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Enhancing Electrical Power Engineering Education in North Sumatra: Evaluating the Effectiveness and Practicality of Consortium Collaborations Between Academia and Industry

Agus Junaidi[1], Marwan Afandi[2], Wanapri Pangaribuan[3], Abd Hamid K[4], Rahmaniar[5]

[1] Universitas Negeri Medan, Indonesia; agusjunaidi@unimed.ac.id
[2] Universitas Negeri Medan, Indonesia; marwanelektro@unimed.ac.id
[3] Universitas Negeri Medan, Indonesia; wanapripangaribuan@unimed.ac.id
[4] Universitas Negeri Medan, Indonesia; abdulhamid@unimed.ac.id
[5] Universitas Pembangunan Panca Budi, Medan, Indonesia; rahmaniar@dosen.pancabudi.ac.id

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ABSTRACT

Simulation technology tools are becoming important learning tools in higher education, facilitating the development of practical and cognitive skills in a safe and widely accessible environment. Simulation technology is applied to practice and develop practical learning skills in a safe environment without real risks. Computers as media and are used to improve learning outcomes and facilitate students in innovative learning. The importance of using simulation media in learning electricity engineering is because inviting students to learn and interact with simulations can improve critical thinking skills, problem-solving, and decision making. The simulation media was developed using the ADDIE model to achieve learning effectiveness targets by observing the parameters of alignment between simulation content and learning outcomes, interactivity that allows students to be actively involved in the learning process, the quality of feedback provided by simulations to help students understand in improving learning outcomes in the field of electricity engineering. The results of testing 21 respondents showed an increase in student involvement and motivation in the pretest results of 65.5 and post-test 83.38 in the experimental class, indicating that there was an increase in learning outcomes from media users. Practicality test > 80% in the practical category shows the implication of using the media provides convenience.

Corresponding Author:
Agus Junaidi
Universitas Negeri Medan, Indonesia; agusjunaidi@unimed.ac.id

1. INTRODUCTION

Electrical engineering students need learning products for simulation programs in the field of electrical power systems in line with the need for learning using computer and information technology (ICT) as a learning aid (B. Baruah, 2021)(Junaidi, Agus, 2022). Simulation technology is a practical and effective medium in helping students understand complex fields of study (Rahmaniar et al., 2022)(Anca, 2021). The field of energy distribution systems studies is one of the interesting topics in research regarding the application of ICT in learning, because it has the characteristics of material that has many mathematical formulations and modeling, so that ICT is needed to complete student learning(Sanfo, 2023; Vargas-montoya, Gimenez, & Fern, 2023). Physically, a platform for learning digital protection operations is implemented to provide students with the opportunity to practice electrical power protection systems (Naseri, 2023). Equipment for testing three-phase distribution network systems, disturbances in electrical power plants, monitoring systems, and digital relay protection systems (Leelaruji & Vanfretti, 2012; Nascimento, 2020). Incorporating a protection scheme platform with communication technology into practical learning activities enhances students' understanding of automation and electric power protection operations (Stamber et al., 2016; Rashed et al., 2023).

The role of technology in learning has a practical impact on students(Khan, Cram, Wang, Tran, & Cavaleri, 2023)(Alyoussef, 2022). Simulation-based educational perspectives and strategies provide freedom for students to explore new ideas that relate to real needs (Miller, Chong, & Stouffs, 2023). The teaching and learning process using simulation technology (Juhary, 2012)with an integrated model with information technology tools is applied in an effort to resolve the tendency for students (Kerimbayev, 2023) weaknesses who have not maximized critical thinking skills to become obstacles in learning electrical engineering (Aljarboa, 2020). The integration of computer simulation technology in learning and teaching skills needs to be optimized, this is related to efforts to strengthen learning implementation strategies to produce learning outcomes with critical skills through analytical abilities and skills to solve problems in learning in line with the 4C competencies needed in today's world of work. (Riset, Tinggi, & Indonesia, 2018;s Anwar et al., 2023).

A strategic program to improve the quality of graduates in the provision of higher education through strengthening quality education and teaching in universities as producers of science and technology-innovation and centers of excellence which includes strengthening the focus in the field of science (Carla, Kreuzer, Hirz, & Pacher, 2024). Internalizing collaboration in learning between academics, practitioners and experts is now a necessity in efforts to improve the quality of Human Resources (HR) in Indonesia(A. M. B, 2023). The role of collaboration between institutions in implementing strengthening research and learning collaboration both between universities and with industry has been formulated based on the policy direction of the Medium Term Development Plan (RPJM-2020-2024)(Indonesia & Regulation, 2024). The implementation of HEIs as producers in developing competitive and innovative human resources then becomes a challenge for universities to continuously increase cooperation in an effort to support the quality of graduates. The teaching and learning process involving cooperation between units and institutions/industry shows beneficial effects for educational institutions and students (Manalu, 2019), including those in the field of electrical engineering who have creative skills, critical and innovative thinking skills through learning independence into the urgency of cooperation in the form of a consortium is needed to improve learning outcomes.

Learning in the field of electrical engineering with various characteristics of electrical engineering study programs in the fields of electric power systems, electrical energy conversion and electrical power engineering is available in 23 universities that have Electrical Engineering Study Programs in North Sumatra. Currently, they have not yet optimized cooperation in the form of specific agreements in preparing profiles. graduates based on user needs. The electrical engineering study program in North Sumatra has a culture and sociography that has the same users as graduates (Triadiarti, Ane, Purba, Irfan, & Halim, 2022), namely the Medan Industrial Area, Agriculture, Plantation and Tourism where graduates work. The distribution of graduate competencies for each study program in each university is expected to be identical, even though each study program has its own uniqueness in scientific development which characterizes the study program. However, equal distribution of graduate competencies is intended as an effort to create quality human resources whose quality is truly felt by users, which is a challenge in itself for each electrical engineering study program, so that the realization of cooperation between study programs through agreement with academics, practitioners and experts in contributing input to the profile, strategies, media and modules taught in universities are an alternative to overcome the problem of competency inequality between study programs in North Sumatra. This empirical study evaluates survey results related to the role of industry in the higher education environment, shows that the participation of industry practitioners in academic engagement activities encourages the quality of learning, and elaborates on the motivation for university-industry collaboration at the individual level. There is a relationship between creativity and learning innovation in the tendency of positive values to encourage efforts to improve quality (Rajapathirana, 2018).

The collaboration that is being built certainly intersects with the Merdeka Belajar Kampus Merdeka (MBKM) policy which is currently the government's policy to strengthen the quality of tertiary graduates, listed in the "Indikator Kinerja Utama" (IKU) in the study program partnership aspect which includes the number of collaborations between graduate study programs at IKU 6 is the achievement target, apart from that there is IKU 2 application of case-methods and team-based projects in learning which is part of efforts to improve the quality of graduates (Kepmendikbud-Ristek No. 210/M/2023), so that the development of learning products for simulation programs in the field of systems studies Tripartite Collaborative (Academics, Experts and Practitioners) based electricity distribution is proposed to be tested for its level of effectiveness and practicality in producing quality human resources and supporting MBKM policies. In the field of electrical engineering, tripartite cooperation is needed to improve the quality of teaching for educators in various study programs in higher education, currently faced with the challenge of producing competitive graduates who can enter the new job market of the 21st century, including in electrical engineering study programs strata one (S1) sector of the 150 KV High Voltage Overhead Line (SUTT) system. Studies in SUTT courses have complexity because the study material is analytical, it becomes complex when the presentation in learning does not pay attention to aspects of using technology as a learning aid with simulation programs. The application of computer and information technology in learning by building a 150KV high voltage overhead line simulation program requires a tripartite cooperation/collaborative model (academics, experts, and practitioners). The collaboration model has more benefits in improving skills through training programs(Mulyadi, Riyanto, & Kristanto, 2024).

The tripartite collaboration method was chosen to develop simulation products that will be used by students as learning aids. Digital media experts from industry practitioners collaborate with a team of researchers to produce SUTT simulation program products for undergraduate level learning that are validated by experts(Dodgson, Gann, & Salter, 2007). Practitioner are involved in providing input on the learning process and plans for cooperation in developing Independent Learning Campus (MBKM), through the Team Based Project and Case Methods models in higher education (Nurhayati et al., 2022) , influences the quality of human resources in global competition. Strategic programs contained in the implementation of higher education in an effort to produce Human Resources (HR), through strengthening quality higher education as producers of science and technology-innovation and centers of excellence which include strengthening the focus of scientific fields according to local regional potential (B. R. B, Perdana, Prasetya, & Prayogi, 2023). The internalization of collaboration in learning between academics, practitioners and experts currently needs to be increased in an effort to strengthen research consortium collaboration between universities and industry based on the policy direction of the Rencana Pembangunan Jangka Menengah (RPJM-2020-2024).

2. METHODS

2.1. Strategy/Approach

In an effort to optimize research achievement targets, the concept of research direction developed in determining the targets is arranged in the block diagram in figure 1.

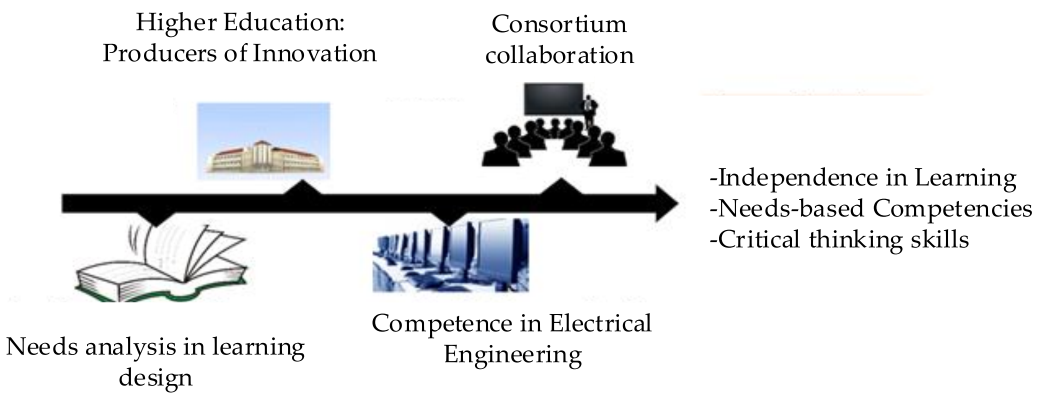

Figure 1. Tripartite Collaboration Model Strategy in Learning

In Figure 1, the block diagram shows the strategies determined in an effort to achieve collaboration goals, namely, Independence in Learning, -Needs-based Competencies and Critical thinking skills. The intended achievement target is to support the optimization of the Independent Campus policy in the Electrical Engineering Study Program in the North Sumatra region. There are 4 main blocks contained in the chart to realize the target of a digital learning home, student learning independence and recognition of the activities carried out by students through the involvement of Colleges that have electrical engineering study programs. Tripartite collaboration, RPS document with collective agreement standards that meets the minimum components contained in PERMENDIKBUD No. 3 of 2020 Article 12 paragraph 3, as well as enrichment of e-Modules which are jointly prepared and implemented in a virtual learning environment.

The primary effort to optimize the independent learning policy is implemented through a tripartite consortium, which involves collaboration among electrical engineering lecturers from various universities, serving as the Main Driving Force (MDF). The MDF operates under a Memorandum of Understanding (MoU) to meet student learning needs. As a formulation team, the MDF is responsible for designing the learning process in the MBKM program, developing a comprehensive syllabus (RPS), and creating standard teaching materials or e-modules based on mutual agreement. In this process, the MDF collaborates with experts from study program associations, professional community groups, and representatives from the business and industry sectors (DUDI) to ensure that the curriculum aligns with real-world demands. The consortium draws on the expertise of study program associations and professional groups in North Sumatra, such as the Electrical Engineering Association Forum, and engages industry practitioners in establishing standards that will guide the consortium. This approach aims to build and optimize the independent campus consortium for electrical engineering study programs in the North Sumatra region.

2.2. Media Development Stage

Collaboration is also implemented in the field of electrical engineering. Applied to learning Electric Power Transmission, a core course on electrical power systems in the electrical engineering study program. Media development through a disturbance simulation program on High Voltage Air Lines is one part of the research activities carried out. The simulation program development stage begins by modeling the high voltage network with the Phi-Nominal model because medium distance high voltage overhead lines are selected.

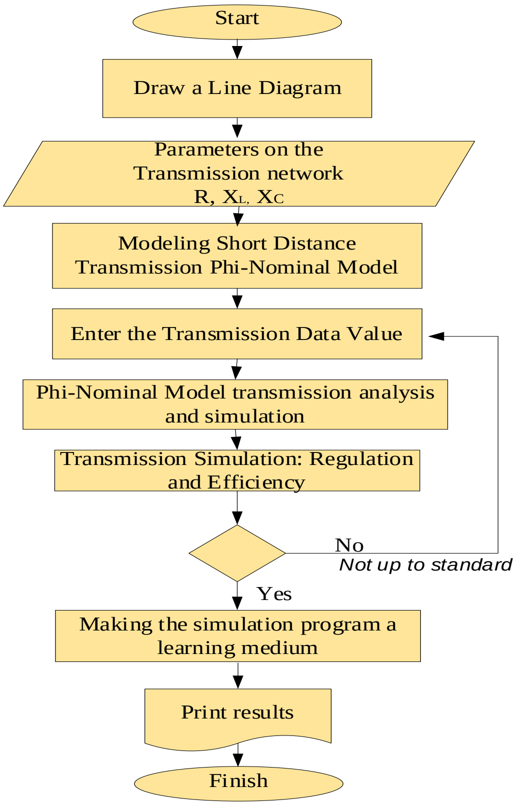

Figure 2. Simulation Program Preparation Stage

Figure 2 shows the stages of creating a simulation program starting from system data on a line diagram with the sending side and receiving side of the high voltage overhead line, then forming a phi-nominal model, then carrying out resistance analysis and Geometric Mean Radius and Geometric Mean Distance to obtain impedance through calculation of transmission line reactance due to XL and XC. From this calculation, the Volatage Regulation (VR) value and transmission line efficiency will be determined. Analysis and simulation of voltage regulation and efficiency in the medium range SUTT Analysis Formulation Model. Classification of medium distance transmission between 80 km to 250 km, using the phi-nominla model as shown in figure 3.

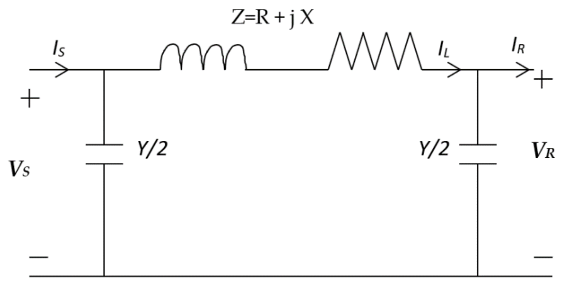

Figure 3. Nominal Phi Transmission Line Model

Where;

I_S = Sending Current (Current from the Sending Side)
I_R = Receiving Current (Receiver side current)
V_S = Sending Voltage (Sending Side Voltage)
V_R = Receiving Voltage (Receiver side voltage)
Y = Transmission Line Shunt Admittance
Z = Transmission Line Series Impedance

Figure 3 shows the Nominal phi Model for the medium distance channel used in the simulation program used in the study.
From the Khircoff Current Law (KCL) the current in series impedance with I_L notation is:

$$I_L = I_R + \frac{Y}{2} V_R \quad (1)$$

From Kirchoff's Voltage Law (KVL) the sender side voltage is written as:

$$V_S = V_R + Z\, I_L \quad (2)$$

Substituting IL from equation (1) into equation (2), we get:

$$V_S = (1 + \frac{ZY}{2}) V_R + Z V_R \quad (3)$$

Sending side current *(I_S)*

$$I_S = I_L + \frac{Y}{2} V_S \quad (4)$$

Substituting V_S and equation (3) into equation (4) will be obtained:

$$I_S = Y(1 + \frac{ZY}{4}) V_r + (1 + \frac{ZY}{2})\ I_R \quad (5)$$

There are constants A, B C and D from equations (3), (4) and (5), namely:

$$A = \left(1 + \frac{ZY}{2}\right) \qquad B = Z$$
$$C = Y\left(1 + \frac{ZY}{4}\right) \qquad D = \left(1 + \frac{ZY}{2}\right) \quad (6)$$

If written in the form of a matrix equation, it will be obtained:

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_S \\ I_S \end{bmatrix} \quad (7)$$

2.3. *Media Content Validation*

After the simulation model based on Figure 2 is complete, media validation is carried out by experts, in this case 3 experts are needed, namely (1). Electricity expert; (2) Expert in the field of Information Technology and computers and (3) Expert in the field of Technology and Vocational Education. The three experts will analyze and validate based on their respective fields, as shown in Figure 4.

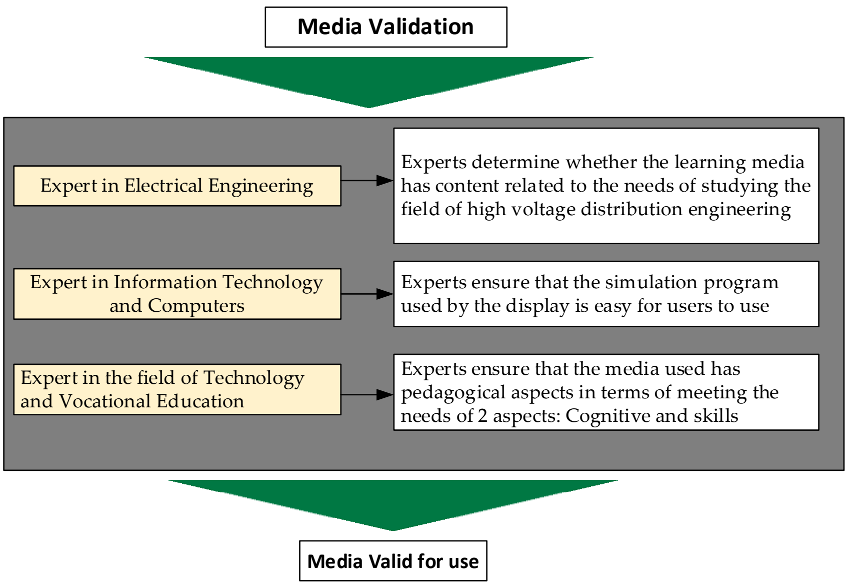

Figure 4. Media Validation by Experts

Media validation by 3 experts used two types of validity instruments used for validity testing, namely content validity with the Aiken'V approach used to analyze media content validity. is an approach formulated by Aiken for Content Validity Coefficient analysis based on the results of expert recommendations of 3 respondents regarding the media items proposed, in this case the extent to which media items in efforts to strengthen/optimize independent campus policies represent the measured needs of users.

In the simulation media, learning material for electrical power distribution systems is input. The material included is based on user needs. There are two types of instruments for collecting data on material needs used in this research, namely (a) questionnaires, and (b) interview/observation rubrics, as the main tool for observing research data. Questionnaires are used to search for information related to the specifications of the data being searched. The questionnaire prepared is used for study tracer, needs assessment and research product assessment, with the substance of the questions in the questionnaire in accordance with the required data collection. The assessment questionnaire from respondents was prepared using Linkert scale assessment criteria. The statements described in the questionnaire to respondents are arranged with scores and selection of descriptions of the contents of the questionnaire according to the criteria of need, shown in Table 1.

Table 1. Assessment Questionnaire Likert Scale Table

Score	Description
5	Very (Good/precise/systematic/consistent/adequate/interesting)*
4	Good/precise/systematic/consistent/adequate/interesting *
3	Sufficient ((Inadequate (Good/precise/systematic/consistent/adequate/interesting)*
2	Less (Good/precise/systematic/consistent/adequate/interesting)*
1	Very Poor (Good/precise/systematic/consistent/adequate/interesting)*

Note: the * mark is a selection according to the criteria for the content of the questionnaire questions.

2.4. Data for Effectiveness and Practicality Testing

The data used to test the effectiveness of the program is user data, namely study programs, lecturers and students who utilize the consortium program, with simulation products, Semester Learning Plans where activities are tested in several subjects in the field of electrical power systems engineering, the subjects chosen include namely Electric Power Transmission.
The effectiveness test formulation is shown in Table 2.

Table 2. Effectiveness Test Equation

Itema	Description	Formulation
Mean	where Σ is the sign of addition (sum), X is each number, and N is the population size	$\mu = \frac{\sum X}{N}$
Std. Deviation	The standard deviation, for purely real or purely imaginary inputs, the standard deviation of j column of the M-by-N input matrix is the square root of the variance, written by the equation	$y_j = \sigma_j = \sqrt{\frac{\sum_{i=1}^{M} \lvert u_{ij} - \mu_j \rvert^2}{M-1}}$ $1 \leq j \leq N$
Std. Error of Mean	Is a value that can be interpreted by how close the average (Mean) of the sample to the population. The larger the sample, the smaller the standard error, and the closer the sample mean approach is to the population mean	$Standar\ error = \frac{\sigma}{\sqrt{N}}$

Effectiveness test analysis with the type of research used is pre-experimental quantitative research using one group pretest-posttest design (Knapp, 2016). The design that will be used in this research can be seen in table 3.

Table 3. The research design is one group pretest-posttest design

Pre-test	**Treatment**	***Post-test***
O_1	X	O_2

Data analysis carried out in this research included descriptive analysis and inferential analysis includes the N-gain test, normality test, homogeneity test, and T-test (Paired Samples T-test). Descriptive analysis to describe the results of the learning process based on the data obtained. Scores from the response questionnaire on the use of electric power system simulation media using descriptive statistics. The following is the formula used to convert:

$$\text{Score/Value} = \frac{\text{Total Values obtained}}{\text{Maximum Value}} \quad (8)$$

The percentage score obtained will be converted into a qualitative value using four criteria. Assessment classification guidelines are in table 4.

Table 4. Qualitative criteria for effectiveness testing

Value Interval	Criteria
81,25% < x ≤100%	Very good
62,50%< x ≤ 81,25%	Good
43,75%< x ≤ 62,50%	Not good
25%< x ≤ 43,75%	Very Not Good

Data for trial analysis was obtained from users (study programs, lecturers and students) with intervals for assessing the practicality of involving practitioners in collaboration are given in table 5.

Table 5. Classification of Practicality Levels of Research Models and Products

Value (%)	Category
80 < P ≤ 100	Very Practical
60 < P ≤ 80	Practical
40 < P ≤ 60	Quite Practical
20 < P ≤ 40	Less Practical
P ≤ 20	Impractical

An analysis of the practicality of the media was carried out using simulation using Simulink Matlab. Measurement. Block diagram of practicality analysis process. As shown in figure 5.

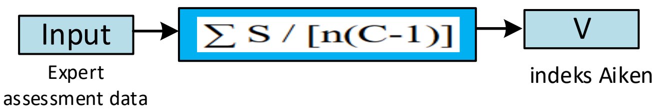

Figure 5. Media Practicality Analysis Model Block by Experts

Figure 4 shows the analysis model to be applied to Simulink Matlab, S is the difference between R and Lo (S=R-Lo), where S is minus the score given by the expert, while Lo is the lowest assessment score and R is the score given by the expert, for n is the number of validators. All parameters based on the equation in image block number 4 are used to determine the V (Aiken index) value.

3. FINDINGS AND DISCUSSION

3.1 Effectiveness Test Analysis in the Control Class and Experimental Class

Data analysis: To determine the level of effectiveness of simulation media in learning electrical power systems which involve tri-partite collaboration in media development, it can be seen through the results of trials through pretests and posttests in the control class which applies power point media and the experimental class which applies simulation media. Analysis of differences in learning outcomes in the control class and experimental class was carried out with the help of simulation media using Simulink, as shown in figure 6.

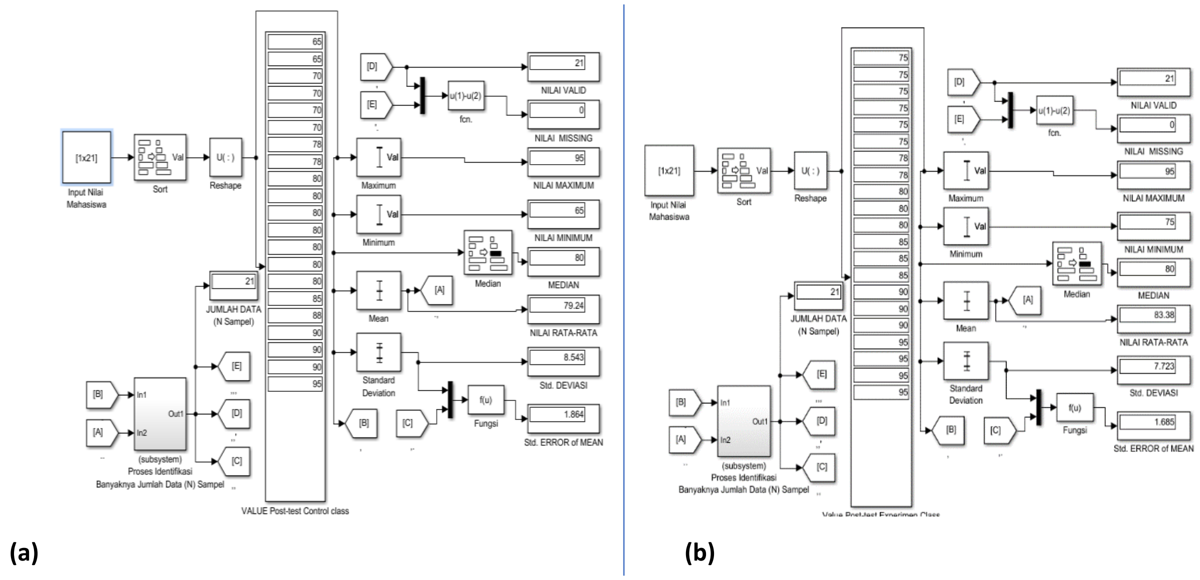

Figure 6. Post-test differences between experimental and control classes are plotted using matlab simulink (a). Simulation learning outcomes in the control class that uses video tutorial media in learning the average value of 79.24 (b) Learning outcomes of experimental classes that use three-party collaboration in developing simulation media average value 83.38

From the simulation results in Figure 5, data is obtained that the pre-test score is clearly control 65, while the post-test result is 75.8. In the control class, learning was treated with simulation tools using power points. Meanwhile, in the experimental class, the pre-test score was 66.5, while the post-test score was 83.38. The experimental class was treated with simulation media with tripartite cooperation. The plot of differences in learning outcomes based on tests in the control class and experimental class is shown in figure 7.

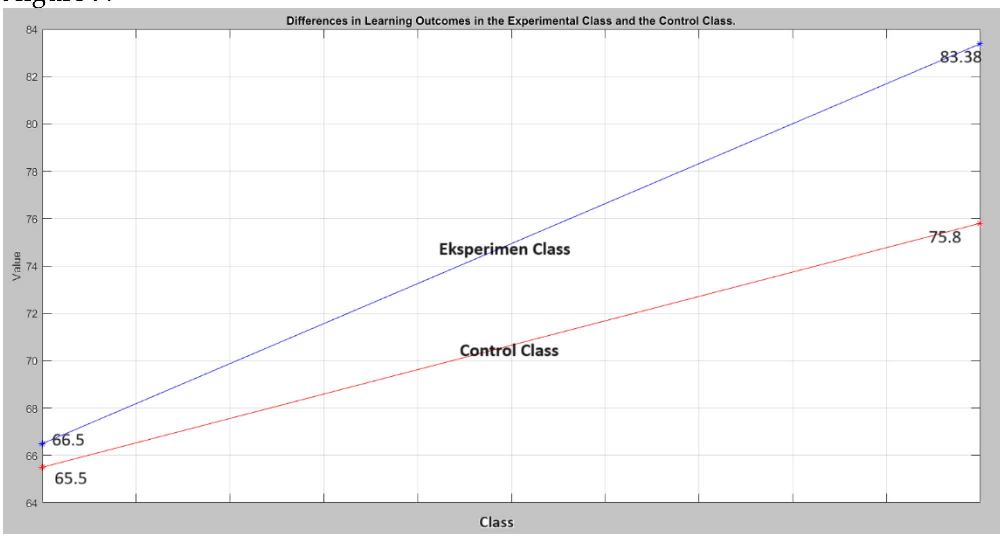

Figure 7. Graph of Differences in Learning Outcomes in the Experimental Class and the Control Class

Figure 7 shows the differences in learning outcomes in the control class and the experimental class. The results of the simulation analysis of simulation media research trials with tripartite collaboration in learning about electrical power transmission show that it is effective in improving learning outcomes. The t-test is used to see the differences in a sample from two groups of data that receive different treatments or measurements. The results of the analysis using SPSS software obtained information about whether or not there were differences between the two groups in both the

experimental class and the control class. In this research, the difference test uses the Mann-Whitney approach, if the significance value is <0.05 then the hypothesis or Ha is "accepted" while if the significance is >0.05 then Ha is "rejected". The process for determining the significance value is carried out with the help of SPSS software and the characteristics of the significance parameters in the results of running SPSS can be seen from the Asymp.sig (2-tailed) result data, meaning that the value shown in Asymp.sig(2-tailed) is to provide information that Ha is "accepted" or Ha is "rejected".
The t-test process of the post-test results of the control class and experimental class was carried out with the help of SPSS IBM 2.2 software, with the t-test results shown in table 6.

Table 6. Table Uji-t

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Value	38.421	63	.000	63.59259	59.4119	65.7733

From table 6, it can be seen that the value in the Asymp.sig(2-tailed) column is 0.00, The significance value shown in the table is 0.00. The significance value of 0.00 means that the hypothesis test results show a very significant difference between the group that used simulation media and the control group that did not use simulation media. Hypothesis decision With a significance value of 0.00 ($p < 0.05$), the null hypothesis (H0) is rejected. This means that there is a significant difference in learning achievement between the experimental group using simulation media and the control class group.

The effectiveness test for the control class and the experimental class, in the control class using Power Point media, showed a change in the average learning outcomes with the average value of the results between the pre-test and post-test in the control class with a significant difference compared to the experimental class which was tested using a tripartite collaboration-based simulation. The difference in learning outcomes in the experimental and control classes can be seen in student interaction in learning visually can increase student learning motivation. Students tend to be more interested and enthusiastic in participating in learning using simulations. Students can learn from mistakes and improve student competence without real risk. Better practical skill development can contribute to the difference in learning achievement of the experimental class higher than the control class. In line with the study of research (Shifa, Perveen, Alam, & Kishore, 2024) through studying the influence of collaborative learning using the ANOVA test, it is also known that the effect of implementing collaborative learning has an influence on learning outcomes through students' creativity and critical thinking, with a total influence of 77.9% for creativity and critical thinking. amounting to 27.1%.

The findings of this study can encourage changes in teaching practices and media development by utilizing simulation technology in the higher education environment. The results of the study have a significant positive impact on the learning process and student learning outcomes. The use of simulation media can increase students' engagement, conceptual understanding, and practical skills, which in turn can lead to improved learning achievement. The implementation of simulation media in learning can help develop students' competencies and readiness to face challenges in the real world.

3.2. Simulation Media Practicality Test Analysis Results

The practicality test was analyzed based on the results of user opinions (21 students in the experimental class) who used simulation media based on tripartite collaboration. 4 aspects in assessing media, namely (1) Media appearance, (2) Data entry on media (3) Ease of use of media and (4) Helpdesk (assistance) on media. Practicality analysis uses the help of Matlab simulation, as shown in Figure 8.

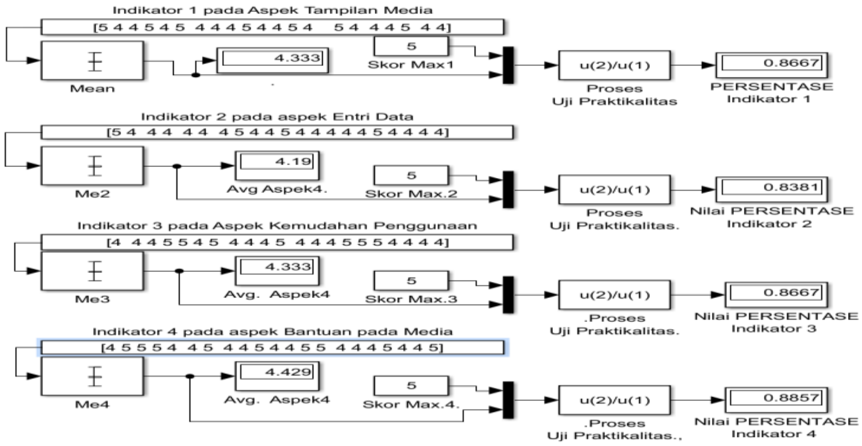

Figure 8. Media Practicality Test Simulation Results by Users.

From Figure 7, you can see the results of practicality in four aspects. Practicality was tested using the maximum value approach compared with the average value of the respondents' assessments. In the display aspect of the test media it was 86.67%, in the data entry aspect it was 83.81%, ease of use was 86.67% and in the media helpdesk aspect it was 88.57%. Of the four aspects, the practicality value is >80%, indicating that the media is very practical for use by users (students). Overall, a practicality threshold of >80% indicates a very high level of success, predictability, design quality, acceptability and potential impact of the studied intervention (Vargas-montoya, Gimenez, & Fern, 2023). This makes the findings highly significant and attractive for decision makers and educational practitioners to consider for implementation in real educational settings. Practicality scores above 80% indicate that the simulation media intervention design was very well prepared and implemented. This indicates that the intervention has gone through a thorough development process and considered the needs and preferences of users (Junaidi, 2022).

4. CONCLUSION

Improving the quality of learning in the field of electrical power engineering in North Sumatra through strengthening the collaboration of a consortium of academics and industry involvement, carried out by analyzing the effectiveness and practicality of producing learning simulation media products for electrical engineering students in universities. The material compiled with industry practitioners and academics has been applied in real terms in the experimental class trials, showing higher student learning outcomes than in the control class. The source of study material obtained from real field data with practitioners arranged media through modeling and simulation is easy for students to use in the practicality test in the very practical category. The implications of simulation media compiled in collaboration with the collaboration team are easily utilized for learning and competency development for students tested in experimental classes and stakeholders in the field of electric power systems. The results of the trial can improve the ability to analyze, make decisions, and manage power system projects in North Sumatra. Collaboratively developed simulation media can facilitate project-based learning because the program used facilitates problem solving with real data, where students can apply theoretical knowledge and develop practical skills needed by users. This is in line with the MBKM policy that encourages students to apply theoretical knowledge and develop practical skills.

The limitations of simulation media research are still tested on case studies or small scales, so the validation and reliability of research results need to be improved. More comprehensive research is needed and with a wider sample reaching not only the province of North Sumatra to ensure consistency and generalization of results based on national level needs mapping. Suggestions for further research improvement are expected to examine ways to integrate simulation media more optimally into the curriculum, learning process, and assessment system. Conduct further development research to utilize the development of virtual reality technology, augmented reality, or artificial intelligence, in the development of more innovative and effective electricity field simulation media.

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