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A Meta-Analysis Approach to Measure the Impact of Project-Based Learning on Learning Outcome

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ABSTRACT

The importance of in depth analysis of previous studies on the impact of project-based learning on student learning outcomes over the past ten years to obtain a clearer picture of learning abilities that can be applied to science learning. This study set out to ascertain how project-based learning models affected the learning results of the students. The effect size (ES) studied is the result of several studies that have been carried out. This research uses meta-analysis, namely reviewing similar research, which is summarized from various research results quantitatively by looking for effect size (ES) values. The study journals used were international journals indexed by Scopus in the last 10 years, totaling 10 journals. Data obtained from the research instrument was analyzed using the effect size formula. The average effect size value obtained was 0,78 which is in the medium category. The study's findings support the notion that implementing the project-based learning (PjBL) paradigm to teach science can enhance students' learning outcomes.

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INTRODUCTION

The development of industry 4.0 is a term often used to describe the 21st century. The development of industry 4.0 is a technological development that supports all human activities, including the realm of education (Shoffa et al., 2021). The 21st century is the century of knowledge or it could also be called the century of education. As time goes by, science and technology become more developed and sophisticated. It is hoped that with the existence of science and technology, it will bring better changes in terms of education in Indonesia. Critical thinking, problem solving, communicating, and collaborating are empathy skills that people must have in the 21st century (Septikasari, 2018). Educators and students must improve their competencies.

Creating quality human resources is very important to be able to compete in this increasingly sophisticated era. Education forms the character and character of students. Education implemented in the 21st century uses the Merdeka curriculum. Merdeka curriculum has diverse intracurricular learning, so students have enough time to learn ideas and strengthen their abilities. The Merdeka Belajar curriculum aims to create more enjoyable education for students and teachers. So far, education in Indonesia has placed more emphasis on the knowledge aspect. The merdeka

curriculum has many advantages that are adjusted to the development of the times. This merdeka curriculum is simpler and more in-depth, provides "independence" for educational units to develop it, and offers a more interactive and relevant learning system. The aim of independent curriculum learning is to realize holistic and contextual student learning (Pratycia et al., 2023). In order for students' learning to go beyond memorization of the content and become more meaningful and practical.

In line with previous research on the effect of product-based project learning on high school students' understanding of concepts and science process skills. The results showed that project based learning had an impact on students' understanding of concepts and science process skills in the classroom. The results showed that learning outcomes and science process skills averaged 80.61 and 80.89 for the experimental class, and 77.08 and 74.64 for the control class. The analysis of the influence between variables produced a biserial coefficient value of 0.33 for learning outcomes and a coefficient of determination of the influence of project-based learning of 10.89% for learning outcomes and a coefficient of determination of the influence of project based learning of 16.06% for science process skills (Anggriani et al., 2019).

Additional studies looked at efforts to improve chemistry students' learning outcomes at SMA Negeri 1 Gombong using the project-based learning (PjBL) model. The findings showed that grade X students at SMK Negeri 1 Gombong could achieve better results in chemistry subjects by using the model (Sugiarsih, 2022). Project-based learning (PjBL) can help students solve problems and improve their learning skills by assisting them to explore, to understand, to organize, and to dig deeper into information during their projects. Project-based learning must be implemented effectively in the learning process and supported by adequate learning resources, according to Bagheri's research.

To solve problems in the teaching and learning process that focus on the products produced by the project, the project-based learning model utilizes projects to give students tasks to explore, assess, interpret, synthesize, and provide information, according to Grant said that the project-based learning model is a student-centered learning model. The first step taken by students is to conduct an in-depth investigation of the subject to be worked on. A research-based approach to meaningful, real, and relevant problems helps students understand learning constructively(Guo et al., 2020). According to Bander, a project-based learning model is a model that allows students to determine how the problem can arise, identify how the problem can arise, and then solve it together.

In addition, students can gain new knowledge and understanding through new experiences related to the lessons they are learning (Goyal et al., 2022). The project-based learning model allows students to be active, creative, and innovative in solving problems. The purpose of this model is for students to be able to compile assignments given by the teacher and produce their own work. This model also provides opportunities for students to work independently, organize learning, and solve problems (Panjaitan, 2023). It is hoped that the project-based learning model can meet the needs of the twenty-first century.

According to Westwood, some of the advantages of the project-based learning model are as follows: 1) PjBL can increase students' desire to learn. Research has shown that PjBL learning increases students' desire to learn in high school; 2) PjBL improves

students' ability to work together and collaborate in learning; 3) PjBL improves students' creative abilities and learning outcomes; and 4) PjBL improves students' academic abilities; 5) PjBL improves students' creative abilities and learning outcomes; 6) PjBL improves students' communication skills because they need to work together with others; 7) PjBL can improve management skills, problem solving, and organizing learning resources; and 8) PjBL makes the learning environment more enjoyable. (Dewi, 2022).

One of the weaknesses of the project-based learning model—which is based on the curriculum used in the twenty-first century—is: (1) it takes a lot of time to solve problems because the project-based learning model requires the creation of products to solve problems, (2) it requires quite a lot of money for the products created, (3) many teachers feel comfortable using traditional classes, where the teacher is the main actor in the class, and (4) There is a lot of equipment provided, (5) Students will experience difficulties when conducting tests and collecting information, (6) Students may be less active in group work, and (7) Students are worried about not being able to understand the topic as a whole when the topics given to each group are different (Niswara et al., 2019).

Therefore, an observation of previous research was conducted on the impact of project-based learning models on student learning outcomes in the last 10 years of scientific papers indexed by Scopus. First, this study highlights the literature on the impact of project-based learning models on students' science learning outcomes. Two approaches—meta-analysis and meta-ethnography—are used to summarize research. The first method examines research results statistically, while the second method is a qualitative summary. The results of the meta-analysis method can be more accurate and credible because they are more objective (focusing on the available data) (Santosa et al., 2021).

Meta-analysis is a statistical technique that combines quantitative evidence from multiple primary studies that test comparable hypotheses. The purpose of meta-analysis is to summarize the evidence and draw general conclusions. In meta-analysis, numerical indices, also known as effect size estimates, are used to describe the results of the studies. Examples of effect size estimates include correlation coefficients, standardized mean differences, and odds ratios. This study used analysis and summary of data from the study and several previous studies (Maharani, 2024).

Meta-analysis is a quantitative and systematic approach to uncovering previous research findings. According to Glass (1976), meta-analysis is a statistical analysis of the results of other people's research with the aim of integrating and reaching conclusions (Glass, 1976). To summarize the findings of two or more studies with the aim of combining, reviewing and summarizing previous research on project-based learning models on students' science learning outcomes.

METHODS

This research used a meta-analysis method. Meta-analysis is an approach that involves searching for literature in the context of scientific research (Novrita et al., 2024). This approach utilizes secondary data originating from articles published in accredited scientific journals. Selection of journal articles is based on certain criteria, namely: (1) The suitability of the article theme with the meta-analysis objectives; (2) Articles published in national and international journals indexed in the last 10 Scopus;

(3) Presenting the mean and standard deviation data required for calculating the effect size.

This research was conducted from April to June 2024. It was started with a search using the keywords project-based learning and learning outcomes. Several articles were obtained and then articles were selected that met the criteria for project-based learning to improve learning outcomes. The availability of data before action and after action in the form of scores. Then the score obtained is explained by looking for the effect size. The meta-analysis research procedures are as follows:

a. Determine and study the research topic that will be summarized.
b. Search for and collect a number of studies on a predetermined topic and select them. Literature searches can be done manually or via internet sites.
c. Researchers determine and study the research themes that will be summarized
d. Calculating the effect size value using the meta-analysis method
e. Identify whether or not there is heterogeneity in the effect size values in the model at this stage.
f. Draw conclusions and interpret meta-analysis research results (Gallucci, 2009).

Coding categories are used to conduct meta-analysis instruments. Coding categories refer to variables used to code and generate information needed to calculate the effect of teaching materials based on the inquiry learning model. The name, year, title, and level of education of the research subjects, the materials used in the research, the type of media used, and the dependent variables of the research are part of the coding categories.

Analysis of meta-analysis research data is done by measuring the effect size of research data in scientific articles. Statistical data of each study were recorded, including mean score, and standard deviation. These values are converted to effect size metrics using the formula that can be seen in Table 1. The following statistical formulas are used to process effect size data. Meanwhile, The effect size decision-making can be seen in Table 2.

Table 1. Statistical formula for calculating effect size

Statistic Data	Formula
Mean and standard deviation of 1 group	$\frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
Mean and standard deviation within groups (post-test only)	$\frac{\bar{x}_E - \bar{x}_C}{SD_c}$
Mean and standard deviation within groups (two groups pre-posttest)	$\frac{\left(\bar{x}_{post} - \bar{x}_{pre}\right)_E - \left(\bar{x}_{post} - \bar{x}_{pre}\right)_C}{\frac{SD_{pre\,C} + SD_{pre\,E} + SD_{Post\,C}}{3}}$

(Demirel & Dağyar, 2016)

Table 2. Decision categories for effect size values

Criteria	Interpretasi
$< 0{,}20$	Low
$0{,}20 - 0{,}80$	Moderate

> 0,80	High

RESULT AND DISCUSSION

This meta-analysis research was conducted to assess the effectiveness of the PjBL model in improving student learning outcomes. Selected journal articles that are relevant to the research focus are obtained from various sources that can be accessed via Google Scholar and Scopus. Next, data from each relevant journal article is analyzed to calculate the effect size. The average effect size is then calculated by considering the moderator variables that have been determined, namely the level of education and type of student learning outcomes. Researchers succeeded in identifying and collecting 10 Scopus-indexed journal articles, each coded 1 to 10. A summary of the effect size results from each journal can be found in Table 3. The recapitulation process aims to present a holistic picture of the impact of the PjBL learning model on science learning outcomes.

Table 3. Sources used for meta-analysis

No/ Code	Article title	Journal title	Journal Rank	Year
1	Project-based learning and problem-based learning models in critical and creative students	Jurnal Pendidikan IPA Indonesia	Q3	2023
2	The effect of authentic project-based learning on attitudes and career aspirations in STEM	Journal of Research in Science Teaching	Q1	2018
3	The Effects of Project Based Learning on Undergraduate Students' Achievement and Self Efficacy Beliefs Towards Science Teaching	Eurasia Journal of Mathematics, Science & Technology Education	Q2	2015
4	Analysisi of student's critical thinking skills of middle school through STEM education project-based learning	Jurnal Pendidikan IPA Indonesia	Q3	2018
5	Developing middle school students' problem-solving ability through interdisciplinary project-based learning	Journal Education for Chemical Engineers	Q1	2024
6	The role of project-based learning in improving the writing ability and sub-writing abilities of 10th grade Amharic speaking students.	Social Sciences & Humanities Open	Q1	2024
7	Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach	Computers and Education: Artificial Intelligence	Q1	2024
8	Developing a weather prediction project-based machine learning course in facilitating AI learning among high school students	Computers and Education: Artificial Intelligence	Q1	2023

9	The influence of flipped clasroom-based project assesment on concept understanding and critical thinking skills in physics learning	Jurnal Pendidikan IPA Indonesia	Q1	2022
10	The effect project-based learning with virtual media assistance on student's ceratívity in physics	Cakrawala Pendidikan	Q3	2017

Table 4. Calculation of the significant influence of using the project-based learning model on student learning outcomes

Article Code	Effect Size	Category
1	2,4	High level influence
2	0,137	Low level influence
3	0,175	Low
4	0,12	Low
5	0,096	Low
6	2,306	High
7	0,24	Moderate level of influence
8	0,32	Moderate
9	1,84	High
	0,72	Moderate
10	0,32	Moderate
Mean	0,78	Moderate level of influence

Based on Table 4, the ES values obtained from each journal have been reviewed from the effect size formula in Table 1. The results of calculating each journal effect size can be seen in Table 4. For the first journal discussing project-based learning and problem-based learning models for creative and critical students. An experiment with a two-by-two factorial design involving students in critical and creative attitudes explains the causal relationship between dependent and independent variables and a two-by-two factorial design (Loewen & Plonsky, 2017) (Zalbidea, 2017). This study was conducted at one of the vocational high schools (SMK) in South Tangerang in the 2021/2022 academic year in class XI pharmacy. Data were collected using descriptive test tools. Because there are accompanying variables that are difficult to control but can be measured by dependent variables, the data were analyzed inferentially using Anacova hypothesis testing (Silaen et al., 2021).

Project-based learning models include students and project reporting, planning projects, making schedules, assessing results, and producing results. In this study, the test instrument used was a validated essay question, which was given both before and after the test. The purpose of this test instrument was to measure students' critical and creative thinking skills before and after learning using the project-based learning model. The project-based learning model was applied to colloidal chemistry material. Descriptive data analysis showed the standard deviation, highest, lowest, average, and median scores, as well as the learning outcomes of students taught using the PjBL model separately.

The chemistry learning outcomes of students taught with PjBL (post-test) have an average of 82.9, while the pretest has 68 with a standard deviation of 6,2. Therefore, the influence size value of 2,4 is obtained, which indicates that students who are included in the category with an influence size value of more than 0,80 will be included

in the high category. So it can be concluded that the colloidal chemistry learning outcomes of vocational high school students are greatly influenced by the use of project-based learning models (Suradika et al., 2023).

The influence of authentic project-based learning on attitudes and career aspirations in STEM is the title of the second journal that will be published next. This study used a quasi-experimental design, with enrollment in PjBL (yes or no) serving as the quasi-experimental variable. This is because students were not randomly assigned to conditions. As part of a longer longitudinal study on student retention, data were gathered using the Survey of All Students (SAS). Every undergraduate student at University X receives an electronic survey called the SAS in the last month of each semester.

The study's measurements were included in an SAS section that was only distributed to applicants who declared on their college applications that they would desire to major in engineering or natural sciences. The institutional review board of the university was followed when gathering the data. Students who fulfilled the requirements for STEM matriculants were added to the study once the SAS was finished.

The study's findings showed that, in the absence of the project-based learning paradigm, the average learning outcome was 3,959, with a standard deviation of 0,903. In contrast, the average value for applying the project-based learning paradigm to STEM subjects was 4,083, with a standard deviation of 0,864. The result is an effect size value of 0,137, falling into the low group since it is less than 0,20. So it may be concluded that the adoption of the project-based learning approach with STEM has an affect on poor skills efficacy (Beier et al., 2019).

Ibrahim Bilgin's research has been published in the third publication the Effect of project-based learning on Undergraduate Students' Achievement and Self-Efficacious Beliefs Regarding Science Teaching. This study set out to ascertain how the Project-Based Learning (PjBL) approach affected the academic performance of undergraduate students as well as their perceptions of PjBL and self-efficacy views toward science education. The research sample comprised of two classes that were chosen at random from a group of seven classes that were enrolled in the Science Teaching Course at a Turkish state university's elementary school education department.

The PjBL approach was used to provide instructions to the randomly allocated treatment group (n = 33). Conventional techniques of instruction (TT) were used to instruct the control group (n = 33). The Science and Technology Teaching Achievement Test (STTAT) and the self-efficacy belief scale (SEBS) were employed as pre- and post-test measures. A control group was included in this investigation, which employed a quasi-experimental pre-test/post-test methodology. One treatment group and one control group were present. In a variety of scenarios when traditional designs are impractical or problematic, researchers can explore causal linkages with the use of quasi-experimental designs.

A total of 265 college students in seven classes at the Department of Education of the State University of Elementary Schools in Turkey made up the sample for this study, which included 66 undergraduate elementary school students in two classes. The teacher used the same approach with the second class. Thirty-two classes were

randomly selected as the control group (n = 33), which received instruction on the same themes using traditional teaching methods, and one class, designated as the treatment group (n = 33), was designated as such. Teaching Achievement Test for Science and Technology (STTAT): The researchers created this test, which has 28 multiple-choice questions covering every topic covered in the course on teaching science and technology.

Two specialists in educational science and one expert in measurement and assessment assessed the test questions. In order to ascertain the impact of the project-based method on students' academic performance, the data collected from the subjects were entered into an Excel data sheet. Thirty-two classes were randomly selected as the control group (n = 33), which received instruction on the same themes using traditional teaching methods, and one class, designated as the treatment group (n = 33), was designated as such. Teaching Achievement Test for Science and Technology (STTAT): The researchers created this test, which has 28 multiple-choice questions covering every topic covered in the course on teaching science and technology. Two specialists in educational science and one expert in measurement and assessment assessed the test questions. In order to ascertain the impact of the project-based method on students' academic performance, the data collected from the subjects were entered into an Excel data sheet.

Table 5. The mean and standard deviation for pre-SEBS and post-SEBS

Groups	Dependent Variables	n	Mean	Standard deviation
Project-based learning	Pre-test	33	70,757	7,504
	Post-test	33	72,969	9,040
Traditional method	Pre-test	33	67, 757	7,504
	Post-test	33	65,757	7,927

Based on Table 5, students in the treatment group who were taught using project-based learning methods obtained higher self-efficacy scores than students in the control group who were taught using traditional methods. From the results the effect size obtained was 0.175. So the effect size value is 0.175 <0.2 which is in the low category. The results showed that students in the treatment group produced better performance on the Post- SEBS and the Post-STTAT. The students in the treatment group expressed mostly positive opinions about the use of the Project-Based Learning method (Bilgin et al., 2015).

The article titled "Analysis of Middle School Students' Critical Thinking Skills Through STEM Education Project-Based Learning," aims to explore the critical thinking abilities of students by implementing STEM education within a Project-Based Learning framework.. This study uses a descriptive research design. The sample in this study was 160 high school students divided into nine groups. The instrument used was a student worksheet to explore initial knowledge with the material on how to purify wastewater to improve critical thinking. Students were asked to design a tool to clean wastewater. Previously, students were given material about colloids, solutions, suspensions, and wastewater. For project-based learning, they found solutions to clean wastewater by designing a wastewater cleaning tool project. The results of the study using the Tukey test showed that the average value of critical

thinking skills in class 1A was 2,92 (SD 0,72); 1B 2,75 (SD 0,65); 1C 2,67 (SD 0,62); 1D 3,03 (SD 0,62), and the average value of critical thinking skills of all students was 2,82. The highest and lowest critical thinking skills of students were in classes 1D and 1C. From the mean and SD values, the average effect size value was obtained as 0,12, so the effect size value of 0,12 <0,20 which means it is in the low category. So it can be concluded that the use of STEM education through Project Based Learning can affect students' critical thinking skills (Mutakinati et al., 2018).

The fifth article is entitled "The Ability to Develop High School Students' Problem Solving through Interdisciplinary Project-Based Learning". This study aims to develop students' problem-solving abilities through a project-based learning model. Students participate in the "homemade oxygenator" project for one month, design and produce oxygenators, and the project displays oxygenators. The sources of this study are project reports, assignments, presentations, questionnaire surveys, tests, and questionnaires. The results show that students creatively create oxygenator projects. students use different principles to produce oxygenator products, this can be seen from clarifying and identifying problems progressively, creating solutions by applying multidisciplinary knowledge, choosing the best solution through group argumentation, and optimizing solutions in continuous practice continuously, so that students can develop problem solving abilities during project assignments. This study uses a case study method (Merriam, 1998) with project-based learning activities on the topic of "homemade oxygenator". The researcher collected and analyzed data from different sources and used various methods and theories or called triangulation. Data collection tools project reports, presentations, contribution survey sheets, tests, and questionnaires. This study was conducted in a junior high school on the east coast of China. The participants in this study were 9th grade students aged 15-16 years. Where students learn 4 methods to produce oxygen in the laboratory: hydrogen peroxide decomposition, potassium permanganate decomposition, potassium chlorate decomposition, and air electrolysis. Data collection in the form of tests compiled by experts with chemistry and chemical engineering courses. The test is in the form of a pre-test and post-test.

The post-test score (79.60±9.65) of participants was an average of 3.68 higher than the pre-test score (75.92±10.73), which was statistically significant ($p<0.05$). In contrast, students in the control class scored 0.25 lower on the post-test (61.13±20.40) than on the pre-test (61.38±16.58). These results indicate that the project-based learning and project-based learning models can improve students' academic grades. More details can be seen in Table 6.

Table 6. The mean and standard deviation for pre-test and post-test

Groups	Dependent Variables	Mean	Standard Deviation	Effect Size
Project-based learning	Pretest	75,92	10,73	0.096
	Posttest	79,60	9,65	
Traditional method	Pre-test	61,38	16,58	
	Post-test	61,13	20,40	

It can be seen in Table 6 that the result of the effect size calculation is 0.096, which means 0.096b <0.20. So it can be interpreted that there is an influence of the project-based learning model on students' problem-solving abilities (Ling et al., 2024).

Research entitled the role of project-based learning in improving writing skills and sub-writing skills of grade 10 students who speak Amharic. The purpose of this study was to determine the role of Project-Based Learning in improving writing and sub-writing skills (content, organization of ideas, choice and use of words, language use, and Mechanism) of students who speak Amharic. The method in this study was quasi-experimental supported by quantitative research analysis. This study was conducted on grade 10 students aged 16 to 19 years. Data analysis used independent T-test and multivariate analysis (MANOVA) methods.

Based on the results of the data analysis, the overall writing and sub-writing ability scores in the experimental class were found to be significantly (p.05) better than the control class. Thus, the study shows that project-based learning has a significant role in improving students' writing and sub-writing abilities. So it is recommended to use a project-based learning model in the teaching and learning process (Alemneh & Gebrie, 2024).

Table 7. Post-Writing ability test results of control and experimental class students independent sample T-test

Test	Dependent Variables	Sample Size	Mean	Std. Deviation	Effect Size
Post-test	Controlled	47	53,957	3,620	2,306
	Expermental	47	62,305	3,446	

Based on Table 7, the average post-test scores of the control and experimental classes were 53,957 and 62,305. So that the effect size was obtained at 2,306, then the effect size value of 2,306> 0,80 is included in the high category. So it can be concluded that the project-based learning model has a role in improving the writing and sub-writing skills of grade 10 students in the Amharic language subject..

The seventh journal entitled developing an artificial intelligence literacy framework: Evaluation of a literacy course for high school students using a project-based learning approach. The purpose of AI literacy is to equip and educate the community with readiness to apply AI. The purpose of this study is to develop an AI Literacy Framework to prepare educated citizens to participate in the future society with a project-based learning model. The sample in this study was 128 course students. The post-course test showed that the course had improved students' ability to use AI concepts in solving problems. Data collection in the form of interview results (Kong et al., 2024). This research is part of an AI literacy project at a university in Hong Kong. (Kong et al., 2023) (Kong et al., 2021).

Table 8. Mean and SD before and after AI literacy course

Component	Before Course		After Course		Effect Size
	M	SD	M	SD	
Overall mean and SD	3,96	0,52	4,09	0,53	0,24

Table 8 shows that the pretest standard deviation was 0,53 and the mean pretest and posttest results were 3,96 and 4,09, respectively. With an effect size of 0,24, the value falls into the medium category, falling between 0,20 and 0,80. Therefore, it can

be said that the project-based learning model, which falls under the medium group, can help high school pupils improve their literacy abilities.

The 9th journal article entitled Developing a Machine Learning Course Based on Weather Prediction Project in Facilitating AI Learning among Secondary School Students. This research is an AI literacy project at a university in Hong Kong to support a program that recruits students from all secondary schools in Hong Kong to develop AI literacy. The AI literacy course consists of three parts. The first two parts are two 9-hour courses on AI concepts in machine learning and deep learning (Kong, Cheung, & Tsang, 2022). With learning steps (1) problem solving; (2) data collection; (3) data preprocessing; (4) training models; and (5) inference and prediction.

Both quantitative and qualitative data were used in this investigation. However, the researcher only considers quantitative study types because meta-analysis only examines effect size. An AI concept test with seven questions is the quantitative tool used to evaluate participants' application of AI principles to real-world problem solving. Table 9 below shows the outcomes of the pretest-posttest.

Table 9. Means and standard deviations learning outcomes

Component	Pretest		Posttest		Effect Size
	M	SD	M	SD	
CT Skills	2,44	1,22	3,63	1,30	0,97

Table 9 shows that the pretest standard deviation is 1,22 and the mean pretest and posttest values are 2,44 and 3,63 respectively. With an effect size of 0,97 and an effect size value more than 0,80, it falls into the strong group. Thus, it can be said that high school students twhofall into the high category can improve their reading abilities through the use of the project-based learning paradigm.

The ninth journal focuses on how project-based learning affects students' conceptual comprehension and critical thinking abilities when studying physics. This study looked at how students' critical thinking abilities in physics classes are impacted by project-based learning in the classroom. This study used a quantitative, one group post-test design. Data were gathered through tests and questionnaires, and then analyzed using Manova and descriptive statistics.

The findings of the study indicate that students who study with project assessments based on the flipped class approach and students who study with traditional simultaneous and partial assessments differ in their critical thinking skills and physics learning outcomes. The assessment style, which has two dimensions—conventional assessment and project assessment based on a flipped classroom—is used as an independent variable in this study. The control group received a traditional evaluation, while the experimental group received a flipped class approach focused on project assessment.

The experimental group underwent multiple learning phases, including the following: the lecturer explained the learning objectives, gave out teaching materials and instructional videos, had students write and present papers, worked on projects, communicated project outcomes, and had lecturers conduct project assessments. Concept understanding, critical thinking abilities, and physics learning outcomes are all partially and simultaneously impacted by flipped classroom-based project

assessment. Students will have the opportunity to collaborate with peers and share ideas through this learning experience.

Students have the opportunity to learn actively and independently through this curriculum, which increases their sense of accountability for both the learning process and its outcomes It is advised to use the novel, constructivist flipped classroom-based project assessment method to enhance conceptual comprehension and critical thinking. Teachers might use the study data as a substitute for innovative learning. They are also beneficial to other researchers in terms of project evaluation, comprehension of concepts, and critical thinking abilities (Rapi et al., 2022).

Based on Table 10, the effect sizes for understanding concepts and critical thinking are 1.84 and 0.72, so the effect sizes for concept understanding are > 0.8 and critical thinking skills are 0.20 - 0.80 so they are in the high and medium categories. Thus, there is an impact of project-based learning on students' conceptual understanding and critical thinking skills in physics classes.

Table 10. A general explanation of critical thinking skills (CTS) and concept understanding (CU)

Statistic	Experimental Group		Control Group		Effect Size	
	CU	CTS	CU	CTS	CU	CTS
MD	81,40	76,10	72,90	67,00	1,84	0,72
SD	8,40	8,20	4,60	11,77		

The influence of project-based learning with virtual media help on students' physics creativity is the title of the final journal. Learning physics should give students the chance to use their imaginations to comprehend the material they are studying (Rudolph & Hoffman, 2014). Using virtual media in a project-based learning model is one attempt to raise the caliber of physics education. The purpose of this study is to evaluate how student creativity is impacted by models that use virtual media. Participants in this quasi-experimental study were seniors from a Mataram high school. The cluster random sampling method was used to determine the research sample, which was then split into two classes. After that, the two sample classrooms were split up into an experimental class and a control class, each with thirty pupils.

When conducting research, students are presented with a project after they have addressed significant issues by utilizing difficulties from an actual setting. Following that, pupils were introduced to virtual media for project execution planning. Establishing the overall project execution timetable is the next stage. Teachers and students work together on this assignment. Students are required to use virtual media to complete an assignment sheet that serves as the project. At every meeting, the instructor grades the work that the students have completed on the assignment sheet. The teacher evaluates the students' assignment/project sheets in the form of a portfolio at the conclusion of the learning exercise. During the assessment phase, the instructor considers the finished product. The table below displays the pretest and posttest findings. Apply the variance test to evaluate the hypothesis. Based on the N-gain test results, increased inventiveness is identified. The findings of the study indicated that both classes' student inventiveness had increased. Compared to the control group, the experimental group's rise in inventiveness was greater. Both classrooms saw an increase in verbal and figurative creativity. Compared to figural creativity, verbal

creativity grows more quickly. The effect size is 0.32, which falls into the medium group and corresponds to an effect size of 0.20-0.80 according to the computation findings. Thus, the use of virtual media in project-based learning has an impact on students' physics creativity.

CONCLUSION

The application of the project-based learning model was found to have an effect on student learning outcomes based on the results of the journal review analysis. The average effect size of the model, which was based on the review of ten (10) articles, was 0,78 falling into the medium category. This, project-based learning is an excellent way to support students in learning activities by helping them uncover concepts and deepen their understanding, which will naturally improve student learning outcomes. The findings of this study open up the possibility of conducting additional experimental research on how teaching materials can enhance student learning outcomes. The project-based learning approach has an impact on learning outcomes, thus it can be utilized as an alternate source of information for chemistry education.

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