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The Impact of Project-Based Flex Blended Learning Model on Critical Thinking Skills of Students in Science Courses

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Abstract: This study aims to analyze the effectiveness of the Project-Based Flex Blended Learning (PjBFBL) model in improving students' critical thinking skills on Ohm's Law material in science courses. The quasi-experimental method uses a Nonequivalent Control Group Design with 41 fourth semester students divided into experimental (PjBFBL) and control (conventional) groups. Instruments include critical thinking tests based on seven indicators (interpretation, analysis, evaluation, inference, explanation, self-regulation, essential questions), analyzed using N-Gain, T-test, and effect size. Results showed the experimental group achieved a moderate N-Gain improvement (0.63) with the highest categories in inference (0.78; high) and explanation (0.73; high), while the control group only had a low N-Gain (0.28). The independent T-test confirmed the significant difference (t (25,092) = 7.230; p<0.05) with an average difference of 35.78% and a large effect size (Cohen's d=2.299). The research conclusion indicates that the PjBFBL model effectively improves critical thinking skills, particularly in multidimensional reasoning and information synthesis, through the integration of authentic projects, hybrid flexibility, and structured collaboration. The findings recommend the adoption of this model in science learning to bridge the 21st century competency gap, noting the need to strengthen the interpretation aspect through more contextualized instruments.

Keywords: Critical thinking skills; Hybrid Learning; Ohm's Law; Project-Based Flex Blended Learning; Science Courses

Introduction

21st century education faces multidimensional challenges that demand a transformation of learning paradigms. In the midst of accelerating technological developments and the demands of the global job market, educational institutions are forced to revitalize curriculum and teaching methodologies to produce graduates who not only master theoretical knowledge, but are also skilled in critical thinking, innovating, and adapting to the dynamics of a technology-based society (Annisa, 2022; Somantri, 2021). This phenomenon is further strengthened by the transition to the era of Society 5.0, where solutions to social and economic problems are expected to emerge from the integration of humanism with technological innovation (Dewi et al., 2022; Radiyah, 2024). However, data from the OECD (2021) reveals that 60% of university graduates in developing countries still fail to meet the critical thinking skills standards required by industry, creating a gap between educational output and the real needs of the workforce. This condition is an alarm for educational institutions to evaluate the effectiveness of the learning model that has been implemented (Abbas et al., 2023; Wahyuni et al., 2021).

The need for critical thinking skills as a basic competency of the 21st century has long been recognized in the educational literature. Facione in (Kurniawan et al., 2023) defines critical thinking as a complex cognitive process that involves the analysis, evaluation, and

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synthesis of information to make rational decisions. However, in reality, research in various scientific fields including science shows that this skill is still a weak point for students. A study (Manik et al., 2020) on chemistry students, for example, found that 72% of participants had difficulty solving two-tier problems that required multidimensional reasoning. Similar findings were reported (Wiyoko, 2019) in the context of PGSD students, where the analysis and evaluation indicators only achieved an average score of 45 out of a scale of 100. This low skill not only impacts academic performance, but also hinders students' capacity to deal with real problems, such as environmental data analysis, innovative product development, or evidence-based decision-making (Mardhani et al., 2022).

The root of this problem lies largely in the conventional learning model that is still dominant in college. The lecture-based one-way approach, as expressed (Ningsih, Edy, & Latifah, 2024), tends to position students as passive objects rather than active participants. In fact, research (Seituni et al., 2021) proves that the lack of discussion and collaboration space in conventional models hinders the development of metacognitive skills that are essential for critical thinking. The post-pandemic trend of blended learning, while offering flexibility, has exacerbated this problem. (Widowati et al., 2021) note that fragmented online interactions reduce the depth of critical discussions, while reliance on digital modules often dwarfs the process of conceptual exploration. The combination of the rigidity of conventional models and the limitations of traditional blended learning creates a learning environment that is not optimal for practicing complex analysis skills.

It is in this context that Project-Based Learning (PjBL) emerges as a promising pedagogical alternative. This model, as tested (Istiqomah et al., 2022) allows students to engage in the completion of real projects ranging from the design of science experiments to simple technological solutions that force them to apply theoretical knowledge in an authentic context. For example, in applied physics courses, students not only memorize the laws of thermodynamics, but design renewable energy prototypes while discussing efficiency and environmental impact. This approach, according to (Rumiani, 2022), organically develops the skills of cause-and-effect analysis, evaluation of alternative solutions, and cross-disciplinary information synthesis. However, the implementation of PjBL independently still has weaknesses, especially in terms of time and space flexibility, which is the main need of the digital generation (Rahmadani et al., 2022).

Innovative solutions emerged through the integration of PjBL with the Flex Blended Learning (FBL) model, a hybrid approach that combines the advantages of structured online learning with intensive face-to-face interactions. As explained (Masanggelo et al., 2024), FBL provides freedom for students to access asynchronous materials independently, while synchronous sessions are focused on project discussions, peer review, and direct guidance from lecturers. This combination creates a learning ecosystem where students not only "do the project", but also reflect on the process through guided online discussion forums and staged presentations. Preliminary research by (Rochmahwati et al., 2024) shows that this hybrid model increases students' intrinsic motivation by 35% compared to conventional PjBL, as it provides space to explore individual interests without sacrificing conceptual depth.

Despite the potential, the effectiveness of the PjBL-FBL model in the context of science courses still needs to be studied more deeply. Critical questions such as: How do the dynamics of online collaboration affect the quality of analysis in science projects? Can the flexibility of time in FBL be compensated with the depth of critical thinking?—not fully answered in the current literature. Research by (Altim et al., 2024) on chemical engineering students found that although PjBL improves laboratory skills, without the right FBL structure, students tend to have difficulty managing time and task priority. These findings suggest that the synergy between flexibility and structure in hybrid models should be carefully designed, particularly for science courses that are loaded with experimentation and quantitative data analysis.

The urgency of this research lies not only in the development of new pedagogical models, but also in the response to the global competency crisis. The World Economic Forum's latest data for 2023 predicts that 44% of today's relevant skills will change in the next five years, with critical thinking skills occupying the top of the most sought-after positions. In the context of science, graduates are not only required to master science concepts, but also be able to analyze contemporary issues such as climate change or biotechnology ethics through a multidisciplinary lens. The PjBL-FBL model proposed in this study is expected to be a blueprint for universities to produce scientists who are not only technically competent, but also critical in assessing the impact of their science on society. As emphasized (León et al., 2024), the integration of 21st century skills in science education is key to shaping a generation capable of bridging laboratory findings with real solutions at the global level.

Method

Research Design

This study was designed with a quasi-experimental approach using the Nonequivalent Control Group

Design to test the effectiveness of the Project-Based Flex Blended Learning (PjBFBL) model in improving students' critical thinking skills in Ohm's Law material. This design involved two groups, namely the experimental group that received the Project-Based Flex Blended Learning (PjBFBL) model learning and the control group that used conventional methods. Both groups were given a pretest before treatment and a posttest after the intervention to compare improvements in critical thinking skills.

Table 1. Research Design

Group	Pre-Test	Treatment	Post-Test
Experiment (Model PjBFBL)	O1	P	O2
Control (Conventional)	O3	K	O4

Information:
O1 : Pre-Test in the experimental class
O2 : Post-Test on the control class
O3 : Pre-Test in the experimental class
O4 : Post-Test on the control class
P : Model Project Based Flex Blended Learning
K : Conventional models

Participants

The research participants consisted of students of the Madrasah Ibtidaiyah Teacher Education Study Program IAIN Sultan Amai Gorontalo academic year 2024/2025 which was divided into 21 students in the experimental group and 20 students in the control group. Sample selection was carried out purposively by ensuring the similarity of the initial characteristics of the two groups, such as the level of material understanding and previous learning experience, to minimize bias.

Research Instruments

The research instruments used include a description based critical thinking skill test with 7 indicators: Interpretation, analysis, evaluation, inference, explanation, self-regulation, and essential questions, which have been validated theoretically and empirically. In addition, observation sheets are used to assess student activities during learning, such as collaboration, project planning, and presentation of results. Student responses to the PjBFBL model were measured through a questionnaire consisting of 21 questions.

Research Procedure

The research procedure is divided into three main stages. In the preparation stage, the researcher conducts preliminary studies, prepares a Semester Implementation Plan (RPS), and develops test instruments and project-based Student Worksheets (MFIs). The implementation phase involves the application of the PjBFBL model in experimental groups with nine syntypes, namely Integrated Curriculum Planning, Provision of Hybrid Learning Resources, Independent Online Learning, Collaborative Face-to-Face Sessions, Project Deepening and Advanced Research, Hybrid Product Development, Hybrid Presentation and Feedback, Holistic Evaluation and Reflection, Follow-up and Enrichment.

Meanwhile, the control group received conventional learning through hands-on learning, demonstrations and limited discussions. Pretests and posttests were given to both groups to measure the improvement of critical thinking skills.

Data Analysis

The collected data was analyzed using the SPSS 27 program with a series of statistical tests. The homogeneity test (Levene's Test) ensures the similarity of variance between the two groups. Independent T-tests confirmed significant differences between the experimental group's critical thinking skills improvement and controls (Sig. 0.000 < 0.05). Relative increase is measured through gain and n-gain..

Result and Discussion

The effectiveness of students' critical thinking skills results was assessed using pretest and posttest questions with 21 multiple-choice questions. The improvement in critical thinking skills among students in the experimental and control classrooms was calculated by N-gain, as shown in the following Table 2.

Table 2. Data on improving critical thinking skills of students in the experimental class and the control class

Class	Pre-Test Mean	Post-Test Mean	Gain	N-Gain	N-Gain Category	N-Gain Percent	Interpretation of Effectiveness
Eksperiment	54.42	82.99	28.57	0.63	Medium	63 %	Quite Effective
Control	54.52	67.62	13.10	0.28	Low	28 %	Ineffective

Table 2 shows data on the improvement of students' critical thinking skills in experimental and control classes. In the experimental class, the average pretest was 54.42, while the average posttest was 82.99. So, the N-gain is 0.63 in the medium category. Meanwhile, in the control class, the average pretest was 54.52 and the average posttest was 67.62. Thus, the N-gain is 0.28 in the low category. The pretest and posttest questions are based on critical thinking skill indicators taken from the opinions of several experts. Indicators of critical thinking skills have several components: Interpretation, analysis, evaluation, inference, explanation, self-regulation, and essential questions. Table 3 provides detailed information on the N-Gain for each indicator.

Table 3. N-Gain for all Critical thinking skills indicators in the Experiment class

Critical Thinking Skills	Pre-Test	Post-Test	Gain	N-Gain	N-Gain Percent	Category
Interpretation	84.13	87.30	3.17	0.20	20.00	Low
Analysis	65.08	77.78	12.70	0.36	36.36	Medium
Evaluation	58.73	80.95	22.22	0.54	53.85	Medium
Inference	42.86	87.30	44.44	0.78	77.78	High
Eksplanatory	41.27	84.13	42.86	0.73	72.97	High
Self regulation	50.79	82.54	31.75	0.65	64.52	Medium
Essential Questions	38.10	80.95	42.86	0.69	69.23	Medium

Table 4. N-Gain for all Indicators of critical thinking skills in the Control class

Critical Thinking Skills	Pre-Test	Post-Test	Gain	N-Gain	N-Gain Percent	Category
Interpretation	76.67	78.33	1.67	0.07	7.14	Low
Analysis	61.67	70.00	8.33	0.22	21.74	Low
Evaluation	61.67	68.33	6.67	0.17	17.39	Low
Inference	46.67	63.33	16.67	0.31	31.25	Medium
Eksplanatory	46.67	66.67	20.00	0.38	37.50	Medium
Self regulation	48.33	65.00	16.67	0.32	32.26	Medium
Essential Questions	40.00	61.67	21.67	0.36	36.11	Medium

Tables 3 and 4 show the N-Gain for each aspect of the critical thinking skills indicator, which includes Interpretation, analysis, evaluation, inference, explanation, self-regulation, and essential questions. Each aspect of critical thinking skills includes 3 multiple-choice questions about ohm's law. Figure 1 illustrates the improvement of students' critical thinking skills indicators in the form of a diagram.

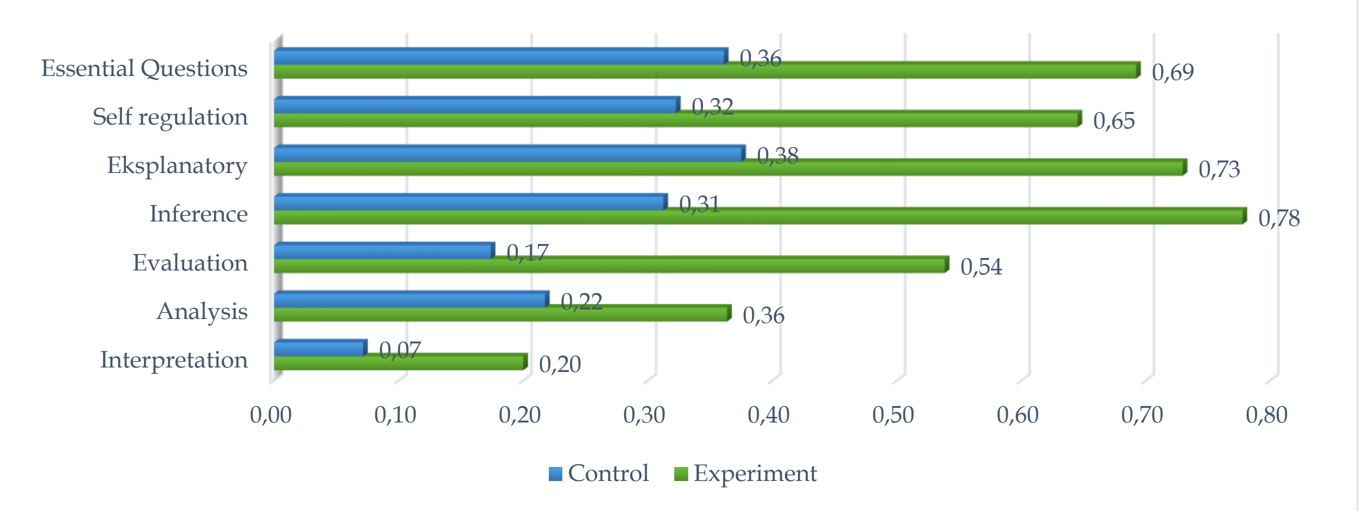

Figure 1. N-Gain Test Result Diagram for Questions per Critical Thinking Skill Indicators

Based on the diagram in Figure 1, the highest N-Gain value of the experimental class was in the Inference indicator, which was 0.78 with the high category, while the control class had an N-Gain value of 0.38 with the medium category. Furthermore, for the lowest N-Gain value in the Interpretation indicator with the experimental class N-Gain 0.20 in the low category and the N-Gain control class 0.07 in the low category, it can be concluded that the N-Gain of the experimental class is higher in all indicators than the control class. This is due to the application of the PjBFBL model in Ohm's legal material in science learning in experimental classes. The influence of the PjBFBL model in improving critical thinking skills was then analyzed using the t-test presented in Table 5.

Table 5. Independent T-Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NGain_Percent	Equal variances assumed	14.447	.000	7.359	39	.000	35.77798	4.86208	25.94348	45.61247
	Equal variances not assumed			7.230	25.092	.000	35.77798	4.94884	25.58756	45.96840

The results of the Levene test showed a significance value of 0.000 ($p < 0.05$), which indicated that the assumption of homogeneity of the variance was not met ($F = 14.447$). Therefore, the T test result used is the line Equal variances not assumed. Based on the independent T test, there was a statistically significant difference in the percentage increase (NGain_Persen) between the two groups (t(25,092) = 7,230; $p < 0.05$). The mean difference between the two groups was 35.78%, with the experimental class having significantly higher values than the control class. The 95% confidence range (25.59% to 45.97%) indicates that this difference is consistent and does not involve zeros, so it can be concluded that the difference is statistically significant as well as practical. The mean difference of 35.78% indicated that the intervention of the PjBFBL model applied to the experimental class had a very large impact on improving critical thinking skills compared to the control class. The high statistical significance ($p < 0.05$) and the narrow confidence range (only about 20%) strengthen the conclusion that the observed effect is not the result of chance, but rather reflects real differences between classes, thus it can be concluded that there is a significant (real) difference in effectiveness between the use of the PjBFBL model and conventional methods to improve critical thinking skills in the science course of Ohm's law subject in fourth-semester students Madrasah Ibtidaiyah Study Program, IAIN Sultan Amai Gorontalo.

Table 6. Test Effect Size

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
NGain_Persen	Cohen's d	15.56163	2.299	1.494	3.086
	Hedges' correction	15.86911	2.255	1.465	3.026
	Glass's delta	20.51587	1.744	.908	2.555

The results of the effect size calculation show that the difference in percentage increase (NGain_Persen) between classes has a very large influence statistically and practically. Based on Cohen's d, the observed effect magnitude was 2,299 (95% CI [1,494, 3,086]), which far exceeded the large effect threshold ($d \geq 0.8$) according to Cohen's criteria. These results are reinforced by Hedges' correction (Hedges' g = 2.255; 95% CI [1.465, 3.026]) which adjusts the bias for small samples, as well as Glass's delta ($\Delta = 1.744$; 95% CI [0.908, 2.555]) which uses the standard deviation of the control group as a standardizer. The entire confidence interval did not include the number 0, thus confirming that the observed effects were significant and consistent.

Cohen's d value of 2.299 indicates that the intervention of the PjBFBL model provides a very drastic improvement in critical thinking skills (about 2.3 standard deviations) compared to the control class. Glass's slightly lower delta (1,744) but remaining in the large effect category confirms that although the calculation uses the standard deviation of the control group (to reduce variance heterogeneity bias), the effect of the intervention is still very pronounced. These results are in line with the previous T-test findings which showed a significant mean difference of 35.78%. Thus, it can be concluded that interventions not only have a statistical impact, but also have high practical relevance in improving the quality of learning. The average Post-Test in the experimental class was greater than in the control class. This is due to the difference in treatment between the experimental and control classes.

The control class used powerpoint media in Ohm's legal material and used a direct learning model with group discussion techniques and preceded by demonstrations and explanations from the teaching lecturer, while the experimental class used the PjBFBL model with various syntax and various learning techniques and methods so that students were more free to manage their time.

Syntax 1 Integrated Curriculum Planning. In this step, the learning process begins with the design of a holistic curriculum that brings together real-world problem-based projects with hybrid activities (online and face-to-face). Teachers formulate challenges or guiding questions that are relevant to the student's context, while directing independent and collaborative learning goals. LMS platforms such as Google Classroom or Moodle are set up as a center for distributing materials, project guides, and hybrid schedules. Students are divided into collaborative groups with specific roles, ensuring that each member actively contributes according to their expertise ((Arya et al., 2023; Moyo et al., 2023)

Syntax 2, Provision of Hybrid Learning Resources, teachers curate digital resources such as interactive modules, concept explaining videos, and online discussion forums to support self-paced learning. Project guides that include objectives, technical steps, and assessment rubrics are uploaded to the LMS so that students can systematically plan their research and assignments. On the face-to-face side, physical facilities such as laboratories, teaching aids, or presentation materials are prepared to facilitate practical exploration (Fauzi et al., 2023; Hartati et al., 2022)

Syntax 3, Self-Paced Online Learning, students learn basic material independently through the LMS, including watching videos, taking formative quizzes, and reading literature related to project topics. They also conduct initial research digitally, such as online surveys, secondary data analysis, or exploration of scientific journals. Discussion forums in LMS are used for brainstorming ideas between group members, allowing for the exchange of ideas before face-to-face sessions (Bizami, Tasir, & Kew, 2022; Handayani, Arafah, & Khaeruddin, 2024).

Syntax 4, Collaborative Face-to-Face Sessions, in this phase, teachers facilitate face-to-face discussions to align conceptual understanding, refine project plans, and answer critical questions. Students work in groups to develop project timelines, divide tasks based on expertise, and design implementation strategies. Direct consultation with teachers is carried out to ensure the suitability of the project with the targeted learning outcomes (Saekawati & Nasrudin, 2021).

Syntax 5, Project Deepening and Advanced Research, students continue their project exploration in a hybrid manner: conducting data analysis or virtual experiments through an online platform, as well as physically testing concepts in the lab or through in-person interviews. Teachers provide real-time feedback via LMS or virtual sessions to guide the process. Supporting technologies such as collaboration applications or digital simulations are used to enrich research results (Jalinus et al., 2017)(Jalinus et al., 2017; Krasnova et al., 2020)

Syntax 6, Hybrid Product Development, students develop project products by combining digital resources (design software, data analysis tools) and physical facilities (workshops, creative materials). Draft presentations are carried out in a hybrid manner, for example through webinars or pitching in class to get input from teachers and peers. The revision process is iterative based on multidimensional feedback, both from online platforms and live discussions (Naviri et al., 2021).

Syntax 7, Hybrid Presentation and Feedback, the final project is presented flexibly, either in-person or virtually, to an audience that includes faculty, other students, and the relevant community. Formative assessments were carried out using rubrics that included online (forum engagement, accuracy of task collection) and face-to-face (product creativity, collaboration dynamics). Feedback from the audience is used as a holistic evaluation material (Wiraprakasa, 2019)

Syntax 8, Holistic Evaluation and Reflection, Teachers conduct summative assessments by combining product quality, online participation, and collaborative contributions. Students reflect on their learning experiences through digital journals and face-to-face group discussions to identify achievements and challenges during the process. Teacher feedback is delivered directly and through the LMS, accompanied by recommendations for further competency development (Oktaria et al., 2021).

Syntax 9, Follow-up and Enrichment, based on the results of the evaluation, teachers upload enrichment materials to the LMS for students who want to delve deeper into the topic, such as advanced tutorials or complex case studies. Additional projects with related themes are offered optionally, allowing students to explore specific interests through a hybrid approach. The curriculum is dynamically revised taking into account student input and findings during implementation, ensuring the sustainability of learning (Maresca et al., 2014).

This model emphasizes flexibility, technology integration, and sustainability, leveraging the power of hybrid learning to create an adaptive, student-centered learning experience. Students' critical thinking skills were then measured using a pretest and posttest with multiple-choice questions.

This study adopts seven indicators of critical thinking skills based on theories from several experts and previous researchers, namely Interpretation refers to the ability to understand and explain the meaning of information or data. This indicator emphasizes how students are able to summarize the core of the reading or material they hear, then convey these ideas clearly to others. This ability not only tests deep understanding, but also effective communication skills (Fanani et al., 2024; Saffanah et al., 2023). Analysis is the skill of breaking down information into small pieces to understand the structure and relationships between ideas. Students are trained to evaluate arguments, identify patterns, and explore connections between different data or concepts. This process encourages critical thinking in solving complex problems (Rusmiyati et al., 2024; Twiningsih et al., 2023; Zahroh et al., 2021). Evaluation includes the ability to assess the validity of arguments, evidence, or information based on specific criteria. Students are taught to compare sources, determine the relevance of data, and test the reliability of information. This skill is the foundation for making objective decisions (Rusmiyati et al., 2024; Saffanah et al., 2023; Twiningsih et al., 2023). Inference involves the process of drawing logical conclusions from the available data. Students are invited to look at implicit implications, make predictions, or develop hypotheses based on facts. This ability encourages deductive and inductive thinking to produce grounded interpretations (Fanani et al., 2024; Nada et al., 2022). Explanatory is the ability to provide a logical reason behind an opinion or decision. Students must be able to explain their analysis process in a structured manner and prove claims with coherent arguments. This trains transparency of thinking and intellectual accountability (Saffanah et al., 2023; Yustiasyah et al., 2023). Self-Regulation is related to the ability of students to monitor and reflect on their own learning process. This includes awareness of strengths and weaknesses, adjustment of learning strategies, and the development of independence. These skills are crucial for building intrinsic motivation and academic responsibility (Paraniti et al., 2024). Essential Questions refer to the ability to formulate fundamental questions that encourage deep exploration. Students are trained to narrow down the focus of the problem, test assumptions, and identify information gaps. The right questions can be the key in unlocking new insights (Qur'aini & Agusta, 2023).

The results showed a variation in improvement in each indicator, with the experimental class receiving the PjBFBL model intervention achieving an N-Gain of 63% (the category of moderately effective), while the control class was only 28% (ineffective). The highest improvement in the experimental class occurred in the inference (N-Gain 77.78%) and explanatory (72.97%) indicators, which correspond to the theory that data-driven reasoning and the skill of communicating logical flows can be developed through project methods. This is supported by a low pre-test on both indicators (inference: 42.86; explanation: 41.27) which increased significantly post-intervention, demonstrating the effectiveness of the learning model in training these skills.

On the other hand, the interpretation indicator recorded the lowest increase (N-Gain 20%) even though the pre-test was already relatively high (84.13). This phenomenon indicates that information understanding skills may have been internalized before, while multiple-choice-based research instruments are less able to measure multidimensional aspects of interpretation. Similar results were seen in the analysis indicator (N-Gain 36.36%), which despite the increase, is still in the medium category. These findings are in line with research (Zahroh et al., 2021) that highlights the need for bias identification exercises and argument logic to optimize critical analysis.

In the evaluation indicator, the experimental class achieved an N-Gain of 53.85%, higher than the control class (17.39%). However, this achievement is still moderate, indicating the need to strengthen learning strategies such as structured debates or peer review to train critical assessments of the validity of arguments. Meanwhile, self-regulation (N-Gain 64.52%) and essential questions (69.23%) in the experimental class showed a moderate improvement, hinting at the importance of integrating self-reflection and open-ended question-formulating exercises in the curriculum.

Overall, this study proves that the PjBFBL model is able to improve critical thinking skills, especially in the aspects of inference and explanation. However, the low improvement in interpretation and analysis demands a reevaluation of measurement instruments as well as more contextual learning designs, such as the use of case studies or analytical essays. The practical implication is that educators need to strengthen methods that encourage argument evaluation, self-regulation through reflection, and the development of essential questions to create a holistic and critical literacy-oriented learning environment.

Conclusion

This study confirms that the application of the Project-Based Flipped Blended Learning (PjBFBL) model significantly improves students' critical thinking skills in Ohm's Law material compared to conventional methods. N-Gain analysis showed a moderate category increase (0.63) in the experimental class, while the control class only reached the low category (0.28). Inference was the highest aspect (N-Gain 0.78; high) in the experimental class, while Interpretation was the lowest aspect (N-Gain 0.20) but still superior to control (N-Gain 0.07).

Statistical tests corroborated the findings: independent T-tests ($t(25{,}092)=7{,}230$; $p<0.05$) showed significant differences with an average difference of 35.78% (95% CI [25.59%-45.97%]). Magnitude of the effect (Cohen's $d=2.299$; Hedges' $g=2{,}255$; Glass's $\Delta=1.744$) indicates a large practical impact ($d>0.8$), with a confidence interval that does not involve zero. These results confirm that PjBFBL is not only statistically effective but also pedagogically relevant in encouraging critical thinking skills, especially in the context of project-based science learning on Ohm's legal material.

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Author's Contributions
All authors were collaboratively involved in the completion of the research. E.A. acts as the main person in charge of designing research flows, validating instruments, developing methodologies, and conducting data analysis. In addition, E.A. is also in charge of revising the substance of the results and discussions as well as proofreading the final manuscript. YH.f.m. contributes to the primary data collection, database organization, and initial data processing. H.Z. plays a role in the preparation of article drafts, language editing according to academic standards, and refinement of the interpretation of research findings.

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Conflict of Interest
The author emphatically states that there are no financial or non-financial conflicts of interest in this study. The research process to the preparation of the article is carried out independently, and all the findings presented are purely the result of objective analysis without influence from any party.

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