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Enhancing Senior High School Students' Critical Thinking in Economics Learning Through the Project-Based Learning Model

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ABSTRACT

Critical thinking is essential in economics education, yet many senior high school students are still taught through memorization-focused methods, limiting the development of higher-order thinking skills. Project-Based Learning (PjBL) offers a potential alternative by engaging students in real-world, inquiry-based tasks. This quasi-experimental study employed a nonequivalent control group pretest–posttest design involving 71 senior high school students. The experimental group received instruction using the PjBL model, while the control group followed conventional teaching. Data were collected using a validated 20-item multiple-choice critical thinking test aligned with Bloom's revised taxonomy (C4–C6). ANCOVA was used to analyze posttest differences, with pretest scores as covariates. Hedges' g and normalized gain (N-gain) were calculated to assess effect magnitude and improvement. ANCOVA results revealed a statistically significant difference in posttest scores favoring the PjBL group ($F = 5.686$, $p = .020$), with a medium effect size (Partial Eta Squared = .078). The experimental group outperformed the control group with a mean posttest score of 67.86 versus 60.00. Hedges' g was 0.522, and N-gain for the PjBL group ($M = 0.558$) exceeded that of the control group ($M = 0.435$). The findings suggest that PjBL is effective in enhancing students' critical thinking in economics, particularly when projects are grounded in real-life contexts such as local inflation data. PjBL implementation requires structured planning, authentic tasks, and clear assessment criteria.

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1. INTRODUCTION

Economics education at the senior high school level aims not only to provide conceptual understanding but also to develop students' abilities to analyze economic phenomena, make decisions, and solve real-world problems (Purba, 2025; Purba et al., 2021). However, students' learning outcomes indicate that critical thinking skills remain suboptimal. According to PISA 2022 data, Indonesia ranks low (reading: 71st, mathematics: 70th, science: 67th out of 81 countries), with the majority of students still below the baseline competency level. In the newly assessed domain of Creative Thinking, students perform relatively better in written and visual expression but show weaknesses in social and scientific problem-solving. This situation underscores a gap between the learning objectives, which emphasize

contextual problem-solving, and classroom practices that do not provide sufficient opportunities for developing critical thinking (OECD, 2022).

Critical thinking is understood as the ability to analyze, evaluate, and integrate information to produce logical and appropriate decisions (Facione, 2015). It constitutes a core 21st-century competency, enabling students to effectively analyze, evaluate, and synthesize information during problem-solving and decision-making processes, both in academic contexts and in real-life situations (Lestari et al., 2025; Rizki & Suprapto, 2024). Nevertheless, many senior high school students still face difficulties in developing critical thinking skills, despite its crucial role in preparing them for higher education and future careers (Indriati et al., 2024).

The low level of students' critical thinking skills is largely attributed to learning models that remain focused on rote memorization, such as lectures and assignments that merely require information repetition (Eckel et al., 2019; Prayogi et al., 2024). An education culture that emphasizes examination scores prompts teachers to teach quickly and efficiently, often neglecting opportunities to practice critical thinking. Furthermore, classroom environments that are not conducive to dialogue discourage students from asking questions or expressing opinions, thereby reducing participation in discussions (Maher & King, 2023; Xuan Mai et al., 2024).

Field studies have found that teachers rarely, if ever, provide students with project-based learning experiences. Observations in schools indicate that economics instruction is still dominated by lectures and exercise-based activities, causing students to memorize concepts without connecting them to real-world situations (Pratiwi et al., 2023). In fact, the characteristics of the economics curriculum offer ample opportunities for students to engage in contextual projects, such as conducting market surveys or developing business plans. Such projects can foster critical thinking skills, as they require students to analyze data, make decisions, and formulate solutions.

Project-Based Learning (PjBL) has emerged as an effective strategy for developing critical thinking skills because it emphasises authentic, relevant projects, enabling students not only to understand concepts theoretically but also to apply them in problem-solving contexts (Goshu, 2024; Thomas, 2000). Research indicates that PjBL enhances critical thinking through collaboration, in-depth investigation, and the resolution of complex problems (Bulu & Tanggur, 2021; Markula & Aksela, 2022). Its effectiveness has been observed in various contexts, such as the use of mind maps in economics lessons Budayani & Meitriana, 2023), the improvement of higher-order thinking skills (Pratiwi et al., 2023) and comparisons with traditional PjBL showing superior outcomes (Munawaroh, 2020). Additional evidence demonstrates critical thinking skill gains with an average N-Gain of 0.6 in temperature and heat material (Sumardiana, 2020), further reinforced by meta-analyses confirming PjBL's advantages over conventional methods, although its success depends on project design and media support (Tafakur et al., 2023). Moreover, effective implementation is influenced by teachers' abilities to design projects according to available time and resources (Sari & Has, 2023).

More broadly, PjBL has been shown to promote active learning, collaboration, and the practical application of knowledge, contributing significantly to the development of critical thinking skills (Dias-Oliveira et al., 2024; Elfeky et al., 2025). Additionally, PjBL supports the development of communication, teamwork, and self-management skills, which are essential for students in the modern era (Ab Wahid et al., 2020; Morini et al., 2025).

Although numerous studies have confirmed the effectiveness of PBL in enhancing critical thinking, most research has focused on science, environmental, and business subjects (Dias-Oliveira et al., 2024; Lestari et al., 2025). The application of PBL in high school economics education has been relatively underexplored, despite the subject's demand for students to analyze abstract concepts while understanding real-world phenomena closely linked to critical thinking skills (Mardani et al., 2021).

Based on this gap, the present study aims to explore the effectiveness of PjBL in improving students' critical thinking skills in high school economics. The research questions include how the implementation of PjBL can enhance students' critical thinking abilities in economics learning, what additional skills—such as communication, teamwork, and problem-solving—can be developed

through PjBL, and how students' critical thinking outcomes compare between those taught using PjBL and those using traditional methods (Maros et al., 2023; Wickramasinghe & Appiah, 2024). This study is expected to provide theoretical contributions by expanding research on PBL effectiveness into the field of economics education at the secondary level. Practically, the findings may serve as a reference for teachers in designing innovative learning strategies that foster students' critical thinking skills. Furthermore, the results are expected to support efforts to prepare young generations to face academic challenges, the workforce, and real-life situations in the 21st century (Susiyanti et al., 2022).

RQ1: To what extent does Project-Based Learning (PBL) lead to higher posttest scores in students' critical thinking skills compared to conventional instruction, when controlling for pretest performance?

RQ2: What is the magnitude of the effect of PBL on students' critical thinking skills, as measured by standardized effect sizes?

2. METHODS

This study employed a quantitative approach with a quasi-experimental method. The research design used was a Non-Equivalent Control Group Design, in which two groups, not randomly selected but with relatively similar abilities, were involved: the experimental class, which was taught using the Project-Based Learning (PjBL) model, and the control class, which was taught using conventional teaching methods (Creswell, 2014). The design can be illustrated as follows:

Table 1. Pretest–Posttest Control Group Experimental Design

Experiment Group	O_1	X	O_2
Control Group	O_3		O_4

Note. O_1 and O_3 represent the pretest scores used to measure students' initial critical thinking abilities. X denotes the treatment, which is the implementation of Project-Based Learning (PjBL), while O_2 and O_4 represent the posttest scores used to assess students' critical thinking skills after instruction.

The research population comprised all 11th-grade students at SMA Negeri Harekakae during the 2024/2025 academic year, second semester. The research sample consisted of two 11th-grade classes enrolled in the Economics specialization, totaling 71 students. Sampling was conducted using purposive sampling, considering that selected classes must be taking Economics, in accordance with the study's focus on examining the effectiveness of Project-Based Learning (PjBL) on students' critical thinking skills (Arikunto, 2016). The study was conducted during the regular school schedule over four sessions (each lasting 90 minutes), with both the experimental and control groups taught by the same teacher. Inclusion criteria for the study required students to be fully enrolled in the Economics course during the current semester.

The following flow illustrates student participation in the study:

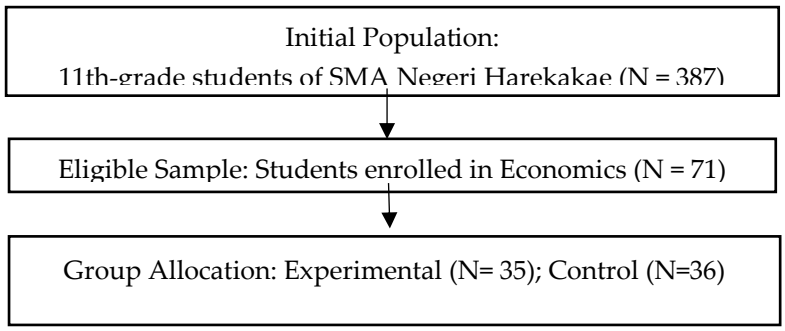

Figure 1. The flow illustrates student participation

Table 2. Demographic Characteristics of Participants in the Experimental and Control Groups

Characteristics	Experiment (n = 35)	Control (n = 36)	Total (N = 71)
Gender			
Male (M)	9 (25.7%)	11 (30.6%)	20 (28.2%)
Female (F)	26 (74.3%)	25 (69.4%)	51 (71.8%)
Age			
17 years old	31 (88.57%)	31 (86.11%)	62 (87.32%)
16 years old	4 (11.43%)	5 (13.89%)	9 (12.68)

Note. The majority of research participants were 17 years old (87.32%) and female (71.8%).

The learning procedure was conducted using the Project-Based Learning (PjBL) model, beginning with an explanation of the relationship between changes in basic commodity prices and inflation. Students then worked in small groups (4–5 members) to conduct interviews with local vendors, collect data on basic commodity prices for 2024–2025, and record the data on worksheets. The collected data were processed to calculate price indices and inflation, which were then visualized in the form of infographics. Group products were presented in class, assessed using a rubric, and concluded with a collective reflection on the connection between their findings and the concept of inflation. In contrast, in the control group, learning was conducted conventionally using lectures, question-and-answer sessions, and exercises. The teacher explained the concepts of prices, price indices, and inflation, provided example calculations, and then students completed similar exercises independently.

The research instrument consisted of a critical thinking skills test based on Higher Order Thinking Skills (HOTS) in a multiple-choice format. Initially, it comprised 25 items covering three main dimensions: analysis, evaluation, and synthesis. Content validation was conducted by three experts using the Content Validity Index (CVI), with 22 items obtaining an I-CVI of 1.00 and 3 items an I-CVI of 0.67; the S-CVI/Ave of 0.96 indicated excellent expert agreement. The three items with I-CVI < 1 were revised, while the remaining items were retained, confirming the content validity of the instrument. Subsequently, after pilot testing and item analysis, 20 items met the quality criteria. Product-Moment correlation (r-table = 0.334; n = 35) showed that 23 items were valid, while 2 were not. Reliability testing using the KR-20 formula yielded r11 = 0.846, classified as very high, indicating good internal consistency. The majority of items demonstrated good to very good discrimination, moderate difficulty levels, with three items categorized as easy. The final item distribution consisted of 14 analysis items, 4 evaluation items, and 2 synthesis items, covering topics such as price changes, price index calculations, and inflation.

Table 3. Results of Validity, Reliability, Difficulty Level, and Discrimination of the Critical Thinking Skills Test Instrument

Statistic	Result	Category
Number of Pilot Test Items	25 items	–
Items Used	20 items	–
Validity (r calculated)	0.321 – 0.658	23 items valid, 2 items invalid
Reliability (KR-20)	0.846	Very high
Difficulty Level (p)	0.49 – 0.74 (mean = 0.61)	Moderate, 3 items easy
Discrimination (r_pb)	0.36 – 0.67 (mean = 0.50)	Good – very good

Note. Validity was determined by comparing the calculated r values with the r-table; reliability was calculated using the KR-20 formula; difficulty levels were categorized as low (<0.3), moderate (0.3–0.7), and high (>0.7); discrimination was categorized as poor (<0.30), good (0.30–0.69), and very good (≥0.70).

Table 4. Distribution of Cognitive Levels (HOTS) in the Critical Thinking Skills Test Instrument

HOTS Level	Item Indicators	Number of Items	Item Numbers
Analysis (C4)	Analyzing the causes of inflation from various factors	3	1, 3, 9
	Calculating price/inflation indices from numerical data	4	2, 15, 19, 20
	Classifying types of inflation based on real cases	4	4, 7, 8, 11
	Linking monetary/fiscal policies to their impacts	3	5, 10, 13
Evaluation (C5)	Evaluating the impact of policies or inflation data	2	6, 16
	Assessing the effectiveness of policies in controlling inflation	2	12, 18
Synthesis (C6)	Formulating conclusions/logic from inflation data and consumption behavior	2	14, 17
Total		20	

Note. Cognitive level categories follow the revised Bloom's taxonomy: C4 (Analysis), C5 (Evaluation), and C6 (Synthesis).

Data were analyzed using Analysis of Covariance (ANCOVA) to examine differences in posttest critical thinking scores between the experimental group (PjBL) and the control group (conventional instruction), controlling for pretest scores. Prior to analysis, ANCOVA assumptions were checked, including tests for linearity, homogeneity of variances (Levene's Test), and homogeneity of regression slopes (Field, 2016). In addition to ANCOVA, effect size was calculated using Hedges' g, which is more suitable for small samples, with interpretation categories: small (0.2), medium (0.5), and large (0.8). A 95% confidence interval (95% CI) was also provided to ensure the reliability of the estimates (Aoki, 2020). Furthermore, N-Gain Score analysis was conducted to measure improvements in critical thinking skills from pretest to posttest within each group, with the following criteria: $g \geq 0.7$ indicates high improvement, g between 0.3 and 0.7 indicates moderate improvement, and $g < 0.3$ indicates low improvement (Hake, 1998).

3. FINDINGS AND DISCUSSION

3.1 Findings

This study aimed to examine the effectiveness of the Project-Based Learning (PjBL) model in enhancing students' critical thinking skills in the Economics subject at the senior high school level. The research data were obtained from the pretest and posttest results of two classes: the experimental class, which used the PjBL model, and the control class, which employed conventional teaching methods. Descriptive statistics of the research data are presented in Table 6.

Table 5. Descriptive Statistics of Students' Critical Thinking Posttest Scores

Group	Mean	Std. Deviation	N
Experimental	67.8571	15.96346	35
Control	60.0000	14.63850	36
Total	63.8732	15.70253	71

Note. The mean indicates that the experimental group achieved higher posttest scores than the control group. Standard deviation reflects the dispersion of scores within each group.

Before performing ANCOVA analysis, the assumptions of the model were tested to ensure its appropriateness. The scatterplot indicated a linear relationship between pretest and posttest scores, fulfilling the linearity assumption. Levene's test showed Sig. = 0.428 > 0.05, indicating that the variances between groups were homogeneous. Additionally, the ANCOVA result for the Group*Pretest

interaction (Sig. = 0.913 > 0.05) was not significant, confirming that the homogeneity of regression slopes assumption was met.

Table 6. Homogeneity Test

F	df1	df2	Sig.
.636	1	69	.428

Note. (Sig.) = 0.428 > 0.05, indicating that the variance of the data between the experimental and control groups can be considered homogeneous.

The results of the study indicated that the overall model was significant (F = 172.383; Sig. = 0.000; R^2 = 0.885), with the pretest and treatment accounting for 88.5% of the variance in posttest scores. The pretest had a significant effect on the posttest scores (F = 477.042; Sig. = 0.000). The group factor (PjBL vs. Conventional) showed a significant difference between the experimental and control classes after controlling for pretest scores (F = 5.686; Sig. = 0.020 < 0.05). The effect size of the group on posttest scores was indicated by Partial Eta Squared = 0.078, which is classified as a medium effect (Table 8).

Table 7. ANCOVA Test Result

Source	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3	5093.403	172.383	.000	.885
Intercept	1	7859.659	266.005	.000	.799
Group * Pretest	1	.354	.012	.913	.000
Group	1	167.990	5.686	.020	.078
Pretest	1	14095.168	477.042	.000	.877
Error	67	29.547			
Total	71				
Corrected Total	70				

Note: There was a significant difference between the experimental and control groups after controlling for the pretest scores (Sig. = 0.020).

To further support the ANCOVA findings, effect size analysis (Hedges' g) and learning gain analysis (N-gain) were conducted for both groups. This analysis aimed to determine the magnitude of the difference in mean posttest scores between the groups, as well as the extent of learning improvement from pretest to posttest. A summary of the comparison results between the two groups is presented in Table 9.

Table 8. Effect Size and Mean N-Gain Result

Groups	Mean	SD	Hedges' g	95% CI	Interpretation	Mean N-Gain	95% CI
Experiment	67.857	15.733	0.522	0.049 -0.995	Medium effect; Significant	0.558	0.515 – 0.601
Control	60.000	13.997				0.435	0.392 – 0.478

Note: Hedges' g: effect size between groups. CI (g): 95% confidence interval of Hedges' g. N-gain: relative improvement from pretest to posttest. CI (N-gain): 95% confidence interval of the mean N-gain for each group. N-gain categories: Low < 0.3, Medium 0.3–0.7, High > 0.7.

The analysis results in the table indicate that the experimental group achieved a higher mean posttest score (M = 67.86; SD = 15.73) compared to the control group (M = 60.00; SD = 13.99). The between-group effect size based on Hedges' g was 0.522 with a 95% CI [0.049 – 0.995], classified as a medium and statistically significant effect. These findings confirm that the implementation of PjBL had a stronger impact compared to the conventional method. Furthermore, the learning improvement from pretest to posttest (N-gain) in the experimental group reached 0.558 with a 95% CI [0.515 – 0.601], which falls into the medium category. In contrast, the control group only achieved an N-gain of 0.435 with a 95% CI [0.392 – 0.478]. This indicates that project-based learning not only results in higher final scores but is also more effective in enhancing students' critical thinking skills compared to conventional learning.

3.2 Discussion

The results of this study indicate that the Project-Based Learning (PjBL) model has a significant effect on students' critical thinking skills in the topic of Price Index and Inflation. The experimental group achieved a higher posttest score by 7.85 points compared to the control group with a medium effect size (Hedges' g = 0.522; 95% CI [0.049 – 0.995]). ANCOVA analysis also confirmed that after controlling for pretest scores, the difference between groups remained significant (F = 5.686; p = 0.020), with the treatment contributing 7.8% to the variance in posttest scores. Practically, these findings emphasize that PjBL is not only statistically significant but also has a substantive impact on enhancing students' critical thinking skills.

These findings align with the research of Sudrajat et al. (2023), which reported that e-learning-based PjBL significantly improves critical thinking skills, and studies by Thio (2025) and Zulkarnaen et al. (2025), which consistently demonstrated increases in critical thinking, creativity, and skills. Similarly, Issa & Khataibeh (2021) emphasised that PjBL effectively develops analytical skills through students' direct engagement in meaningful learning experiences. In the context of economics education, PjBL allows abstract topics, such as inflation, to become more concrete—for example, by calculating inflation using field data collected by students. This approach aligns with the 21st Century Skills framework and the 4C principles, as authentic projects enable students to practice critical thinking, collaboration, communication, and problem-solving simultaneously (Saimon et al., 2023).

In this study, students were asked to interview local vendors and calculate inflation in their own communities, making learning more contextual and relevant. This approach actualizes the principle of starting from students' real-life experiences, increasing motivation and enabling them to integrate theoretical concepts into practical contexts. Integrating real-world data, such as inflation rates, into theoretical studies also provides numerous educational benefits. One major advantage is increased engagement; when students see the direct application of the economic concepts they study, their interest and motivation significantly increase (Bart et al., 2018). Moreover, working with real data develops critical problem-solving skills, as students learn to manage complex and unstructured information while applying theoretical knowledge to real situations. This experience not only deepens understanding but also enhances analysis, reasoning, and accurate decision-making abilities (Varlamis, 2025; Wolfe, 2020).

Williamson (2024) confirmed that PjBL effectively enhances high school students' critical thinking by providing autonomy in the learning process. With the context of interviews and local inflation calculations, students not only understand the theory of inflation but also practice it directly through data processing and analysis. Furthermore, real-world data provide a concrete context for abstract concepts, making them easier to understand and more relevant, as demonstrated in the use of economic data in macroeconomics education (Wolfe & Halova, 2020). Visualization and analysis of real data further deepen students' understanding (Greengrove et al., 2020; Urban-Woldron, 2015).

Collaborative work in PjBL also allows students to discuss, share ideas, and develop communication and reasoning skills, which are crucial components of higher-order thinking (Papagiannis & Pallaris, 2024). Similar findings were reported by Milara and Orduña (2024), who stated that interdisciplinary integration in STEAM-based PjBL can enhance creativity and critical thinking because students are required to connect multiple concepts to solve real-world problems. Thus, the application of projects based on local inflation data in this study not only strengthens the relevance of learning but also facilitates the development of data analysis, critical, reflective, and adaptive skills that are essential for facing 21st-century challenges (Olugboja, 2025).

Mechanistically, the improvement in critical thinking appears to be facilitated by three main elements of PjBL: 1) investigating product prices and calculating indices encourages students to interpret data critically; 2) collaboration in small groups allows for idea exchange and meaning negotiation; 3) producing a public report on local inflation trains students to present their analyses systematically and responsibly. Although these finding is consistent with the meta-analysis by Zhang et al., (2024) which reported positive effects of PjBL on critical and analytical thinking skills, several

threats to validity should be noted. First, selection bias cannot be completely eliminated despite controlling for pretest scores. Second, there is a potential Hawthorne effect, where students in the experimental group are more motivated due to the novelty of the treatment. Third, familiarity with the test may also influence posttest outcomes.

The generalizability of the results is also limited because the study was conducted in a single school, within one semester, and focused on the topic of Price Index and Inflation. Therefore, these results cannot be directly applied to other subjects or broader populations. Practical implications for teachers include providing trigger-question templates, critical-thinking assessment rubrics, and community data-collection protocols to ensure a more structured implementation of PjBL. Future research is recommended to be conducted at multiple sites with random teacher assignments, to explore hybrid PjBL models with digital support, and to assess process aspects such as collaboration quality and fidelity of implementation.

4. CONCLUSION

The results of this study indicate that Project-Based Learning (PjBL) leads to higher posttest scores in students' critical thinking skills compared to conventional learning, even after controlling for initial differences. The observed effect falls into the medium category, indicating that PjBL is not only statistically significant but also substantively meaningful in the context of economics education. These findings demonstrate that PjBL has a substantial impact, particularly in the topic of Price Index and Inflation. Practically, implementing PjBL requires teachers to design projects that are relevant to students' real-life contexts, provide clear assessment instruments, and ensure effective collaborative processes. Thus, PjBL can be considered an approach that is not only empirically valid but also pedagogically relevant for enhancing critical thinking skills in economics learning.

REFERENCES

Ab Wahid, M., Lee, W.-K., & Baharudin, F. (2020). Implementing Project-Based Learning for Sustainability Management Course at Postgraduate Level. *Asian Journal of University Education*, *16*(2), 84. https://doi.org/10.24191/ajue.v16i2.10300

Aoki, S. (2020). Effect sizes of the differences between means without assuming variance equality and between a mean and a constant. *Heliyon*, *6*(1), e03306. https://doi.org/10.1016/j.heliyon.2020.e03306

Arikunto, S. (2016). *Prosedur Penelitian Suatu Pendekatan Praktik*. Jakarta: Rineka Cipta.

Bart, A. C., Subramanian, K., Anderson, R. E., & Hamid, N. A. (2018). Preparing, Visualizing, and Using Real-world Data in Introductory Courses. *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, 676–677. https://doi.org/10.1145/3159450.3159616

Budayani, N. K. S. & Meitriana, M. A. (2023). Efektivitas Model Pembelajaran Project Based Learning Berbantuan Mind Map terhadap Keterampilan Berpikir Kritis dalam Pembelajaran Ekonomi pada Siswa Kelas X di SMAS Dharma Kirti Sengkidu. *Ekuitas: Jurnal Pendidikan Ekonomi*, *11*(1), 86–97. https://doi.org/10.23887/ekuitas.v11i1.61204

Bulu, V. R., & Tanggur, F. (2021). The Effectiveness of STEM-Based PjBL on Student's Critical Thinking Skills and Collaborative Attitude. *Al-Jabar: Jurnal Pendidikan Matematika*, *12*(1), 219–228. https://doi.org/10.24042/ajpm.v12i1.8831

Creswell, J. M. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches 4th ed*. New York: Sage Publication.

Dias-Oliveira, E., Pasion, R., Vieira da Cunha, R., & Lima Coelho, S. (2024). The development of critical thinking, team working, and communication skills in a business school–A project-based learning approach. *Thinking Skills and Creativity*, *54*, 101680. https://doi.org/10.1016/j.tsc.2024.101680

Eckel, J., Zavaritskaya, O., Schüttpelz-Brauns, K., & Schubert, R. (2019). An explorative vs. traditional practical course: how to inspire scientific thinking in medical students. *Advances in Physiology Education*, *43*(3), 350–354. https://doi.org/10.1152/advan.00120.2018

Elfeky, A. I. M., Hassanein, M. S.-E. A.-A., Mohamed, A. Z. A. A. S., & Elbyaly, M. Y. H. (2025). How Project-Based Learning Improves Critical Thinking Skills for Sustainable Development. *International Journal of Environmental Sciences*, *11*(1s), 650–658. https://doi.org/10.64252/097gh455

Facione, P. A. (2015). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. The Delphi Report. California Academic Press.

Field, A. (2016). *Discovering Statistics Analysis of Covariance (ANCOVA)*. London: Sage.

Goshu, B. S., & Ridwan. M. (2024). Exploring the role of project-based learning in fostering critical thinking skills. *Britain International of Linguistics, Arts and Education (BIoLAE) Journal*, *6*(3), 149–166.

Greengrove, C., Lichtenwalner, S., Palevsky, H., Pfeiffer-Herbert, A., Severmann, S., Soule, D., Murphy, S., Smith, L., & Yarincik, K. (2020). Using Authentic Data from NSF's Ocean Observatories Initiative in Undergraduate Teaching: An Invitation. *Oceanography*, *33*(1). https://doi.org/10.5670/oceanog.2020.103

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Indriati, L., Mai, N., & Tan, H. Y.-J. (2024). Enhancing Authentic Assessment in Large-Class Design Education Through Authentic Project-Based Learning. *International Journal of Learning, Teaching and Educational Research*, *23*(9), 432–452. https://doi.org/10.26803/ijlter.23.9.22

Issa, H. B., & Khataibeh. A. (2021). The effect of using project-based learning on improving the critical thinking among upper basic students from teachers' perspectives. Pegem Journal of Education and Instruction. *Pegem Journal of Education and Instruction*, *11*(2), 52–57.

Kay, K. (2011). How education leaders can build critical thinking, communication, collaboration, and creativity into their educational system. *Edutopia*.

Lestari, N. A., Setyaningrum, K., Jauhari, A., Puspita, F. D., Putri, D. N. B., Mufida, R., Hudha, M. N., & Sya'roni, I. (2025). Integrated project-based inquiry science learning model in environmental education related on climate change to improve critical thinking skills. *E3S Web of Conferences*, *640*, 01011. https://doi.org/10.1051/e3sconf/202564001011

Maher, K., & King, J. (2023). Language anxiety and learner silence in the classroom from a cognitive-behavioral perspective. *Annual Review of Applied Linguistics*, *43*, 105–111. https://doi.org/10.1017/S0267190523000077

Mardani, Supriatno, & Rahmatan, H. (2021). *Application of free inquiry-based module to improve critical thinking skill of Islamic Senior High School students in Bireuen State*. 050030. https://doi.org/10.1063/5.0041847

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: how teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, *4*(1), 2. https://doi.org/10.1186/s43031-021-00042-x

Maros, M., Korenkova, M., Fila, M., Levicky, M., & Schoberova, M. (2023). Project-based learning and its effectiveness: evidence from Slovakia. *Interactive Learning Environments*, *31*(7), 4147–4155. https://doi.org/10.1080/10494820.2021.1954036

Morini, C., Inacio Junior, E., Azevedo, A. T. de, Sanches, F. E. F., & Avancci Dionisio, E. (2025). Vertically integrated project: uniting teaching, research, and community in favor of sustainability. *International Journal of Sustainability in Higher Education*, *26*(3), 672–696. https://doi.org/10.1108/IJSHE-08-2023-0349

Munawaroh, M., Raharjo. S., & Kusumawardani. T. (2020). Analysis Design Student Critical Ability with Problembase Learning and Project-Based Learning Models (Case Study In Jombang Indonesia). *PalArch's Journal of Archaeology of Egypt / Egyptology*, *17*(4), 1964–1977.

OECD. (2022). *PISA 2022 Results (Volume I): Excellence and Equity in Education. OECD Publishing.*

Olugboja, A. (2025). Integrating AI and Data Mining Tools into Information Systems Courses-A Case Study of Successes, Challenges, and Student Outcomes. *2025 14th International Conference on Educational and Information Technology (ICEIT)*, 476–483. https://doi.org/10.1109/ICEIT64364.2025.10975941

Papagiannis, P., & Pallaris, G. (2024). *Evaluating 21st Century Skills Development through Makerspace Workshops in Computer Science Education*. ArXiv, https://arxiv.org/abs/2411.05012},

Pratiwi, N., Ahman, E., & Disman. (2023). Efektivitas Model Project Based Learning (PjBL) dalam Pembelajaran Ekonomi SMA pada Kurikulum Merdeka. *Jurnal Neraca: Jurnal Pendidikan Dan Ilmu Ekonomi Akuntansi*, *7*(2), 143–154. https://doi.org/10.31851/neraca.v7i2.14313

Prayogi, S., Bilad, M. R., Verawati, N. N. S. P., & Asy'ari, M. (2024). Inquiry vs. Inquiry-Creative: Emphasizing Critical Thinking Skills of Prospective STEM Teachers in the Context of STEM Learning in Indonesia. *Education Sciences*, *14*(6), 593. https://doi.org/10.3390/educsci14060593

Purba, S. E. E. (2025). Flipped Classroom: A Pathway to Increase Self-Regulated Learning. *Jambura Economic Education Journal*, *7*(2), 586–597. https://doi.org/10.37479/jeej.v7i2.28397

Purba, S. E. E., Kristiani, K., Sangka, K. B., & Hussain, O. K. (2021). The Flipped Classroom: An Overview of its Impact on Economics Learning. *International Journal of Pedagogy and Teacher Education*, *5*(1), 26. https://doi.org/10.20961/ijpte.v5i1.49750

Rizki, I. A., & Suprapto, N. (2024). Project-Oriented Problem-Based Learning Through SR-STEM to Foster Students' Critical Thinking Skills in Renewable Energy Material. *Journal of Science Education and Technology*, *33*(4), 526–541. https://doi.org/10.1007/s10956-024-10102-2

Saimon, M., Lavicza, Z., & Dana-Picard, T. (2023). Enhancing the 4Cs among college students of a communication skills course in Tanzania through a project-based learning model. *Education and Information Technologies*, *28*(6), 6269–6285. https://doi.org/10.1007/s10639-022-11406-9

Sari, F. I., & Has. Z. (2023). Pengaruh Model Pembelajaran Project Based Learning Terhadap Hasil Belajar Siswa Sma Negeri 1 Pekanbaru. . *PEKA: Jurnal Pendidikan Ekonomi Akuntansi*, *11*(2), 96–102.

Sudrajat, S., Isa Anshory, M., Rahman, A., Ma'sum, H., Aisyah, S., & Santosa, T. A. (2023). The Effect Project Based Learning Model Based E-Learning on Students' Critical Thinking Skills: A – Meta-analysis. *Edumaspul: Jurnal Pendidikan*, *7*(2), 2433–2443. https://doi.org/10.33487/edumaspul.v7i2.6666

Sumardiana, S. (2020). Pengaruh Kemampuan Berpikir Kritis Siswa Dengan Project Based Learning Materi Suhu Kalor. *Jurnal Ilmiah Global Education*, 94–100. https://doi.org/10.55681/jige.v1i2.43

Susiyanti, Y., Juandi, D., & Suparman. (2022). *Does project-based learning have a positive effect on student' mathematical critical thinking skills? A meta-analysis*. 070009. https://doi.org/10.1063/5.0102486

Tafakur, T., Retnawati, H., & Shukri, A. A. M. (2023). Effectiveness of project-based learning for enhancing students critical thinking skills: A meta-analysis. *JINoP (Jurnal Inovasi Pembelajaran)*, *9*(2), 191–209. https://doi.org/10.22219/jinop.v9i2.22142

Thio, A. T., C. Asri Budiningsih. & Dewi. R. P. (2025). Effective Project-Based Learning Strategies to Enhance Critical Thinking, Creativity, Communication, and Collaboration Skill. *Wacana Akademika: Majalah Ilmiah Kependidikan*, *9*(1), 21–33.

Thomas, J. W. (2000). *A review of research on project basedlearning*. San Rafael, CA: Autodesk Foundation.

Urban-Woldron, H. (2015). Motion sensors in mathematics teaching: learning tools for understanding general math concepts? *International Journal of Mathematical Education in Science and Technology*, *46*(4), 584–598. https://doi.org/10.1080/0020739X.2014.985270

Varlamis, I. (2025). Messy Data in Education: Enhancing Data Science Literacy Through Real-World Datasets in a Master's Program. *Education Sciences*, *15*(4), 500. https://doi.org/10.3390/educsci15040500

Wickramasinghe, I., & Appiah, E. (2024). Impact of project-based learning in teaching probability and statistics. *International Journal of Mathematical Education in Science and Technology*, 1–18. https://doi.org/10.1080/0020739X.2024.2438374

Williamson, E. (2024). The Effectiveness of Project-Based Learning in Developing Critical Thinking Skills among High School Students. *European Journal of Education*, *1*(1), 1–11.

Wolfe, M. H. (2020). Integrating data analysis into an introductory macroeconomics course. *International Review of Economics Education*, *33*, 100176. https://doi.org/10.1016/j.iree.2020.100176

Xuan Mai, L., Ngoc, L. K., & Thao, L. T. (2024). Factors Hindering Student Participation in English-Speaking Classes: Student and Lecturer Perceptions. *Sage Open*, *14*(3). https://doi.org/10.1177/21582440241266297

Zhang, W., Guan, Y., & Hu, Z. (2024). The efficacy of project-based learning in enhancing computational thinking among students: A meta-analysis of 31 experiments and quasi-experiments. *Education and Information Technologies*, *29*(11), 14513–14545. https://doi.org/10.1007/s10639-023-12392-2

Zulkarnaen, Z., Rahayu, S., & Artayasa, I. P. (2025). Trends in Project-Based Learning for Developing Critical Thinking Skills in Science Education: A Bibliometric Review. *International Journal of Science Education and Science*, *2*(1), 26–34. https://doi.org/10.56566/ijses.v2i1.258