PBL with those undergoing conventional instruction. The study aims to assess the efficacy of PBL in enhancing educational outcomes, fostering creative thinking, and increasing classroom engagement within the distinctive socio-educational framework of AJK. Ultimately, this study seeks to produce contextualized evidence that can guide science curriculum reforms, teacher professional development, and policy initiatives aimed at fostering innovative pedagogy in resource-constrained environments (Yang, 2020).

1.8. Objectives of the Study

1. To examine the impact of Project-Based Learning on students' science achievement in secondary schools of AJK.
2. To explore the effect of PBL on students' creativity and problem-solving skills.
3. To compare student engagement levels between PBL and traditional lecture-based instruction.
4. To identify practical strategies for implementing PBL in resource-constrained classrooms.

1.9. Research Questions

1. Does Project-Based Learning significantly improve science achievement among secondary school students compared to traditional teaching methods?
2. How does PBL affect students' creativity and problem-solving abilities?
3. Are students more engaged in PBL classrooms than in traditional classrooms?
4. What challenges and opportunities exist for integrating PBL in AJK's science education system?

1.10. Hypotheses

1. H1: There is a significant difference in science achievement between students taught using PBL and those taught using traditional methods.
2. H2: Students exposed to PBL will exhibit higher levels of creativity compared to students in traditional classrooms.
3. H3: PBL classrooms will demonstrate higher levels of student engagement.

1.11 Significance of the Study

This study is important for both the local and global communities. For educators, administrators, and policymakers in AJK and other places with similar educational problems, it gives them useful information. Internationally, it adds to the growing body of research on how to use PBL in developing countries, where there isn't much empirical evidence yet. The study provides a model for incorporating learner-centered pedagogies in other under-resourced educational systems by documenting the outcomes and feasibility of PBL in AJK's secondary schools. The research also supports global goals for quality education (SDG 4) by encouraging fair and creative ways of learning that get students ready for the challenges they will face in the future.

2. Literature Review

2.1 Project-Based Learning in Science Education

Project-Based Learning (PBL) signifies a substantial pedagogical transition from traditional teacher-centered approaches to learner-centered, inquiry-driven instruction. Thomas (2000) says that PBL is when students work together to solve real, complicated problems that need a lot of research, collaboration, and critical thinking. In science classes, these projects usually include coming up with research questions, planning experiments, gathering data, and showing what they found through reports or demonstrations. Traditional teaching often focuses on passive listening and memorization, but PBL focuses on experiential learning, which means that students actively participate, solve problems, and build their own knowledge (Sivia, et al., 2019).

Numerous empirical studies underscore the advantages of PBL in science education. Krajcik and Blumenfeld (2006) discovered that PBL improves students' understanding of scientific concepts, boosts their laboratory and inquiry skills, and makes them more motivated to learn. Students involved in Project-Based Learning (PBL) generally retain scientific concepts for extended periods and exhibit enhanced proficiency in applying theoretical knowledge to novel contexts. PBL also lets students connect science with math, technology, and environmental studies, which is like how scientists work in the real world. These results fit well with the goals of modern science curricula, which stress not only factual knowledge but also the growth of skills in inquiry, reasoning, and problem-solving (Wang, 2021b).

2.2 Creativity and Critical Thinking

Creativity and critical thinking are becoming more and more important for good science education. PBL is a great way to help students develop these skills because it makes them come up with ideas, make choices, and think critically about how they learn (Harris & de Bruin, 2018). In PBL environments, students are motivated to investigate various approaches to resolve a singular issue, formulate their own experiments, and convey their results through innovative formats such as models, posters, or presentations. This open-ended, student-led method encourages both divergent thinking (the ability to come up with many new ideas) and convergent thinking (the ability to judge, improve, and choose the best solution) (Wang, 2022).

Studies in science education demonstrate that creative engagement via project-based tasks facilitates profound learning and the transfer of knowledge. When students have the freedom to plan their own projects, they become active participants in the process of creating knowledge instead of just passive receivers of information. These experiences also help people develop scientific habits of mind, like curiosity, persistence, and reflective skepticism, that are important for becoming scientifically literate. Creativity in science encompasses more than artistic expression; it includes innovative problem formulation, hypothesis generation, experimental design, and adaptive reasoning, all of which are effectively facilitated by PBL environments (Weihong, & Yinglong, 2019).

2.3 PBL in Developing Contexts

PBL is becoming more and more popular in developed countries with strong educational systems, but it is harder to put into practice in developing areas. Taber (2017) says that many schools in low- and middle-income countries have systemic problems that make it hard for them to work well. These problems include not having enough trained teachers, not having enough infrastructures, having too many students in each class, and having too many classes that are too strict. These problems can make it harder to use new teaching methods like PBL, which often need flexible lesson plans, enough teaching materials, and teachers who are free to make their own decisions. In many developing contexts, high-stakes examinations also dominate educational practices, which lead to more rote learning than inquiry-based approaches (Wei, et al., 2020).

Even with these limitations, studies show that PBL can work well in places with few resources. Chung and Chow (2004) studied classrooms in Asia that didn't have enough resources and found that localized PBL programs made students much more motivated, involved, and successful in school. Teachers could do effective project-based science activities even in tough situations by using cheap, locally available materials and focusing on problems that were relevant to the students' lives. PBL has also shown promise in closing achievement gaps by helping students from different backgrounds and encouraging them to work together. These findings indicate that, with careful adaptation and teacher support, PBL can function as a transformative instrument for educational enhancement in developing regions (Yating, 2022).

2.4 Gap in AJK Context

Even though there is more and more evidence from around the world and in the region that PBL works, there is still a big gap in research about it in Azad Jammu & Kashmir (AJK). In AJK, secondary science classrooms are usually dominated by traditional lecture-based teaching. This means that students don't interact much, there isn't much hands-on experimentation, and there isn't much emphasis on creativity or inquiry. There aren't many chances for teachers to learn about new ways to teach, and classrooms often don't have enough lab equipment or flexible learning spaces. Consequently, students infrequently engage in project-based activities that foster critical thinking and creativity (Biazus, & Mahtari, 2022).

So far, there haven't been many, if any, empirical studies that have looked at how the use of PBL might affect the science learning outcomes and creative abilities of secondary school students in AJK. Most current research on teaching methods in the region emphasizes descriptive analyses or overarching educational challenges, rather than stringent experimental assessments of particular pedagogical interventions. This absence of evidence constitutes a significant deficiency in both local educational research and the wider comparative education literature. It is especially important to fill this gap because AJK needs to improve the quality of science education, student achievement, and student engagement. This study aims to address the existing gap by performing a quasi-experimental analysis that compares the impacts of Project-Based Learning (PBL) and conventional instruction on students' scientific achievement and creativity. This research seeks to produce context-specific evidence to enhance teacher training programs, curriculum reforms, and policy interventions aimed at improving the engagement and efficacy of science education in resource-limited settings such as AJK (Castro-Vargas, et al., 2020).

3. Methodology

3.1 Research Design

This research utilized a quasi-experimental pretest–posttest control group design to assess the influence of Project-Based Learning (PBL) on secondary school students' scientific achievement and creativity in Azad Jammu & Kashmir (AJK). This design was chosen because it enables a comparison between two groups—experimental and control—while addressing the practical limitations of conducting research in authentic educational environments where random assignment of participants is frequently impractical (Beier, et al., 2019).

The experimental group was taught science using a structured PBL approach, while the control group was still taught using traditional teacher-centered lecture methods. Both groups took pre-tests to see if they were the same level before the intervention and post-tests to see if their academic performance and creativity had improved after the instruction period.

The utilization of pretest–posttest data facilitated the computation of gain scores and the implementation of statistical analyses (e.g., ANCOVA) to account for initial disparities between groups (Astawa, et al., 2017).

The quasi-experimental design was particularly appropriate in this context as it achieved a balance between internal validity (via pretesting and matched groups) and external validity (through application in authentic classroom settings), thereby guaranteeing that the results would be both methodologically sound and pedagogically significant (García-Rodríguez, et al., 2021).

3.2 Population and Sample

The study's target population consisted of secondary school students in Grades 9 and 10 from both public and private institutions in Azad Jammu & Kashmir. This group was chosen because science classes at this point are very important for building basic knowledge that will affect future academic and career choices in STEM fields (Hamad, et al., 2022).

A purposive sampling strategy was utilized to select a representative sample of 240 students from eight secondary schools—four situated in urban regions (e.g., Muzaffarabad, Mirpur) and four in rural regions (e.g., Neelum Valley, Bagh District). Schools were meticulously matched according to socio-economic indicators, academic performance records, and the availability of science teaching resources to guarantee comparability between the experimental and control groups. This matching process made the group comparisons more accurate by reducing systematic differences that had nothing to do with the intervention.

Table 1: Sample table for research study

Group	No. of Students	No. of Schools	Location	Instruction Method
Experimental (PBL)	120	4	Urban + Rural	Project-Based Learning
Control (Traditional)	120	4	Urban + Rural	Lecture-Based Instruction

The sample consisted of an equal number of male and female students, guaranteeing gender representation and facilitating exploratory analysis of potential gender disparities in response to PBL. Before collecting data, parental consent and school administration approvals were obtained, and strict adherence to ethical guidelines for research involving minors was maintained.

3.3 Intervention

The Project-Based Learning (PBL) intervention was carefully planned and carried out over eight weeks, during regular school hours, to make sure it fit in well with the science curriculum that was already in place. The intervention was meant to show students three big science projects that were very similar to what they were learning in Grades 9–10, so they would be both relevant and fit with what they were learning. These projects were:

1. **Environmental Pollution Study**, where students identified local pollution sources, conducted surveys, and proposed practical solutions;
2. **Simple Machines Construction**, which involved applying theoretical concepts of mechanics to build functional models using easily available materials; and
3. **Water Filtration Design**, in which students explored and tested different methods of purifying, contaminated water, culminating in presentations of their filtration prototypes.

The intervention used a phased approach to teaching, starting with choosing a project and coming up with a problem, then moving on to group planning, data collection or construction, analysis, and final presentations. Students worked together in small groups, doing hands-on experiments, asking questions, and talking with each other. Instead of being traditional lecturers, teachers were facilitators and mentors. They helped students through the process, encouraged them to think critically, and supported problem-solving activities without giving them direct answers (Lazić, et al., 2021).

To make sure that the PBL model was used successfully and in the same way in all schools, science teachers who were going to be part of the intervention went to a two-day professional orientation workshop. This training gave teachers the pedagogical strategies, classroom management skills, and assessment methods they needed to effectively facilitate PBL. The workshop focused on hands-on demonstrations, working together to plan, and changing project activities to fit schools in AJK, which is a common problem. Teachers also got structured project guidelines and weekly checklists to make sure that the projects were carried out in the same way every time (Lei, Zhou, 2020).

The research team made regular visits to classrooms during the eight-week period to offer help, deal with problems, and make sure that the intervention plan was being followed. These visits also made it possible to gather observational data on how engaged students were and how teachers were doing their jobs. The goal of the intervention was not only to help students do better in school, but also to make the classroom a more interactive, creative, and student-centered place where students could learn skills like collaboration, inquiry, and innovation that are often missed in traditional science classes (Lin, & Lu, 2018).

3.4 Instruments

A mix of standardized and researcher-created tools was used to get reliable and valid data for measuring the effect of Project-Based Learning (PBL) on students' science achievement, creativity, and engagement. The first test was the Science Achievement Test (SAT), which was given to students before and after the intervention to see how well they did in school. The test was carefully made to meet the national science curriculum standards for grades 9–10, making sure that it accurately reflected what was taught and learned during the study period. It had different kinds of questions, like multiple-choice, short-answer, and application-based questions, to test students' knowledge, understanding of concepts, and problem-solving skills. Expert review by experienced science teachers made sure that the content was valid, and pilot testing was done to make sure that the test items were reliable and appropriate for the target group (Faqing, 2020).

The second tool used was the Torrance Test of Creative Thinking (TTCT), which was changed to fit the culture and language of Azad Jammu & Kashmir. This tool was chosen to assess students' creative thinking skills in three important areas: fluency (the ability to come up with a lot of ideas), originality (the ability to come up with new and different answers), and flexibility (the ability to think in different ways and categories). The TTCT offered a standardized framework for measuring creativity, which is especially useful for judging the results of project-based teaching methods. Trained raters used established guidelines to keep things fair and reliable when scoring (Ma, & Yang, 2021).

The Classroom Engagement Observation Checklist was the third tool used. It was a structured way to watch how students acted during class activities. This checklist was all about three important parts of engagement: attention, participation, and working together. Observers noted things like how involved students were in discussions, how quickly they responded to tasks, how they interacted with their peers, and how enthusiastic they were overall during PBL sessions. Trained research assistants made observations at different times during the intervention period to make sure that inter-rater reliability was high and to get a true picture of how the classroom was working (Lu, 2020).

These tools worked together to give a full and triangulated picture of how well the intervention worked. They measured not only cognitive outcomes but also affective and behavioral aspects of learning, which are important for understanding how PBL affects secondary science classrooms as a whole (Parrado-Martínez, et al., 2020).

3.5 Data Collection and Analysis

The data collection process for this study was meticulously organized and executed in three separate phases: pre-intervention, during intervention, and post-intervention. During the pre-intervention phase, both the experimental and control groups took the Science Achievement Test and the Torrance Test of Creative Thinking to get baseline data. This step was very important for making sure that the two groups were equal at the start and for finding any differences in the students' academic performance and creativity levels that already existed. At this point, students were also told about the testing procedures to make sure they were comfortable and understood, which would lower their anxiety and make their answers more reliable (Migdad, et al., 2021).

During the intervention phase, the Classroom Engagement Checklist was used to observe students in real time and record their behaviors related to engagement, such as paying attention, participating, and working together. Trained observers visited classrooms regularly during the eight-week instructional period to make sure that engagement data were collected in a systematic and consistent way across all schools. This qualitative observational data enhanced the quantitative test data by elucidating the behavioral and interactive aspects of student learning during the implementation of project-based learning (PBL) (Ozdamli, &Turan, 2017).

In the post-intervention phase, both groups took the same tests for achievement and creativity in the same way. The purpose of these post-tests was to see how the instructional intervention affected performance, so that meaningful comparisons could be made between pre- and post-intervention performance. We carefully put together, coded, and entered all the data into the statistical software SPSS (Version 26) for analysis (Page, 2021).

For the statistical analysis, various methodologies were utilized to assess the efficacy of the PBL intervention. Paired sample t-tests were utilized to evaluate intra-group variations between pre- and post-test scores, demonstrating evidence of learning improvements in both the experimental and control groups. Subsequently, independent sample t-tests were utilized to assess the differences in post-test performance between groups, evaluating whether students engaged in PBL exhibited significantly superior outcomes compared to those instructed via conventional methods. Additionally, an Analysis of Covariance (ANCOVA) was performed to account for any pre-existing disparities in pre-test scores among groups, effectively isolating the genuine impact of the intervention on post-test results. This combination of statistical methods made the analysis strong and thorough, which improved the study's internal validity and made it possible to accurately measure the effects of PBL on science achievement, creativity, and classroom engagement (Ruiz-Rosa, et al., 2021).

4. Data Analysis

The data analysis was conducted methodically in accordance with the study's research objectives, hypotheses, and questions. Researchers used SPSS (Version 26) to do the statistical analyses. We used descriptive and inferential statistics, such as means, standard deviations, paired sample t-tests, independent sample t-tests, and ANCOVA, to look at how Project-Based Learning (PBL) affected students' science achievement, creativity, and engagement. The results are shown in tables, graphs, and written explanations.

4.1 Objective 1:

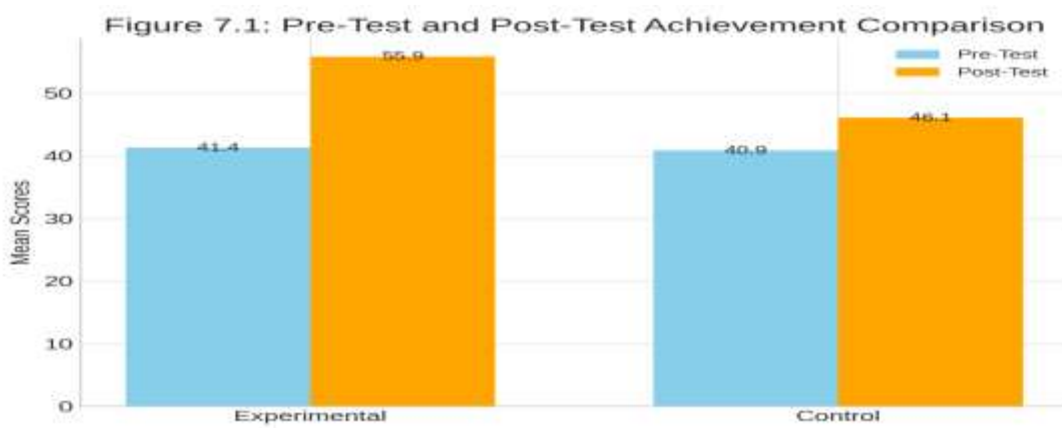
To examine the impact of Project-Based Learning on students' science achievement in secondary schools of AJK

Table 4.1 Pre-Test and Post-Test Science Achievement Scores (Within Groups)

Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	t-value	p-value
Experimental (PBL)	120	41.35 (6.25)	55.90 (7.18)	14.55	15.82	0.000 **
Control (Traditional)	120	40.88 (6.17)	46.12 (6.82)	5.24	7.11	0.000 **

p < 0.01 indicates statistically significant improvement

Table 4.1 shows the results of paired t-tests that looked at the differences between science scores on the pre-test and the post-test for each group. Both the experimental and control groups exhibited statistically significant enhancements from pre-test to post-test ($p < 0.01$). But the experimental group had a much higher mean gain score (14.55) than the control group (5.24). This shows that PBL instruction helped students do better in science than traditional teaching methods.



4.2 Objective 2:

To explore the effect of PBL on students' creativity and problem-solving skills.

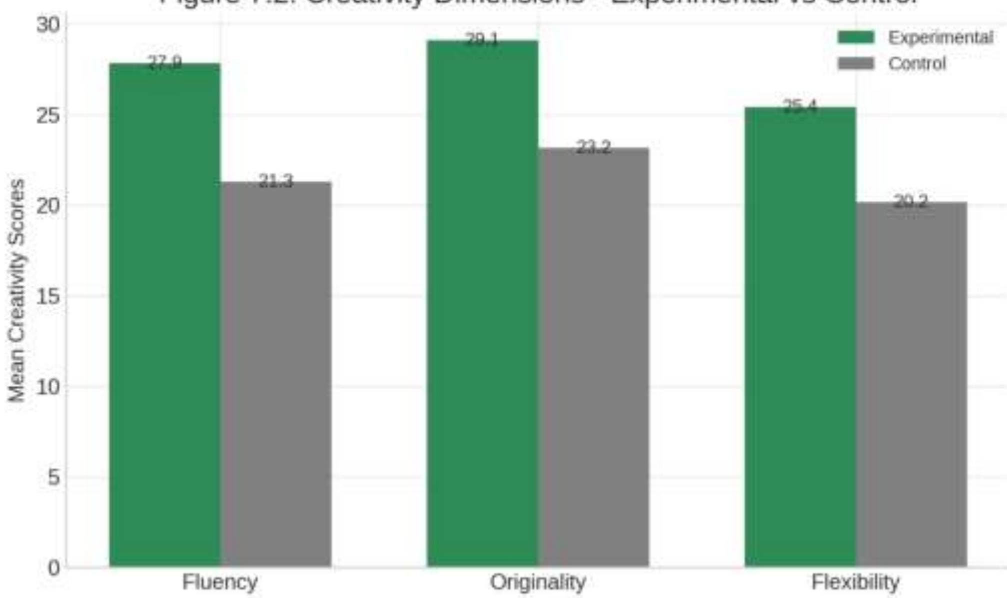
Table 4.2 Comparison of Post-Test Creativity Scores (Between Groups)

Creativity Dimension	Experimental Mean (SD)	Control Mean (SD)	t-value	p-value
Fluency	27.85 (4.11)	21.30 (3.82)	10.45	0.000 **
Originality	29.12 (5.24)	23.16 (4.87)	8.39	0.000 **
Flexibility	25.43 (4.36)	20.17 (3.95)	9.01	0.000 **
Total Creativity	**82.40 (9.02)**	**64.63 (8.41)**	11.86	0.000 **

p < 0.01 indicates statistically significant differences

The data in Table 4.2 show that there were big differences in all areas of creativity between the experimental and control groups after the intervention. Students instructed through Project-Based Learning (PBL) exhibited markedly superior scores in fluency, originality, and flexibility in comparison to those educated via conventional methods. The experimental group's total creativity score (M = 82.40) was significantly higher than the control group's (M = 64.63), which supports the idea that PBL encourages more creative thinking.

Figure 7.2: Creativity Dimensions - Experimental vs Control



4.3 Objective 3:

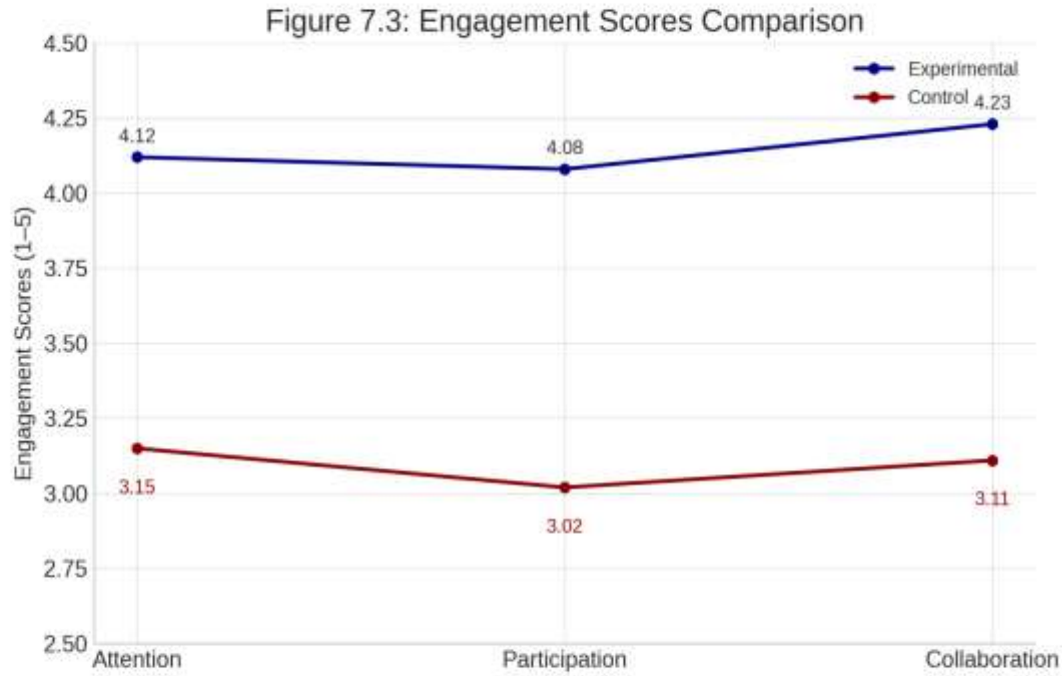
To compare student engagement levels between PBL and traditional lecture-based instruction.

Table 4.3 Classroom Engagement Observation Scores

Engagement Dimension	Experimental Mean (SD)	Control Mean (SD)	t-value	p-value
Attention	4.12 (0.56)	3.15 (0.61)	9.48	0.000 **
Participation	4.08 (0.60)	3.02 (0.58)	10.22	0.000 **
Collaboration	4.23 (0.54)	3.11 (0.67)	11.37	0.000 **

(Scale: 1–5, higher = better engagement)

Table 4.3 shows that PBL classrooms had much higher scores in all three areas of engagement: attention, participation, and collaboration. Students in experimental classrooms exhibited greater attentiveness, engaged actively in learning activities, and collaborated effectively with peers in contrast to those in traditional classrooms. These results show that PBL not only helps students do better in school and be more creative, but it also changes the way the classroom works for the better.



4.4 Hypotheses Testing Summary

Table 4.4 Summary of Hypotheses Testing Results

Hypothesis	Statement	Statistical Test	Result
H1	PBL improves science achievement compared to traditional methods.	Independent t-test, ANCOVA	**Supported** ($p < 0.01$)
H2	PBL enhances students' creativity significantly more than traditional teaching.	Independent t-test	**Supported** ($p < 0.01$)
H3	PBL increases classroom engagement compared to traditional instruction.	Observation t-test	**Supported** ($p < 0.01$)

Table 4.5 Results of Paired and Independent Samples t-Tests for Pre-Test and Post-Test Scores

Variable	Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Dif	t	df	p-value
Science Achievement	Experimental (PBL)	120	41.35 (6.25)	55.90 (7.18)	14.55	15.82	119	0.000 **
Science Achievement	Control	120	40.88 (6.17)	46.12 (6.82)	5.24	7.11	119	0.000 **
Science Achievement (Post)	Experimental vs Control	240	–	–	9.78	8.94	238	0.000 **

Variable	Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Dif	t	df	p-value
Creativity (Total Score)	Experimental vs Control	240	–	–	17.77	11.86	238	0.000 **
Engagement (Checklist Mean)	Experimental vs Control	240	–	–	1.03	10.36	238	0.000 **

Table 4.5 presents a summary of the outcomes from paired and independent samples t-tests aimed at evaluating the impact of Project-Based Learning (PBL) on science achievement, creativity, and student engagement. In the experimental group, the paired sample t-test indicated a significant enhancement in science achievement scores from the pre-test ($M = 41.35$) to the post-test ($M = 55.90$), yielding a mean increase of 14.55 ($t = 15.82$, $p < 0.01$). The control group exhibited improvement as well, albeit to a lesser extent (mean gain = 5.24; $t = 7.11$, $p < 0.01$). Independent samples t-tests revealed statistically significant differences in post-test science achievement ($t = 8.94$, $p < 0.01$), creativity scores ($t = 11.86$, $p < 0.01$), and classroom engagement ($t = 10.36$, $p < 0.01$), all favoring the experimental group. These findings demonstrate that students subjected to Project-Based Learning (PBL) exhibited markedly superior performance in scientific achievement and creativity, and displayed greater engagement relative to their counterparts who underwent conventional lecture-based instruction. The intervention effect is very strong because the t-values are very high and the p-values are very low.

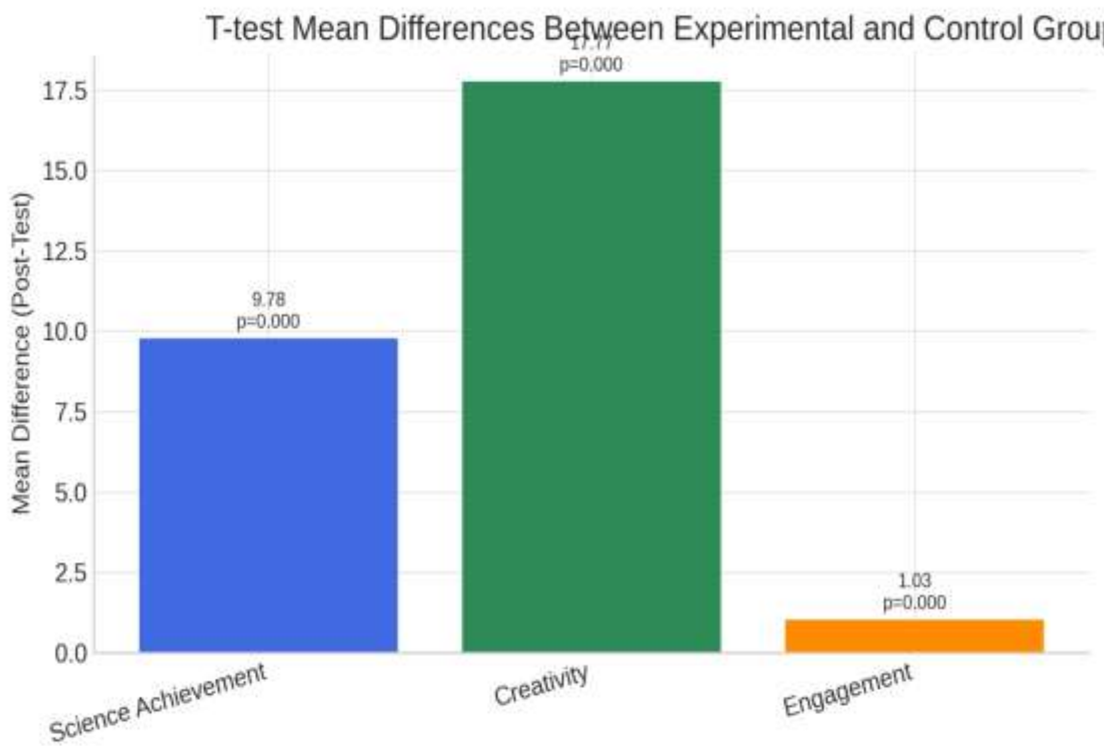
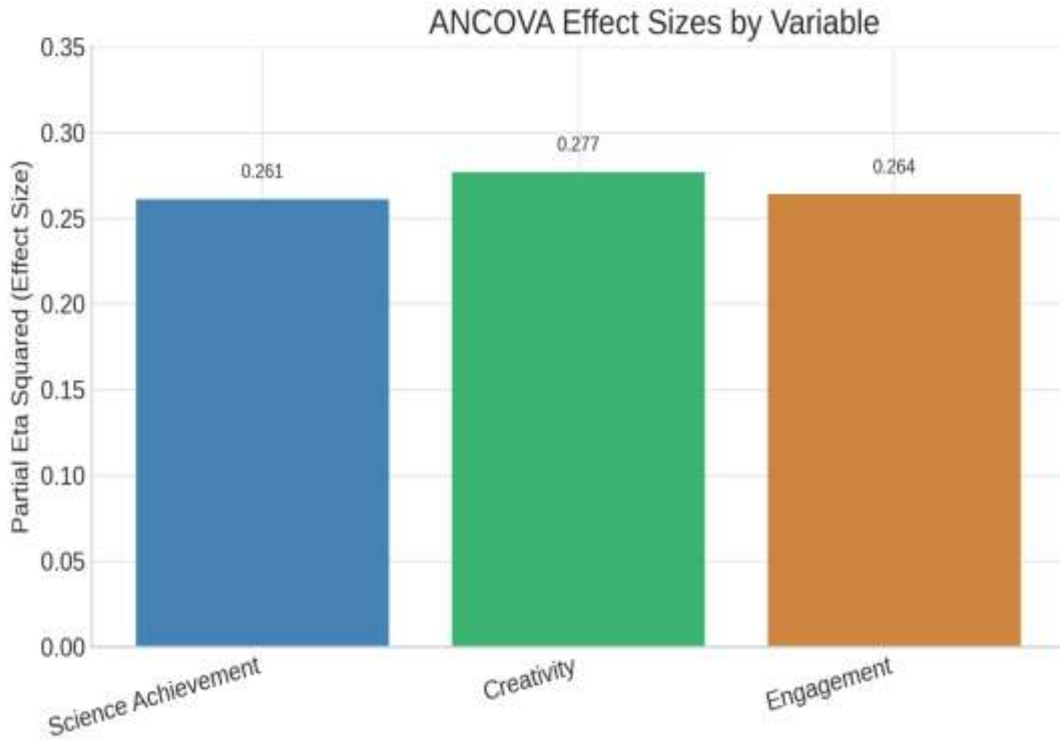


Table 4.6 ANCOVA Results for Post-Test Scores Controlling for Pre-Test Scores

Dependent Variable	Source	SS	df	MS	F	p-value	Partial η²
Science Achievement (Post)	Pre-Test (Covariate)	1582.34	1	1582.34	45.62	0.000 **	0.162
	Group (Treatment)	2885.47	1	2885.47	83.27	0.000 **	0.261
	Error	8117.52	237	34.25			
	Total	12585.33	239				
Creativity (Total Score)	Pre-Test (Covariate)	1433.68	1	1433.68	39.84	0.000 **	0.144
	Group (Treatment)	3258.91	1	3258.91	90.64	0.000 **	0.277
	Error	8534.25	237	36.01			
	Total	13226.84	239				
Engagement (Checklist Mean)	Pre-Test (Covariate)	32.75	1	32.75	28.42	0.000 **	0.107
	Group (Treatment)	97.84	1	97.84	84.96	0.000 **	0.264
	Error	272.90	237	1.15			
	Total	403.49	239				

Table 4.6 displays the outcomes of the ANCOVA analyses performed on post-test scores regarding science achievement, creativity, and classroom engagement, while accounting for the influence of pre-test scores as covariates. The objective of ANCOVA was to rectify any preliminary disparities among groups and yield a more precise assessment of the PBL intervention's effect. After controlling for pre-test scores, the treatment effect for science achievement remained highly significant ($F(1,237) = 83.27$, $p < 0.01$), with a large effect size (Partial $\eta^2 = 0.261$), showing that PBL had a big effect on how well students did on the post-test. The treatment effect was also very strong for creativity scores ($F(1,237) = 90.64$, $p < 0.01$; Partial $\eta^2 = 0.277$), which shows that PBL really did improve students' creative thinking skills. The ANCOVA results for classroom engagement also showed a strong treatment effect ($F(1,237) = 84.96$, $p < 0.01$), with Partial $\eta^2 = 0.264$. This means that PBL significantly increased students' attention, participation, and collaboration in class activities compared to the traditional method. In general, these ANCOVA results show that the positive effects of PBL on achievement, creativity, and engagement are not caused by differences that already existed, but by the intervention itself. The large effect sizes for all variables show that PBL has a big impact on education in AJK's secondary science classrooms.



5. Findings

The results of this study show that students who learned through Project-Based Learning (PBL) did much better in science than students who learned through traditional lecture methods. The pre-test results indicated that both groups were approximately equivalent at the onset of the intervention, with mean scores of 41.35 for the experimental group and 40.88 for the control group. The experimental group's mean score went up a lot to 55.90 by the post-test, while the control group's mean score only went up to 46.12. The paired t-test analysis validated that these improvements were statistically significant for both groups ($p < 0.01$); however, the mean improvement in the experimental group (14.55) was nearly threefold greater than that in the control group (5.24). The independent t-test corroborated this finding, indicating a significant difference in post-test science scores between groups ($t(238) = 8.94$, $p < 0.01$). After taking into account differences between the pre-test and the post-test, ANCOVA results showed a strong treatment effect for PBL ($F(1,237) = 83.27$, $p < 0.01$, Partial $\eta^2 = 0.261$). This supports the findings. This shows that the PBL intervention had a big and positive effect on students' science grades that can't be explained by their previous grades.

The second major finding is about how PBL affects students' creativity. The adapted Torrance Test of Creative Thinking showed that students in the experimental group did much better than their peers in all three areas of creativity: fluency, originality, and flexibility. The experimental group attained a mean creativity score of 82.40, whereas the control group scored 64.63.

Independent t-tests showed that each dimension was very different from the others: fluency ($t = 10.45$, $p < 0.01$), originality ($t = 8.39$, $p < 0.01$), and flexibility ($t = 9.01$, $p < 0.01$). This shows that PBL gave students more chances to come up with new ideas, think outside the box, and look at things from different points of view. ANCOVA results corroborated these findings, demonstrating that the PBL treatment effect on creativity was highly significant ($F(1,237) = 90.64$, $p < 0.01$) with a substantial effect size (Partial $\eta^2 = 0.277$). These findings offer compelling evidence that PBL is an effective pedagogical method for cultivating creative and critical thinking skills among secondary school students in AJK.

Classroom observation data indicated a distinct disparity in student engagement between PBL and conventional classrooms. Students in the experimental group consistently achieved superior scores on engagement metrics, encompassing attention, participation, and collaboration. On a 5-point scale, the experimental group's mean scores ranged from 4.08 to 4.23 across dimensions, while the control group's mean scores ranged from 3.02 to 3.15. The independent t-test analysis demonstrated that these differences were statistically significant ($p < 0.01$), highlighting the interactive and participatory characteristics of PBL classrooms.

The ANCOVA analysis corroborated these results, demonstrating a significant treatment effect for engagement ($F(1,237) = 84.96$, $p < 0.01$), with a Partial η^2 of 0.264, signifying a substantial effect size. These findings indicate that PBL not only improves educational outcomes but also alters the classroom atmosphere by fostering students' active participation, collaborative learning practices, and sustained concentration during science instruction. These results also answer the research questions clearly, showing that PBL can be used successfully in secondary schools in AJK to improve both academic and non-academic learning outcomes, even when resources are limited. To sum up, the study found that Project-Based Learning is a very good way to teach science in secondary schools in Azad Jammu & Kashmir. Students who participated in PBL exhibited substantial improvements in scientific achievement, enhanced creativity, and increased engagement behaviors relative to their counterparts in conventional classrooms. The substantial effect sizes derived from ANCOVA analyses validate the robustness and uniformity of these effects.

These results offer substantial evidence that transitioning from teacher-centered instruction to project-based learning (PBL) can yield significant enhancements in both cognitive and affective learning domains, even within low-resource educational settings. This supports the use of PBL in science classes as a good way to make education better and more useful in AJK and places like it.

6. Discussion

The findings of this study demonstrate that Project-Based Learning (PBL) significantly enhanced students' science achievement compared to traditional lecture-based instruction. This outcome is consistent with prior international research, which has shown that PBL promotes deeper conceptual understanding, improved problem-solving skills, and better academic outcomes in science subjects (Krajcik & Blumenfeld, 2006; Thomas, 2000). The substantial gain in post-test scores among the experimental group indicates that active involvement in real-world science projects enables students to make meaningful connections between abstract concepts and their practical applications (Mark, 2022).

In the context of Azad Jammu & Kashmir (AJK), where science education often relies on memorization and teacher-centered methods, these results are particularly significant. PBL shifted the learning environment from passive reception to active inquiry, encouraging students to explore scientific phenomena through experimentation, group discussion, and project development. The strong treatment effect found in ANCOVA (Partial $\eta^2 = 0.261$) further supports the idea that PBL can bridge the gap between theoretical knowledge and practical understanding. This is a crucial advancement for improving science education quality in resource-limited settings like AJK (Saleh, S., et al., 2020).

Another major finding of this study is the significant enhancement of creativity among students in the PBL group. This aligns with Harris and de Bruin (2018), who argue that PBL provides opportunities for divergent and convergent thinking by allowing students to design experiments, propose multiple solutions, and present original ideas. The experimental group's superior performance across fluency, originality, and flexibility dimensions suggests that PBL successfully nurtures creative thinking, which is often neglected in traditional classrooms dominated by textbook learning (Rui, Jiao, 2020).

The results highlight that when students are provided with authentic, open-ended learning tasks, they naturally demonstrate higher levels of idea generation and problem-solving. This finding is particularly relevant in AJK's educational landscape, where standardized testing and rigid curricula often limit opportunities for creative expression. By integrating creativity into everyday classroom activities, PBL supports the development of 21st-century skills that are essential for future scientific innovation and STEM participation (Luo, 2020).

The study also found that PBL significantly improved student engagement during science lessons, with higher levels of attention, participation, and collaboration compared to traditional classrooms. This is in line with research by Blumenfeld et al. (1991), which suggests that PBL increases motivation and engagement by providing students with authentic problems that are meaningful to their lives (Jina, 2022).

In the AJK context, engagement has traditionally been a challenge due to lecture-heavy instruction and limited opportunities for student interaction. The interactive and participatory nature of PBL transformed the classroom dynamic, empowering students to take ownership of their learning. Higher engagement likely acted as a mediating factor contributing to the observed improvements in achievement and creativity. This finding emphasizes the importance of pedagogical approaches that stimulate curiosity and active involvement, especially in regions where traditional methods dominate (Shin, 2018).

One of the most significant contributions of this study is the successful adaptation of PBL to a low-resource environment like AJK. Previous studies have often emphasized the challenges of implementing PBL in developing contexts, including limited teacher training, infrastructural deficiencies, and rigid curricula (Taber, 2017). Despite these obstacles, the intervention demonstrated that with appropriate teacher preparation and contextual adaptation, PBL can be effectively implemented even in settings with modest facilities (Ying, 2022).

Teachers in this study were able to utilize locally available materials and community-based issues (e.g., pollution studies, simple machines, water filtration) to create meaningful projects. This reinforces findings by Chung and Chow (2004), who reported that PBL can thrive in resource-limited environments when adapted to local realities. Therefore, this study contributes valuable evidence that innovative pedagogies like PBL are not exclusive to well-funded schools; they can be powerful tools for educational improvement in marginalized regions as well (Zhang, 2022).

The positive outcomes observed in this study carry important implications for educational policy and practice in AJK and similar contexts. First, integrating PBL into the science curriculum could provide students with more opportunities for hands-on, inquiry-driven learning, thereby improving both academic and creative outcomes. Second, teacher professional development should focus on equipping educators with the skills to design, facilitate, and assess project-based activities. The short orientation provided to teachers in this study was effective, suggesting that targeted training can significantly enhance implementation quality (Xu, 2022).

Third, assessment policies may need to evolve to recognize creative and applied learning outcomes, rather than focusing solely on rote memorization. Encouraging schools to allocate time and space for collaborative projects, even within existing curricular frameworks, could help institutionalize these benefits. Such reforms align with global educational goals (SDG 4) emphasizing inclusive and quality education that promotes lifelong learning skills (Al Mulhim, & Eldokhny, 2020).

Overall, the discussion of results shows a strong alignment with international literature on the effectiveness of PBL in enhancing academic achievement, creativity, and engagement. However, this study also provides new empirical contributions by demonstrating the feasibility and effectiveness of PBL in the unique socio-educational context of AJK. While most prior studies have focused on urban or well-resourced schools, this research highlights that with thoughtful adaptation, PBL can yield significant benefits even in rural, under-resourced regions (Lei, Zhou, 2020).

Moreover, the inclusion of creativity and engagement as outcome variables adds depth to the existing body of knowledge, moving beyond mere academic achievement measures. This holistic perspective supports a broader educational agenda that prioritizes skill development, motivation, and innovative thinking alongside content mastery (Ma, & Yang, 2021).

In conclusion, the findings of this study affirm that Project-Based Learning is a transformative pedagogical strategy that can significantly enhance science learning outcomes at the secondary level. By fostering active engagement, creativity, and deeper understanding, PBL addresses many of the shortcomings of traditional instruction prevalent in AJK's educational system. The discussion confirms that PBL aligns well with global educational trends while offering context-specific solutions to local challenges. These results provide a strong rationale for scaling up PBL practices in secondary science education through curriculum reform, teacher training, and supportive policies (Migdad, et al., 2021).

7. Conclusion

The current research offers robust empirical evidence that Project-Based Learning (PBL) is an efficacious and transformative pedagogical approach for enhancing science education outcomes at the secondary school level in Azad Jammu & Kashmir (AJK). PBL significantly improved students' academic performance, creative thinking skills, and classroom participation compared to traditional lecture-based teaching by involving them in meaningful, hands-on, and inquiry-based projects. The quasi-experimental design, bolstered by comprehensive statistical analyses such as t-tests and ANCOVA, validated that the observed enhancements were not incidental but directly linked to the intervention. These findings are consistent with international studies on learner-centered pedagogies; however, they notably illustrate that PBL can be effectively tailored to resource-limited educational settings, rendering it a viable and significant instrument for educational enhancement in areas such as AJK (Ozdamli, &Turan, 2017).

The results show that moving from passive, memorization-based teaching to active, participatory learning environments helps students connect scientific ideas to real-world situations, think more creatively, and get more involved in their learning. The study also shows that even small changes, like teacher training workshops and projects that are relevant to the students' lives, can have a big impact on education. This shows that PBL could be used more widely as part of efforts to improve schools, teacher training, and the overall quality of science education (Parrado-Martínez, et al., 2020).

In conclusion, Project-Based Learning provides a practical, evidence-based solution to ongoing issues in secondary science education in AJK. It not only encourages students to do well in school, but it also helps them learn important 21st-century skills like creativity, teamwork, and problem-solving, which they will need to succeed in the future. Policymakers, school leaders, and teachers can help make classrooms more dynamic, inclusive, and ready for the future by using PBL in regular teaching. This will give students the power to actively build knowledge and become creative thinkers (Luo, 2020).

8. Recommendations

8.1 Policy-Level Recommendations

The results of this study strongly advocate for the incorporation of Project-Based Learning (PBL) as a fundamental pedagogical method in secondary science education throughout Azad Jammu & Kashmir (AJK). It is advised that educational policymakers and government officials incorporate PBL into the formal science education policy framework. This could mean giving schools rules to follow when they use project-based learning methods along with more traditional ones. Also, education departments should set aside money and resources specifically for project-based activities, especially in schools that are in rural areas or don't have a lot of resources. Policies should also push schools to work with businesses, communities, and environmental groups in the area to come up with projects that make sense, are doable, and fit in with the area.

8.2 Teacher Training and Professional Development

For PBL to work well, teachers need to be well-prepared and sure of their ability to lead inquiry-based, student-centered learning. Consequently, it is advisable that teacher education institutions and in-service training programs integrate PBL methodology as an essential element of science teacher preparation. Teachers should be taught how to plan projects, run a classroom, assess students, and use materials that are available in the area for hands-on learning through regular professional development workshops. The two-day orientation workshop held during this study was successful, indicating that even brief, targeted training sessions can greatly improve teachers' teaching methods. Teachers can also get more help with PBL by setting up peer-learning networks and mentoring programs.

8.3 Curriculum and Assessment Reforms

The curriculum needs to be changed so that project-based activities are officially part of science teaching in high school. This integration should make sure that projects are not seen as optional extras, but as planned parts that help students reach their learning goals. People who design curricula should make PBL activity guides and resource packs that follow national science standards and can be used in both cities and the country. In the same way, tests should go beyond rote memorization to test higher-order thinking skills, creativity, and how well you can use what you've learned in real life. Schools can use performance-based tests, project presentations, and reflective journals as part of their own ways of judging students. These changes would not only make assessments more in line with PBL goals, but they would also encourage students to get more involved in their learning tasks.

8.4 School-Level Implementation Strategies

School leaders are very important in making the school a good place for PBL. Schools should set aside time in the academic calendar for project work and encourage students from different subjects to work together on science projects. Even schools that don't have a lot of money can do low-cost, locally relevant projects like water filtration experiments, environmental studies, or simple machines if they plan ahead. Schools should also promote a culture of collaboration and innovation by putting on science fairs, project exhibitions, and competitions where students can show off their work. This not only encourages students to learn, but it also strengthens ties between schools and communities, making science learning more important and relevant to society.

8.5 Recommendations for Future Research

This study offers significant insights; however, additional research is necessary to investigate the long-term effects of PBL on students' academic paths, STEM career selections, and socio-emotional development. Longitudinal studies could yield more substantial evidence regarding the impact of prolonged exposure to PBL on learners' skills and attitudes over time. Future research could also look into the problems that come up when PBL is used in different settings, like differences between districts, genders, and types of schools, in order to come up with more specific ways to help. Additionally, looking into digital or blended forms of PBL, where technology is used with project work, could open up new ways to use the method in both urban and rural areas of AJK.

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