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Enhancing Learning Outcomes in Basic Electricity and Electronics: The Power of Simulation Media in Problem-Based Learning

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Abstract

This study investigates the impact of simulation media in problem-based learning on student learning outcomes in Basic Electricity and Electronics. The research problem addresses the low student engagement and learning performance due to conventional teaching methods. The purpose of this study is to compare the effectiveness of Livewire and Proteus simulation media in enhancing students' understanding of direct current circuit analysis. This research employs a quasi-experimental method with a Two-Group Pretest-Posttest Design. The study sample consists of 64 tenth-grade students from the Electrical Power Installation Engineering program at SMK Negeri 1 Percut Sei Tuan, divided into two groups: one using Livewire simulation and the other using Proteus simulation in problem-based learning. Data was collected through pretests and posttests, analyzed using t-tests to determine differences in learning improvement. The results reveal that students using Livewire simulation media achieved significantly higher post-test scores (average 80.3) compared to those using Proteus simulation media (average 63.7). These findings suggest that Livewire is more effective in facilitating conceptual understanding and problem-solving skills. The implications highlight the need for integrating technology-based learning tools to enhance vocational education outcomes. Schools and educators should consider incorporating simulation-based learning strategies to improve student engagement and academic performance.

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Introduction

Education is a process to influence students to develop noble characters. The key elements of education are learning and teaching [1]. Learning is a process of changing individual behavior to acquire knowledge, attitudes, and skills. In carrying out learning, students must have high interest and willingness to spark their learning spirit to achieve high performance. Meanwhile, teaching is an interaction that occurs between educators and students along with learning resources in a given environment [2].

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Vocational High School (SMK) is a secondary education institution that primarily prepares students to work in specific fields [3]. SMK educates its students to have knowledge, attitudes, and skills as technicians in technology fields according to their chosen study program [4]. Additionally, SMK is obligated to improve the quality of graduates in their respective fields, so that graduates are ready for both work and further education. If students can master the material delivered by educators, these goals can be achieved. Learning achievement indicates that students have good mastery of the material. Student achievement can be seen from each student's learning outcomes. Written tests and practical tests are methods to determine these learning outcomes. The test results then become benchmarks for student achievement [5].

One of the fields managed in the SMK curriculum is electricity and electronics. Based on the National Education Department curriculum [6], the electrical and electronics department at SMK aims to: 1) prepare students to enter the workforce and develop professional attitudes in electronics expertise, 2) enable them to choose careers, compete, and develop themselves in basic electronic engineering, 3) become middle-level workers to fill business world needs now and in the future, 4) become productive, adaptive, and creative citizens. So that conclusion can be drawn the Electrical and Electronics Department at SMK aims to equip students with the skills and mindset needed for professional success. Its objectives include preparing students for the workforce with strong professional attitudes, enabling career selection and competitiveness in basic electronic engineering, training middle-level workers to meet industry demands, and fostering productive, adaptive, and creative citizens [7].

Based on discussions and observations with a teacher at SMK Negeri 1 Percut Sei Tuan, information was obtained that many teachers still use conventional learning models in the classroom, such as having students take notes or dictating material to students and using the same teaching approach for all learning materials. This teacher-centered learning causes students to be less active and less interested in participating in teaching and learning activities. This also causes students to be noisy or discuss matters outside the lesson material. This situation results in unsatisfactory student learning outcomes or scores below the minimum completion criteria. Using such teaching methods causes students' learning motivation to decrease and affects their learning outcomes [8].

The teacher also mentioned several problems that can affect the decline in student learning outcomes. Regarding student characteristics, they are less aware of their strengths and weaknesses in receiving subject matter. When teachers ask questions, only a few students try to answer, while others remain silent. Students lack self-confidence, courage to answer questions, and motivation in following the basic electricity and electronics learning process [9]. They are still fixated on looking at books when completing assignments and haven't been able to installs the belief that their lessons have value and are useful for their lives. There is also no willingness from students to generate and maintain interest as an effort to foster student curiosity needed in the learning process [3].

Furthermore, student learning outcomes are not yet optimal. From the observations made, there are still several students whose scores are below the Minimum Completion Criteria standard. Teachers rarely use variations in teaching basic electricity and electronics, even though varied learning would give a positive impression, make the learning process less monotonous, and reduce student boredom during the learning process. From discussions with teachers who teach basic electricity and electronics in class X Electrical Power Installation Engineering, they say that student motivation in learning competencies for analysing direct current electrical circuits is still relatively low.

According to Martín-Blas and Serrano-Fernández [10] states that cooperative learning is a learning model that is currently widely used to create student-oriented teaching and learning activities, especially to address problems teachers find in activating students who cannot cooperate with others, aggressive students, and those who are indifferent to others [11]. One cooperative learning model that can be used to improve students' mathematical communication skills is Problem Based Learning (PBL), which is a learning model characterized by using problems as a context for students to learn critical thinking and problem-solving skills while gaining knowledge [12], [13]. Based on Sibuea, et al. [14] state that PBL involves developing curriculum and teaching systems that simultaneously develop problem-solving strategies and foundational knowledge and skills by placing students in active roles as solvers of poorly structured everyday problems. These two definitions suggest that PBL is a learning environment directed by everyday problems.

Research by Suhada, et al. [13] states that the influence of problem-based learning models can improve student learning outcomes in electrical motor installation at SMKN 7 Surabaya by 81.74% compared to before implementing the learning model. With these results, student learning outcomes can be categorized as good or high. Similarly, Sibuea, et al. [15] states that the use of learning models can improve student learning outcomes. Besides learning models improving learning outcomes, the use of media in classroom teaching is a necessity that cannot be ignored. This can be understood considering that the learning process experienced by students is based on various activities to add knowledge and insights for life in the present and future [16]. In this case, educational media is one of the effective supports in helping the learning process occur. According to Sriadhi, et al. [17] statement that research results have proven the effectiveness of using teaching aids or media in classroom learning processes, especially in improving student achievement. Limited media use in the classroom is thought to be one cause of weak student learning quality.

One type of media that can be used to improve student learning outcomes is computer-based learning media [17]. In basic electricity and electronics subjects, there are many simulation software options that can be chosen as learning media in the classroom, including Livewire and Proteus [18], [19]. Besides being quite comprehensive, this software also comes with animations that can visualize the basic concepts of analyzing direct current electrical circuits. Livewire and Proteus electronic simulation software are learning media that play an important role in simulating electronic circuits [20], [21]. Students can try to create a circuit and then test it without having to build the actual circuit. Students will learn many electronic symbols, thus increasing their knowledge. Students can experiment and explore the knowledge given by teachers by creating new circuits without fear of circuit damage or failure. Students can realize their designs by building actual circuits after the simulated circuits work well. However, both software programs must have many differences, from features to usage methods [22], [23]. Based on the discussion presented above, there are three research problems in this study:

1. How are students learning outcomes in basic electricity and electronics subjects, specifically in analyzing direct current electrical circuits material, when using Livewire simulation media in problem-based learning?
2. How are students learning outcomes in basic electricity and electronics subjects, specifically in analyzing direct current electrical circuits material, when using Proteus simulation media in problem-based learning?
3. How does the comparison of student learning outcomes differ between those taught using Livewire media in problem-based learning versus those taught using Proteus media in problem-based learning?

Research Methods

This study was conducted at Vocational High School Negeri 1 Percut Sei Tuan, located at Jl. Kolam No. 3, Kenangan Baru, Deli Serdang, North Sumatra. The research was carried out during the odd semester of the 2018/2019 academic year. The population in this study consisted of all students who were the subjects of the research, specifically all tenth-grade students of the Electrical Power Installation Engineering program at SMK Negeri 1 Percut Sei Tuan in the 2018/2019 academic year, comprising three classes.

The sample represents a portion of the population selected for research. In this study, the sample consisted of two randomly selected classes: X-TITL 1 and X-TITL 2. Class X-TITL 1 served as Experimental Class 1, using Livewire simulation media in problem-based learning, with a total of 32 students. Meanwhile, Class X-TITL 2 served as Experimental Class 2, using Proteus simulation media in problem-based learning, with a total of 30 students. This research is an experimental study involving two classes with different treatments [24]. The research design used was the Post-test Only Control Design, which evaluates differences in learning outcomes by comparing the post-test results of Experimental Class 1 and Experimental Class 2. Table 1 presents the research design.

Table 1. Research Desain

Class	Pre-Test	Treatment	Post-Test
Experiment 1	P_A	X_1	P_A
Experiment 2	P_A	X_2	P_A

Description:

X_1 : Learning with Livewire simulation media on problem-based learning models.

X_2 : Learning with Proteus simulation media on problem-based learning models.

P_A : *Pre- test and Post- test*

The research design scheme that will be carried out in this research can be seen in the following chart. Figure 1 presents a schematic of the research framework:

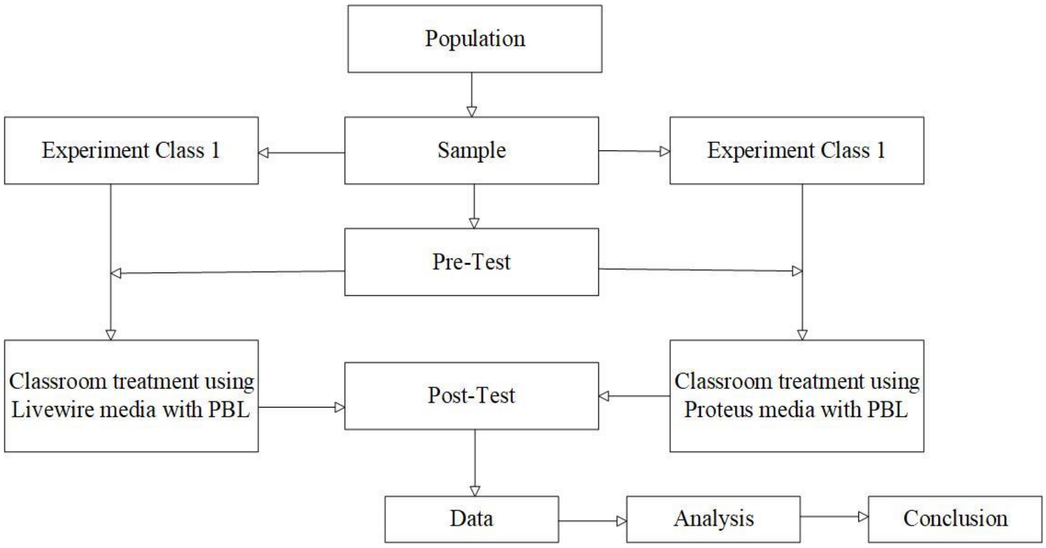

Figure 1. Research framework scheme.

The data required in this study consists of students' learning outcomes after the teaching treatment, assessed through tests as previously explained. The post-test is conducted after the lesson material has been delivered to determine the extent of students' learning achievements. The collected data must first undergo testing. The normality test aims to determine whether the sample follows a normal distribution. The test used for this purpose is the Liliefors test. Meanwhile, the homogeneity test is conducted to assess whether the two datasets in the study have the same variance. A prerequisite for conducting the homogeneity test is that both datasets must be normally distributed. If both groups have the same variance, they are considered homogeneous. The research hypothesis was tested using the t-test with the hypothesis:

$$H_a = \mu_a \geq \mu_0 \quad (1)$$

$$H_0 = \mu_a \leq \mu_0 \quad (2)$$

H_a : Student learning outcomes in basic electricity and electronics subjects are higher when using livewire simulation media in problem-based learning models than when using proteus simulation media in problem-based learning models.

H_0 : Student learning outcomes in basic electricity and electronics subjects are lower when using livewire simulation media in problem-based learning models than when using proteus simulation media in problem-based learning models.

The criteria for hypothesis testing are:

If $t_{count} > t_{table}$ then Ha is accepted at a significance level of 0.05

If $t_{count} < t_{table}$ then Ha is rejected

Results and Discussion

After conducting research on the problems taken, the next step that must be taken is to analyze the data collected. This research was conducted at SMK Negeri 1 Percut Sei Tuan in the 2018/2019 Academic Year in the subject of Basic Electricity and Electronics. The research sample was taken from 2 classes, namely class X TITL 1 which was given livewire simulation media treatment in problem-based learning and class X TITL 2 which was given proteus simulation media treatment in problem-based learning. The posttest results in the class that applied livewire simulation media in problem-based learning obtained the lowest score of 61 and the highest score of 96 with an average value of 80.3. The posttest results in the class that applied proteus simulation media in problem-based learning obtained the lowest score of 42 and the highest score of 88 with an average value of 63.7.

A. Data with Livewire Simulation Media Treatment in Problem-Based Learning

At the beginning of the session, a pre-test was administered, and this class was given treatment using Livewire simulation media in problem-based learning. At the end of the lesson, a post-test was conducted to assess students' learning outcomes. The assessment of pre-test and post-test results for the class that received the Livewire simulation media treatment in problem-based learning was measured on a score range of 0 to 100. The following learning outcome data is presented in Table 2.

Table 2. Learning outcomes

Class	Data	Lowest Score	Highest Score	Average
Pretest	*Livewire* with PBL	19	54	31,4
Posttest		61	96	80,3

From Table 2 of the pre-test results in the Livewire simulation media class, it can be observed that students' initial ability or knowledge in the subject of Basic Electricity and Electronics, specifically in analyzing direct current circuits, is still lacking. This is evidenced by the highest student score being 55, while the lowest score is 19. The average pre-test score for the Livewire simulation media class in problem-based learning is 31.4. These results indicate that students' initial knowledge of analyzing direct current circuits is still insufficient, highlighting the need for special treatment to improve their understanding.

After implementing a combination of media and instructional models in the teaching and learning process, student learning outcomes in the Livewire simulation media class using problem-based learning improved. This is evident from the highest score in the class, which reached 96, while the lowest score was 61. The average score in the class was 79.87. This indicates that the use of Livewire simulation media in problem-based learning can enhance student learning outcomes, as it provides a better understanding of the material, enabling students to grasp the concepts more effectively and positively impacting their academic performance.

B. Data with Proteus Simulation Media Treatment in Problem-Based Learning

At the beginning of the session, a pre-test was administered, and this class was given treatment using Proteus simulation media in problem-based learning. At the end of the lesson, a post-test was conducted to assess students' learning outcomes. The assessment of pre-test and post-test results for the class that received the Proteus simulation media treatment in problem-based learning was measured on a score range of 0 to 100. The learning outcome data for the Proteus class on PBL is presented in Table 3 below.

Table 3. Proteus class students' learning outcomes in PBL

Class	Data	Lowest Score	Highest Score	Average
Pre test	Proteus with PBL	19	46	30,1
Post test		42	88	63,7

From Table 3, the pre-test results in the Proteus simulation media class indicate that students' initial ability or knowledge in the subject of Basic Electricity and Electronics, specifically in analyzing direct current circuits, is still lacking. This is evident from the highest student score being 46, while the lowest score is 19. The average pre-test score for the Proteus simulation media class in problem-based learning is 30.1. These results suggest that students' initial knowledge of analyzing direct current circuits is still insufficient, necessitating special treatment to enhance their understanding.

After implementing the treatment by integrating media with a learning model in the teaching and learning process, students' learning outcomes in the Proteus simulation media class within problem-based learning improved. This is reflected in the highest score in the class, increasing to 88, while the lowest score rose to 42. The average score in the class also improved to 63.7. These findings indicate that using Proteus simulation media in problem-based learning can enhance students' learning outcomes. By applying this treatment, students gained a better understanding of the material, which positively impacted their academic performance.

After obtaining student learning data, the data must be tested for analysis requirements, namely normality and homogeneity tests, to obtain different test data from the two classes. Data normality test and pretest and posttest of the livewire and proteus simulation media treatment class on problem-based learning using the Lilliefors test to see the normality of the research data. The normality test data is presented in Table 4 below.

Table 4. Normality Test Results

No	Data	Class	L_{count}	A	L_{table}	Conclusion
1.	*Post test*	Livewire Simulation Media in Problem Based Learning	0,094	5%	0,164	Normal
		Proteus Simulation Media in Problem Based Learning	0,111		0,161	Normal

Table 4 above shows that the posttest data of the livewire and proteus simulation media treatment class in problem-based learning $L_{count} \leq L_{table}$ with $\alpha = 0.05$, so it is normally distributed. The homogeneity test of the pretest and posttest data in the livewire and proteus simulation media treatment class in problem-based learning uses the two-variance equality test at a significance level of $\alpha = 5\%$. The results of the homogeneity test calculation are shown in Table 5 below:

Table 5. Data Homogeneity Test Results

Data	Class	Varians	F_{count}	α	F_{table}	Conclusion
Pretest	Livewire Simulation Media in Problem Based Learning	105,2	1,4	5%	1,78	Homogen
	Proteus Simulation Media in Problem Based Learning	73,2				
Posttest	Livewire Simulation Media in Problem Based Learning	86,9	1,65	5%	1,78	Homogen
	Proteus Simulation Media in Problem Based Learning	166,7				

C. Hypothesis Testing of Learning Outcomes

Hypothesis testing in this study includes a test of the difference in the final value of the treatment class, the livewire simulation media treatment class and proteus in problem-based learning. To test the hypothesis, a different test (t-test) was used, a test of the difference in the posttest value of the livewire simulation media class in problem-based learning and the proteus simulation media class in problem-based learning obtained t_{count} = 19.5 while t_{table} = 1.673 or $t_{count} > t_{table}$ (19.5 > 1.673), so that Ha is accepted and H0 is rejected or the learning outcomes of students taught using livewire simulation media are better than students taught with proteus simulation media in problem-based learning. The summary of the results of the hypothesis test calculations is shown in Table 6 below.

Table 6. Hypothesis Test Results

No	Class	Average	T_{count}	α	t_{table}	Conclusion
1	Livewire Simulation Media in Problem Based Learning	80,36	19,5	5%	1,673	There is a significant difference
2	Proteus Simulation Media in Problem Based Learning	63,78				

Based on the Table 6. above, the experimental class taught using Livewire simulation media in problem-based learning achieved an average learning outcome score of 80.36, while the class taught using Proteus simulation media in problem-based learning obtained an average score of

63.78. The data shows that $t_{count} > t_{table}$ (19.5 > 1.673), leading to the conclusion that H_a is accepted and H_0 is rejected. This indicates that students taught using Livewire simulation media in problem-based learning performed better than those taught using Proteus simulation media in the subject of Basic Electricity and Electronics for Grade X students at SMK Negeri 1 Percut Sei Tuan in the 2018/2019 academic year.

D. Discussion

The purpose of this research is to analyze the effectiveness of simulation media in problem-based learning (PBL) to enhance students' learning outcomes in Basic Electricity and Electronics. Specifically, this study compares two different simulation tools, Livewire and Proteus, to determine which media provides a more significant impact on students' understanding and problem-solving abilities. The findings indicate that students using Livewire simulation media in PBL achieved higher post-test scores compared to those using Proteus simulation media. This suggests that Livewire provides a more effective learning experience, enabling students to visualize circuit analysis concepts more clearly.

This research aligns with previous studies on the effectiveness of technology-based learning in vocational education. A study by Yuliana, et al. [12], Sibuea, et al. [14] demonstrated that PBL significantly improves students' motivation and learning outcomes in electronic subjects. Similarly, Sriadhi, et al. [17], Suhada, et al. [13] found that virtual laboratory-based learning enhances students' engineering competencies, supporting the idea that simulation media is a crucial tool in technical education. However, this study expands upon these findings by directly comparing two different simulation tools within the same learning model. The results reinforce the idea that selecting the right simulation media can significantly influence students' comprehension and performance.

The impact of this research is significant for vocational education. By incorporating simulation-based learning, educators can provide students with interactive and engaging experiences that bridge theoretical knowledge and practical application. The findings suggest that schools should invest in technology-enhanced learning tools and train teachers in their effective implementation. This shift can improve students' readiness for the workforce by strengthening their technical skills and problem-solving abilities.

Despite its contributions, this study has several limitations. First, the research was conducted in a single vocational high school, which may limit the generalizability of the results. Additionally, the study only focused on one subject area, Basic Electricity and Electronics, meaning its findings may not fully apply to other vocational disciplines. Future research should explore the effectiveness of simulation media across different technical subjects and in a broader range of educational institutions. It would also be beneficial to investigate the long-term impact of simulation-based learning on students' skill retention and workplace readiness.

The results of this study provide valuable insights for improving vocational education. Schools should actively integrate simulation media into the curriculum to enhance students' engagement and technical competencies.

Additionally, teachers should receive professional development on how to effectively use technology-enhanced learning tools to optimize student outcomes. Policymakers in vocational education should consider these findings when designing training programs that align with industry demands. Ultimately, the integration of advanced learning technologies can transform vocational education, making it more relevant and effective in preparing students for future careers.

Conclusion

This study aimed to analyze the effectiveness of simulation media in problem-based learning (PBL) to enhance student learning outcomes in Basic Electricity and Electronics, specifically comparing Livewire and Proteus simulation tools. The findings indicate that Livewire simulation media significantly improves students' understanding, with an average post-test score of 80.3, compared to 63.7 for Proteus users, demonstrating a strong impact in addressing the research problem of low engagement and comprehension in vocational education. The results highlight the importance of integrating interactive learning technologies to bridge the gap between theoretical knowledge and practical application. However, this study has certain limitations, including a restricted sample size from a single vocational high school and a focus on one subject area, which may affect the generalizability of the findings. Future research should explore the application of simulation media across different technical subjects and a broader range of educational institutions to validate these findings further. Additionally, long-term studies could assess the retention of knowledge and its impact on students' career readiness. The implications of this research for vocational education emphasize the need for schools to invest in digital learning tools, provide teacher training for effective implementation, and develop curricula that incorporate simulation-based learning strategies. By adopting these recommendations, vocational education can better equip students with the technical skills and problem-solving abilities required in modern industries, ensuring that graduates are better prepared to meet workforce demands.

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Author Contributions

Bima Mustaqim: conceptualization; formal analysis; data curation; methodology. Demitila Okola Opetu: methodology; data curation. Sahat Siagian: Writing-review and editing; validation; data curation. Agus Junaidi: Formal analysis; data curation; writing-review and editing. Abdul Muin Sibuea: validation; writing-original draft; methodology.

Availability of data and materials

All data is available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

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