JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Effect of Project-Based Learnıng (PjBL) on Study Results and Critical Thinking Ability of Students ın Lathe Engıneerıng Lessons

Suyono[1*], Wawan Purwanto[1], Hasan Maksum[1], Refdinal[1]

[1] Faculty of Engineering, Universitas Negeri Padang, padang, Indonesia.

Received: August 22, 2024
Revised: January 14, 2025
Accepted: April 25, 2025
Published: April 30, 2025

Corresponding Author:
Suyono
yonsontri@gmail.com

DOI: 10.29303/jppipa.v11i4.8926

Abstract: This study aims to determine the effect of project-based learning (PHJBL) on learning outcomes and critical thinking skills of students in lathe machining techniques at SMK Negeri 2 Merangin. This study uses an experimental method, with the design used is a pre-experimental design in the form of a one group pretest-posttest design. The research sample used XI TP2 class students. The following variable relationship with simple linear analysis technique. The results showed that the value of learning outcomes 87.50% of students increased by 9.79%. The value of students' critical thinking skills increased by 11.51%. The percentage of students who have reached the predicate competent in the final learning outcomes of 95.80% increased by 80.50% compared to before the establishment of the project-based learning model by referring to the standard score set.

Keywords: Critical thingking ability; Project-Based Learning (PjBL); Study results

Introduction

Learning in vocational schools has different characteristics from learning activities in general school (Rafsanjani et al., 2024; Cattaneo et al., 2025). The focus of the learning process in SMK is to acquire knowledge, skills, attitudes, and occupational principles required by industry and the world of work (Edy & Sumarta, 2025; Ikhsannudin & Hatmojo, 2025). In the SMK curriculum structure, vocational learning hours get the most allocation. In the revised SMK 2013 curriculum in 2018 as stipulated by the Ministry of Education and Culture's Regulation No.07/2018, the allocation of vocational learning hours reaches 33 hours out of a total of 48 hours/week. Vocational learning activities require more in the form of practical learning in workshops or laboratories (Krull et al., 2025; Nikolic et al., 2025; Théric et al., 2025). This is so that learners can master all competencies according to the demands of the curriculum and the demands of developments in the field (Alawyah et al., 2024; Hatija et al., 2025). In the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 20 of 2016 concerning Graduate Competency Standards (SKL) for primary and secondary education levels, as well as the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 34 of 2018 concerning National Education Standards (SNP) for Vocational High Schools (SMK), it is explained that one of the graduate competencies determined for SMK is the ability to think logically, critically, creatively, and innovatively in the decision-making process. These competencies are expressed in the form of key competencies and must be acquired through the learning process in preparation for students to enter the world of industry, employment, entrepreneurship, or connecting to universities and the like (Oksila et al., 2025; Sari et al., 2025; Théric et al., 2025).

How to Cite:
Suyono, Purwanto, W., Maksum, H., & Refdinal. (2025). Effect of Project-Based Learnıng (PjBL) on Study Results and Critical Thinking Ability of Students ın Lathe Engıneerıng Lessons. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 427–434. https://doi.org/10.29303/jppipa.v11i4.8926

In the 21st century era, the rapid development of technology requires that education must be able to produce humans who are able to think critically, systematically, creatively, have the ability to solve a problem, and have a commendable character (Budiyanto et al., 2024; Higgins, 2014). One of the current and future competency demands is the ability to think critically (Imjai et al., 2025; Zainuddin et al., 2025). Critical thinking refers to a mental process that aims to reach a rational decision, which ultimately determines whether to believe or act on something (Bhat & Bisati, 2025; Stanovich, 2025). From this understanding, it can be interpreted that critical thinking is a directed and conscious effort, which is focused on achieving certain goals or objectives (Normile, 2025; Rezaee & Saleh, 2025; Steinert et al., 2025). The main purpose of critical thinking is to assess and decipher information so that individuals can make informed and well-reasoned decisions (Wexler et al., 2020; Wijayati et al., 2022). In learning, critical thinking becomes a benchmark in understanding knowledge and skill materials (Fahruddin et al., 2025; Torres, 2024). This phenomenon will have a significant impact on the quality of student learning which will ultimately affect their learning achievement in the educational environment (Erdem & Koçyiğit, 2025). Skills in critical thinking are considered a necessity, as they play an important role in solving problems and are the foundation for making informed and reliable decisions (Calaguas & Dungca, 2025; Wakuma, 2025; Xu et al., 2025).

Vocational schools, in this case especially SMK in the field of technology and engineering, must be able to produce graduates with qualified skills and have the right ratio between soft skills and hard skills (Hastutiningsih et al., 2024; Rahayu et al., 2024). Achieving a balance between the two requires innovation in the implementation of learning activities. On the other hand, learning innovation needs to be done to meet the demands of the quality of graduates who can adjust to the development of competency needs in the workplace. According to Munadi (2008), the implementation of education in SMK must be able to integrate three aspects of competence, namely attitudes, knowledge, and skills as a whole competency formation process. Quoted from Ardhana (2000) at this time known as the century of knowledge, requires learning activities that refer to problems, inquiry, discovery, creation and projects. With this kind of learning approach, learners will have greater opportunities to explore various aspects of learning thoroughly (affective, cognitive, and psychomotor) in addition to the development of all their intelligence such as emotional, spiritual, social, and other intelligence. It is expected that interactive learning activities can create opportunities for students to develop various aspects of learning and all intelligence in learners to achieve a balance between hard and soft skills as a reflection of complete competence. OECD (2018) and Thomas (2000) states that one of the learning models that can be used to support the development of creativity, critical thinking, problem solving skills, interactivity, and the ability to solve real problems through investigation is project-based learning (PjBL).

Vocational High School (SMK) Negeri 2 Merangin is one of the educational units that opens the field of technology and engineering expertise. As an educational institution engaged in technology and engineering, SMK Negeri 2 Merangin aims to produce educated graduates, who have adequate knowledge and skills as well as good attitudes, mentality, and personality, as preparation for a career in the industrial world, running an independent business, or continuing their studies to college. In order to achieve this goal, students are equipped with the mastery of theoretical and practical knowledge, both of which complement each other and become capital to enter the real world of work after graduation (Saktilia & Wulandari, 2024). Seeing the learning conditions from the results of the interview, it is necessary to improve changes in strategies in carrying out the teaching and learning process that are different from the previous learning model, namely by applying learning models that can accommodate and develop the ability to think critically, creatively, actively, confidently, independently and be able to collaborate (Ratnady et al., 2024; Yusuf et al., 2024). Therefore, in this study, researchers suggest and work with vocational subject teachers to apply one of several learning models, namely the Project-Based Learning Model in the learning process of Lathe Machining Engineering subjects in the Machining Engineering department of SMK Negeri 2 Merangin in the second semester of the 2023/2024 academic year.

Method

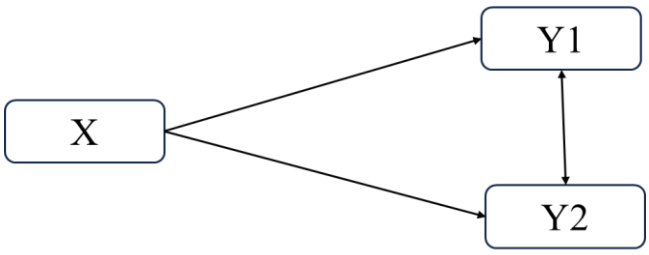

Figure 1. Relationship model between variables

Description:
X : PJBL Learning Model
Y1 : Learning Outcome
Y2 : Critical thinking skills

This research uses an experimental method, with the design used is a pre-experimental design in the form of a one group pretest-postest design. The research sample used XI TP2 class students. The following variable relationship in this study can be described in Figure 1.

To find the magnitude of the relationship between X and Y1, and X and Y2, simple linear regression analysis techniques can be used.

Result and Discussion

Prerequisite Test Analysis

Normality Test and Homogeneity Test of Learning Outcome Scores

The normality test was conducted to determine whether the research data in the form of learning outcomes were normally distributed or not. The normality test of learning outcomes was carried out on two groups of values, namely the initial value of learning outcomes and the final value of learning outcomes. In this study, because the number of samples is small (less than 50 samples), the Liliefor normality test technique (L test) is used using the Excel program. The basis for decision making in this test is if $L_{count} < L_{table}$ then the data is normally distributed and vice versa if $L_{count} > L_{table}$ then the data is not normally distributed. From the test results, the following data were obtained (See Table 1).

Table 1. Normality test results on learning outcomes

Statistic	Learning Outcomes	
	Initial assessment	Final assessment
L_{count} Value	0.0696	0.0890
L_{table} Value		0.1766
Conclusion	Data is not normally distributed	Data is normally distributed

Table 2. Homogeneity test results on learning outcomes

Statistic	Learning outcomes	
	Initial assessment	Final assessment
Varian value	8.2992	7.2561
F_{count} value		1.1438
F_{table} value		2.0144
Conclusion	Data is homogeneously distributed	

The homogeneity test was conducted to determine whether the research data in the form of learning outcomes came from a homogeneous sample or not. The homogeneity test of learning outcomes was carried out on two groups of data, namely the initial value of learning outcomes and the final value of learning outcomes. To test homogeneity in this study, the Fisher test technique (F test) was used using the Excel program. The basis for decision making in this test is if $F_{count} < F_{table}$ then the data is homogeneous and vice versa if $F_{count} > F_{table}$ then the data is not homogeneously distributed. From the test results, the following data were obtained (See Table 2).

Normality Test and Critical Thinking Ability Homogeneity Test

The normality test was conducted to determine whether the research data in the form of critical thinking skills test scores were normally distributed or not. The normality test was carried out on two groups of values, namely the initial value (pretest) and the final value (posttest). In this study, because the number of samples is small (less than 50 samples), the Liliefor normality test technique (L test) is used using the Excel program. The basis for decision making in this test is if $L_{count} < L_{table}$ then the data is normally distributed and vice versa if $L_{count} > L_{table}$ then the data is not normally distributed. From the test results, the following data were obtained.

Table 3. Normality test results on critical thinking skills test scores

Statistic	Critical Thinking Ability Test Scores	
	Pretest	Posttest
L_{count} Value	0.7276	0.9128
L_{table} Value		0.1766
Conclusion	Data is not normally distributed	Data is not normally distributed

The homogeneity test was conducted to determine whether the research data in the form of critical thinking ability test scores came from homogeneous samples or not. The homogeneity test was carried out on two groups of data, namely the initial value (pretest) and the final value (posttest). To test homogeneity in this study, the Fisher test technique (F test) was used using the Excel program. The basis for decision making in this test is if $F_{count} < F_{table}$ then the data is homogeneous and vice versa if $F_{count} > F_{table}$ then the data comes from an inhomogeneous population.

Table 4. Homogeneity test results on critical thinking ability test scores

Statistic	Critical Thinking Ability Test Scores	
	Pretest	Posttest
Variance value	43.2065	22.2797
F_{count} value		1.9393
F_{table} value		2.0144
Conclusion	Data is homogeneously distributed	

Linearity Test of Variable X Against Variable Y1

The linearity test at this stage is carried out to determine the form of the relationship between variable X (application of the PjBL model) to variable Y1 (student learning outcomes) is linear or not. The linearity test is carried out by comparing the average value (means) of two groups of data, namely the questionnaire data on the application of PjBL and the data on the final total score of students' learning outcomes. The basis for decision making in this test is if the sig value of deviation for linearity> 0.05 then it is concluded that there is a linear relationship between variable X and variable Y1 and vice versa if the sig value of deviation for linearity < 0.05 then it is concluded that there is no linear relationship between variable X and variable Y1. Based on Table 3, the sig value of deviation from linearity = 0.541 > 0.05, it can be concluded that there is a linear relationship between variable X and variable Y1.

Table 5. Linearity test results of variable X against variable Y1

			Sum of Squares	df	Mean Square	F	Sig.
Learning outcomes * PjBL	Between Groups	(Combined)	121.475	16	7.592	1.170	0.440
		Linearity	25.629	1	25.629	3.949	0.087
		Deviation from Linearity	95.846	15	6.390	0.984	0.541
	Within Groups		45.434	7	6.491		
	Total		166.910	23			

Linearity Test of Variable X Against Variable Y2

The linearity test at this stage is carried out to determine the form of the relationship between variable X (application of the PjBL model) to variable Y2 (critical thinking skills of students) is linear or not. The linearity test is carried out by comparing the average value (means) of two groups of data, namely the questionnaire data on the application of PjBL and the posttest data on the critical thinking skills of students. The basis for decision making in this test is if the sig deviation value for linearity > 0.05 then it is concluded that there is a linear relationship between variable X and variable Y2 and vice versa if the sig deviation value for linearity < 0.05 then it is concluded that there is no linear relationship between variable X and variable Y2. Based on the data in Table 1, the sig deviation from linearity value = 0.834 > 0.05, it can be concluded that there is a linear relationship between variable X and variable Y2.

Table 6. Linearity test results of X against Y2 variables

			Sum of Squares	df	Mean Square	F	Sig.
Critical Thinking Ability Test Scores * PjBL	Between Groups	(Combined)	369.206	16	23.075	1.128	0.461
		Linearity	196.393	1	196.393	9.598	0.017
		Deviation from Linearity	172.813	15	11.521	0.563	0.834
	Within Groups		143.229	7	20.461		
	Total		512.435	23			

Hypothesis Test

Hypothesis is defined as a temporary answer to the formulation of research problems. The formulation of the problem can be a statement about the relationship between two or more variables, comparison (comparison), or independent variables. In research, there are two kinds of hypotheses, namely the null hypothesis (Ho) and the alternative hypothesis (Ha). The null hypothesis states "nothing", for example there is no influence/relationship between one variable and another. The hypothesis being tested is the null hypothesis.

In this research, hypothesis testing is carried out to determine whether there is a significant effect of the application of project-based learning models (variable X) on student learning outcomes (variable Y1) and on students' critical thinking skills (variable Y2) in lathe machining techniques subjects. The hypothesis testing process in this study is explained as follows.

Hypothesis Testing of the Effect of Variable X on Y1

Variable X in this case is project-based learning, while variable Y1 is student learning outcomes. The hypothesis to be tested is formulated:

Ho = There is no effect of the application of the project-based learning model (PjBL) on student learning outcomes.

Ha = There is an effect of the application of the project-based learning model (PjBL) on student learning outcomes.

After testing the analysis requirements on student learning outcomes data, it was concluded that the data

was normally distributed and homogeneous. From the linearity test results it is also concluded that the relationship between variables is linear. With these conditions, the analysis technique for hypothesis testing can use simple linear regression analysis techniques. A summary of the results of simple linear regression statistical analysis in the form of the R Square (R^2) test using the SPSS version 26 program is shown as follows.

Table 7. Correlation value and coefficient of determination test R square

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.400[a]	0.154	0.115	2.53414

a. Predictors: (Constant), PjBL

Table 8. Output significance value of simple linear regression test results (R square)

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.629	1	25.629	3.991	.058[b]
	Residual	141.281	22	6.422		
	Total	166.910	23			

a. Dependent Variable: Learning outcomes
b. Predictors: (Constant), PjBL

Table 9. Gression coefficient output of simple linear regression test results

Coefficients[a]						
Model				Standardized Coefficients Beta	t	Sig.
1	(Constant)	69.862	5.560		12.564	0.000
	PjBL	0.081	0.041	0.392	1.998	0.058

a. Dependent Variable: Learning outcomes

The basis for deciding whether there is an effect of variable X on variable Y1 is by comparing the significance value (sig) with a probability value of 0.05. If the sig value < 0.05 means that variable X has an effect on Y1, and vice versa if the sig value > 0.05 means that variable X has no effect on variable Y. Based on the output table above, the sig value is 0.000 < 0.05, meaning that it can be stated that variable X has an effect on variable Y1.

The coefficient of determination (R square or R^2). The coefficient of determination is used to determine the value of the contribution of variable X (application of PjBL) to variable Y1 (student learning outcomes). From the table, the coefficient of determination (R square) is 0.154, this implies that the effect of variable X (application of PjBL) on student learning outcomes is 15.40%. Correlation / relationship value (R). The R value describes the magnitude of the correlation or relationship between variable X and variable Y1. Based on the output table, the correlation value (R) is 0.400. When associated with the correlation category, this value is included in the moderate category.

Simple linear regression is expressed by the equation: Y = a + b.X, where a is a consistent constant of the dependent variable, while b is the regression coefficient of variable X. When looking at the output table, the constant value of a is 69.862 and the value of b is 0.081. By obtaining the values of a and b, the regression equation becomes Y = 69.862 + 0.081. X. The constant value a of 69.862 means that the consistent value of the student learning outcomes variable is 69.862. While the b value of 0.081 states that every 1% addition of PjBL value, the value of learning outcomes increases by 69.862. The regression coefficient is positive.

Based on the results of the regression test output and its interpretation, where a significance value of 0.000 < 0.05 is obtained, which states that there is an effect of the application of project-based learning on student learning outcomes, and the correlation value between variable X and variable Y1 is 0.400, it can be decided that the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted.

Hypothesis Test of the Effect of Variable X on Variable Y2

Variable X in this case is project-based learning, while variable Y2 is the critical thinking ability of students. After testing the analysis requirements on the data from the test results of students' critical thinking skills, it was concluded that the data was not normally distributed but homogeneous. From the linearity test results, it is concluded that the relationship between variables is linear. With the condition of data that is not normally distributed, the analysis technique for hypothesis testing uses an alternative analysis technique, namely the Mann Whitney U Test. This technique is classified as an alternative non-parametric statistical alternative to the t test for data that is not normally distributed. The purpose of the Mann Whitney t test is also to determine whether there is a difference in the means of two unpaired sample data. In this t-test, the samples used do not necessarily have to be equal in number. The hypothesis to be tested is formulated:

Ho = There is no difference in students' critical thinking skills between before and after the application of the project-based learning model (PjBL).

Ha = There is a difference in students' critical thinking skills between before and after the application of the project-based learning model (PjBL).

The basis for decision making in the man whitney statistical test is if the Asymp sig value is less than the probability of 0.05 (Asymp sig < 0.05), it indicates that

there is an average difference between the two groups tested so that Ho is rejected and Ha is accepted, and vice versa if the Asymp sig value > 0.05, it indicates that there is no average difference so that Ho is accepted and Ha is rejected. Based on statistical tests using the SPSS version 26 program, the output of the Mann Whitney U test results on the critical thinking ability test scores/critical thinking (CT) scores of XI TP2 class students is as follows.

Table 10. Result Output of Mann Whitney test

Ranks				
	Group	N	Mean Rank	Sum of Ranks
Value CT	Pretest	24	13.98	335.50
	Posttest	24	35.02	840.50
	Total	48		

Table 11. Statistical data on results Mann Whitney

Test Statistics[a]	
	Value CT
Mann-Whitney U	35.500
Wilcoxon W	335.500
Z	-5.216
Asymp. Sig. (2-tailed)	0.000
a. Grouping Variable: Group	

Based on the test statistic output table above, it is known that the Asymp sig (2 tailed) value is 0.000 < 0.05, it can be concluded that there is a difference in the critical thinking ability of students between before the application of the PjBL learning model and after the application of the PjBL learning model. Because there is a significant difference, it can be said that there is an effect of applying a project-based learning model (PjBL) on the critical thinking skills of XI TP2 class students in lathe machining engineering subjects.

Conclusion

After this research is carried out and based on the results of data processing, it can be concluded that: The application of project-based learning models has an effect in improving learning outcomes and critical thinking skills of students in lathe machining engineering subjects in class XI TP2 SMK Negeri 2 Merangin. The increase in learning outcomes and critical thinking skills of students can be seen from the following: The value of student learning outcomes increased by 9.79% with a completeness rate of 87.50%. The value of students' critical thinking skills increased by 11.51%. The percentage of students who have achieved a competent predicate on the final learning outcome of 95.80% increased by 87.50% compared to before the application of the project-based learning model with reference to the KKM value set at 75. Project-based learning is one of the good learning models to be applied to vocational learning in order to improve learning outcomes and critical thinking skills of students, because with project-based learning all aspects of learning can be covered in it to provide a better learning experience. This is supported by data on students' responses to the implementation of project-based learning of 82.73%.

Acknowledgments
Thanks to the supervisor who has helped me to complete this article.

Author Contributions
Conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft preparation, S.; writing-review and editing, validation, supervision, visualization, W.P., H.M., and R. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Alawyah, K., Giatman, G., Rizal, F., & Irfan, D. (2024). Needs Analysis of Augmented Reality (AR) Based Learning Media Development in Road and Bridge Construction Subjects. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6993–6700. https://doi.org/10.29303/jppipa.v10i9.8475

Ardhana, W. (2000). Reformasi Pembelajaran Menghadapi Abad Pertengahan. *Seminar dan Diskusi Panel Nasional Teknologi Pembelajaran V*. Program Studi Teknologi Pembelajaran, Program Pascasarjana Universitas Negeri Malang.

Bhat, A. M., & Bisati, A. A. (2025). Rationality in the Qur'an: Integrating Reason and Revelation for Contemporary Islamic Education. *Dirasah International Journal of Islamic Studies*, *3*(1), 1–17. https://doi.org/10.59373/drs.v3i1.40

Budiyanto, B., Kabri, K., Harapan, E., & Purwanto, M. B. (2024). 21st Century English Learning: A Revolution in Skills, Critical Thinking, Creativity, and Visual Communication. *Asian Journal of Applied Education (AJAE)*, *3*(1), 43–54. https://doi.org/10.55927/ajae.v3i1.7841

Calaguas, G., & Dungca, E. (2025). Jacks of All Trades: The Lived Experiences of Out-of-Field Non-Government Basic Education Teachers. *Journal of*

Basic Education Research, *6*(1), 37–46. https://doi.org/10.37251/jber.v6i1.1394

Cattaneo, A. A. P., Antonietti, C., & Rauseo, M. (2025). How Do Vocational Teachers Use Technology? The Role of Perceived Digital Competence and Perceived Usefulness in Technology Use Across Different Teaching Profiles. *Vocations and Learning*, *18*(1), 5. https://doi.org/10.1007/s12186-025-09359-4

Edy, S., & Sumarta, S. (2025). Challenges and Opportunities of the Islamic Religious Education (PAI) Curriculum at Armaniyah Vocational High School (SMK) Bekasi in Facing Modern Work Demands. *Edukasi Islami: Jurnal Pendidikan Islam*, *14*(01), 201–214. https://doi.org/10.30868/ei.v14i01.8097

Erdem, C., & Koçyiğit, M. (2025). The Interplay Among School Climate, Instructional Quality and Teacher Job Satisfaction: Mediation of Teacher Motivation. *International Journal of Educational Development*, *114*, 103231. https://doi.org/10.1016/j.ijedudev.2025.103231

Fahruddin, F., Kurniawanti, M. R., Nurgiansah, T. H., & Gularso, D. (2025). Development of Teaching Materials for Evaluating History Learning to Improve Students' Critical Thinking Skills. *Journal of Education and Learning (EduLearn)*, *19*(1), 530–541. https://doi.org/10.11591/edulearn.v19i1.20882

Hastutiningsih, A. D., Ardiyanto, A., & Miftakhi, D. R. (2024). Evaluation of Competency Standards for Vocational High School Graduates in the Era of Industrial Revolution 4.0. *International Journal of Educational Management and Innovation*, *5*(3), 213–225. https://doi.org/10.12928/ijemi.v5i3.10102

Hatija, M., In'am, A., Khozin, K., & Faridi, F. (2025). Implementation of the Independent Curriculum in Improving the Quality of Education at State Islamic Senior High Schools. *Tafkir: Interdisciplinary Journal of Islamic Education*, *6*(1), 58–76. https://doi.org/10.31538/tijie.v6i1.1344

Higgins, S. (2014). Critical Thinking for 21st-Century Education: A Cyber-Tooth Curriculum? *PROSPECTS*, *44*(4), 559–574. https://doi.org/10.1007/s11125-014-9323-0

Ikhsannudin, W., & Hatmojo, Y. I. (2025). The Effectiveness of Developing the Teaching Factory Learning Model in the Concentration of Industrial Automation Engineering Expertise. *AIP Conference Proceedings*, *3281*(1), 020008. https://doi.org/10.1063/5.0261685

Imjai, N., Yordudom, T., Yaacob, Z., Saad, N. H. M., & Aujirapongpan, S. (2025). Impact of AI Literacy and Adaptability on Financial Analyst Skills Among Prospective Thai Accountants: The Role of Critical Thinking. *Technological Forecasting and Social Change*, *210*, 123889. https://doi.org/10.1016/j.techfore.2024.123889

Krull, A. A., DiGuardo, M. A., Deeds, M. C., Skaer, C. A., Soiney, K. A., Wadewitz, M., Wiltshire, T. D., Gastineau, D. A., Dietz, A. B., & Jacob, E. K. (2025). Fellowship Training for Cellular Therapy Laboratory Directors. *Cytotherapy*. https://doi.org/10.1016/j.jcyt.2025.01.013

Munadi, Y. (2008). *Media Pembelajaran: Sebuah Pendekatan Baru*. Jakarta: Gaung Persada Press.

Nikolic, S., Suesse, T. F., Grundy, S., Haque, R., Lyden, S., Lal, S., Hassan, G. M., Daniel, S., & Belkina, M. (2025). Assessment Integrity and Validity in the Teaching Laboratory: Adapting to GenAI by Developing an Understanding of the Verifiable Learning Objectives Behind Laboratory Assessment Selection. *European Journal of Engineering Education*, 1–29. https://doi.org/10.1080/03043797.2025.2456944

Normile, I. H. (2025). A Model for Understanding and Expanding the Scope of Critical Thinking. *Studies in Philosophy and Education*. https://doi.org/10.1007/s11217-024-09976-x

OECD. (2018). *PISA for Development Assessment and Analytical Framework: Reading, Mathematics and Science*. Paris: OECD Publishing.

Oksila, D., Giatman, G., Irfan, D., & Alawyah, K. (2025). Validity and Effectiveness of E-Module-Based Learning Media in Informatics Subjects. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 431–440. https://doi.org/10.29303/jppipa.v11i2.9861

Rafsanjani, T. A., Abdurrozaq, M., & Inayati, F. (2024). Strategies for Implementing Character Education Curriculum to Mitigate Adolescent Delinquency at SMK Muhammadiyah Mayong. *Solo International Collaboration and Publication of Social Sciences and Humanities*, *3*(01), 27–40. https://doi.org/10.61455/sicopus.v3i01.220

Rahayu, S., Ghinaya, Z., Al Dhahrani, J., Sabitri, Z., Meirawan, D., Muktiarni, M., Sukadi, S., Purwanto, D., & Iswardhany, R. (2024). *The Level Analysis of Student Employability Skill for the Needs of the Work Industry in Vocational Education in the VUCA World* (pp. 258–265). https://doi.org/10.2991/978-2-38476-198-2_35

Ratnady, H. D., Tindangen, M., Maasawet, E. T., Hakim, A., Daniel, D., Herliani, H., Hudiyono, Y., & Hardoko, A. (2024). Development of Science Learning Modules with Computer-Based Test (CBT) Assessments to Train Critical Thinking Skills of Students at SMP Negeri 7 Bontang. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6564–6573. https://doi.org/10.29303/jppipa.v10i9.8391

Rezaee, A. A., & Saleh, E. (2025). Critical Thinking in the Cultural Components of EFL Textbooks: CCR

Model and Its Application. *Thinking Skills and Creativity*, *57*, 101782. https://doi.org/10.1016/j.tsc.2025.101782

Saktilia, Y. R., & Wulandari, D. (2024). Pembuatan E-Pocket Book Berdasarkan Studi Isolasi Bakteri Endofitik Tumbuhan Laban Penghasil Senyawa Metabolit Sekunder sebagai Bahan Pengayaan Kimia Bahan Alam. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 6080–6094. https://doi.org/10.29303/jppipa.v10i8.7515

Sari, R. E., Ambiyar, A., Giatman, M., & Adri, M. (2025). Development of a Formative Assessment Model for the Pancasila Student Profile Strengthening Project for the Independent Curriculum. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 664–672. https://doi.org/10.29303/jppipa.v11i1.9665

Stanovich, K. E. (2025). The Puzzle of Myside Bias and Actively Open-Minded Thinking in the Conceptualization of Critical Thinking. In *Critical Thinking Across Disciplines, Vol. 1* (pp. 1–27). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-82644-3_1

Steinert, S., Marin, L., & Roeser, S. (2025). Feeling and Thinking on Social Media: Emotions, Affective Scaffolding, and Critical Thinking. *Inquiry*, *68*(1), 114–141. https://doi.org/10.1080/0020174X.2022.2126148

Théric, V., Cheneval-Armand, H., Delserieys, A., & Brandt-Pomares, P. (2025). Integrating Academic and Vocational Subjects in Vocational Education and Training: A Case Study in France. *Journal of Vocational Education & Training*, 1–26. https://doi.org/10.1080/13636820.2025.2461589

Thomas, J. W. (2000). *A Review of Research on Project Based Learning*. California: The Autodesk Foundation.

Torres, C. A. (2024). Paulo Freire: A Thinker of Praxis, an Itinerant Thinker, a Universal Thinker. *Globalisation, Societies and Education*, *22*(1), 7–23. https://doi.org/10.1080/14767724.2023.2289164

Wakuma, O. K. (2025). An Investigation into Anxiety Levels and English Learning Outcomes of High School Students with a Particular Focus on Grade Nine. *Discover Education*, *4*(1), 45. https://doi.org/10.1007/s44217-025-00436-3

Wexler, J., Swanson, E., Kurz, L. A., Shelton, A., & Vaughn, S. (2020). Enhancing Reading Comprehension in Middle School Classrooms Using a Critical Reading Routine. *Intervention in School and Clinic*, *55*(4), 203–213. https://doi.org/10.1177/1053451219855738

Wijayati, P. H., Ardiyani, D. K., & Hidayat, E. (2022). Feedback Strategies: An Effort to Enhance the Critical Thinking Skills of Daf-Learners in Indonesia. *International Journal of Education*, *15*(2), 79–88. https://doi.org/10.17509/ije.v15i2.29076

Xu, Z., Niu, M., Du, W., & Dang, T. (2025). The Effect of Sleep Quality on Learning Engagement of Junior High School Students: The Moderating Role of Mental Health. *Frontiers in Psychology*, *16*. https://doi.org/10.3389/fpsyg.2025.1476840

Yusuf, M., Yunginger, R., & Nainggolan, R. (2024). Quality of Physics Teaching Module Based on Problem-Based Learning Model Integrated with PhET Simulation on Energy and Its Transformation. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3007–3016. https://doi.org/10.29303/jppipa.v10i6.7037

Zainuddin, Z., Amrullah, A. M. K., & Zuhriyah, I. A. (2025). The Challenges of Developing Islamic Education Curriculum and Strategies for Its Development in Facing Future Competency Demands. *Tafkir: Interdisciplinary Journal of Islamic Education*, *6*(1), 111–126. https://doi.org/10.31538/tijie.v6i1.1316