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# Project Based Learning and Student Academic Achievement: Cumulative Evidence from Meta-Analysis

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## Abstract

Project based learning is a more essential mode to enhance students' achievement in educational practices. Focus of this review is Project-Based Learning but not the various "close approaches" such as inquiry-based learning and problem based. This meta-analysis is done for finding how the project-based learning approach impacts the academic achievement of students. Literature related to the research question was searched from various databases covering studies published between 2000 and 2023. Codification is an important step; therefore, all the studies carefully selected for meta-analysis were coded. The study's eight research looked at how project-based learning benefited students' academic performance. The Effect size for each study was obtained by using Cohen's d value. Analysis shows that the project-based learning strategy outperforms as compared to traditional approaches in terms of helping pupils in a variety of areas. The size of the effect was between 0.13 to 3.70. Interval of confidence has been discovered 1.217(95 % Cl, SE= 0.379) concerning the achievement of the students with a variety of standards. It is investigated that all existing literature included indicates that learning through projects has a positive influence on achievement. Transitional variables dissection has been done at meta-analysis studies, distinct areas, academic tier, number of included participants, total time, and varieties of publications. Among these studies, three exhibited a large effect size, one a medium, three showed a small effect size, and one study showed a very small effect size. Among these studies, the largest effect size is observed at the elementary level. The study highlighted the positive effect of project base learning and can be used as an effective strategy for improving the educational achievement of learners in different subjects as compared to conventional teaching methods.

***Keywords:*** Academic Achievement, Project-Based Learning, Meta-Analysis, Effect Size

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## Introduction

Teaching is not an automated process; rather, it is a convoluted and arduous profession. It is a complex, sensational, and stimulating job. Teaching requires flexibility, versatility, and vivacity of mind, which go beyond the mechanical procedure of step-by-step (Parveen & Batool, 2012). Education plays a substantial role in enlightening potential students. The education objectives of the 21st century demand that students be adequately prepared to solve problems and harness technology for the progress of society. The aim of education in today's world is to build students who are perceptive thinkers and innovative, who can improve effectively to the world. Worldwide, instructors' expectation to refine children's learning results, like involvement, concern, commitment, determination, and desire in STEM and related disciplines (Bertrand & Namukasa, 2023).

Academic achievement in its broadest sense refers to the thinking abilities and communicative, mathematical, scientific, and social science capacities that enable a student to excel in any area of life. Moreover, these kinds of achievement are challenging to evaluate; many scholars depend on the limited explanation that is mostly restricted to the scoring and results. Academic achievement represents an individual's performance outcome, which indicates the extent to which a person achieved the targeted goals that were focused on in the instructional environment. Teachers put their efforts to improve performance of students in academic by using variety of teaching techniques. Researchers also perform variety of experiments for finding approaches which serve student and guide teachers.

Project-based learning emphasizes experiential learning and student-centered approaches. Project-Based Learning has its theoretical origins in the progressive education movement. Progressive education is intended to foster profound learning through active engagement by connecting it with real-world issues and challenges (Hilton & Pellegrino, 2012; Peterson, 2012). The core of the "project method" was in "an activity undertaken by students that really interested them" (Ravitch & Lashley,2001). Kilpatrick introduced the "project method", widely familiar as the earliest formal model of PBL (Peterson, 2012). Although Kilpatrick's ideas gained important traction among educators during the progressive education era, they have since progressed considerably to meet the needs of contemporary educational contexts.

Project based learning (PBL) is a thoughtful way in which pupils work on practical projects and produce a final product or presentation for a group of people. It focuses the creation and modification of new

knowledge and is connected to constructivism. The project itself, an act of creation that takes place over time and involves students in a productive investigation, is the central component of PBL. It consists of two main parts: products/artifacts that show students' solutions and a question that arranges learning activities. PBL includes several essential components, such as student voice and choice, revision and reflection, a public audience, and inquiry directed by the central question. Students collaborate independently and consciously to finish a project, defining issues, exchanging ideas, creating inquiries, gathering and evaluating data, and sharing.

PBL is a teaching method that is widely used in numerous subjects, including social science, technology, mathematics, technology, and sciences. It increases pupils' motivation to learn, interest in content, and completion of projects. PBL benefits include improved attitudes towards learning and subject matter, as well as the growth of metacognitive skills like self-regulation and self-monitoring. It also supports self-directed and self-regulated learning, allowing students to pursue their interests.

## Literature Review

Project-based learning (PBL) is generally specified as an instructional strategy where students react to real-world problems or issues thorough investigation process. PBL fosters students' ability to think critically, lets them express their creativity, and motivates them to work collaboratively, encouraging them to obtain the knowledge independently and present it. PBL often requires students to voluntarily engage in the suggested relevant learning activities, which are primarily teamwork-based. PBL incorporates projects into learning and places students in real-world settings where they are able to utilize and discover the issues that are intricate and pertinent to the professional practice, they are training for.

Students learn in PBL environments primarily by using iterative processes to develop knowledge and make meaning. of inquiry, participatory education, exchange, and reflection. The main goal of projects is to have students draw links between tasks, discipline-specific concepts, and fundamental theoretical knowledge through questions or problems (Martinez,2022).

Today learning places a strong emphasis on collaborative, multidisciplinary, student-centered, and combined with issues and practices from the actual world. This strategy is reportedly popular and successful in a range of educational contexts (Mergendoller &Thomas 2005).Numerous studies conducted over the past ten years have demonstrated the effect of project-based learning as a teaching technique to increase students'

enthusiasm for studying and encourage pupils to participate in educational activities. Project-based learning method as a primary factor in fostering learners minds to face the 21st-century global challenges that are affecting the environment and economy (Chen et al.,2019).

PBL has the potential to improve student's enthusiasm and engagement in secondary school classrooms while also offering strong academic content together with real-world applications of that knowledge in a particular industry area. Combined projects are inspected in certain publications "as a pointer of the consistency of teaching and learning. (Martinez,2022).

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Project-based learning method as a primary factor in fostering young minds to deal positively with 21st-century global challenges that are impacting the economy and environment (Chen et al.,2019). In another study conducted in the subject of Social Studies, the effect of PBL is investigated as a teaching method (Wynn & Okie, 2017). The results of data showed that PBL teachers were comfortable in teaching with PBL method. Prospective teachers felt satisfied organizing and carrying out PBL because they had joined in a number of PBL activities during the methods course. Furthermore, in contrast to the traditional learning environment that was dominant in their classrooms, these candidates clearly stated the high potential in PBL to develop the learning atmosphere (Wynn & Okie, 2017).

PBL is a method that helps students get involve with real-world projects, according to research. The aptitudes required for completing tasks in the real world are diverse. It is critical to keep in mind that a project can have its roots in one curriculum area, but it can however apply to any area of traditional academic study. There are empirical evidences that PBL helps students develop their research, problem-solving, and higher-order thinking skills (Gultekin ,2005). Furthermore, more students also enjoy interacting with each other. It gives them chance to interact with each other, communicate effectively and the social interaction improves indirectly.

According to research, students enrolled in PBL programs outperform their peers in outmoded direct teaching programs on

standardized exams and project tests. They also acquire analytical thinking skills in addition to the practical application of their acquired knowledge (Boaler, 1999).

Students who used a project-based approach to mathematics were less inclined to regard math as a collection of discrete skills and more able to grasp how their learning could be applied. Children also naturally orient themselves when they are deeply engaged in the subject matter of their research.

According to Mioduser, 2006, project-based learning (PBL) plays an important contribution as a teaching strategy to help students acquire knowledge and solve problems. The results of study indicate a notable rise in formal knowledge as determined from standardized secondary exams. It likewise rise the scope of technological knowledge among the students. They gained and applied; a high degree of overall performance concerning the set of design skills studied.

Certain academics have noted that PBL activities have the potential to enhance primary school children' self-directed learning (Wolk ,1994). This is possible because students get motivated and show readiness in doing new, amazing tasks. Learning environment plays a vital role in fostering learning of students. A PBL environment stimulates student motivation in a number of ways, including through regular supervisor meetings, official and informal group discussions, and distributing the lead (Zhou, Kolmos & Nielsen 2012). Informal group discussions and finding solutions together enhance collaboration and communication within the team.

According to a study conducted by Chiang & Lee (2016), PBL affects the vocational high school's learning enthusiasm and problem-solving skills. Students at the occupational high school do not have an innate dislike of education. PBL activities encourage them to learn more than traditional teacher-centered instruction does. They can be motivated to learn, and PBL might be the catalyst. According to Ravitz (2010), "this method uses "projects" as vehicles to inspire students. The outcome established that PBL had a favorable influence on students' motivation to learn. If a more PBL-style teaching approach is used, it inspires teachers and students(Ravitch, & Lashley, 2001).

## Problem Statement

Educators and economists recognize the importance of designing, using technology, finding solutions to problems, creative skills, and critical thinking skills in mathematics and engineering. Ayaz et al. (2015) mentioned project base learning method as a primary element in fostering youthful intellect to address 21st-century worldwide issues that are influencing commerce and ecology. But unfortunately, even though

science teachers use traditional methods in schools, it fosters rote learning. Teachers take PBL method which does not focus on academic achievement and in their opinion only academic achievement can measure students' learning. It creates a gap in modern expectations of science education (application, problem solving skills) and practices in the science education. One of the reasons for this is not knowing the overall effect of different studies conducted in different parts of the world. There are a number of studies that are required to analyze for more findings by comparing and contrasting their results. Therefore, it is imperative to do a meta-analysis to determine how PBL affects students' academic progress. As this method of teaching, as mentioned above, may have the potential to fulfill the expected learning in 21st century. The study aims to find the effect of the PBL model on the Academic Achievement of students.

## Purpose of the study

Through a comparison and contrast of the findings from similar prior research, the aim of this study is to ascertain the association among the dependent and independent variables. A comprehensive examination of the studies documented in the literature has been conducted. Another aspect of research is identifying the attributes contributing to altering the outcomes of PBL in education, i.e. methodology, classroom environment, discipline of children, size, duration, and time, but they were not included because no information was given.

## Research Question

What is the effect of the PBL method on the academic achievement of students?

## Research Methodology

This section of the study comprises the research method implemented, collection of data, inclusion, exclusion conditions, selection, and analysis of quality studies, coding of data, analyzing the data, and representing the data.

### Model of Research

In this study, the effect of the PBL methodology on students' academic achievement was examined using the meta-analysis method. A statistical process application called meta-analysis is used to summarize and discuss individual findings. The meta-analysis provides the

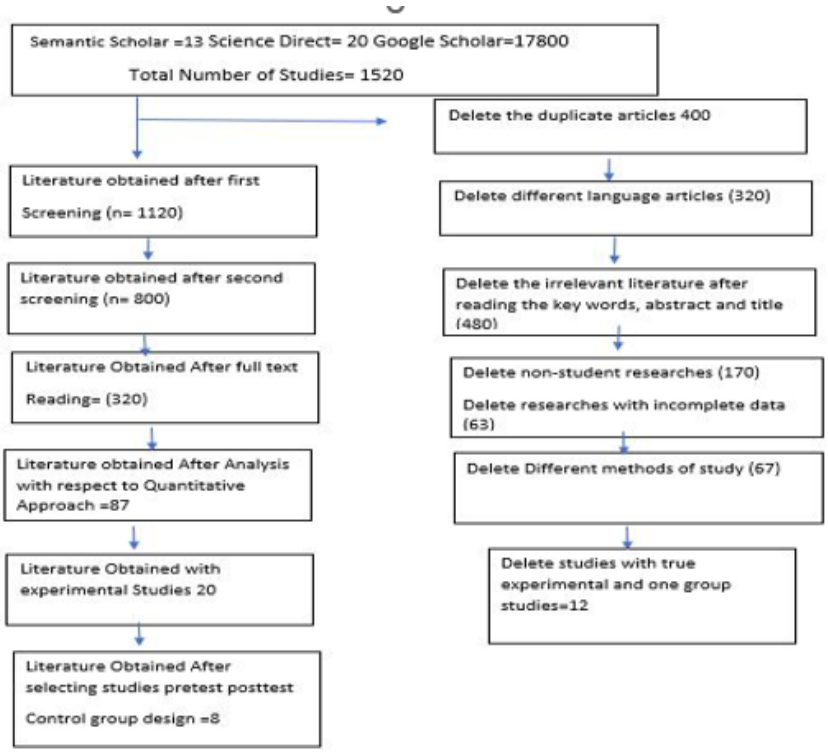
evaluation between the investigational studies and the combination of studies to find the statistical evidence for the effectiveness of PBL on the Academic Achievement of students.

## Related articles and Studies

Articles were searched by the researcher. Researcher employed several Data bases included Google Scholar, Semantic Scholar, and Science Direct. Boolean search strings ("project-based learning", OR "PBL approach" OR "STEM Approach") AND (Academic Achievement" OR "Learning Outcome ") are used to identify relevant studies. At the initial stage, 1520 articles were searched from databases. Duplicate articles and articles in different languages were removed. The exclusion reasons and search process are described in Figure 1.

**Figure 1**

*PRISMA (Preferred Reporting Items for Systematic reviews and Meta-*




*Analyses) flow diagram for inclusion of studies*.

## Selection of Studies

The studies encompassed in the research are based on eight research articles published in scientific journals between 2000 – 2023 worldwide. Articles are sorted on the inclusion and exclusion criteria. Those articles are selected that have a quasi-experimental, pretest-posttest control group design.

**Table 1**

*Sample for Systematic Literature Review Selection Criteria Based on Inclusion and Exclusion Criteria*

| | | |
|---|---|---|
| 1. | When the per-defined key words are included in the title key words or in the abstract. | Inclusion |
| 2. | The articles published in peer reviewed journals. | Inclusion |
| 3. | The paper should be written in the English language. | Inclusion |
| 4. | Paper including any evidence about project-based learning and its effect on Academic Achievement | Inclusion |
| 5. | Papers that are published before 2000. | Exclusion |
| 6. | Papers that are not published. | Exclusion |
| 7. | Papers that are not original articles. | Exclusion |

## Codification of Data

Codification is an important step; all the studies selected for meta-analysis were coded. Codification was done by using a table with general information about the article and determining whether the study is suitable for study or not. Articles are coded with the information featuring the article name, topic, year, number of participants, effect size of the articles, and statistical information from the study. Codification forms are used for general information. Codification was done carefully so to avoid any error. Reliability of the study is important and is required to be evaluated by more than two experts for reliable results.

## Results

The data is analyzed by calculating the effect size of articles. Effect size for each article is calculated. Effect size of articles is calculated by using Cohen's d formula. Effect size for all studies was different. Different tests were used to investigate the effect size of different studies. The weights of studies were calculated.

Analysis was done by using the meta-analysis software Jamovi.

Categorization of Effect size is done by using the Cohen (2007). According to which

$0 \leq$ Effect size value $\leq 0.20$ "poor",

$0.21 \leq$ Effect size value $\leq 0.50$ "modest",

$0.51 \leq$ Effect size value $\leq 1.00$ "moderate",

$0 \leq$ Effect size value has "strong" effect level

For the reduction of the quality problem, only those studies were included that fit quantitatively and with the demand of meta-analysis. Statistical result combination was done by the statistics. Heterogeneity of studies was calculated by using the test. There are two models that can be used i.e. Fixed effect Model and Random effect model. Here, the fixed effect model is used as the studies have the same design and the subjects of the studies were also the same.

Data associated with the heterogeneity, composed of the Q statistic, are also given. $I^2$, established as a supplement of the Q statistics for heterogeneity of findings, could provide a transparent outcome. Overall effect size, publication bias, forest plot, and funnel plot were also produced during data analysis.

## Meta Analysis

Results regarding meta-analyses are presented in this section. The process of combining the findings from the analysis and their interpretation is used to obtain an understanding of the meta-analysis results.

## General Effect Size Result

Results of Meta Analysis associated to the outcome of the Project-based learning method on the academic achievement of learners in classroom are presented here:

By following the Method of Meta-Analysis, firstly, the effect

size will be calculated. Here, we calculated heterogeneity by using the data from Table 1. The Fixed Effect model is used to calculate the general effect size.

**Table 2**

*Fixed-Effects Model (k = 8)*

| | Estimate | Se | Z | p | CI Lower Bound | CI Upper Bound |
|---|---|---|---|---|---|---|
| Intercept | 0.475 | 0.379 | 1.25 | 0.210 | -0.267 | 1.217 |
| | . | . | . | . | . | . |

*Heterogeneity Statistics*

| Tau | Tau² | I² | H² | R² | df | Q | p |
|---|---|---|---|---|---|---|---|
| 0.000 | 0 (SE = NA) | 0% | 0.436 | . | 7.000 | 3.055 | 0.880 |

When we compute the homogeneity value of studies constructed on the fixed effect model, we got Q=3.055, exceeding the 7 degrees of freedom value for confidence interval 95%. The value of Q shows the observed variance between studies to the expected variance shared by a common effect size. The value of Tau and Tau square is 0, which shows no variability, indicating perfect homogeneity. $I^2$ is

estimated at 0% which shows a very low value for heterogeneity. The high value of p=0.880 shows that there is no significant heterogeneity among the studies.

The Q statistic (3.055) with a high value of p (0.880) supports the conclusion of no significant heterogeneity, which shows that the studies are homogeneous.

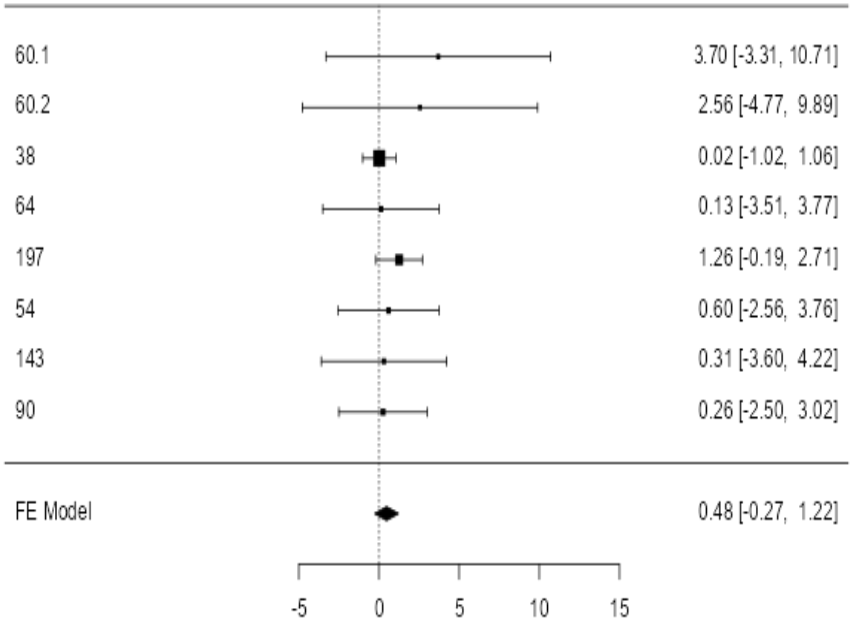
Here, the average effect size value is positive (+0.475), which shows the transaction effect is in favor of the experimental group. Therefore, the PBL approach has an optimistic effect on students' academic achievement.

**Forest Plot**

The forest plot illustrates the distribution of effect size values of primary studies using the Fixed Effect Model. It is shown in Figure 1.

**Figure 2**

*Forest Plot Showing the Effect Size Distribution Values of Studies*



Dotted points indicate the study's effect size; straight lines indicate the confidence interval with 95 % of the effect size, with the lowest and highest points. The size of the squares shows the weight of the study. The rhombic shape at the end shows the combined effect size of the studies.

In the above forest graph, the minimum limit value is -0.19, and the maximum upper limit effect size is 10.71. Upon examining the effect size of all eight articles, they show a positive effect size and enhance the effect of the PBL method of teaching. No study shows a negative effect size, which shows none of the study show favors for the control group approach.

The Overall tests show no proof of publication bias in the study. The tests used for finding the studies' biasness in meta-analysis are shown in

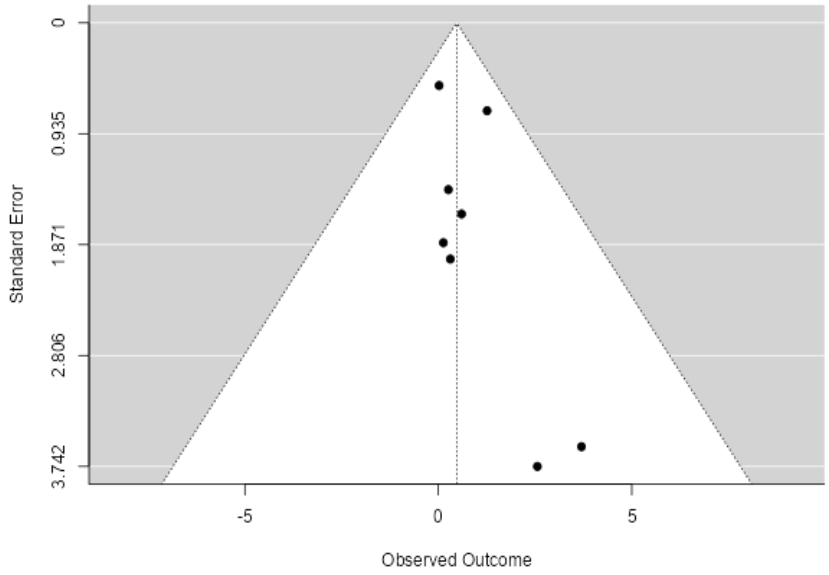
**Table 3**

*Publication Bias Assessment*

| Test Name | Value | P |
|---|---|---|
| Fail-Safe N | 0.000 | 0.067 |
| Kendall's Tau | 0.286 | 0.399 |
| Egger's Regression | 0.820 | 0.412 |

**Figure 3**

*Effect Size's Funnel Plot*




In case of publication bias, the funnel plot distribution shows a low publication bias. Effect sizes on the plot seem to follow a symmetrical distribution, which shows low publication biasness. Funnel Plot created as shown in the above figure is using the trim and fill technique of Duval and Tweedie trim and fill method.

## Discussion

This research applied meta-analysis to systematically review and quantitatively analyze 08 quasi-experimental research papers issued among 2000 to 2023. There are certain limitations to meta-analysis. The first of these, with its own drawbacks, is the meta-analysis. Another limitation is that the pretest-posttest control group design studies are only included in the study. These studies have been done across the world. Study was also limited to the articles in which academic achievement for science subject were analyzed.

The question of study is "how the project-based learning approach effects the academic achievement of pupils. Those articles were chosen for which particularly the effect of PBL was analyzed and specifically for science subject. A total of 8 studies were approached, in which the total participants were 727. As we compute the homogeneity value of articles according to the fixed effect model, we found Q = 3.05 with a confidence level of 95% for 7 degrees of freedom value. The Effect size of different studies varies between 0.13 to 3.70. It is found that all studies show a encouraging effect of Project-Based Learning on the Academic Achievement of students as compared to the traditional method of teaching.

The results of this meta-analysis are very alike to the meta-analysis conducted by Kaşarcı (2013) conducted particularly on the foundation of the literature available in the setting of Turkey schools. This meta-analysis shows that the effect of the PBL approach on academic achievement in the area of science is positive. The effect size value was between 0.763-1.273. The confidence interval has been found with effect size of 1.018. The analysis exposed that teaching by using PBL optimistically enhances students interest, motivation and indirectly improves overall learning of pupil in science. So, in comparison with traditional teaching PBL helps learners in understanding difficult concepts. Added to it a study conducted by Ayaz et al., (2015) identified the position of project-based learning affects the academic performance of science students. This study reviewed the available literature related to the research problems and had statistical data research particularly done in Turkey. The results of meta-analysis show that project-based learning is more productive than traditional learning approaches in science. This shows the optimistic results of intervention (PBL). The effect size of the PBL approach is find between 0.77- 1.218. The analysis of data show the confidence interval to be 0.997 for the academic achievements of science students. Among 42 studies, 3 show a low effect size, while the other 39 show a high effect size. It is not calculated why the three show a poor effect size which shows a gap for further studies.

The findings of this meta-analysis further highlights that project-based learning fosters critical thinking, teamwork, creative thinking and problem-solving skills, which are vital for success in modern science education. However, this meta-analysis has certain limitations, as only those studies were comprised that are based on the subject of science, and the method of research was mainly pre-test post-test control group designs may limit the generalizability of the findings. Additionally, the

diversity in implementation styles, duration, and contextual settings could have influenced the range of effect sizes observed.

## Conclusion

When the results are examined after meta-analysis, it is concluded that the project-based learning method has an optimistic effect on the Academic Achievement of pupils. It can be particularly used in elementary teaching to raise the academic performance of students. By integrating project-based learning into the early year science education, educators can foster a more engaging, active, and meaningful learning environment. This learning technique can enhance readiness for learning, enthusiasm and motivation among learners. Project-based learning not only improves academic achievement of pupils but also builds essential 21$^{st}$-century skills such as communication, collaboration, critical thinking, and problem-solving skill.

## Recommendations

This study unfolds the effectiveness of PBL teaching strategy for science learning. Teachers can use PBL approach in their lesson plans for fostering learning of students**.** This is recommended for further research in support of a meta-analysis on other factors involved in the project-based learning, like time period, effect size of different studies, sample size and its effect, location, etc. It is also recommended for scholars to find the effect of PBL on various subjects, particularly by doing a comparison based on different grade levels.

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