INVOTEK

Jurnal Inovasi Vokasional dan Teknologi

http://invotek.ppj.unp.ac.id/index.php/invotek

Vol. 23, No. 3, Oct 2023

ISSN: 1411 – 3411 (p)
ISSN: 2549 – 9815 (e)

Impact of Variable Speed Drive Jobsheet Integrated with Project-Based Learning Model on Electric Motor Control Skills of Vocational Students

Herlin Setyawan[1], Sukardi[2 *], Risfendra[2], Meri Yulianti Putri[1], Vivi Oktavia[1], Ambiyar[3], Rizky Ema Wulandari[3]

[1] Master's Program in Technology and Vocational Education, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Kampus UNPAir Tawar Padang, Indonesia-25131

[2] Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Kampus UNPAir Tawar Padang, Indonesia-25131

[3] Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Kampus UNPAir Tawar Padang, Indonesia-25131

**Corresponding author: sukardiunp@ft.unp.ac.id*
Doi: https://doi.org/10.24036/invotek.v23i3.1155

This work is licensed under a Creative Commons Attribution 4.0 International License

Abstract

The problem in this study is that many students in the electrical power installation engineering (EPIE) class have not mastered the skills of electric motor control (EMC). This is because the teacher still uses traditional methods in the learning process. Namely, the teacher actively explains the material according to practical experience rather than referring to EMC learning objectives. This study aims to apply a variable speed drive (VSD) jobsheet based on project-based learning (PjBL) in the EMC learning process and measure the effectiveness of the jobsheet applied. The research method used was a pre-experiment with an intact group comparison research design. The research subjects were taken from 11^{th}-grade students of vocational schools majoring in electrical power installation engineering and were assessed using a questionnaire instrument to evaluate students' EMC performance. Data analysis techniques used were independent t-test and effect size test. Based on the independent t-test analysis results, the t-value is larger than the t-table (t = 4.936 > 1.99962), and the significance value is 0.000, which shows a significant difference in skills between the experimental and control classes. Based on the effect size analysis, the value is 1.243, which means the jobsheet can improve students' EMC skills in the large category. Based on these two results, it is known that the PjBL-based VSD jobsheet is effective in the EMC learning process. Thus, it is expected that EPIE vocational high schools can use the PjBL-based VSD Jobsheet in the EMC learning process.

Keywords: Jobsheet, Variable Speed Drive, Project-Based Learning, Vocational High School, Electric Motor Control.

1. Introduction

Variable speed drive (VSD) controlled electric motor control systems are an essential innovation in energy efficiency and precision control in today's industry. VSD, often referred to as variable frequency drives (VFD), can regulate an electric motor's speed variably according to specific requirements [1]. This allows optimization of energy use, as the motor can operate at a speed appropriate to the task's demands, avoiding excessive power consumption at light loads or vice versa. This system is one of the systems being widely developed in the era of the industrial revolution 4.0 to optimize and efficiently use electrical energy in industrial production systems [2], [3]. Therefore, a VSD-based electric motor control system is one of the abilities that the vocational high school students need in the current era of industrial development 4.0, especially in electrical power installation engineering.

The development of industry 4.0 has also had a significant impact on the education sector, changing paradigms and providing new opportunities for curriculum development and learning. During

Received date 18/01/2024, Revised date 21/02/2024, Accepted date 14/03/2024

the technological development of the industrial revolution, educational institutions applied cutting-edge technologies in the learning process, such as the internet of things (IoT), artificial intelligence, augmented reality, and virtual reality. These are just some of the advanced tools that Education 4.0 brings into the classroom. Industry 4.0 also encourages the development of 21st-century thinking skills, namely creativity, problem-solving, and digital literacy, to address future problems [4], [5]. Education 4.0 involves technological transformation and emphasizes the importance of collaboration, student engagement, and student-centered learning approaches. Students learning will be more relevant and significant if they are actively involved in the learning process [6], [7].

This development is in line with the current implementation of the independent curriculum, where in its application, students are the leading center in the learning process (student-centered learning) instead of the teacher [8], [9]. The concept of an independent curriculum in vocational schools provides a foundation for developing more adaptive and relevant education to industry needs. In this independent curriculum, vocational schools can design learning programs based on technological developments and laboratory market demands [10]. The project-based learning (PjBL) learning paradigm will be used in this research to replicate the industry's method of instruction. In the learning process, PjBL will place students in an active role, where they are involved in investigating, problem-solving, and applying knowledge in a challenging and real project [11]. However, many schools still apply conventional learning methods, presenting material in a lecture manner and only presenting material based on the practical experience of educators. This will result in a gap in the skills that actual students must have [12]. Thus, this problem must be addressed to produce quality vocational school graduates.

This research will examine new strategies to improve student skills in electric motor control systems for electric power installation engineering students in the industrial era 4.0. By developing a variable-speed drive jobsheet based on PjBL. Previous research has shown a critical need to improve the way electric motor control systems are learned by providing real-world experiences they must master [12]–[14]. This need will be met with the PjBL-based VSD jobsheet, which utilizes cutting-edge VSD technology combined with project-based learning to allow students to directly engage with electric motor control systems and evaluate their control skills in a practical environment. In establishing a novel teaching and learning approach in this standalone curriculum development, this research is vital in building the aptitude students should master according to industry needs.

Many previous studies have applied the PjBL learning model in the learning process and obtained favorable results in learning in vocational schools. Applying the PjBL learning model in the learning process in vocational schools can improve student learning outcomes and skills through these learning objectives [15], [16]. In addition, applying the PjBL learning model can also improve the critical thinking skills and creativity of vocational school students in the learning process of electric motor installation. So, applying the PjBL learning model in vocational schools is necessary because it can increase the effectiveness of the learning process based on the excellent learning outcomes obtained by students [17], [18].

Research in the electric motor control (EMC) learning process has been done before. However, no researchers have examined the effectiveness of jobsheets and PjBL learning models in improving the EMC skills of vocational school students majoring in EPIE. Previous research only examines the effect of the PjBL learning model on students' creativity skills. This study only applied the PjBL learning model, did not use other teaching tools, and did not measure students' electric motor installation skills [18]. Previous research also discussed that the PjBL learning model can improve students' knowledge majoring in EPIE in EMC [16]. So, this research will be conducted by applying jobsheets and PjBL learning models to the EMC learning process to improve students' EMC skills. Through this research, we will get a new understanding of the impact of improving students' EMC skills through jobsheets and PjBL learning models.

Thus, this study aims to reveal the improvement of EMC system skills in EPIE students by implementing PjBL-based VSD jobsheets in the EMC learning process. Thus, the main objective of this study was to demonstrate the effectiveness of a novel experiential learning approach utilizing a PjBL-based VSD jobsheet to assist students in developing a deeper understanding of electric motor control systems. By setting clear research objectives, this research can improve the readiness of students majoring in electrical power installation engineering to face obstacles in dynamic electric motor control systems. The need for the application of experiential learning, such as the PjBL learning mode, and mastery of electric motor control system skills are critical factors in preparing to enter the industry;

therefore, this research should be put into practice as soon as possible [19]. Students will learn more actively through project-based learning, which will help them develop critical thinking and problem-solving abilities that can encourage them to master EMC skills. In addition, through jobsheets, students can work by the standard operational procedures (SOP) that are applied and can test the products they make themselves. This is to the needs of the industry, and the industry emphasizes that workers who can work by the applicable SOP [20]–[22].

Using PjBL-based VSD jobsheets as teaching aids, students will gain hands-on experience managing complex electric motor control systems. Thus, they will be better prepared for a career in a fast-moving and growing industry. In addition, this research also aims to advance the implementation of learning in electrical power installation engineering by the demands of independent curriculum implementation and industrial development. This learning is hoped to stimulate students' interest in learning more about the latest technology and technological trends in electric motor control systems by introducing the PjBL-based VSD jobsheet into the curriculum. Considering there is still a lack of research on the application of jobsheets and learning models in the EMC field, this research provides a more thorough understanding of the real benefits of VSD jobsheets based on the PjBL learning model, which enables vocational students to engage in contextual and authentic learning experiences. The expected outcome of this research is to lay the foundation for developing more effective learning methodologies and contribute to the evolution of curricula that are more adaptive to future industry demands.

2. Research Method

2.1 Research Design

The research approach used in this study is pre-experimental intact-group comparison with the number of classes used in this study in two classes, namely the control class and the experimental class. The two classes were used to compare EMC skills after the learning process. The research procedure used is that during the learning process, the experimental class is given more attention, namely the application of variable speed drive jobsheets and the PjBL learning model during the EMC learning process. In the control class, students are only treated like they were in the previous learning process according to what the EMC subject teacher does. Only one test was conducted using this research method, namely the post-test. The post-test will be conducted in both classes in the study, and the test results will be based on the data analysis techniques used in this research. Table 1 displays the pre-experimental research design with an intact group comparison research design. Table 1 shows that the treatment (X) was only given to the experimental class, not the control class. Post-test (O_1) is the only test given to the experimental class, while Post-test (O_2) is the only test given to the control class. The same testing instrument was used to test the skills of both classes.

Table 1. Pre-Experimental Research Design with Intact-Group Comparison

Class	Treatment	Posttest
Experimental	X	O_1
Control		O_2

2.2 Research Subject

Sixty-three students enrolled in the Vocational High School 1 West Sumatra in the class XI Electrical Power Installation Engineering Program who are learning how to install electric motors in 2023 became the research sample. There are two learning classes totaling sixty-three pupils: the experimental class has thirty-one students, while the control class has thirty-two students. In the 31-person experimental class, the project-based learning-based variable speed drive jobsheet facilitated learning. However, the resulting jobsheet was not applied in the control class during the learning process.

2.3 Research Instruments

In designing a study, selecting and developing research instruments play a crucial role. The tools or techniques used to collect the data needed to address research problems are research instruments. The success of a study often depends on the extent to which the research instrument can measure the variables

P-ISSN: 1411-3414
E-ISSN: 2549-9815

under study validly and reliably. Table 2 displays the instrument grid used to measure how well students have learned the variable-speed drive-based electric motor control system. This instrument was created using the competencies that students need to master in order to learn the electric motor control system.

Table 2. Student Performance Assessment Grid

No	Skill Aspect		Indicators
1	Work Preparation	1.1	Preparation of practical clothes
		1.2	Preparation of tools and materials and main components of VSD
2	Work Process Implementation	2.1	Read the jobsheet before practice
		2.2	Use tools and materials according to their function
		2.3	Assemble the working circuit
		2.4	Following the work procedure
		2.5	Testing the circuit
3	Work Result	3.1	Correctness of working circuit
		3.2	Trouble working circuit
		3.3	Timeliness of work completion according to the subject hours of Electric Motor Installation
4	Occupational Safety and Health	4.1	Use tools and materials according to procedures
		4.2	Perform work in accordance with the SOP
		4.3	Return and clean tools and materials according to procedures
5	Report and Practicum Results	5.1	Make a Practicum report, explain the results of theoretical observations, draw conclusions
6	Attitude	6.1	Learners are focused and serious
		6.2	Cooperate in group practice

2.4 Data Analysis Technique

The data analysis technique used in this study is a parametric data analysis technique, so the data used before analysis must pass two prerequisite tests, namely the data normality test and the data homogeneity test. The post-test data of the experimental class and control class must fulfill both prerequisite tests. If the data obtained does not meet these requirements, it cannot be continued to the data analysis stage of the difference and effect tests using PjBL-based VSD jobsheets.

Two data analysis techniques were used to analyze the skills of experimental and control class students to determine the effectiveness of the PjBL-based VSD jobsheet in the EMC learning process. The data analysis techniques used were independent t-test and effect size analysis techniques. The independent t-test data analysis technique is used to compare the average of the two groups so that the difference in EMC skills of experimental and control class students is known. The effect size data analysis technique is used to measure the impact of the PjBL-based VSD jobsheet in improving the EMC skills of experimental group students. These two tests are used to measure the effectiveness of the PjBL model-based VSD jobsheet in improving the EMC skills of EPIE students. If the results state a difference with a particular impact, then the VSD jobsheet based on the PjBL learning model can be declared effective. If both tests show no difference in learning outcomes and no impact is produced, the jobsheet is declared ineffective in improving students' EMC skills. Combining these two data analysis techniques can ensure the extent to which the effectiveness of the VSD jobsheet based on the PjBL learning model can improve students' EMC skills.

Therefore, these two methods can provide a more comprehensive and informative statistical analysis to evaluate research results. For the effect size data analysis technique, the results of the data analysis obtained will be interpreted in the form of criteria so that the category of the level of impact of the use of educational technology developed is known. The effect size criteria proposed by Cohen are shown in Table 3 [23], [24]. The magnitude of the impact obtained on the application of PjBL-based VSD jobsheets in EMC learning can be observed through the interpretation table, as shown in Table 3.

P-ISSN: 1411-3414
E-ISSN: 2549-9815

Table 3. Interpretation of effect size Cohen's d

No	Effect Size Value Range	Criteria
1	$0.8 \leq d \leq 2.0$	Large
2	$0.5 \leq d < 0.8$	Medium
3	$0.2 \leq d < 0.5$	Small

3. Result and Discussion

3.1 Result

The jobsheet created is a PjBL-based VSD jobsheet used to regulate the speed of a 3-phase motor. Based on the subject matter of the applied jobsheet practicum language as shown in Figure 1. The subject matter of the jobsheet language is EMC learning, namely, how to assemble the VSD trainer and VSD settings using the 3-phase motor nameplate. The jobsheet consists of six projects or subject matter, namely (1) set motor parameters and jog dial with analog, (2) forward reverse with fixed speed, (3) forward reverse using the jog dial with analog, (4) 2-speed motor control, (5) 4-speed motor control, and (6) 8-speed motor control. Students have been declared competent in EMC systems using VSD by completing these six projects. To create a good and systematic jobsheet, the format of the jobsheet writing consists of eight discussion points, namely (1) Practicum Title, (2) Practicum Objectives, (3) Brief Theory, (4) Tools and Materials, (5) Working drawings, (6) Experimental steps, (7) Safety, and (8) Conclusion. The writing format applies to all jobsheets created. So that it will produce a complete jobsheet and is ready to be used by students to conduct EMC practicum.

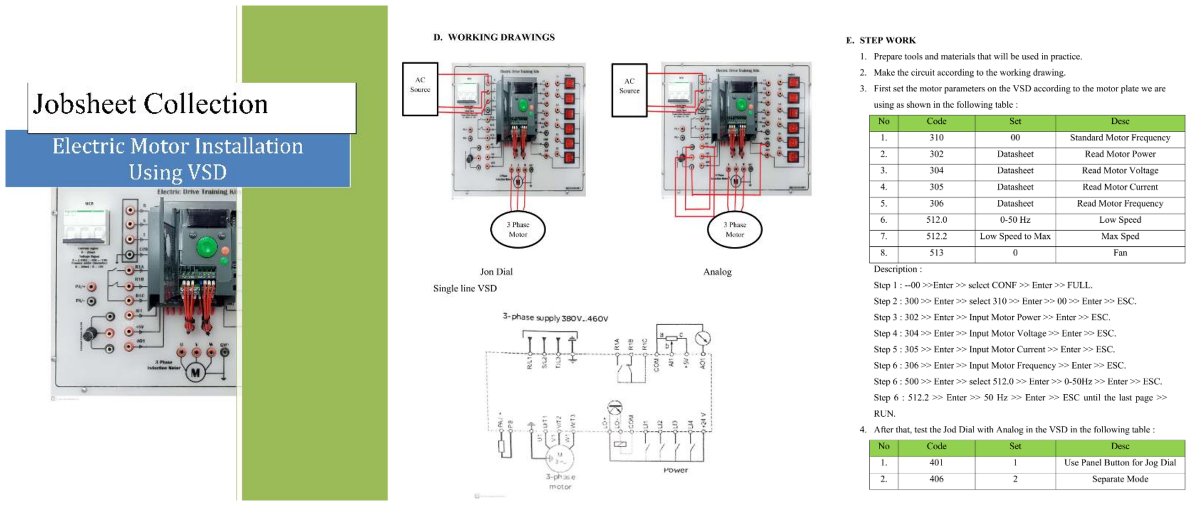

Figure 1. PjBL-Based VSD Jobsheet

This PjBL-based VSD jobsheet is a teaching material designed to support student learning through practical projects on electric motor control systems. This jobsheet design allows students to apply the knowledge and skills they have acquired to an assignment or project. This PjBL-based VSD jobsheet combines students' conceptual learning and practical skills to create a holistic and contextual learning experience for students. This jobsheet was created based on learning objectives and resources related to variable-speed drive-based electric motor control systems. By applying the PjBL approach, learning develops conceptual understanding and fosters students' collaboration, problem-solving, and creativity abilities. This idea is in line with the main objectives of the current electrical power installation engineering curriculum, especially in learning electric motor installation, which emphasizes student-centered learning and developing students' creativity and problem-solving abilities in creating an electric motor control system.

The quantitative data used in this study were gathered from evaluating students' practicum execution abilities. The assessment was carried out using a student performance assessment instrument developed previously, as shown in Table 2. Teachers, who monitored each student's performance during the learning process, conducted the assessment. Data collection utilizing research instruments was

P-ISSN: 1411-3414
E-ISSN: 2549-9815

conducted once by the research design, explicitly following learning in the control and experimental classes. Analysis of tests of differences in students' skills in implementing the PjBL-based VSD jobsheet will be carried out using post-test data obtained from the control class and the experimental class. Normality and homogeneity tests must be performed on the given data before analyzing the independent test and effect size. Hasil posttest dari kelas eksperimen dan kelas kontrol digunakan untuk melakukan tes ini. Table 4 presents the findings from analyzing the normality of the post-test data.

Table 4. Kolmogorov-Smirnov Z Normality Test Results

Descripsion		Post-test Control	Post-test Experiment
N		32	31
Normal Parameters[a,b]	Mean	69.130	80.320
	Std. Deviation	8.816	9.188
Most Extreme Differences	Absolute	.119	.067
	Positive	.071	.047
	Negative	-.119	-.067
Test Statistic		.119	.067
Asymp. Sig. (2-tailed)		.200[c,d]	.200[c,d]

Note: a. Test distribution is Normal, b. Calculated from data, c. Lilliefors Significance Correction, d. This is a lower bound of the true significance.

Table 4 displays the results of the normality test. The 2-tailed significance values for the experimental and control class post-test data are 0.200 and 0.200, respectively. Consequently, the control class post-test data's significance value ($\alpha = 0.200 > 0.05$) is higher than the conventional significance value of 0.05. Similar findings apply to the experimental class post-test data, where the obtained significance value ($\alpha = 0.200 > 0.05$) exceeds the usual significance value of 0.05. One may infer from this data that both the experimental and control classes' post-test results exhibit a normal distribution. As shown in Figure 2 for the control class post-test data and Figure 3 for the experimental class post-test data, the data is represented as a histogram graphic connected to the normality curve to make it easier to read the normality of the gathered post-test data.

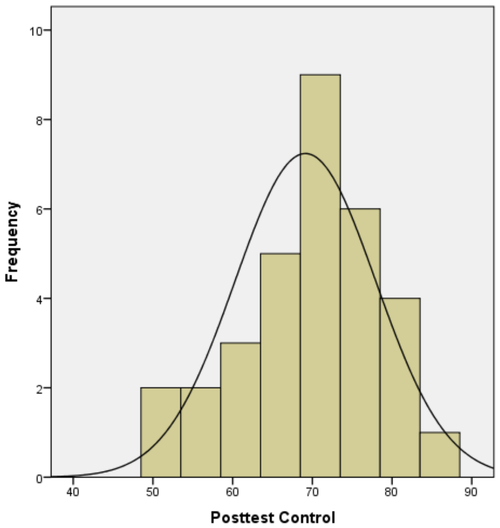

Figure 2. Histogram and Normality Curve of Control Class Posttest Data

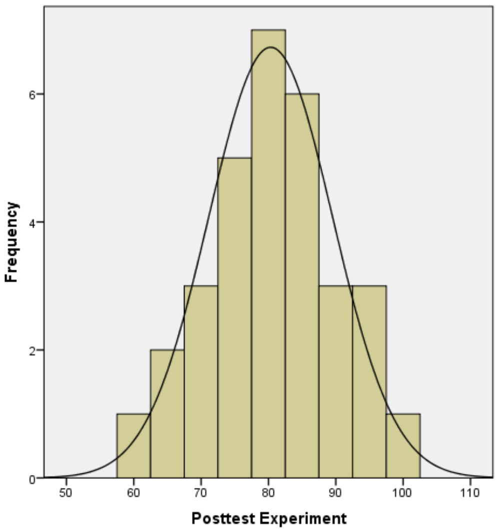

Figure 3. Histogram and Normality Curve of Experimental Class Posttest Data

The following prerequisite test for parametric statistical analysis is testing the homogeneity of the data obtained. Using the Levene analysis technique, homogeneity testing was done simultaneously on post-test data from the control and experimental classes. The conclusion of the homogeneity test can be drawn: if the p-value obtained is more significant than 0.05, then the data is declared homogeneous, and if the p-value obtained is smaller than 0.05, then the data is declared inhomogeneous [4]. The findings of the homogeneity analysis are displayed in Table 5. The significance value is the p-value, which indicates the test results' significance. In this case, the significance value is 0.705. Considering that the p-value obtained is 0.705 > 0.05, which is greater than the conventional significance level of 0.05, it can be concluded that there is substantial homogeneity between the post-test results of the control and experimental classes.

Table 5. Homogeneity Testing Results

Levene Statistic	df1	df2	Sig.
.145	1	61	.705

The resulting control and experimental class posttest data passed the normality and homogeneity precondition criteria for parametric statistical testing. Because this test uses two classes, namely the experimental and control classes, the data collected must meet the prerequisite test criteria for parametric statistics. The first test used to compare the learning outcomes of the experimental and control classes was the independent t-test. The data analysis results in Table 6 show that 0.000 is the determined 2-tailed significance value. According to this conclusion, the resultant t-test significance value (α = 0.000 < 0.05) is less than the widely accepted significance value of 0.05. Because the data used meets the requirements of the homogeneity test, the independent t-test is the result of the calculation of equal variances assumed. These findings demonstrate that the t table value obtained is 1.99962, and the calculated t value achieved is 4.936 with a degree of freedom (df) of 61. In addition, this finding also shows that the calculated t value obtained (t = 4.936 > 1.99962) is greater than the t table value. The two analysis conclusions show that the experimental and control classes' posttest results are significantly different. These findings show that in the area of skills, the experimental class has better skills than the control class. From these results, it can be concluded that applying the VSD jobsheet based on the PjBL learning model can improve students' skills, as shown by the difference in learning outcomes for the control and experimental classes.

Table 6. Independent t-Test Results

	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
						Lower	Upper
Equal variances assumed	4.936	61.000	.000	11.198	2.268	6.662	15.733
Equal variances not assumed	4.933	60.672	.000	11.198	2.270	6.658	15.737

The second data analysis technique is the effect size test, which is carried out to test how much the impact of the PjBL-based VSD jobsheet on EMC learning can improve students' EMC skills. The effect size data analysis method is used to carry out this test, and Table 7 displays the results of the effect size test. If Cohen's d criteria are applied to the effect size of 1.243 (d = 1.243), the data analysis results classify the effect size as large. These results show that the VSD jobsheet based on the PjBL learning model significantly improves students' EMC skills. This finding is even more evident when looking at the mean scores from the control and experimental classes. The control class scored 69.13 on average, while the experimental class scored an average of 80.32. These findings indicate that the PjBL-based variable speed drive jobsheet significantly influences student learning outcomes in skill mastery. Based on these two tests, the jobsheet developed is effectively used to improve students' electric motor installation skills. This decision-making process is also based on previous research. In particular, if the learning procedures produce higher learning outcomes and a real impact, then it can be said that the research successfully increased students' skill levels [25]–[27].

Table 7. Effect Size Test Results

Posttest	N	Mean	Std. Deviation	Effect Size	Criteria
Control class	32	69.13	8.816	1.243	Large

Experimetal class	31	80.32	9.188	

More specifically, Table 8 displays the evaluation findings for the experimental and control groups. Table 8 demonstrates how every ability area assessed for the experimental class improved. The average assessment for the experimental class was higher than that of the control class in every category. These results reinforce that the PjBL-based variable speed drive jobsheet can improve student skills in electric motor control systems. However, one skill has stayed the same: occupational safety and health. This is because schools still need complete safety and health equipment. This makes students scramble to use the equipment. The experimental class showed no significant difference in the occupational health and safety skills aspect of 0.47. These results show that there is no improvement in students' occupational health and safety skills.

Table 8. Summary of Achievements in Each Skill Aspect

No	Skill Aspect	Mean Value	
		Control Class	Experimental Class
1	Work preparation	66.65	82.93
2	Execution of the work process	61.74	77.69
3	Work results	75.00	87.49
4	Occupational safety and health	78,73	78.26
5	Report and practical results	64.25	84.73
6	Attitude	68.41	76.82

3.2 Discussion

In order to increase students' practical learning skills in the area of electric motor control systems in the Industrial Era 4.0, this research uses PjBL-based variable speed drive jobsheets as teaching materials. The purpose of the PjBL-based variable speed drive jobsheet is to match student competencies with industry demands in electric motor control systems. That way, it will provide practical experience to students in utilizing electric motor control systems to run machines in industry later. This PjBL-based variable speed drive jobsheet was created to improve students' skills in electric motor control systems and their relation to the current state of industrial control.

The independent t-test results show that using the PjBL-based variable speed drive jobsheet shows a significant difference in EMC skills between the control and experimental classes. The experimental class has a higher EMC skill score than the control class. Based on these results, the VSD jobsheet using the learning model can improve students' skills. Additionally, the average skill value of the pupils in the experimental class increased noticeably. By using the PjBL learning model in the jobsheet, learning will take place more actively, and students will be the key to the learning process. These results are consistent with earlier studies that showed how practical learning aids developed by the requirements of certain learning materials can successfully enhance students' practical skills [22], [28]. In addition, it is imperative to make adjustments that are aligned with the ongoing development of the industry to ensure that the skills of engineering students can adapt to the constantly evolving industrial equipment [29].

The impact of using PjBL-based variable speed drive jobsheets to improve students' electric motor control system skills was assessed using effect size analysis. The analysis's conclusions showed that using the PjBL-based variable speed drive jobsheet had a significant impact. The outcomes demonstrated how well it worked to help students gain proficiency using the electric motor control technology. It has been proven that using a PjBL-based variable speed drive jobsheet as a teaching aid can improve students' understanding of electric motor control systems. Students make substantial advances in their abilities, making them more capable and prepared to face difficulties in electric motor control systems in practical situations. This finding is consistent with previous research showing the beneficial effects of tailor-made training aids for the learning process on student aptitude [4]. Even though some research indicated a moderate impact, the aggregate results nonetheless demonstrated the advantages of raising pupils' skill levels [13], [14], [30].

P-ISSN: 1411-3414
E-ISSN: 2549-9815

Research in the field of EMC has been done a lot before. However, there is still nothing that discusses the effectiveness of VSD jobsheets based on the PJBL learning model to improve students' EMC skills. as done by previous research that examines the impact of applying the PjBL learning model on student creativity in EMC learning has not measured students' EMC skills [18]. In addition, previous research has discussed increasing students' EMC knowledge through the PjBL learning model [16]. Based on these two studies, we have yet to discuss how other teaching materials contribute to developing students' EMC skills. So, in the research, we gained a broad and in-depth understanding of the use of VSD jobsheet teaching materials and PjBL learning models in the learning process. Based on the results obtained by combining the VSD jobsheet with the PjBL learning model, it is proven that it effectively improves the EMC skills of students majoring in EPIE at vocational high schools. From these results, the PjBL learning model can improve student creativity and learning outcomes (knowledge) and, if combined with suitable teaching materials, can also improve student skills.

Based on the results obtained, this research reveals the usefulness of the PjBL learning model and VSD jobsheet in improving vocational student skills. This research shows that the PjBL learning model and VSD jobsheet can improve students' EMC skills. The study's results can be used by educators as a reference and learning material in EMC learning so that student competence can be achieved optimally. In its application, this jobsheet is used by the PjBL learning steps. So, by using the PjBL-based variable speed drive jobsheet, students will be trained and directed to complete the project of independently making an electric motor control system. By actively involving students in learning projects, the skills obtained by students will increase, in this case, the skills in the electric motor control system. The objectives of the current autonomous curriculum implementation created this jobsheet. In vocational schools, students are the center of learning (student-centered learning), carried out by industry needs. This is consistent with earlier research that demonstrates how student-involved learning can enhance students' comprehension of a subject and make learning more engaging for them [12], [31]. The researcher has added the actual contribution of this research so that it can be applied by educators in the learning process. Improvements were made based on suggestions from reviewers.

In addition to revealing the novelty of the impact of using the PjBL learning model and the VSD jobsheet in the learning process, this study also has limitations in revealing these results. The research only reveals the impact of one school, which means that the VSD jobsheet integrated with the PjBL learning model only has a good impact on one school and has not revealed the results of other schools. It is recommended that further research be carried out by schools in West Sumatra so that the impact of applying the VSD jobsheet integrated with the PjBL learning model in the learning process can be known comprehensively. This is because each school has different characteristics and different problems. Increasing the research sample through various vocational schools will increase the accuracy and acceptance of the products developed [13].

4. Conclusion

This research applies the PjBL-based VSD jobsheet in the learning process, which consists of six projects that students will do to master EMC skills using VSD. Based on the results of the independent t-test test conducted, the t-count value is greater than the t-table ($t = 4.936 > 1.99962$), and the p-value obtained is smaller than the significance value limit, namely ($\alpha = 0.000 < 0.05$). So, from these results, there is a significant difference between the skills of the experimental class and the control class, where the experimental class has better skills. Based on the second test, the effect size gets a value of 1.243, which is included in the large category. It can be interpreted that the VSD jobsheet based on the PjBL learning model significantly improves students' EMC skills. Based on these two test results, it can be concluded that the VSD jobsheet based on the PjBL learning model is effectively used to improve the EMC skills of students majoring in EPIE vocational secondary schools. Therefore, to improve students' skills in the field of electric motor control systems, this research offers in-depth information about the benefits of PjBL-based VSD jobsheets. Through research, educators can apply VSD jobsheets that integrate with the PjBL learning model in EMC learning to improve students' EMC skills. It is hoped that the results of this study will be useful for vocational high schools, especially in the field of electrical power installation engineering, to improve the efficiency of the learning process to improve the EMC skills of students majoring in EPIE vocational high schools.

P-ISSN: 1411-3414
E-ISSN: 2549-9815

References

[1] G. Jia, M. Li, B. Shi, X. Yu, and X. Liu, "A variable frequency injection method for modular multilevel converters in variable speed drives," *Energy Reports*, vol. 9, pp. 939–947, Sep. 2023, doi: 10.1016/j.egyr.2023.04.198.

[2] R. Wrobel, "A technology overview of thermal management of integrated motor drives – Electrical Machines," *Therm. Sci. Eng. Prog.*, vol. 29, no. January, p. 101222, Mar. 2022, doi: 10.1016/j.tsep.2022.101222.

[3] M. M. Lumertz, S. T. C. A. dos Santos, P. R. U. Guazzelli, C. M. R. de Oliveira, M. L. de Aguiar, and J. R. B. A. Monteiro, "Performance-based design of pseudo-sliding mode speed control for electrical motor drives," *Control Eng. Pract.*, vol. 132, no. January 2022, p. 105413, 2023, doi: 10.1016/j.conengprac.2022.105413.

[4] A. Aswardi, D. T. Putra Yanto, C. Dewi, H. Zaswita, M. Kabatiah, and R. Kurani, "Human Machine Interface-Based Control Training Kit as Innovative Learning Media to Enhance Students' Automation Control Skills in the Industry 4.0 Era," *TEM J.*, vol. 12, no. 4, pp. 2157–2165, Nov. 2023, doi: 10.18421/TEM124-26.

[5] E. Tosello, N. Castaman, and E. Menegatti, "Using robotics to train students for Industry 4.0," *IFAC-PapersOnLine*, vol. 52, no. 9, pp. 177–183, 2019, doi: 10.1016/j.ifacol.2019.08.185.

[6] M. Roll and D. Ifenthaler, "Learning Factories 4.0 in technical vocational schools: can they foster competence development?," *Empir. Res. Vocat. Educ. Train.*, vol. 13, no. 1, p. 20, Dec. 2021, doi: 10.1186/s40461-021-00124-0.

[7] Risfendra, Sukardi, and H. Setyawan, "Uji Kelayakan Penerapan Trainer Programmable Logic Controller Berbasis Outseal PLC Shield Pada Mata Pelajaran Instalasi Motor Listrik," *JTEV (Jurnal Tek. Elektro dan Vokasional)*, vol. 6, no. 2, p. 48, 2020, doi: 10.24036/jtev.v6i2.108508.

[8] J. B. Manalu, P. Sitohang, N. Heriwati, and H. Turnip, "Prosiding Pendidikan Dasar Pengembangan Perangkat Pembelajaran Kurikulum Merdeka Belajar," *Mahesa Cent. Res.*, vol. 1, no. 1, pp. 80–86, 2022, doi: 10.34007/ppd.v1i1.174.

[9] Sukardi, R. Mayefis, and Usmeldi, "Effectiveness of Mobile Learning Media on Computer Assembly at Vocational High School," *J. Phys. Conf. Ser.*, vol. 1594, no. 1, pp. 347–361, 2020, doi: 10.1088/1742-6596/1594/1/012012.

[10] K. Satriyanto, "Analysis of The Implementation of The Independent Curriculum at Vocational High Schools (SMK) Centers of Excellence," *J. Soc. Res.*, vol. 2, no. 10, pp. 3786–3792, Sep. 2023, doi: 10.55324/josr.v2i10.1468.

[11] R. Maor *et al.*, "Relationships between metacognition, creativity, and critical thinking in self-reported teaching performances in project-based learning settings," *Think. Ski. Creat.*, vol. 50, no. June 2022, p. 101425, Dec. 2023, doi: 10.1016/j.tsc.2023.101425.

[12] R. Amanulloh, B. Santosa, and M. Sayuti, "Development of Integrated Welding Jobsheet Production Based Learning in Vocational High School," *J. Vocat. Educ. Stud.*, vol. 6, no. 1, pp. 167–180, Jun. 2023, doi: 10.12928/joves.v6i1.7654.

[13] M. Badruttamam and H. Hadromi, "Development Of Android-Based Interactive Jobsheet On Electrical Measuring Equipment Materials In Vocational School," *J. Educ. Res. Eval.*, vol. 10, no. 1, pp. 37–47, Apr. 2021, doi: 10.15294/jere.v10i1.50048.

[14] H. Pratama, M. N. A. Azman, N. A. Zakaria, and M. Khairudin, "Development of programmable logic controller teaching aids on electrical motor installation course among vocational school students in Aceh, Indonesia," in *Challenges of Science*, Institute of Metallurgy and Ore Beneficiation, Satbayev University, Nov. 2021, pp. 117–127. doi: 10.31643/2021.19.

[15] B. Sababha, Y. Alqudah, A. Abualbasal, and E. AlQaralleh, "Project-Based Learning to Enhance Teaching Embedded Systems," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 12, no. 9, pp. 2575–2585, Jun. 2016, doi: 10.12973/eurasia.2016.1267a.

[16] W. Wardaningsih, W. Wakhinuddin, and A. Ahyanuardi, "Effectiveness of Project-Based Learning to Increase Students Learning Outcomes and Students Learning Activity on Electric Motors Installation at Vocational High School Article Info," *J. Educ. Dev. JED*, vol. 8, no. 1, pp. 1–6, 2020, doi: 10.15294/JED.V8I1.32393.

[17] F. T. Eldiva and N. Azizah, "Project Based Learning in Improving Critical Thinking Skill of Children with Special Needs," vol. 296, no. Icsie 2018, pp. 348–355, 2019, doi: 10.2991/icsie-18.2019.64.

[18] U. Usmeldi and R. Amini, "Creative project-based learning model to increase creativity of vocational high school students," *Int. J. Eval. Res. Educ.*, vol. 11, no. 4, pp. 2155–2164, 2022, doi: 10.11591/ijere.v11i4.21214.

[19] M. O. Ajayi and O. T. Laseinde, "A review of supply chain 4IR management strategy for appraising the manufacturing industry's potentials and shortfalls in the 21st century," *Procedia Comput. Sci.*, vol. 217, no. 2022, pp. 513–525, 2023, doi: 10.1016/j.procs.2022.12.247.

[20] M. Garduno-Aparicio, J. Rodriguez-Resendiz, G. Macias-Bobadilla, and S. Thenozhi, "A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics-Related Courses," *IEEE Trans. Educ.*, vol. 61, no. 1, pp. 55–62, Feb. 2018, doi: 10.1109/TE.2017.2741446.

[21] M. Bruri Triyono, G. Nur Indriatno Putra Pratama, and T. Köhler, "The future of vocational competence: Perspective of vocational teachers, industries, and educational expert," *Int. J. Instr.*, vol. 16, no. 4, pp. 543–560, 2023, [Online]. Available: www.e-iji.net

[22] K. Nutonen, V. Kuts, and T. Otto, "Industrial Robot Training in the Simulation Using the Machine Learning Agent," *Procedia Comput. Sci.*, vol. 217, no. 2022, pp. 446–455, 2022, doi: 10.1016/j.procs.2022.12.240.

[23] D. T. P. Yanto, M. Kabatiah, H. Zaswita, N. Jalinus, and R. Refdinal, "Virtual Laboratory as A New Educational Trend Post Covid-19: An Effectiveness Study," *Mimb. Ilmu*, vol. 27, no. 3, pp. 501–510, 2022, doi: 10.23887/mi.v27i3.53996.

[24] J.-C. Goulet-Pelletier and D. Cousineau, "A review of effect sizes and their confidence intervals, Part I: The Cohen's d family," *Quant. Methods Psychol.*, vol. 16, no. 4, pp. 422–423, 2020, doi: 10.20982/tqmp.16.4.p422.

[25] P. Coufal, "Project-Based STEM Learning Using Educational Robotics as the Development of Student Problem-Solving Competence," *Mathematics*, vol. 10, no. 23, 2022, doi: 10.3390/math10234618.

[26] R. Çakır, Ö. Korkmaz, Ö. İdil, and F. Uğur Erdoğmuş, "The effect of robotic coding education on preschoolers' problem solving and creative thinking skills," *Think. Ski. Creat.*, vol. 40, no. October 2020, p. 100812, Jun. 2021, doi: 10.1016/j.tsc.2021.100812.

[27] S. Turan and F. Aydogdu, "Effect of coding and robotic education on pre-school children's skills of scientific process," *Educ. Inf. Technol.*, vol. 25, no. 5, pp. 4353–4363, 2020, doi: 10.1007/s10639-020-10178-4.

[28] W.-Y. Lu and S.-C. Fan, "Developing a weather prediction project-based machine learning course in facilitating AI learning among high school students," *Comput. Educ. Artif. Intell.*, vol. 5, no. June, p. 100154, 2023, doi: 10.1016/j.caeai.2023.100154.

[29] M. R. Gonçalves *et al.*, "Robotic4all project: Results of a hands-on robotic surgery training program," *Laparosc. Endosc. Robot. Surg.*, vol. 6, no. 1, pp. 1–8, Mar. 2023, doi: 10.1016/j.lers.2023.01.002.

[30] Tafakur, Sukaswanto, M. Solikin, and F. R. Wardani, "The Development of Training Kit For Basic Electronic Control on Automotive Field," *J. Phys. Conf. Ser.*, vol. 1700, no. 1, p. 012069, Dec. 2020, doi: 10.1088/1742-6596/1700/1/012069.

[31] E. Susatya, A. K. Triatmaja, E. Suratno, and F. Faisyal Fachri, "Impact of the Center of Excellence Vocational High School Program on the Interest of New Learners," *J. Vocat. Educ. Stud.*, vol. 6,

P-ISSN: 1411-3414
E-ISSN: 2549-9815

no. 1, pp. 62–75, Jun. 2023, doi: 10.12928/joves.v6i1.7256.