JPPIPA 10(10) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

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

The Impact of the Project-Based Learning (PjBL) Model Assisted by Liveworksheet Media on Critical Thinking Skills of Vocational High School Students

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Received: August 8, 2024
Revised: September 27, 2024
Accepted: October 25, 2024
Published: October 31, 2024

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DOI: 10.29303/jppipa.v10i10.8785

Abstract: This study investigates the effectiveness of the Project-Based Learning (PjBL) model integrated with Liveworksheet media in enhancing the critical thinking skills of vocational high school students. Employing a true experimental design with a pretest-posttest control group approach, the research compared two groups: the experimental group using PjBL with Liveworksheet and the control group receiving conventional instruction. Data collected from pretest and posttest assessments revealed that the experimental group demonstrated a significant improvement in critical thinking skills, with an average posttest score of 81, compared to 64 in the control group. The pretest scores showed no significant differences between the groups, indicating a similar starting point. Post-intervention results were analyzed using statistical tests, confirming the normal distribution and equal variances of data. The hypothesis testing further validated a substantial difference in critical thinking skills, favoring the PjBL model with Liveworksheet media. These results underscore the effectiveness of this innovative teaching approach in fostering critical thinking skills among vocational students.

Keywords: Critical thinking skills; Liveworksheet media; Project-based learning (PjBL)

Introduction

The 21st century demands that the education sector prepares students to face global challenges in the era of society 5.0, emphasizing critical thinking as an essential skill (Pardana et al., 2024). Critical Thinking Skills involve the ability to access, analyze, and synthesize information, which can be learned, trained, and mastered (Redecker et al., 2011). Developing these skills is particularly important for vocational or technical students, including those in Audio Video Technology (Agustiana et al., 2024).

Vocational education's relevance to the fourth industrial revolution and the availability of reliable labor is increasingly important (Ammirato et al., 2023). Data from the Central Statistics Agency (BPS) in 2017 indicated that Vocational High Schools (SMKs) had the highest unemployment rates at 9.27%. This issue arises from an educational system that overly emphasizes hard skills while neglecting soft skills. The government's policies to revitalize SMK education aim to reduce unemployment rates among graduates by addressing this imbalance (Sunariah et al., 2022).

The "Freedom to Learn" Curriculum (KMB) and 21st-century learning models both promote student-centered learning, emphasizing critical thinking, creativity, communication, and collaboration skills (Hunaepi et al., 2023). Higher-order thinking skills, such as critical thinking, are highly demanded in the workplace (Diena et al., 2023; Karuru et al., 2023; Thornhill-Miller et al., 2023). Educational institutions should thus design learning experiences that develop these skills in students, preparing them for future employment and innovation (Aithal et al., 2023).

The low critical thinking skills of students are attributed to their difficulties in analyzing information, challenges in solving complex problems, and lack of active participation in discussions or activities that

How to Cite:
Defira, R., Huda, A., Anwar, M., & Ambyar, A. (2024). The Impact of the Project-Based Learning (PjBL) Model Assisted by Liveworksheet Media on Critical Thinking Skills of Vocational High School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(10), 8238–8245. https://doi.org/10.29303/jppipa.v10i10.8785

require critical thinking. The teaching methods employed by teachers remain conventional, monotonous, and less interactive, accompanied by the continued use of traditional learning media. Aoun (2017) states that automated machines are gradually replacing workers in the era of artificial intelligence. This underscores the necessity of developing individuals who possess strong innovation and critical thinking skills. Project-based learning in vocational schools equips students with the technical skills and critical thinking abilities essential for becoming successful innovators and adapting to changes in their work environments. Furthermore, project-based learning provides students with opportunities to collaborate, face challenges, and discover creative solutions to real-world problems. It encourages students to develop critical thinking skills through hands-on experiences in analyzing, evaluating, and solving problems in environments similar to real-life situations.

Project-based learning (PjBL) is a powerful method for fostering critical thinking skills in vocational schools (Baidowi et al., 2023). PjBL allows students to apply critical thinking contextually and meaningfully through practical projects, enhancing their technical and cognitive competencies (Fawaas et al., 2024). Practical projects in PjBL enable students to collaborate, face challenges, and find creative solutions to real-world problems, making it a valuable approach in vocational education (Santana et al., 2024; Triono Ahmad et al., 2023).

Preliminary studies at SMK Negeri 1 Bangkinang and SMK Negeri 1 Tapung revealed that students' critical thinking skills in the Audio Video System Planning and Installation (AVSPI) course were relatively low. A critical thinking skills test indicated that students' performance in interpretation, analysis, inference, and evaluation was suboptimal. These findings align with other research showing that vocational high school students often struggle with critical thinking, particularly in problem-solving and evaluation.

To address these issues, teachers need to create engaging learning environments that motivate students and foster independent learning. Project-Based Learning (PjBL) provides such an environment by encouraging students to engage in complex activities, solve real-world problems, and collaborate effectively (Wijnia et al., 2024). Additionally, the use of innovative learning media, such as Liveworksheet, can further enhance the learning experience by making it more interesting and interactive, helping students to achieve better learning outcomes.

Internet-based learning media can assist teachers in enhancing students' understanding of learning materials, particularly in vocational education, which is more focused on practical learning than theoretical knowledge (Sidik et al., 2021). Its roles include serving as a substitute, optional supplement, and complementary resource (Alfia et al., 2023). The appropriate use of media can stimulate students' interest and motivation to learn, which in turn impacts their critical thinking abilities. The lack of students' ability to analyze information, challenges in solving complex problems, and insufficient active participation in discussions or activities requiring critical thinking are the primary issues faced by teachers in the learning process. The conventional, monotonous, and less interactive teaching methods used by educators, along with the reliance on traditional learning media, contribute significantly to these challenges.

Liveworksheet, as an interactive digital tool, offers numerous advantages in the PjBL framework. It allows for the creation of dynamic, engaging, and personalized learning activities that can be accessed anytime and anywhere. This flexibility supports continuous learning and enables students to work on projects at their own pace. Furthermore, Liveworksheet can provide instant feedback, helping students to reflect on their learning process and improve their critical thinking skills progressively.

The integration of Project-Based Learning (PjBL) and interactive media such as Liveworksheet represents a strategic approach to developing critical thinking skills among vocational students. By creating meaningful and engaging learning experiences, educators can better prepare students for the demands of the modern workforce, ultimately reducing unemployment rates and nurturing a generation of innovative thinkers. This approach necessitates a collaborative effort from educators, policymakers, and the education system as a whole to effectively embrace and implement these innovative teaching strategies.

The integration of PjBL and Liveworksheet not only addresses the deficiencies in critical thinking skills but also aligns with the digital transformation in education. By leveraging technology, educators can create more effective and stimulating learning environments that resonate with the digital-native generation. This approach ensures that students are not only prepared for the technical demands of their future careers but also equipped with the cognitive skills necessary to adapt and thrive in a rapidly changing world.

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policymakers, and the education system as a whole to embrace and implement these innovative teaching strategies effectively.

Method

This research employs an experimental method with a quantitative approach. The aim is to determine the effect of the Project-Based Learning (PjBL) model supported by Liveworksheet media on students' critical thinking skills. This method allows the researcher to measure changes in critical thinking skills before and after treatment and compare the results with a control group that does not receive the intervention.

The research design used is a True Experimental Design with a Pretest-Posttest Control Group Design. In this design, two groups are randomly selected from the population: the experimental group, which receives the PjBL treatment with Liveworksheet, and the control group, which uses conventional methods. Both groups are given a pretest to measure initial abilities and a posttest after the treatment to assess learning outcomes and critical thinking skills.

The research procedure involves several stages, including preliminary studies at SMKN 1 Bangkinang and SMKN 1 Tapung, problem analysis, proposal preparation, and development of teaching materials. Following this, instrument validation by experts, pilot testing of instruments on students outside the research sample, pretest administration, treatment of the experimental group, and posttest administration are conducted. Data collected are then processed and analyzed to determine the effectiveness of the treatment. The research population consists of all class XI Audio Video Engineering students in SMKs in Kampar Regency for the 2023/2024 academic year. The sample is taken using simple random sampling, with two classes randomly chosen from three available classes. Class XI TAV1 is assigned as the experimental group, while Class XI TAV2 is the control group. Both classes are given pretests and posttests to measure changes in critical thinking skills.

Variables in the study include the independent variable, which is the PjBL model with Liveworksheet media, and the dependent variable, which is students' critical thinking skills. Critical thinking skills are measured using a validated posttest. Indicators of critical thinking skills include the ability to interpret, analyze, evaluate, conclude, explain, and self-regulate.

The research instruments include teaching materials and data collection tools. Teaching materials include lesson plans based on the PjBL model and Student Worksheets (LKPD) in the form of Liveworksheet media. Data collection tools consist of test sheets for learning outcomes, critical thinking skills questionnaires, and observation sheets for the implementation of the PjBL model by teachers.

Data collection is carried out using tests, questionnaires, and observations. Test techniques are used to measure students' learning outcomes before and after the treatment. Questionnaires are used to assess students' critical thinking skills, while observations are used to monitor the implementation of the PjBL model by the teacher. The collected data are analyzed using statistical software to determine the validity and reliability of the instruments.

Table 1. Critical Thinking Skills Indicators

Indicator	Description
Interpreting	Clearly stating meaning and significance Identifying arguments
Analyzing Evaluating	Credibility of statements Drawing logical conclusions
Concluding Explaining	Presenting procedures
Self-Regulation	Monitoring oneself

Instrument validity and reliability tests are conducted to ensure that the instruments are used to measure what they are supposed to and produce consistent data. Instrument validity is tested by correlating item scores with total scores, while reliability is tested using the Alpha-Cronbach coefficient method. Valid and reliable instruments will ensure accurate and trustworthy research results.

After data collection and statistical analysis, the research results will be presented to show the effectiveness of the PjBL model with Liveworksheet in improving students' critical thinking skills. These results are expected to serve as a basis for implementing more effective teaching models in schools and contribute to better educational development.

Result and Discussion

The pretest and posttest results from both classes were collected to evaluate the improvement in students' critical thinking skills. The data was processed and analyzed to observe the differences in pretest and post-test scores between the two groups and to measure the effectiveness of using Liveworksheet media within the Project Based Learning (PjBL) model. This analysis will serve as the basis for prerequisite testing and hypothesis testing. Description of the pretest and posttest data for the experimental and control classes is shown in Table 2.

Based on Table 2, the pretest and posttest data for the experimental and control classes provide insight into changes in critical thinking skills before and after the intervention. Initially, the experimental class had an average pretest score of 57, slightly higher than the control class's average of 54. The minimum score in the experimental class was 25, while in the control class it

was 31, with both classes having a maximum score of 81. The standard deviation for the pretest indicates similar initial variability in both groups, with the experimental class at 13.91 and the control class at 12.86.

Table 2. Pretest and Posttest Data for Experimental and Control Classes

Data	Pretest Experiment	Pretest Control	Posttest Experiment	Posttest Control
N	30	30	30	30
Minimum	25	31	56	38
Maximum	81	81	100	100
Average	57	54	81	63
Standard Deviation	13.91	12.86	13.14	17.41

Following the implementation of the Project- Based Learning (PjBL) model supported by Liveworksheet media, posttest results showed a significant difference. The experimental class's average posttest score rose to 81, reflecting substantial improvement from the pretest. Conversely, the control class's average posttest score increased to 63. Although both groups showed improvement, the experimental class exhibited a more substantial gain, highlighting the effectiveness of the teaching method.

The minimum posttest score in the experimental class also increased to 56, compared to 38 in the control class. The maximum score remained at 100 for both groups, but the experimental class showed a more consistent achievement, with a lower standard deviation of 13.14 compared to the control class's 17.41.

This significant difference indicates that the PjBL model supported by Liveworksheet media not only improved overall learning outcomes but also resulted in more uniform student achievements. This suggests that students in the experimental class benefited more consistently from the intervention than those in the control class.

The pretest was designed to measure various aspects of critical thinking skills. Participants were asked to complete tasks that required analytical thinking, problem-solving, and critical assessment of information. Therefore, the pretest results can be used as a basis for designing more effective learning programs aimed at enhancing participants' critical thinking skills.

Based on Table 3, the pretest data regarding aspects of critical thinking skills in both the control and experimental classes show relatively balanced results. The measured aspects include interpretation, analysis, evaluation, inference, explanation, and self-regulation. In the control class, the highest percentage was in the analysis aspect at 58.93%, while the lowest was in inference at 54.53%. In the experimental class, the highest percentage was in inference at 57.20%, while the lowest was in analysis at 54.67%.

Table 3. Pretest Data by Critical Thinking Skills Aspects

Aspect	Control Class	Experimental Class
Interpretation	56.67%	56.33%
Analysis	58.93%	54.67%
Evaluation	55.00%	56.67%
Inference	54.53%	57.20%
Explanation	55.50%	55.83%
Self-regulation	56.00%	55.22%
Average	56.11%	55.99%
Category	Moderate	Moderate

Although there are minor variations in each aspect, overall, both classes fall into the "Moderate" category. The average pretest score for the control class was 56.11%, while for the experimental class, it was 55.99%. The close average pretest scores between the control and experimental classes indicate that both groups had nearly the same initial ability in critical thinking skills. This is crucial to ensure that any differences observed in the posttest results can be more clearly attributed to the given intervention rather than differences in initial abilities.

With the "Moderate" category prevailing in all aspects for both classes, it is evident that there is significant room for improvement in students' critical thinking skills through effective learning processes. The posttest data that measures students' critical thinking skills provides insights into the development of these skills after the learning process.

Table 4. Posttest Data by Critical Thinking Skills Aspects

Aspect	Control Class	Experimental Class
Interpretation	70.67%	87.89%
Analysis	69.73%	83.07%
Evaluation	69.00%	81.33%
Inference	68.27%	86.40%
Explanation	68.33%	89.50%
Self-regulation	66.89%	89.89%
Average	68.81%	86.35%
Category	High	Very High

Based on Table 4, the post-test data evaluating critical thinking skills shows a significant difference between the control and experimental classes. In the control class, the average percentage of critical thinking skills was 68.81%, which falls into the High category. Conversely, the experimental class, which implemented the Project Learning (PjBL) model supported by Liveworksheet media, achieved an average percentage of 86.35%, classified as Very High. This difference indicates that the application of PjBL with Liveworksheet media had a more positive impact on students' critical thinking skills compared to the methods used in the control class.

The posttest results demonstrate that every aspect of critical thinking skills-interpretation, analysis, evaluation, inference, explanation, and self-regulation-

was achieved with higher percentages in the experimental class. For example, in the interpretation aspect, the experimental class scored 87.89% in the Very High category, while the control class only scored 70.67% in the High category. Significant differences are also observed in other aspects, with the experimental class consistently achieving better results than the control class.

These findings emphasize the effectiveness of the Project Based Learning (PjBL) model supported by Liveworksheet media in enhancing students' critical thinking skills. The results provide a strong foundation for continuing and expanding the use of PjBL with Liveworksheet media in educational contexts to achieve better outcomes in critical thinking skills development. Adjustments and similar strategies should also be considered for the control class to improve overall critical thinking skills.

Prerequisite data analysis involves examining the pretest scores collected from the control and experimental classes. This process includes normality testing and homogeneity testing. Normality testing aims to ensure that the data distribution follows a normal pattern, while homogeneity testing checks for equal variances among groups. The pretest data were thoroughly processed using SPSS 26 statistical software, allowing for accurate and detailed analysis to determine if the data meet the criteria for further statistical analysis.

The normality test determines whether the data obtained follow a normal distribution. This test was conducted on the pretest scores, including those from the experimental and control classes. To test normality in both classes, the Kolmogorov-Smirnov test with a significance level of 5% was used. The hypothesis tested in the normality test is as follows:

H0 = The sample is normally distributed

H1 = The sample is not normally distributed

Table 5. Normality Test Results

Class				Data
	Statistic	df	Sig.	Description
Experiment	0.121	28	0.200	Sig. > α
Control	0.157	28	0.059	Data Normal

Table 5 presents the normality test results for posttest data in both the experimental and control classes. For the experimental class, the normality test statistic is 0.121 with 28 degrees of freedom and a significance value (Sig.) of 0.200. Since this significance value is greater than α = 0.05, the data distribution in the experimental class is considered normal, meeting the assumptions needed for further statistical analysis.

For the control class, the normality test statistic is 0.157 with 30 degrees of freedom and a significance value of 0.059. Although this value is slightly below α = 0.05, it is still close to the threshold, suggesting that the data distribution in the control class can also be considered normal.

The homogeneity test assesses whether the variances of pretest scores are equal among the groups. To determine homogeneity, Levene's test was conducted, with the following hypotheses:

H0 = The variance of pretest scores is equal across groups (homogeneous).

H1 = The variance of pretest scores is not equal across groups (non-homogeneous).

Table 6. Homogeneity Test Results

Lavene Statistics	Pretest
Sig.	0.459
α	0.05
Description	Homogeneous

Based on Table 6, the homogeneity test results for the posttest data indicate that the variances between the experimental and control classes are homogeneous. This test is conducted to ensure that the variances of the two groups are uniform, which is a critical assumption in statistical analyses comparing two groups.

The results show a Levene's statistic value of 0.459 with a significance value (Sig.) of 0.459. Since this significance value is greater than α = 0.05, it can be concluded that the variances of the post-test data between the experimental and control classes are homogeneous. This implies that there is no significant difference in variances between the two groups, and the data from both classes can be considered similar in terms of value distribution.

Based on the prerequisite data analysis, the post-test results from both the control and experimental classes indicate that the data are normally distributed and that the variances of the post-test data between the two classes are homogeneous. Thus, the conditions for proceeding to the next statistical analysis have been met. Therefore, parametric statistical testing using the t-test will be applied to examine the differences between the two groups. The hypotheses for this test are as follows:

H0 : There is no significant difference in critical thinking skills between students in the experimental class and students in the control class.

H1 : There is a significant difference in critical thinking skills between students in the experimental class and students in the control class.

The decision about the null hypothesis (H0) is based on the Asymp. Sig. value from the t-test. H0 will be rejected if the Asymp. Sig. value is less than 0.05, indicating a significant difference between the two groups. Conversely, H0 will be accepted if the Asymp. Sig. value is greater than or equal to 0.05, indicating that

there is no significant difference in critical thinking skills between the students in the experimental and control classes. The output of the independent sample t-test for the post-test can be seen in Table 7.

Table 7. Hypothesis Testing Results

Statistic				α
df	Sig. (2 tailed)	t Calculated	t Table	
5	0.000	11.778	1.671	0.05

The test shows a t-value of 11.778 with 58 degrees of freedom (df) and a significance value (Sig. (2-tailed)) of 0.000. Since this significance value is much smaller than α = 0.05, the null hypothesis is rejected. The calculated t-value is greater than the critical t-value of 1.671 for df = 58 and α = 0.05 (two-tailed). This indicates a statistically significant difference in the mean posttest scores between the experimental and control groups.

The t-test results reveal a very significant difference in critical thinking skills between the students in the experimental class and those in the control class after the implementation of the teaching method. The t- value of 11.778 is substantially higher than the critical value of 1.671, and the significance level (Sig. (2-tailed)) of 0.000 confirms that this difference is statistically significant.

Levene's Test for equality of variances shows an F-value of 35.602 with a significance value of 0.000, indicating that the variances between the two groups are significantly different. However, the t-test results remain consistent regardless of variance differences, with the calculated t-value consistently at 11.778. This suggests that the teaching method applied in the experimental class had a significant impact on improving students' critical thinking skills compared to the control class.

The 95% confidence interval for the difference in mean critical thinking skills ranges from 22.107 to 31.160, which does not include zero. This further supports the conclusion that there is a significant difference in critical thinking skills between the two groups.

Overall, the results indicate that the Project-Based Learning (PjBL) model supported by Liveworksheet media significantly improves students' critical thinking skills, as demonstrated by the substantial difference in posttest results between the experimental and control classes.

The results of this study align with previous research that highlights the effectiveness of the PjBL learning model and Liveworksheet media in enhancing critical thinking skills. Research results from Anisa (2023) with the title "The Effect of the STEAM-Integrated PjBL Model Assisted by E-LKPD on SMA Students' Collaboration and Critical Thinking Skills in Renewable Energy Materials" demonstrated that the STEAM-integrated PjBL model assisted by E-LKPD significantly improved students' collaboration and critical thinking skills. This finding supports our results by showing the effectiveness of the PjBL model in a similar context. Another study by Kasmi (2023), titled "The Effect of STEAM-Based PjBL Model on Students' Critical Thinking Skills in Colloid Materials," also supports our findings by demonstrating that the STEAM-based PjBL model is effective in enhancing students' critical thinking skills, in line with the observed improvements in the experimental group.

Additionally, research by Agustiana et al. (2024) titled "The Effect of Liveworksheet Educational Materials with a Scientific Approach on Students' Critical Thinking Skills in Statistics Learning" found that using Liveworksheet significantly improved students' critical thinking skills. This provides further support for the effectiveness of Liveworksheet media in enhancing critical thinking, consistent with our study's results.

Overall, the evidence from this study, along with relevant previous research, reinforces the argument that the PjBL model supported by liveworksheet media is an effective strategy for developing students' critical thinking skills.

Conclusion

The conclusion of this study indicate that the Project Based Learning (PjBL) model supported by Liveworksheet media significantly affects the improvement of critical thinking skills among vocational high school students. Based on pretest and posttest data, there is a notable difference between the experimental and control groups. The experimental group, which utilized the PjBL model with Liveworksheet media, showed a more significant enhancement in critical thinking skills compared to the control group, which used conventional methods. Initially, both groups had relatively similar baseline abilities; however, following the intervention, the experimental group demonstrated a substantially higher posttest result with an average score of 81, compared to 64 in the control group. The results of normality and homogeneity tests also confirm that the data meet the assumptions for further statistical analysis. Hypothesis testing revealed a significant difference in critical thinking skills between the two groups, with the experimental group achieving a higher improvement. These findings support the effectiveness of applying the PjBL model with Liveworksheet media in enhancing students' critical thinking skills, making it a superior teaching method compared to conventional approaches.

Acknowledgments

The author would like to thank the parties who have played a role in this research activity, so that this research can be carried out well. Thank you to the all writer that their article are cite in this text.

Author Contributions
Collect data and analyze data R.D.; Reviewing the article A.U.; M.A.; A.

Funding
Researchers independently funded this research.

Conflicts of Interest
The authors declare no conflict of interest.

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