Journal of Educational Sciences
Journal homepage: https://jes.ejournal.unri.ac.id/index.php/JES
P-ISSN 2581-1657
E-ISSN 2581-2203

The Effectiveness of Project-Based Learning Assisted by the Digital IoT Blynk Simulation on Improving the Practical Skills of Grade X Mechatronics Students at SMKN 8 Malang

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ARTICLE INFO

Article history:

Received: 24 Aug 2025
Revised: 31 Aug 2025
Accepted: 10 Sept 2025
Published online: 30 Sept 2025

Keywords:

Project-Based Learning (PjBL)
Internet of Things (IoT)
Blynk
Practical Skills
Vocational Education
Industry 4.0
Learning Effectiveness

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Article Doi:

https://doi.org/10.31258/jes.9.5.p.4748-4764

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A B S T R A C T

The rapid development of digital technology in the Society 5.0 era has driven the need for vocational education to adapt to industrial automation demands. However, practical learning in many vocational schools remains conventional, limiting students' exposure to IoT-based systems. This study aimed to determine the effectiveness of the Project-Based Learning (PjBL) model integrated with the IoT Blynk platform in improving students' practical skills. The research employed a quantitative approach with a quasi-experimental design using two groups: an experimental class applying IoT Blynk–based PjBL and a control class using conventional methods. Data were collected through pretests, posttests, and observations, and analyzed using the Wilcoxon and Mann-Whitney tests, as well as the N-Gain score. The results showed significant differences between groups ($U = 204.500$; $Z = -4.796$; $p < 0.001$). The N-Gain score for the experimental class (0.62) was higher than for the control class (0.39), indicating medium–high improvement. These findings confirm that integrating Blynk IoT with PjBL effectively enhances students' practical skills, motivation, and readiness for Industry 4.0.

1. Introduction

The rapid advancement of digital technology in the era of Society 5.0 has had a significant impact across various sectors, including vocational education. The modern industrial world increasingly relies on automation and control systems based on the Internet of Things (IoT), a concept that integrates physical devices with internet networks, enabling real-time remote monitoring and control. This shift requires Vocational High Schools (SMKs) to adapt their practical learning

processes to the digitalized and automated demands of modern industries. According to Prasetyo & Hidayat (2017), the development of an Android-based IoT learning medium effectively improved students' practical skills, indicating the importance of digital adaptation in vocational learning. However, in practice, most vocational schools still rely on conventional methods, particularly in control system practices that use manual devices. As a result, students often lack hands-on experience with automation and digital technologies that are essential in today's industrial landscape.

IoT has become a key platform in mechatronics and automation education, as it helps students understand the fundamental concepts of automatic control using microcontroller devices such as ESP8266 or ESP32, which can be connected to cloud-based applications like Blynk. Through this system, students can design and control electronic devices such as lights, motors, and sensors remotely via the internet rather than through manual switches. Consequently, IoT serves as a smart control medium that integrates programming, electronics, and communication network skills competencies highly relevant to the 21st century and to the needs of Industry 4.0. Several previous studies have supported the integration of Project-Based Learning (PjBL) with IoT technology (Wibowo & Nandika, 2022) .

For example, Wardana et al. (2021) emonstrated that introducing IoT in SMK Dwija Bhakti 1 Jombang improved students' understanding and satisfaction by 95%. Likewise, Wara & Bambang (2021) reported that the ESP32-based IoT trainer they developed achieved high validity (89%) and practicality (88.7%), resulting in learning outcomes above the minimum competency criteria. More recent research by Arin et al. (2024) onfirmed that IoT-based learning devices were highly effective in improving students' psychomotor skills, achieving a validity rate of 97.9%. These studies confirm the great potential of IoT integration in enhancing students' competencies. However, studies focusing specifically on the effectiveness of Blynk-based control projects integrated into regular vocational classroom learning are still limited. Based on preliminary observations at SMKN 8 Malang, particularly in Grade X Mechatronics, practical learning remains dominated by conventional methods. Teachers typically deliver lessons through demonstrations using manual devices such as switches and basic control circuits (Firdaus et al., 2021).

While this approach helps students grasp basic electrical and control concepts, it lacks relevance to the technological advances of IoT-based automation in modern industries. This gap highlights the need for innovative learning models that connect classroom practice with industrial technology. To address this issue, this study applies a Project-Based Learning (PjBL) model integrated with the IoT Blynk platform and the ESP8266 microcontroller as the main control component (Pongoh et al., 2022). Through an IoT-based lamp control project, students are guided to design, program, and test automatic control systems connected to the internet. This approach not only enhances students' technical competence but also fosters creativity, collaboration, and problem-solving skills through active and experiential learning. Therefore, this study aims to determine the effectiveness of the Project-Based Learning (PjBL) model integrated with the IoT Blynk platform in improving the practical skills of Grade X Mechatronics students at SMKN 8 Malang.

2. Methodology

This study employed a quantitative approach with a quasi-experimental design of the Nonequivalent Control Group Design type. This design was chosen because, in the context of vocational education at SMK, it is not possible to conduct full randomization of students, as class groupings are predetermined by the school. Therefore, the study involved two existing class groups: Class A as the experimental group, which received project-based learning integrated with smartphones and the IoT Blynk platform, and Class B as the control group, which received conventional project-based learning using manual switches. Both groups were given pretests and posttests to compare their practical skills before and after the treatment. This approach is consistent with the study by Nugraha and Sulistyo (2019), who used a similar design to evaluate the effectiveness of Project-Based Learning (PjBL) on practical skills in vocational schools. The research data consisted of primary and secondary data. Primary data were obtained directly from 70 students of Grade X in the Mechatronics program at SMKN 8 Malang. The total number of participants involved in this study can be seen in Table 1, which presents the distribution of students in each class group.

Table 1. Number of Students

No	Class	Number of Students
1	A	35
2	B	35
Total		70

Source: Class X Data of SMK 8 Malang

Data collection techniques in this study were carried out through several methods. First, interviews with teachers were conducted, and pretests and posttests were administered to students to measure the improvement in practical skills. Second, structured observation using observation sheets was employed to assess students' practical performance during the learning process. Third, student worksheets (LKS) served as both a learning medium and an assessment instrument for project completion. Data analysis consisted of two main stages: preliminary tests and hypothesis testing. The preliminary tests included normality tests (Shapiro-Wilk or Kolmogorov-Smirnov) and homogeneity tests (Levene's Test) to ensure that the data met the assumptions of parametric statistics.

This study applied several statistical analysis techniques to evaluate the effectiveness of the implemented learning model. If the data were normally distributed and homogeneous, a Paired Sample T-Test was used to analyze pretest and posttest differences within each group, and an Independent Sample T-Test was used to compare results between groups. If the normality assumption was not met, non-parametric tests such as the Wilcoxon Signed-Rank Test and the Mann-Whitney U Test were applied instead. In addition, the N-Gain score was calculated to determine the level of improvement in students' practical skills and to evaluate the effectiveness of the treatment in more detail. The instruments used in this study consisted of pretests and posttests that measured students' practical skills. Each instrument item was designed using a five-point Likert scale, which allows students

to express their level of agreement or performance. The scoring scheme for the Likert scale can be seen in Table 2, which illustrates the range and description of each scale category.

Table 2. Likert Scale

Scale	Description
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Stongly Agree

Source: (Sugiyono, 2020)

The validity and reliability of the research instruments were tested before being used for data collection. The validity test aimed to ensure that each item accurately measured the intended construct. The assessment results were averaged and interpreted according to the validity categories presented in Table 3, which shows the interpretation of the average score range for determining validity levels.

Table 3. Average Score of Validity Test

Average Score Range	Validity Category
3,25 - 4,00	Very Valid
2,40 – 3,24	Quite Valid
1,75 – 2,49	Less Valid
1,00 – 1,74	Invalid

Source: (Arikunto, 2015)

Furthermore, the reliability test was conducted using the Cronbach's Alpha technique with the help of SPSS 24 for Windows. This test determined the consistency of the items in the instrument. The interpretation of reliability scores based on Cronbach's Alpha values can be seen in Table 4, which categorizes the reliability levels of the instrument.

Tabel 4. Average Score of Reliability Tast

Average Score Range	Reliability Category
0,00 – 0,20	No Reliability
0,21 – 0,40	Acceptabel Reliability
0,41 – 0,60	Good Reliability
0,61 – 0,80	Very Good Reliability
0,81 – 1,00	Excellent Reliability

Source: (Sandu Sitoyo, 2015)

Meanwhile, the data analysis techniques used in this study included the normality test. When the data were found to be not normally distributed, non-parametric tests were applied. The implementation tests used consisted of the Wilcoxon Signed-Rank/Rank Sum Test, the Mann-Whitney U Test, and the N-Gain test to measure the effectiveness of the learning intervention.

Research Design

This study implemented a quasi-experimental research design using the *pretest–posttest control group model*. This design was chosen because it allows comparison between a group that receives treatment and another that does not, enabling the researcher to determine the influence of the applied learning model more accurately. The research population consisted of all 10th-grade Mechatronics students enrolled at SMKN 8 Malang during the academic year in which the study was conducted. This population was considered relevant because all students had similar learning experiences and educational backgrounds in the field of mechatronics and automation. The sampling technique applied in this study was purposive sampling, chosen based on specific criteria relevant to the research objectives. The main consideration was that the selected students had completed the *Basic Control Systems* course and demonstrated basic competency in using digital tools and simulation applications.

The sample consisted of two separate groups: one as the experimental class and the other as the control class. The experimental class was provided with learning treatment through the Project-Based Learning (PjBL) model integrated with IoT Blynk, while the control class was taught using the conventional demonstration method. Both groups underwent a pretest and a posttest to assess the students' level of practical skills before and after the implementation of the learning treatment. The pretest served as the baseline measurement, while the posttest was used to identify learning progress and improvement after the treatment.

The design of this experiment aimed to evaluate the effectiveness of IoT Blynk based PjBL in enhancing students' practical competencies in mechatronic control systems. This approach was compared directly with the outcomes achieved through traditional demonstration-based instruction. Through this quasi-experimental framework, the study ensured that both the control and experimental groups had equivalent conditions except for the treatment variable. This approach was intended to maintain internal validity and minimize potential external biases that might influence the results. The following diagram illustrates the research design model implemented in this study, showing the pretest and posttest stages for both groups and identifying the treatment given to the experimental group.

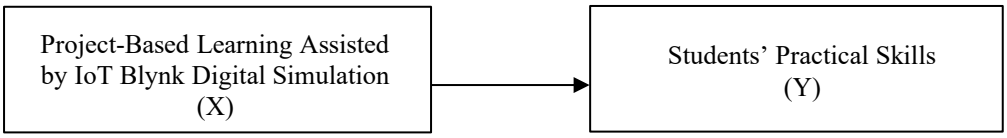

Figure 1. Research Design

3. Results and Discussion

Classroom Conditions

To visually observe the classroom conditions, refer to Figure 2, which illustrates the learning atmosphere in the Mechatronics workshop at SMKN 8 Malang.

Figure 2. Classroom Atmosphere

This study was conducted in two tenth-grade Mechatronics classes at SMKN 8 Malang, each consisting of 35 students, resulting in a total of 70 participants. The experimental class comprised 26 male and 9 female students, while the control class included 27 male and 8 female students. Most of the students were between 15 and 17 years old and had previously taken basic electrical and control system courses in the first semester. Based on initial observations and interviews with teachers, it was found that the students were generally familiar with basic wiring and switch control, but had limited experience using Internet of Things (IoT)-based systems. In their regular learning activities, they typically practiced manual control using relays and physical switches in the school's electrical laboratory. The school's facilities included an electronics workshop equipped with breadboards, sensors, and microcontroller kits, but the use of IoT technologies such as NodeMCU or ESP8266 had rarely been implemented prior to this study (Herlina et al., 2022).

Learning activities in both classes were conducted in a practical workshop setting with adequate access to tools and network facilities. However, the conventional learning method still dominated classroom activities, where the teacher demonstrated procedures and students replicated them individually or in small groups without further innovation. As a result, students tended to follow instructions rather than explore or modify circuits creatively. The level of student collaboration was relatively low, and learning motivation varied depending on their interest in technology. These initial conditions highlight the need for a more

engaging and participatory learning model, such as Project-Based Learning (PjBL), to enhance students' practical abilities and learning independence (Susanna & Murdianto, 2024)

Implementation of the PJBL-Based IoT Blynk Learning Model

The *Project-Based Learning* (PjBL) model was implemented over four weeks, consisting of six sessions covering the stages of project orientation, design, assembly, programming, testing, and evaluation. The learning implementation process can be seen in Figures 3 and 4 below.

Figure 3. Students working collaboratively in assembling IoT-based control circuits during the PjBL implementation.

Figure 4**.** Hands-on practice session using NodeMCU ESP8266 as part of the IoT Blynk project activity.

During the treatment, students in the experimental class were divided into small groups of five to six members. Each group was assigned to design and build a smart lamp control system using NodeMCU ESP8266, sensors, and the Blynk IoT

application. The teacher acted as a facilitator by providing guidance on project planning, component selection, and coding logic, while the students were responsible for circuit design and troubleshooting. Data were collected during and after the implementation phase through pretests, posttests, and observation sheets assessing students' psychomotor performance. Meanwhile, the control class continued with conventional practice using manual switches through direct teacher demonstrations. After all project tasks were completed, a posttest was administered, followed by the calculation of N-Gain and non-parametric statistical tests to evaluate the effectiveness of the learning intervention (Alim Syahbana et al., 2023).

Result Analysis Test Results of Student Data

This study was conducted to determine the implementation of Project-Based Learning (PjBL) integrated with smartphones and IoT Blynk to improve the practical skills of grade X Mechatronics students at SMKN 8 Malang. The following are the results of the research instrument testing and data analysis techniques:

1. The instrument trial was conducted with a sample of 30 Grade X Mechatronics students at SMKN 4 Malang. The results showed that the research questionnaire was valid and ready to be used in the main study. For more detailed information, please refer to Table 5.
2. In this study, the classes were divided into two groups: the experimental class and the control class. Before beginning the practical activities, students were given a pretest to measure their initial understanding. The experimental class then received treatment using the PjBL model integrated with smartphones and IoT Blynk, while the control class used a conventional learning model with manual switches. Finally, students were given a posttest to evaluate and compare the results after the treatment.

Table 5. Result Analysis Test Results of Student Data

Statistical Data	Pre-Test		Post-Test	
	Experimental	Control	Experimental	Control
Lowest Score	60	50	106	92
Highest Score	148	132	163	139
Avarage	94	84	138	118

Based on the table above, the average pretest score for the experimental class is 94, while for the control class it is 84. The average posttest score for the experimental class is 138, whereas for the control class it is 118. These results indicate an improvement in students' practical skills.

Result Normality Test

The normality test was conducted to determine whether the research data, both from the experimental and control classes, were normally distributed or not. This test serves as an initial step before deciding the type of statistical test to be used in the subsequent data analysis. In this study, the normality test was performed using

SPSS 24 for Windows with the Kolmogorov–Smirnov or Shapiro–Wilk method, depending on the number of samples used. For more detailed information, the complete results of the normality test can be seen in Table 6 below.

Table 6. Result Normality Test and Shapiro-Wiks Test

		Test of Normality			Shapiro-Wilk		
	Class	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Result	Pre-Test (Experimental)	0.145	35	0.060	0.919	35	0.014
	Pre-Test (Control)	0.147	35	0.53	0.882	35	0.001
	Pre-Test (Experimental)	0.85	35	0.200	0.986	35	0.918
	Pre-Test (Control)	0.158	35	0.27	0.932	35	0.032

The normality test was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk methods with a significance level of 0.05. The data are considered normally distributed if the Sig. value is greater than 0.05. Based on the test results, it was found that the pretest of class A (Sig. = 0.014), the pretest of class B (Sig. = 0.001), and the posttest of class B (Sig. = 0.032) were not normally distributed, while the posttest of class A (Sig. = 0.918) was normally distributed. Since most of the data were not normally distributed, the hypothesis analysis in this study was conducted using non-parametric tests.

Results of the Wilcoxon Test for the Experimental Class

The Wilcoxon Signed Rank Test was conducted to determine whether there was a significant difference between the pretest and posttest scores in the experimental class. This test was chosen because the data were not normally distributed, making it more appropriate to use a non-parametric statistical test. For more detailed information on the results of the Wilcoxon test in the experimental class, see Table 7 below.

Tabel 7. Results of the Wilcoxon Test for the Experimental Class

		N	**Mean Rank**	**Sum of Ranks**
Pretst-Postest Eksperimen	Negative Rank	0	0.00	0.00
	Positive Ranks	35	18.00	630.0
	Ties	0		
	Total	35		
Pretest-Postest	Negatif Ranks	0		
	Positive Ranks	35	0.00	0.00
	Ties	0	18.00	630.00
	Total	35		

Based on the Wilcoxon test results, all 35 students in the experimental class showed an improvement in their scores. The Negative Ranks, which represent a decrease between the pretest and posttest scores, were 0 in terms of N, mean rank, and sum

of ranks. This indicates that no students experienced a decline in performance after the implementation of the Project-Based Learning model integrated with IoT Blynk.

Results of the Wilcoxon Test for the Control Class

The Wilcoxon test for the control class was conducted to determine whether there were significant differences between the pretest and posttest scores after the implementation of conventional learning methods. This analysis aimed to identify the extent of improvement in students' practical skills within the control group, which did not receive the IoT Blynk–integrated Project-Based Learning treatment. For a more detailed overview of the Wilcoxon test results in the control class, see Table 8 below.

Table 8. Results of the Wilcoxon Test for the Control Class

	Pretset-Posttest Eksperimen	**Pretset-Posttest Kontrol**
Z	-5.160	-5.160
Asymp. Sig. (2-tailed)	< 0.001	< 0.001

If the Asymp. Sig. (2-tailed) value is less than 0.05, it indicates a significant difference. The results of the Wilcoxon test show that both the experimental and control classes experienced significant differences between the pretest and posttest scores. In the experimental class, the Z value was -5.160 with a p-value < 0.001, while the control class also obtained a Z value of -5.160 with a p-value < 0.001. Therefore, it can be concluded that students' learning outcomes and practical skills improved in both groups; however, further analysis is required to determine the difference in effectiveness between the two classes.

Mann-Whitney Test Results for the Experimental and Control Classes

To examine whether there is a significant difference between the performance of students in the experimental class and those in the control class, the Mann-Whitney U test was conducted. This non-parametric test is appropriate for comparing two independent groups when the assumption of normality is not met. The analysis aimed to determine the effectiveness of the IoT Blynk integrated Project Based Learning model compared to conventional learning. For a more detailed presentation of the Mann-Whitney U test results between the two classes, see Table 9 below.

Table 9. Mann-Whitney Test Results for the Experimental and Control Classes

	Class	**N**	**Mean Rank**	**Sum of Ranks**
Results	Class Experimental	35	47.16	165.50
	Class Control	35	23.84	834.50
	Total	70		

A total of 70 students participated in the two classes. The difference in students' learning outcomes at the posttest stage between the experimental and control classes was analyzed using the Mann-Whitney U test. The results showed that the average

score of the experimental class (47.16) was higher than that of the control class (23.84). This indicates that the project-based learning model, combined with the use of smartphones as a control tool, is more effective than the conventional teaching method.

Mann-Whitney U and Wilcoxon Test Results

To determine whether there were significant differences in students' learning outcomes between the experimental and control classes, both the Mann-Whitney U test and the Wilcoxon Signed-Rank test were conducted. The Mann-Whitney U test was used to compare the posttest scores between two independent groups, while the Wilcoxon test examined the differences between pretest and posttest scores within each group. These analyses provided statistical evidence regarding the effectiveness of the implemented learning model. The Mann-Whitney U test yielded a value of U = 204.500, with Z = -4.796 and Asymp. Sig. (2-tailed) < 0.001, indicating a significant difference between the two classes. A detailed summary of these results can be seen in Table 10 below.

Table 10. Mann-Whitney U and Wilcoxon Test Results

	Results
Mann-Whitney U	204.500
Wilcoxon W	834.500
Z	-4.796
Asymp. Sig. (2-tailed)	<0.001

N-Gain Test Results

To further evaluate the improvement in students' learning outcomes, the N-Gain score was calculated. The N-Gain provides a measure of the effectiveness of the learning intervention by comparing pretest and posttest scores. The formula used to calculate N-Gain is as follows:

$$\text{N Gain} = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

The N-Gain Test was conducted to assess the extent of students' improvement after the learning intervention. This calculation allows for the assessment of both individual and group learning gains, indicating the degree to which the intervention contributed to students' progress. The analysis showed that the N-gain result for the experimental class was 0.62, while for the control class it was 0.39, suggesting that the experimental class experienced a higher level of learning improvement. A detailed summary of these findings is presented in Table 11 below.

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Table 11. N-Gain Test Results

Exsperimen	**Control**
0.62	0.39

The quantitative analysis results indicate that both groups, experimental and control, experienced an improvement in practical skills after the treatment was applied. However, the increase in the experimental class was significantly greater than in the control class. Descriptively, the average pretest score in the experimental class was 94, while the control class had an average of 84. After the treatment, the posttest scores rose to 138 in the experimental class and 118 in the control class. These findings provide an initial indication that the implementation of Project-Based Learning (PjBL) integrated with smartphones and the Blynk application has a more positive impact on students' practical skills.

The initial data processing indicated that some of the data were not normally distributed, prompting the researcher to use a non-parametric statistical approach. The Wilcoxon test results showed a significant improvement within each group (Wilcoxon test: $Z = -5.160$; $p < 0.001$), meaning that the learning process in both classes contributed to an increase in individual scores. Furthermore, the Mann-Whitney test on the posttest data between the two groups revealed a statistically significant difference ($U = 204.500$; $Z = -4.796$; $p < 0.001$). The mean rank of the experimental class was higher, around 47.16, compared to the control class, which was only about 23.84. Therefore, it can be concluded that the implementation of the smartphone- and Blynk-assisted PjBL model is more effective in enhancing practical skills than conventional learning methods in the context of this study. These quantitative findings align with various studies in Indonesia reporting the effectiveness of IoT devices and applied learning models in vocational education for instance, the design and development of Blynk-based lamp control systems recommended as a practical learning medium in vocational high schools (SMK) (Abdussomad et al., 2019).

The analysis of the improvement in learning effectiveness is further supported by the N-Gain calculation. The results showed that the experimental class achieved an N-Gain score of 0.62, which, according to the classification by Hake (1999), falls into the medium high category. Meanwhile, the control class only obtained an N-Gain score of 0.39, which is classified as medium. This indicates that the improvement in students' practical skills in the experimental class was more optimal and significant compared to the control class.

The pedagogical interpretation of these differences can be explained through three main mechanisms, which are also widely documented in the vocational education literature in Indonesia. First, the Project-Based Learning (PjBL) approach provides authentic task contexts, thereby enhancing student engagement and facilitating practical skills. Studies on the application of PjBL in mechatronics competency development in vocational high schools (SMK) have shown significant improvements in learning outcomes when students are directly involved in collaborative and authentic projects. Therefore, it is reasonable that students engaged in device control projects using smartphones and the Blynk application demonstrated improved practical competencies and faster acquisition of technical application skills. These findings are also consistent with various studies on PjBL implementation in vocational education, which consistently indicate that this model

enhances learning motivation, active student engagement, and practical skills that are relevant to workplace demands (Roemintoyo & Budiarto, 2023).

Second, the integration of IoT devices (NodeMCU/ESP8266/ESP32) with the Blynk platform provides a hands-on laboratory experience that directly represents Industry 4.0 technologies Anjani & Adibah (2020). Students not only connect hardware components but also learn networking concepts, basic programming, debugging, and real-time feedback, which accelerates the trial-and-error process and enhances problem-solving (troubleshooting) skills. Studies on the development of IoT trainers or training kits in vocational high schools (SMK) have shown that NodeMCU/ESP8266-based kits are suitable as practical learning media (in terms of material, media, and user feasibility) and directly improve students' practical skills. The implementation of such training kits can enhance mastery of IoT device practice while simultaneously supporting learning in networking and basic programming, which are relevant competencies for mechatronics education (Aryanta, 2024).

To reinforce previous research findings, Abdussomad et al. (2019) demonstrated that Blynk-based learning media are effective as practical tools in vocational high schools (SMK). Roemintoyo & Budiarto (2023) emphasized that Project-Based Learning (PjBL) can enhance motivation and competencies among vocational students. Aryanta (2024) showed that IoT trainers based on NodeMCU/ESP8266 are feasible for improving practical skills in SMK. Accordingly, this study not only supports these prior studies but also contributes new insights by testing the effectiveness of a Blynk-based lamp control project in the context of practical learning in vocational education.

Overall, the results of this analysis demonstrate that the implementation of a project-based learning model supported by smartphones and Blynk IoT can significantly enhance students' practical skills. The integration of this technology not only promotes improved learning outcomes but also fosters students' motivation, creativity, and technical abilities. Therefore, this model can be recommended as an innovative learning strategy in vocational education, particularly to prepare students for the challenges of the workforce in the era of Industry 4.0 and Society 5.0. This aligns with Sujarwanto (2023), who emphasizes the importance of integrating Science, Technology, Engineering, and Mathematics (STEM) approaches and technology in science and vocational education in Indonesia.

Discussion

The results of the study indicate that the implementation of the Project-Based Learning (PjBL) model integrated with the Blynk IoT platform is more effective in enhancing the practical skills of tenth-grade Mechatronics students at SMKN 8 Malang compared to conventional learning methods. Descriptively, the average pretest score in the experimental class was 94, which increased to 138 in the posttest, while the control class scores rose from 84 to 118. Furthermore, the Mann-Whitney U test yielded an Asymp. Sig. (2-tailed) < 0.001, indicating a significant

difference between the two groups. The N-Gain value for the experimental class was 0.62 (medium–high category), whereas the control class achieved 0.39 (medium category). The following discussion elaborates on the meaning of these findings in the context of relevant theories and previous research (Sari et al., 2025).

Enhancement of Practical Skills through Blynk IoT-Based Project-Based Learning (PjBL) Model

The findings of this study demonstrate that implementing the PjBL model with Blynk IoT support creates a more meaningful learning experience, as students not only understand theoretical concepts but also directly engage in designing, programming, and testing internet-based automatic control systems. This approach promotes greater cognitive and psychomotor engagement. This condition aligns with Ahmed (2024), who stated that the application of Project-Based Learning in vocational education enhances student engagement, motivation, and competencies because learning focuses on completing real-world projects aligned with industry needs. Therefore, students' practical skills improve not only through technical exercises but also through critical thinking and authentic problem-solving processes during the project. In the context of IoT learning, students in the experimental class were required to program the NodeMCU ESP8266, integrate hardware with the Blynk application, and ensure that the system operates correctly via the internet. These activities demand interdisciplinary understanding, ranging from electronics and networking to basic programming, which accelerates the development of their practical skills compared to students in the control class, who only practiced using manual switches (Puspita et al., 2024).

The Effectiveness of IoT Integration on Vocational Students' Competency Readiness

The integration of the Internet of Things (IoT) in practical learning plays a crucial role in preparing students to meet the competency demands of Industry 4.0. The Blynk IoT platform enables students to understand remote control mechanisms and real-time monitoring, which are widely applied in industrial automation systems. Nagini (2023) supports this by stating that the implementation of IoT-based learning media using ESP8266 microcontrollers effectively enhances mastery of automatic control system concepts by providing hands-on experiences that closely resemble real industrial systems. Furthermore, the findings of this study align with Ahmed (2024) who developed an IoT trainer based on NodeMCU/ESP8266 and demonstrated that the device is highly feasible as a practical learning medium in vocational high schools (SMK), with validity exceeding 90% and significantly improving students' psychomotor skills. Therefore, the implementation of PjBL combined with Blynk IoT in this study can be regarded as a concrete example of adaptive and relevant vocational education, addressing the technological needs of today's industry.

Comparison of Effectiveness with Conventional Learning

Based on the Wilcoxon Signed Rank Test, both the experimental and control classes showed significant improvements in practical skills after the treatment. However, the Mann-Whitney test demonstrated that the improvement in the experimental class was significantly higher than in the control class. This indicates that the Blynk IoT-assisted PjBL model is superior to conventional learning methods that still rely on manual switch systems (Firdaus et al., 2021). This can be explained through constructivist theory, where students build their own knowledge through real experiences. In project-based learning, students do not merely receive knowledge from the teacher but also discover concepts through direct exploration and experimentation. In contrast, conventional methods involve more demonstrative learning activities and provide fewer opportunities for students to engage in critical and creative thinking. Yunitasari et al. (2025) support these findings, concluding that Blynk-based learning media are effective for practical training in vocational high schools, as they enhance learning motivation, accelerate understanding of digital control concepts, and produce higher skill achievement compared to traditional learning methods.

4. Conclusion

The findings of this study demonstrate that the implementation of a project-based learning (PjBL) model integrated with the IoT Blynk platform successfully improved the practical skills of Grade X Mechatronics students at SMKN 8 Malang. Through the integration of IoT technology, students were able to directly design, program, and test automation systems, thereby gaining authentic experiences that closely reflect the real practices of modern industry. The research question regarding the effectiveness of IoT-based PjBL in enhancing students' competencies was answered positively. Students not only showed improvements in their technical performance but also developed higher levels of creativity, motivation, and collaboration during the project implementation process.

These aspects reflect the holistic learning outcomes expected in vocational education aligned with Industry 4.0 and Society 5.0 demands. Overall, the study can be considered successful in demonstrating that combining PjBL with IoT Blynk offers an effective, engaging, and future-oriented learning approach. This model encourages students to become active learners who can apply theoretical knowledge to practical contexts while developing essential problem-solving and teamwork skills. Therefore, IoT-based PjBL is recommended as an innovative instructional strategy for vocational schools, particularly in mechatronics and related technical fields, to bridge the gap between classroom learning and industrial technological advancements.

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How to cite this article:

Adelia, C., & Ningrum, G. D. K. (2025). The Effectiveness of Project-Based Learning Assisted by the Digital IoT Blynk Simulation on Improving the Practical Skills of Grade X Mechatronics Students at SMKN 8 Malang. *Journal of Educational Sciences*, *9(5)*, 4748-4764.