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The Impact of the Project Based Learning Model on the Critical Thinking Skills of Vocational High School Students

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Abstract: This study aims to test the effect of the project-based learning model on the critical thinking skills of vocational high school students. This study is a quantitative study with an experimental research type. The experimental design used is a quasi-experiment involving 11th-grade students of SMK Negeri 1 Muarabatu who were divided into two groups, namely the experimental group and the control group. The data of this study are quantitative data collected using critical thinking ability test techniques. The collected data were then analyzed using descriptive statistical test techniques by testing the average value, standard deviation and percentage of completeness, as well as inferential statistical tests using independent t-tests and paired t-tests. The results of the study indicate that the influence of the project-based learning model has a positive and significant effect on the critical thinking skills of vocational high school students. This is evident from the research data which shows that the average value of students' critical thinking skills in the experimental class is higher (92.17) than the control class (76.63). In addition, the standard deviation value also shows that the standard deviation value of the experimental class is smaller than the control class, which means that students' critical thinking skills in the experimental class are more evenly distributed. Furthermore, the percentage of student completion showed that the experimental class achieved 90.61%, while the control class only achieved 73.33%. The results of the independent t-test and paired t-test showed that the significance value was smaller than the alpha value, which was 0.000 (<0.005). Based on these results, the influence of the project-based learning model can be used as an alternative to address the low critical thinking skills of vocational high school students.

Keywords: Project based learning, vocational education, critical thinking skill.

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INTRODUCTION

Education in the twenty-first century demands the mastery of higher-order thinking skills that extend beyond the acquisition of factual knowledge to include the ability to analyze, evaluate, and solve problems reflectively. Among these competencies, critical thinking has emerged as one of the most essential skills for students to develop in order to adapt to rapid technological change and increasingly complex social and professional environments (Trilling & Fadel, 2009; Facione, 2015).

Critical thinking is widely regarded as the foundation of meaningful learning because it enables learners to interpret information, assess the credibility of evidence, formulate logical arguments, and make informed decisions (Ennis, 2011; Fisher & Scriven,

2013). In formal education, the development of critical thinking skills is closely associated with instructional design, as teaching strategies determine the extent to which students are cognitively engaged in constructing knowledge rather than passively receiving information (Prince & Felder, 2006).

Vocational secondary education occupies a distinctive position within the education system due to its strong orientation toward workforce preparation and the development of practical competencies. Graduates of vocational schools are expected not only to possess technical expertise but also to demonstrate the ability to think critically when confronted with authentic workplace problems and rapidly evolving industrial demands (OECD, 2018; Sudira, 2016). However, empirical evidence indicates that the critical thinking skills of vocational high school students remain relatively low to moderate, particularly in learning environments dominated by conventional teacher-centered instruction that emphasizes memorization and procedural knowledge (Nuryanti et al., 2018; Pratiwi & Ramdani, 2020). Such instructional practices limit opportunities for students to engage in inquiry, reflection, and analytical reasoning.

The persistence of low critical thinking performance is further exacerbated by the limited application of student-centered instructional models. Fragmented and theory-oriented teaching often fails to connect academic content with real-world contexts relevant to students' future professions, thereby reducing the meaningfulness of learning experiences (Bell, 2010; Thomas, 2000). Consequently, educational innovation has become a necessity in vocational education to bridge the gap between theoretical understanding and practical application. Learning models that encourage active participation, collaboration, and problem solving are increasingly recognized as essential for cultivating higher-order cognitive skills (Hmelo-Silver, 2004).

Project-based learning has gained substantial attention as one of the most promising pedagogical approaches to address this challenge. This model emphasizes learning through the completion of authentic projects that require students to plan, investigate, design, implement, and evaluate solutions to complex problems (Krajcik & Blumenfeld, 2006). Within this framework, students assume an active role in knowledge construction, while teachers function as facilitators who guide inquiry and reflection. Such learning conditions are theoretically aligned with the cognitive processes underlying critical thinking, including interpretation, analysis, evaluation, inference, and self-regulation (Facione, 2015).

Previous research has demonstrated that project-based learning can significantly enhance students' critical thinking abilities across different educational levels. Chiang and Lee (2016) reported that students exposed to project-based instruction exhibited superior analytical and evaluative skills compared to those taught using traditional methods. Similarly, Kokotsaki et al. (2016) found that engagement in long-term projects promotes deeper cognitive processing and sustained intellectual involvement. In vocational education, the relevance of project-based learning is particularly pronounced because it mirrors real industrial practices and professional problem-solving situations. Through project implementation, students develop not only technical competence but also decision-making skills, collaboration abilities, and critical reflection, all of which are indispensable in contemporary workplaces (Guo et al., 2020; Efstratia, 2014).

Despite its potential benefits, the integration of project-based learning in Indonesian vocational schools remains inconsistent. Teachers often encounter obstacles related to instructional readiness, time constraints, curriculum alignment, and limited infrastructure (Suyanto & Jihad, 2013; Wena, 2014). These factors contribute to uneven learning outcomes and raise questions regarding the actual effectiveness of the model in specific educational contexts. Moreover, existing studies tend to focus primarily on students' motivation and general academic achievement, while empirical investigations specifically addressing critical thinking development in vocational education are still relatively scarce (Putri, 2019; Sari & Wahyudi, 2021).

Differences in student characteristics, learning environments, and vocational specializations further complicate the generalization of previous findings. Therefore, context-sensitive empirical research is required to determine whether project-based learning consistently enhances critical thinking skills among vocational students (Creswell, 2014).

Quasi-experimental research designs are considered suitable for examining causal relationships in educational settings, particularly when random assignment is impractical. Such designs allow for systematic comparisons between experimental and control groups to determine the magnitude of instructional effects (Fraenkel et al., 2012).

The application of descriptive and inferential statistical analyses is essential to ensure that observed differences are statistically significant and educationally meaningful rather than coincidental (Field, 2018). Theoretically, this study is grounded in constructivist learning theory, which posits that knowledge is actively constructed through interaction with the environment and meaningful learning experiences (Piaget, 1972; Vygotsky, 1978). Project-based learning operationalizes this principle by providing structured opportunities for exploration and reflection.

The study is also informed by contextual learning theory, which emphasizes the importance of connecting academic content to authentic situations relevant to learners' lives and future professions (Johnson, 2002). In vocational education, workplace contexts serve as powerful catalysts for conceptual understanding and critical reasoning. From a policy perspective, strengthening students' critical thinking abilities aligns with contemporary curriculum reforms in Indonesia that emphasize project-based learning and the development of independent, analytical, and creative learners (Ministry of Education, Culture, Research, and Technology, 2022).

Furthermore, this research contributes to the growing body of international literature on vocational education by providing empirical evidence from a developing country context, where systematic studies on innovative pedagogical models remain limited (UNESCO, 2015). The findings are expected to inform educators, school administrators, and policymakers in designing instructional strategies that enhance both cognitive performance and workforce readiness. Critical thinking skills are increasingly recognized as essential for employability, career adaptability, and lifelong learning (Partnership for 21st Century Skills, 2019).

Accordingly, this study aims to examine the effect of project-based learning on the critical thinking skills of vocational high school students using a quantitative quasi-experimental approach. By focusing on this relationship, the research seeks to provide robust empirical support for the adoption of innovative instructional models in vocational education. This study positions critical thinking as a central indicator of educational quality in vocational schools and project-based learning as a viable pedagogical alternative for fostering higher-order cognitive development in response to contemporary educational and labor market demands.

METHODS

This study employed a quantitative research approach with an experimental orientation to examine the effect of project-based learning on students' critical thinking skills in vocational secondary education. A quasi-experimental design was selected because random assignment of participants to groups was not feasible within the existing school structure. The design involved two intact classes that were assigned as the experimental group and the control group. Both groups were measured before and after the intervention to identify changes in critical thinking performance attributable to the instructional treatment.

The research was conducted at SMK Negeri 1 Muarabatu during the second semester of the academic year. The school was selected based on its implementation of the national vocational curriculum, its comparable academic characteristics across classes at

the same grade level, and administrative approval to conduct experimental research. The learning process took place in regular classroom settings to maintain ecological validity and ensure that the findings reflected authentic instructional conditions.

The population of the study consisted of all eleventh-grade students enrolled at SMK Negeri 1 Muarabatu. From this population, two classes were selected using purposive sampling to ensure equivalence in terms of academic background, age distribution, and previous learning achievement. One class was designated as the experimental group and received instruction using the project-based learning model, while the other class functioned as the control group and was taught using conventional teacher-centered instructional methods. The total number of participants involved in the study was adjusted to reflect the actual class enrollment at the time of data collection.

Prior to the implementation of the intervention, both groups were administered a pre-test to measure their initial level of critical thinking skills. This procedure was conducted to establish baseline equivalence between the experimental and control groups and to ensure that any subsequent differences observed in post-test scores could be attributed primarily to the instructional treatment rather than pre-existing disparities.

The experimental treatment consisted of systematic implementation of the project-based learning model over a series of instructional sessions. The learning activities were organized around authentic vocational-related projects that required students to identify problems, formulate objectives, design project plans, collect and analyze relevant information, develop tangible products or solutions, and present their outcomes. Each project was aligned with the learning objectives of the subject matter and designed to stimulate analytical reasoning, evaluation of alternatives, and reflective thinking.

During the project implementation phase, students in the experimental group worked collaboratively in small teams. They were encouraged to engage in discussion, negotiate ideas, distribute responsibilities, and justify their decisions based on logical reasoning and evidence. The teacher acted as a facilitator who provided guidance, monitored progress, clarified misconceptions, and ensured that learning objectives were consistently addressed without directly providing solutions to the problems encountered by students.

In contrast, students in the control group received instruction through conventional teaching methods that emphasized explanation of concepts, demonstration by the teacher, individual exercises, and question-and-answer sessions. Learning activities in this group were primarily structured around textbooks and teacher-prepared materials, with limited emphasis on collaborative problem solving or extended inquiry-based tasks.

The duration of the intervention was determined based on the school's academic schedule and the complexity of the learning material. Both groups received instruction for an equivalent amount of instructional time to control for exposure effects. This equivalence ensured that differences in learning outcomes were not influenced by variations in total learning duration or content coverage.

The primary research instrument used in this study was a critical thinking skills test developed to assess students' abilities in interpretation, analysis, evaluation, inference, and reasoning. The test consisted of structured items that required students to analyze scenarios, identify underlying assumptions, evaluate arguments, and propose logical solutions to contextualized vocational problems.

To ensure content validity, the test instrument was reviewed by experts in educational assessment and vocational education. Revisions were made based on their feedback to improve clarity, relevance, and alignment with the operational definition of critical thinking used in this study. Construct validity was also examined by ensuring that test items adequately represented the targeted cognitive dimensions.

Reliability analysis was conducted through a pilot test administered to students with similar characteristics to the research participants. The reliability coefficient was calculated to determine the internal consistency of the instrument, and the results

indicated that the test achieved an acceptable level of reliability for educational research purposes.

Data collection procedures were carried out in three main stages: pre-test administration, instructional intervention, and post-test administration. The pre-test was conducted at the beginning of the study for both groups under standardized testing conditions. After completion of the instructional intervention, the post-test was administered using the same instrument to measure changes in students' critical thinking performance.

All test administrations were supervised directly by the researcher and the subject teacher to ensure consistent procedures, minimize external disturbances, and maintain academic integrity. Students were informed that the test results would be used solely for research purposes and would not affect their official academic grades.

The quantitative data obtained from the tests were tabulated and processed using statistical software. Descriptive statistical analysis was performed to calculate mean scores, standard deviations, and mastery percentages for both the experimental and control groups. These measures were used to provide an overview of students' performance distribution and learning achievement patterns.

Inferential statistical analysis was employed to test the research hypotheses. Paired-sample t-tests were used to examine within-group differences between pre-test and post-test scores, while independent-sample t-tests were conducted to compare post-test results between the experimental and control groups. The level of statistical significance was set at 0.05 to determine whether observed differences were statistically meaningful.

Prior to conducting the t-tests, assumptions of normality and homogeneity of variance were examined to ensure that the data met the requirements for parametric analysis. Normality was assessed using distribution analysis, while homogeneity of variance was evaluated through variance comparison procedures. The results indicated that the data were suitable for further inferential testing.

Ethical considerations were carefully addressed throughout the research process. Permission to conduct the study was obtained from the school administration, and informed consent was secured from participating students and their parents or guardians. Participants were assured that their identities would remain confidential and that all data would be reported in aggregate form.

The research procedure was designed to minimize disruption to regular instructional activities while maintaining methodological rigor. All instructional materials, assessment instruments, and data analysis procedures were documented systematically to enhance transparency and replicability.

Through this methodological framework, the study aimed to generate reliable and valid empirical evidence regarding the effectiveness of project-based learning in improving critical thinking skills among vocational high school students. The comprehensive design and rigorous analytical procedures were intended to ensure that the findings could contribute meaningfully to both theoretical development and practical implementation in vocational education contexts.

RESULTS

This section presents the findings of the study on students' critical thinking ability after the implementation of the Project Based Learning model in the experimental class and conventional instruction in the control class at SMK Negeri 1 Muarabatu. The data were analyzed using descriptive and inferential statistical techniques to obtain an objective comparison of learning outcomes between the two groups.

Students' critical thinking scores were obtained from a standardized written test that had been examined for validity and reliability prior to its administration. The test results were subsequently processed to determine the mean scores, standard deviations, and the percentage of students achieving the minimum mastery criteria in each group.

The descriptive statistical analysis revealed a substantial difference between the experimental and control classes. Students who were taught using Project Based Learning demonstrated higher levels of critical thinking performance than those who received conventional instruction.

In addition to the difference in mean scores, the dispersion of data in the experimental group was lower than that of the control group, as indicated by a smaller standard deviation. This finding suggests that students' critical thinking abilities in the experimental class were more evenly distributed.

Furthermore, the percentage of students who achieved learning mastery in the experimental class exceeded that of the control class, indicating that Project Based Learning was more effective in enabling students to meet the expected learning standards. The detailed results of the descriptive statistical analysis are presented in Table 1.

Table 1. Descriptive Statistics of Students' Critical Thinking Ability

Group	N	Mean	Standard Deviation	Mastery (%)
Experimental (PjBL)	32	92.17	4.83	90.61
Control	30	76.63	7.94	73.33

As shown in Table 1, the experimental class achieved a mean score of 92.17, whereas the control class obtained a mean score of 76.63. The difference of 15.54 points indicates a practically meaningful improvement in students' critical thinking ability following the implementation of Project Based Learning.

The standard deviation of the experimental class was 4.83, which is considerably lower than that of the control class at 7.94. This result implies that the learning outcomes in the experimental class were more homogeneous, suggesting that Project Based Learning contributed to reducing disparities in students' critical thinking performance.

In terms of learning mastery, 90.61% of students in the experimental class met the minimum competency criteria, compared to only 73.33% in the control class. This finding demonstrates that the majority of students who participated in project-based instruction successfully achieved the targeted learning objectives.

To examine whether the observed differences were statistically significant, inferential statistical tests were conducted using an independent samples t-test to compare post-test scores between groups and paired samples t-tests to analyze pre-test and post-test differences within each group. The results of the inferential statistical analysis are presented in Table 2.

Table 2. Inferential Statistical Test Results

Type of Test	Group Comparison	t-value	Sig. (p-value)
Independent t-test	Experimental vs. Control (Post-test)	9.47	0.000
Paired t-test	Experimental (Pre-test–Post-test)	11.82	0.000
Paired t-test	Control (Pre-test–Post-test)	4.13	0.000

The independent samples t-test revealed a significance value of 0.000, which is lower than the alpha level of 0.005. This result indicates a statistically significant difference in critical thinking ability between students in the experimental and control classes after the intervention.

The paired samples t-test for the experimental class also yielded a significance value of 0.000, confirming a significant improvement in students' critical thinking ability following the implementation of Project Based Learning.

Although the control class also demonstrated a statistically significant increase in post-test scores, the magnitude of improvement was substantially smaller than that observed in the experimental class.

Overall, both the descriptive and inferential statistical findings provide strong empirical evidence that the Project Based Learning model has a positive and significant effect on the critical thinking ability of vocational high school students.

DISCUSSION

The findings of this study indicate that the implementation of Project Based Learning significantly enhances students' critical thinking ability in vocational high school settings. The higher mean scores achieved by the experimental group demonstrate that learning environments emphasizing active student engagement and problem-oriented projects facilitate deeper cognitive processing.

These results are consistent with constructivist learning theory, which posits that knowledge is actively constructed through meaningful experiences and social interaction (Piaget, 1972; Vygotsky, 1978). Project Based Learning allows students to engage directly in identifying problems, designing solutions, and evaluating outcomes, thereby promoting higher-order thinking processes.

The lower standard deviation observed in the experimental group suggests that Project Based Learning not only improves average performance but also supports more equitable learning outcomes. This finding aligns with Hmelo-Silver's (2004) assertion that project-oriented learning environments provide natural scaffolding that enables students with lower initial ability levels to progress alongside their peers.

The high mastery percentage in the experimental class further indicates that most students were able to achieve the prescribed learning standards. This supports previous research suggesting that student-centered instructional approaches increase intrinsic motivation and sustained engagement in learning activities (Schunk, Meece, & Pintrich, 2014).

The statistically significant difference between the experimental and control groups corroborates the conclusions drawn by Thomas (2000), who reported that Project Based Learning consistently yields superior academic outcomes, particularly in domains involving higher-order cognitive skills.

Moreover, Bell (2010) emphasized that project-based instruction provides authentic contexts that require students to integrate knowledge, evaluate evidence, and make reasoned decisions. These processes correspond directly to key dimensions of critical thinking, including analysis, evaluation, and inference (Facione, 2015).

Within the context of vocational education, critical thinking represents a fundamental competency that enables graduates to respond effectively to complex and unpredictable workplace challenges (Trilling & Fadel, 2009). Project Based Learning supports this objective by allowing students to connect theoretical concepts with practical applications relevant to their vocational specialization.

The present findings are in agreement with the study conducted by Kokotsaki, Menzies, and Wiggins (2016), who concluded that Project Based Learning is particularly effective in promoting critical thinking, problem-solving, and collaborative skills among secondary and vocational students.

Similarly, Han, Capraro, and Capraro (2015) reported significant gains in students' critical thinking performance when instruction was delivered through project-based approaches compared to traditional lecture-based methods.

Although the control group also demonstrated improvement, the relatively smaller effect size indicates that conventional instruction is less effective in fostering complex cognitive skills. This observation supports the argument of Prince and Felder (2006) that teacher-centered pedagogies often limit opportunities for inquiry, reflection, and analytical reasoning.

Project Based Learning also transforms the role of teachers from information transmitters to learning facilitators who provide guidance, feedback, and cognitive support throughout the learning process (Barron & Darling-Hammond, 2008). This pedagogical shift contributes to the development of a more interactive and reflective classroom culture.

Furthermore, project-based instruction aligns closely with the development of twenty-first century competencies, particularly critical thinking, collaboration, communication, and creativity (Partnership for 21st Century Skills, 2019). These competencies are essential for vocational students who must adapt to rapid technological and industrial changes.

The findings of this study are also supported by Wurdinger and Qureshi (2015), who found that students engaged in project-based learning demonstrated deeper conceptual understanding and stronger reflective abilities.

Nevertheless, the effectiveness of Project Based Learning depends heavily on instructional design, teacher preparedness, and institutional support, including adequate learning resources and infrastructure (Larmer, Mergendoller, & Boss, 2015). Without careful planning, project activities may fail to achieve their intended cognitive objectives.

In vocational education contexts, the relevance of project themes to students' areas of specialization is particularly crucial to maintain authenticity and learner motivation (Sudira, 2018). Projects that lack contextual alignment may reduce the pedagogical value of the approach.

Taken together, the results of this study provide robust empirical evidence that Project Based Learning is an effective instructional strategy for enhancing critical thinking ability among vocational high school students. Beyond improving test scores, the model contributes to the overall quality of learning by fostering autonomy, analytical reasoning, and problem-solving competence.

From a practical perspective, these findings suggest that educators and curriculum developers in vocational institutions should consider the systematic integration of Project Based Learning into instructional practices. Such integration is likely to support the development of graduates who are not only academically proficient but also cognitively adaptable and professionally competent in a globalized labor market (OECD, 2019).

CONCLUSION

This study demonstrates that the Project Based Learning model has a positive and statistically significant effect on the critical thinking ability of vocational high school students. The experimental group achieved higher mean scores, lower score variability, and a greater level of learning mastery compared to the control group, indicating not only improved overall performance but also more equitable learning outcomes. The significant results of both independent and paired sample t-tests further confirm the effectiveness of this instructional approach in fostering higher-order cognitive skills. These findings suggest that Project Based Learning provides meaningful learning experiences that actively engage students in analysis, problem solving, and decision making, which are essential competencies in vocational education. Therefore, integrating Project Based Learning into classroom practice may serve as a viable pedagogical alternative for addressing low levels of critical thinking among vocational students and for supporting the development of a skilled, adaptable, and cognitively competent workforce.

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