Optimizing Critical Thinking Skills of Vocational Students: Integrating Project-Based Learning with Learning Style Diversity

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Abstract: Critical thinking is the 21st-century cognitive competency that current graduates clearly require to adapt to global changes in the world of work and technology. This skill plays a crucial role in helping students process information logically and solve problems rationally. Therefore, a learning model that focuses on developing higher-order thinking skills is needed. This study aims to examine the extent to which project-based learning influences the enhancement of students' critical thinking skills based on their learning style. This study adopts a quantitative approach with a true experimental design. There were 52 vocational high school students as participants, who were separated into an experimental class and a control class. The study used an independent sample t-test of post-test score and N-gain score to address its research questions with a significance level of 0.05. The result of the t-test showed ($t = 3.11$; $p = 0.003 < 0.05$), which means that the post-test score for the experimental class was 84.00 higher than the control class, which was 79.76. Meanwhile, the N-gain score showed a score of 0.67, which means that the effectiveness of the learning model used at the medium level is considered effective enough. These findings emphasized that integrating project-based learning with diverse learning styles contributes significantly to developing critical thinking skills of students, especially for the kinesthetic learning style. Critical thinking skills enhancement is reflected in the project implementation stage, where students actively analyze and compile information in infographic projects that are aligned with their learning styles.

Keywords: critical thinking skills, learning styles, project-based learning

INTRODUCTION

Recent developments in education in the 21st-century underscore that learning success is not measured solely by mastery of knowledge but also by the development of various skills. Currently, the strengthening of high-level thinking

skills is receiving enhanced attention. The term 21st-century skills is employed to denote the abilities regarded as essential for success in the current global context. These skills are categorized into four distinct areas: critical thinking, creativity, communication, and collaboration (Muchson, 2023). Critical thinking skills are widely regarded as being of paramount importance for students to acquire. It is defined as the ability to analyze information, evaluate arguments, and make logical decisions (Changwong et al., 2018). The capacity to engage in critical thinking is a pivotal factor in determining a student's ability to comprehend and process material in depth. Furthermore, it is a fundamental component of preparing vocational high school students in to face the challenges of an increasingly competitive workforce.

In the contemporary educational context, Project-Based Learning has emerged as the model of learning that is in alignment with the demands of 21st-century skills in developing critical thinking skills. In the studies conducted by Anggito et al. (2021); Kristiyanto (2020); Rusnawati et al. (2021) showed that Project-Based Learning contributed to developing the learning quality. The learning model effectiveness was explained by providing an opportunity for students to interact directly in the learning process, which can create meaningful learning and provide a positive influence on students' critical thinking skills. This learning model places students at the center of learning, which requires students to be active in identifying problems, searching for information, discussing, and producing learning outcomes (Wang, 2023; Zainina Zahwa Amalia et al., 2023). It has also been evidenced that the application of Project-Based Learning effectively enhances critical thinking skills in English learning, especially in argumentative text-based materials. However, the effectiveness of learning is also influenced by the diverse characteristics of individual students in receiving and processing information (Suciani et al., 2022). This phenomenon is referred to as the VARK learning style.

The VARK learning style was developed by Fleming, which is widely used in educational studies and categorized into four types: visual, auditory, read/write, and kinesthetic (Leasa et al., 2020; Noviska & Anastasia, 2023). Each type

influences how students understand material, participate in learning, and complete assigned tasks. In line with the statement by Rahmi et al. (2024); Indriyani & Nurmasitah (2025) emphasized that the variations in learning styles can influence how students respond and interact in receiving the information. Designing lessons considering VARK learning styles and Project-Based Learning also has the potential to create a more meaningful learning experience (Rini et al., 2020). According to Damayanti et al. (2023), Nurmasyitah et al. (2023), and Rohana et al. (2023), the diversity of learning styles, including visual, auditory, read/ write, and kinesthetic, has influenced levels of student engagement in the implementation of Project-Based Learning. The differences influenced the effectiveness of the knowledge construction process. Therefore, adjusting learning strategies is an important factor in optimizing learning outcomes.

The implementation of Project-Based Learning in vocational high schools with consideration for diverse learning styles and the development of students' critical thinking skills, particularly in the context of analytical exposition text, remains underexplored. Most studies only examine the effect of Project-Based learning on learning outcomes or critical thinking skills in general, without considering the characteristics of students' learning styles. Therefore, research is needed to empirically examine the effectiveness of Project-Based Learning in enhancing critical thinking skills while considering differences in vocational students' learning styles.

The novelty of this study lies in testing the effect of the Project-Based Learning model that is integrated with VARK learning styles on the critical thinking skills of vocational high school students in Analytical Exposition Text. The research problems are formulated as follows: (1) How significant is the difference in critical thinking skills enhancement between students who learn using the Project-Based Learning model considering the diversity of learning styles, and students who learn using conventional learning? (2) How effective is the application of Project-Based Learning in enhancing students' critical thinking skills considering the learning styles diversity? In this way, the objectives of this study are not only to examine the influence of implementing Project-Based

Learning by considering learning styles diversity but also to assess the effectiveness of the learning model on enhancing the critical thinking skills of vocational high school students.

METHODS

This research applied a quantitative approach with a true experimental design using a pretest-posttest control group design (Creswell & Creswell, 2018). The research subjects were divided into two groups: experimental and control. SMK Batik 2 Surakarta is chosen as the research site because it is a center of excellence school that focuses on developing competency-based learning quality and educational innovation. All the eleventh-grade vocational high school students enrolled in the 2025-2026 academic year were selected as the population of the study. The cluster random sampling technique was used, considering that each vocational program is a cluster with relatively homogeneous characteristics in the learning process (Creswell & Creswell, 2018).

Based on the results of the random selection, a total of 52 students from two classes were chosen as the research sample. The Office Management program was designated as the experimental group, consisting of 26 students, and received Project-Based Learning as a treatment. The Beauty and Spa program was designated as the control group consisting of 26 students and received conventional instruction. The selection of this sample aimed to obtain an objective representation of the population.

This research instrument used an objective test. The form of the test is multiple-choice. The test consists of three stages, namely tryout, pre-test, and post-test. The test instrument consists of 30 items developed based on critical thinking skills indicators. It includes analyzing, evaluating, and making conclusions. The formulation of instrument indicators refers to the Higher-Order Thinking Skills framework in Bloom's revised taxonomy in A Taxonomy for Learning, Teaching, and Assessing (Wilson, 2016). Each item is designed in accordance with the established indicators to ensure the suitability of learning objectives and the measurement of student abilities.

The process of collecting data was conducted systematically. In the first stage, a tryout was given to students outside the research sample to determine the validity, reliability, difficulty level, and discriminating power of the questions. The second stage was the implementation of a pre-test is given before the learning treatment to the experimental and control groups. The third stage was the provision of learning treatment during several meetings. The final stage was the administration of a post-test after all treatments had been completed.

To test the hypothesis, the data were analyzed through a series of instrument feasibility tests, including validity and reliability tests, as well as prerequisite tests including normality and homogeneity tests. The hypothesis testing process was executed using an *Independent Sample T-test* and the significance level was set at $\alpha = 0.05$. The results of the analysis were interpreted to ascertain the significance of the differences found in the effectiveness of the applied learning models. To measure the level of treatment effectiveness, the analysis was conducted using the *N-gain Score*. The N-gain calculation was used to determine the level of enhancement in student learning outcomes based on the difference between the pre-test and post-test scores. The N-gain value is then classified into high, medium, or low categories to determine the level of effectiveness of the treatment applied.

RESULTS AND DISCUSSION

The validity of the instrument was tested using *Pearson Product-Moment* to determine the level of correlation between each item score and the total score (Field, 2017). The results of the validity test demonstrated that most of the items exhibited a correlation coefficient (calculated r) that exceeded the tabulated r at a significance level of 0.05.

Table 1. Result of Validity and Reliability Test

No.	*Calculated r*	Validity Test *r* table 5%	Note	Reliability Test *CA*
1	0.509	0.404	Valid	0.796
2	0.498	0.404	Valid	
3	0.438	0.404	Valid	
4	0.412	0.404	Valid	
5	0.461	0.404	Valid	
6	0.407	0.404	Valid	
7	0.542	0.404	Valid	
8	0.430	0.404	Valid	
9	0.467	0.404	Valid	
10	0.494	0.404	Valid	
11	0.404	0.404	Valid	
12	0.455	0.404	Valid	
13	0.424	0.404	Valid	
14	0.444	0.404	Valid	
15	0.437	0.404	Valid	
16	0.543	0.404	Valid	
17	0.461	0.404	Valid	
18	0.527	0.404	Valid	
19	0.550	0.404	Valid	
20	0.669	0.404	Valid	
21	0.514	0.404	Valid	
22	0.519	0.404	Valid	
23	0.404	0.404	Valid	
24	0.420	0.404	Valid	
25	0.453	0.404	Valid	
26	0.557	0.404	Valid	
27	0.526	0.404	Valid	
28	0.398	0.404	Invalid	
29	0.398	0.404	Invalid	
30	0.449	0.404	Valid	

The total of 28 items tested fulfilled the validity criteria with a correlation coefficient range of 0.404 to 0.669. Meanwhile, 2 items were found to be invalid and were replaced. This result declared that the instrument was suitable for use as a research instrument.

In addition, reliability was tested by means of a Cronbach's Alpha analysis. It showed a reliability coefficient of 0.796, which is classified as high reliability.

These findings suggest that the instrument is capable of accurately measuring students' thinking skills.

The Result of the Prerequisite Analysis Test

Prior to the testing of the hypothesis, a prerequisite analysis of the data was conducted. This comprised a normality test using Kolmogorov-Smirnov and a homogeneity test using Levene's Test.

Table 2. Result of Normality and Homogeneity Test

Data	N	Statistic Test	Group	Sig.
Pretest	26	Kolmogorov-Smirnov	Experimental Class	0.094
			Control Class	0.112
		Levene's Test	Experimental and Control	0.142
Posttest	26	Kolmogorov-Smirnov	Experimental Class	0.088
			Control Class	0.109
		Levene's Test	Experimental and Control Class	0.161

The normality test findings on the pre-test and post-test data using the Kolmogorov-Smirnov test indicated that the significance values are greater than 0.05. Based on this, the pre-test and post-test data in both groups can be concluded to be normally distributed.

The results of Levene's test for variance homogeneity showed a significance value of 0.142 (> 0.05) for the pre-test data. Meanwhile, for the post-test data, the homogeneity test showed a significance value of 0.161 (> 0.05). The results of the homogeneity test indicate that the variance of the pre-test and post-test data between the experimental group and the control group is homogeneous.

Following the declaration that the pre-test and post-test data satisfied the assumptions of normality and homogeneity, the subsequent analysis focused on comparing the post-test scores for critical thinking skills between the experimental group and the control group.

Table 3. Result of Independent Sample T-Test

Group	N	Mean	SD	t	Sig.
Experimental Class	26	84.00	4.86	3.11	0.003
Control Class	26	79.76	4.77		

Based on the table above, the results of the independent samples t-test show that the experimental group obtained higher average post-test scores than the control group. The analysis results show that there is a significant difference between the two groups ($p < 0.05$) with a p-value of 0.003. The findings of the study indicate that the treatment given has a significant impact on the development of students' critical thinking skills in comparison with a more conventional learning model.

The analysis of the effectiveness of the treatment in enhancing students' critical thinking skills was conducted using a *normalized gain* test by comparing the pre-test and post-test scores in the experimental group.

Table 4. Result of N-gain Score

N	Mean			
	Pretest	Posttest	N-gain Score	In percent
26	51.12	84.00	0.667	66.7%

The results show that the average N-gain value obtained was 66.7%, which is classified as effective enough in improving students' critical thinking skills. These findings form the basis for further discussion of the differences in critical thinking skills achievement between the two groups, which are then linked to the findings of previous studies.

The results demonstrated a substantial difference in critical thinking skills among the groups. Based on the result of the independent sample t-test ($t = 3.11$; $p = 0.003 < 0.05$), the research hypothesis stating that the application of Project-Based Learning can enhance students' thinking skills can be accepted. The application of Project-Based Learning in the experimental group provided a learning experience that was more conducive to enhancing students' higher-order

thinking skills. The average critical thinking skill score of the experimental group (M = 84.00; SD = 4.86) was higher than that of the control group (M = 79.76; SD = 4.77). The findings of this study demonstrate that project-based learning contributes more effectively to the development of higher-order thinking skills. The enhancement can be explained by the characteristics of project-based learning, which requires students to actively contribute to identifying problems, designing solutions, integrating various sources of information, and systematically evaluating work results. The process aligns with Dewey's theory of Project-Based Learning stages as follows.

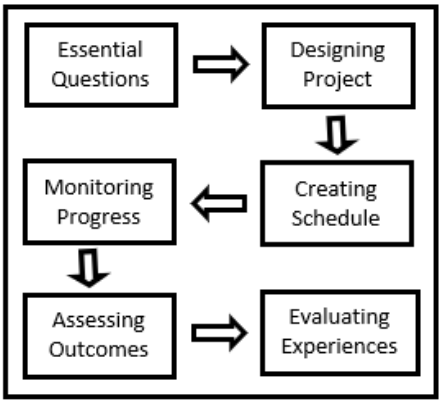

Figure 1. Stages of the Project-Based Learning Model

The stages provide opportunities for students to engage in higher-order thinking through inquiry, decision making, information analysis, and reflection on the work they produce. In the project monitoring stage, students engage in a process of in-depth information analysis. This stage provides students with real-world experience in directly participating in the process of searching for, selecting, and processing information relevant to the project. This active involvement encourages students to critically analyze information, evaluate the quality of sources, and construct evidence-based arguments. This stage sharpens students' critical thinking skills because they learn to interpret information rather than simply accepting or memorizing it.

The results of this study in line with the theory of several studies by Adawiyah and Mahmuddin (2023), Andini and Rusmini (2022), and Trisdiono et al. (2019) explained that project-based learning significantly improves critical

thinking skills through a series of activities involving problem analysis, evaluation, decision making, and independent knowledge construction. In addition, the theory of Hattie and Zierer (2019) also emphasized that learning strategies which place students as the center of learning activities have a strong influence on the development of complex thinking skills and the quality of learning outcomes. The active involvement of students in deep thinking processes also has an impact on improving the quality of student reasoning. Consequently, the enhancement of critical thinking skills in the experimental group can be interpreted as the result of more intensive cognitive involvement in project-based learning processes.

These findings are also in line with the theoretical perspective of Project-Based Learning, which emphasizes the importance of designing learning that focuses on students' thinking processes. Learning that is designed with more emphasis on authentic activities, collaboration, and problem solving as a means of developing higher-order cognitive competencies. The previous research also showed that the implementation of project-based learning encourages students' analytical, reflective, and evaluative abilities more deeply than conventional learning approaches (Tafakur et al., 2015; Zhang & Ma, 2023). In the context of this study, the effectiveness of learning in the experimental group is also related to the diversity of students' learning styles within the Visual, Auditory, Read/Write, and Kinesthetic (VARK) framework.

The learning style framework developed by Neil Fleming explains that individuals process information through different learning modality preferences (Hamid et al., 2024). The compatibility between the learning model and learning styles contributes to an increase in students' conceptual understanding and cognitive engagement. The variety of learning activities involving visual representation, verbal interaction through discussion, text-based information processing, and direct involvement in project implementation enable students to process information according to their learning preferences. Learning strategies that are aligned with students' learning style characteristics contribute to a deeper understanding and improve the quality of the reasoning process.

In this research, the learning model distribution with students' learning styles were relative balanced. It was shown in percentage form that the visual and auditory learning style was 26.7%. Meanwhile, read-write and kinesthetic learning style was 23.1%. The distribution of learning styles in the experimental group showed that there were no dominant differences in students' learning styles. The students' critical thinking skills enhancement can be seen from the average increase in their scores, as follows.

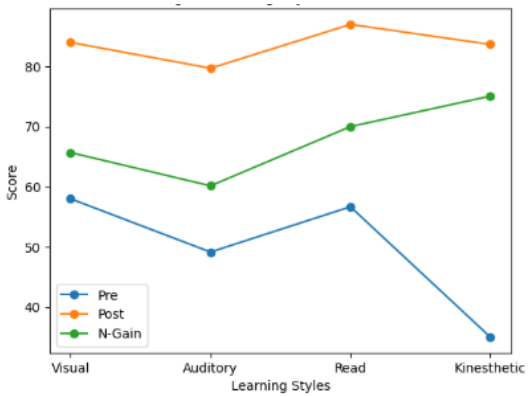

Figure 2. Learning Style Distribution and N-gain Enhancement

Based on Figure 2, the number of students in the visual and auditory learning style group was higher. However, the greatest enhancement in students' critical thinking skills occurred in the kinesthetic learning style group. The N-gain scores for each learning style group showed the percentage 65.68% for visual style; 60.15% for auditory style; 70% for read-write style, and 75.07% for kinesthetic style. It means that the implementation of the Project-Based Learning model was more effective for the kinesthetic learning style, which emphasized practical activities and direct involvement in the learning process.

The result of the N-gain score calculation also strengthens the theory of the effectiveness of the Project-Based learning model in enhancing critical thinking skills. To assess the effectiveness of the learning model, the effectiveness level categories are shown in the table as follows.

Table 5. The Effectiveness Level Categories

Percentage (%)	Mean
< 40	Ineffective
40 - 55	Less Effective
56 - 75	Quite Effective
>76	Effective

(Hake, R. R. 1999)

Table 6. Table of N-gain Score Criteria

Limitation	Category
N-gain<0,3	Low
0.3 < *N-gain* <*0.7*	Medium
N-gain >0.7	High

(Meltzer in Syahfitri, 2008)

Based on the N-gain score table, the mean showed 0.666, which indicated that the effectiveness of the learning model used in medium level. While in percentage, the value showed 66.7%, which indicated the learning model used was quite effective in helping students to enhance their critical thinking skills.

In contrast, the achievements of the control group show that conventional learning tends to provide less varied learning experiences. This is indicated by the relatively large standard deviation (SD = 4.77), which identifies higher heterogeneity in student abilities in the control group. This figure explains that the conventional learning approach tends to be less adaptable to differences in student learning characteristics, so that the development of critical thinking skills is not evenly distributed.

Teacher-centered learning models focus more on conveying information, thereby hindering students' cognitive involvement in deep thinking processes. The dominant focus on completing tasks and delivering material limits student involvement in the investigative and reflective activities necessary for the development of critical thinking skills. In addition, limitations in facilitating different learning styles have the potential to reduce the effectiveness of the learning process because students' cognitive needs are not optimally accommodated. These findings expand on previous research by showing that the

effectiveness of Project-Based Learning is not only influenced by the characteristics of investigative learning activities, but also by their suitability to students' learning preferences. This study provides empirical evidence to support the argument that implementing Project-Based Learning while considering diverse learning styles is a relevant pedagogical approach for optimally improving students' critical thinking skills.

CONCLUSION

This study demonstrates that the implementation of Project-Based Learning was a significant factor in enhancing the critical thinking skills of students. The findings of this study identify that students' direct involvement in investigative activities, problem solving, solution development, and systematic evaluation of results play a role in encouraging higher-level thinking processes in students. In addition, the effectiveness of project-based learning is also related to its characteristics, which allow it to be applied to a variety of student learning styles through varied and adaptive learning experiences.

The learning model that is in line with learning style characteristics allows students to process information more optimally, which can affect the quality of understanding and critical reasoning skills. Thus, a project-oriented learning model that is responsive to students' learning style characteristics can be considered an effective pedagogical approach to improving students' critical thinking skills. Further research is expected to explore the application of this learning model in a broader context and involve other variables such as learning motivation or long-term learning outcomes to strengthen the generalization of research findings. Subsequent research may also consider using a mixed-methods research design to obtain a more in-depth picture of the learning process and the interaction between the learning model and the individual characteristics of students.

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