JPPIPA 11(7) (2025)

Jurnal Penelitian Pendidikan IPA

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

Development of Stand Alone Interactıve E-Modules on the Subject of Fundamentals of Network Engıneerıng and Telecommunıcatıons in SMK Imelda Medan

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Received: May 21, 2025
Revised: June 05, 2025
Accepted: July 25, 2025
Published: July 31, 2025

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DOI: 10.29303/jppipa.v11i7.11428

Abstract: The development of interactive learning media is an urgent need at SMK Imelda Medan, especially in the subject of Fundamentals of Network Engineering and Telecommunications. This research aims to develop a standalone interactive E-Module that is valid and effective to improve student learning outcomes. The method used is Research and Development (R&D) with the 4-D model (define, design, develop, disseminate), involving experimental and control classes. The research sample consisted of 108 students of class X Computer and Network Engineering Expertise Programme, selected through purposive sampling. Data analysis included validity, reliability, effectiveness, and statistical tests such as Kolmogorov-Smirnov, Levene, MANOVA, and effect size calculation. The validation results showed that the E-Module was valid and reliable with a loading factor value > 0.7, AVE > 0.5, and reliability value > 0.8. The average score of experimental class students was higher (86.04), especially in practice with a difference of 10.67 points. The paired sample t-test showed a significant difference ($p < 0.001$) with a very large effect size (Cohen's $d > 1.8$). MANOVA confirmed significant multivariate differences. This study proved the high effectiveness of the E-Module and made theoretical, practical, and pedagogical contributions to digital learning in vocational education.

Keywords: Interactive e-module development; Learning outcomes; Network and telecommunication engineering; Stand-alone e-module

Introduction

Education is a fundamental element in developing the quality of sustainable human resources (Leader et al., 2022). As a transformative process, education is not just a transfer of knowledge, but a systematic effort to develop individual potential holistically, equipping students with the ability to think critically, adaptively, and innovatively in facing the complexity of contemporary life challenges (Djonomiarjo, 2020). The main purpose of education is to empower learners to be able to actualize their potential, develop personal and professional competencies, and prepare them to play an active role in the ever-changing social and economic dynamics.

In the context of competency development, vocational education has a strategic role as a vehicle to prepare students to enter the professional realm competently (Avana et al., 2023). Vocational education is defined not simply as a technical skills training program, but rather as a comprehensive education system that integrates the development of knowledge, skills and professional attitudes (Hamalik, 1990). Through a practice-based and contextualized learning approach,

How to Cite:
Nasution, M., Jalinus, N., Irfan, D., Giatman, M., & Syaifullah, L. (2025). Development of Stand Alone Interactıve E-Modules on the Subject of Fundamentals of Network Engıneerıng and Telecommunıcatıons in SMK Imelda Medan. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 664–671. https://doi.org/10.29303/jppipa.v11i7.11428

vocational education aims to foster adaptive competencies that allow graduates to not only be technically skilled, but also able to innovate and develop in a dynamic work environment.

The process of achieving these educational goals is largely determined by the quality of learning. Learning is a systematic interaction between educators, students, and learning resources in an effort to transform knowledge, values, and skills (Rusman, 2017). Learning media plays a crucial role as an instrument that facilitates the process of transmission and construction of knowledge, presents a representation of abstract concepts to be more concrete, and increases motivation and active involvement of students in the learning process (Arsyad, 2011). The use of media that is innovative and appropriate to the characteristics of the material and learners can significantly improve the effectiveness and quality of the learning experience.

The success of the education and learning process can ultimately be measured through learning outcomes, which include cognitive, affective, and psychomotor aspects (Bloom et al., 1956). Learning outcomes are not simply a representation of material mastery, but rather a comprehensive indicator of competency achievement that includes knowledge, skills, attitudes, and applicative abilities in a real context. Each stage of achieving learning outcomes is a reflection of the quality of interaction between students, educators, curriculum, media, and learning environment (Sudjana, 2016). Based on the observations of researchers in the subject of Fundamentals of Network Engineering and Telecommunications, learning problems were identified which were characterized by low student learning outcomes as can be seen in Table 1.

Table 1. Learning Outcomes of Network and Telecommunication Engineering Fundamentals Subjects Even Semester Academic Year 2023/2024

Class	Number of Students	Average Score	
		Number	Letters
X TKJ 1	35	67.98	B-
X TKJ 2	34	51.84	C-
X TKJ 3	32	72.72	B

Based on data from the learning outcomes of the Fundamentals of Network Engineering and Telecommunications subject in the even semester of the 2023/2024 school year, there are variations in learning outcomes in three classes. Class X TKJ 1 with 35 students obtained an average score of 67.98 (predicate B-), X TKJ 2 with 34 students recorded the lowest average score of 51.84 (predicate C-), and X TKJ 3 with 32 students achieved the highest average score of 72.72 (predicate B). This significant difference indicates potential obstacles or variations in the learning process that need to be studied in more depth.

Researchers have also conducted literature studies on factors that influence learning outcomes including the application of learning models (Batubara, 2020; Malla et al., 2018; Polii, 2024; Sukardi et al., 2019), learning approaches (Syaifullah et al., 2024), learning methods (Ronald, 2017; Zaus et al., 2018), learning media (Aurora et al., 2019; Rifdarmon et al., 2023; Sitompul et al., 2018; Suryani et al., 2020), assessment instruments (Hartina et al., 2020; Hasana et al., 2017; Pratiwi et al., 2015), curriculum (Chalim, 2018; Sari, 2019), and intrinsic and extrinsic factors (Afianti et al., 2019; Kurniati et al., 2021; Wigati et al., 2018).

Researchers analyzed the subject of Fundamentals of Network Engineering and Telecommunications, identified that one of the main causes of low learning achievement is the limitation of learning media. One of the media used is a conventional learning module that has a number of significant weaknesses, including: less interactive, unable to accommodate the diversity of learning styles of students, and limited in presenting multimedia content that can improve comprehensive understanding of concepts.

The impact of the limited learning media is evident in the achievement of varied learning outcomes and tends to be low. Class X TKJ 2 with an average score of 51.84 (predicate C-) clearly shows that conventional learning methods and media have not been able to optimally facilitate the process of knowledge construction and competency development of students. Low motivation to learn, lack of active involvement of students, and difficulty in understanding complex concepts of network engineering and telecommunications are direct consequences of learning media that are not responsive to contemporary learning needs.

In an effort to overcome the problems described in the previous paragraph, the researcher offers a solution by developing a standalone interactive E-Module that is systematically designed to overcome learning problems. This interactive E-Module is not just a conventional digital media, but a pedagogical instrument that integrates technology, interactive multimedia concepts, and contextual learning approaches. Through innovative features such as multimedia content, self-evaluation, interactive navigation, and self-learning capabilities without dependence on internet connection, the stand alone interactive E-Module aims to transform students' learning experience.

Several researchers have proven the effectiveness of E-Modules in transforming students' learning experience, especially in subjects that require understanding of complex concepts (Ameriza et al., 2021; Ramadhan et al., 2021). Follow-up studies

confirmed that electronic modules based on contextual approaches can significantly increase learning engagement and motivation (Delianti et al., 2020; Natalia et al., 2021). Research findings reinforce the argument that E-Module innovation is a pedagogical instrument that integrates technology and cutting-edge learning approaches (Ermiyati et al., 2024; Putri et al., 2023). This is in line with the need for learning media transformation that is responsive to the dynamics of contemporary education.

Related research specifically emphasizes the effectiveness of designing interactive learning media, which supports the idea of this research in developing standalone interactive E-Modules (Jafnihirda et al., 2023). A number of studies also strengthen the argument by showing the potential of electronic modules in accommodating diverse learning styles and improving conceptual understanding (Dermawan et al., 2020; Khairani et al., 2022). Although there have been many studies on E-Modules, there is a significant research gap in the subject of Fundamentals of Network Engineering and Telecommunications. Some studies identify that the majority of research focuses on certain fields, while the need for learning media development in network engineering and telecommunications is still very open (Putra et al., 2022).

The urgency of this research lies in overcoming complex learning problems. By developing a standalone interactive E-Module that is able to function without dependence on internet connection, this research offers an innovative solution to overcome the limitations of conventional media. Interactive features, multimedia content, and self-evaluation capabilities aim to transform students' learning experience, increase motivation, and facilitate comprehensive knowledge construction. This research does not simply produce new learning media, but rather makes a significant contribution in developing pedagogical approaches that are responsive to the needs of contemporary vocational education, particularly in the field of network engineering and telecommunications. Therefore, the development of standalone interactive e-modules in the subject of Fundamentals of Network Engineering and Telecommunications at SMK Imelda Medan is very important to do.

Method

This research employs a Research and Development (R&D) approach using the Define, Design, Develop, and Disseminate (4-D) model and utilizes an experimental design involving control and experimental classes. The research population includes all grade X students of the Computer and Network Engineering Program consisting of three study groups with a total of 108 students, with samples selected using purposive sampling technique. Data analysis includes validity and reliability tests and effectiveness through a series of statistical tests, including normality tests using Kolmogorov-Smirnov, homogeneity tests using the Levene method, MANOVA analysis, and effect size calculations to measure the impact of E-Module implementation

Result and Discussion

The results of this study are seen from the effectiveness of the developed e-modules. The instruments used in the research have gone through the stages of questionnaire instrument testing and test instrument testing, Effectiveness is seen after the success of the test.

Paired Sample t-Test Results

The paired sample t-test was conducted to compare two interrelated variables, namely the pre-test with the post-test. This statistical analysis aims to determine significant changes between pairs of variables tested using a 95% confidence degree ($\alpha = 0.05$). The results of the paired sample t-test in this study can be seen in Table 2.

Table 2. Paired sample t-Test Test Results

Paired Samples Test									
Pair	Mean	Paired Differences				t	df	Significance	
		Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			One-Sided p	Two-Sided p
Pre Test – Post Test	-17.73	7.71	1.11	-19.97	-15.50	-15.92	47	<.001	<.001
Pre Test – Practice	-14.43	7.90	1.14	-16.73	-12.12	-12.66	47	<.001	<.001
Post Test – Practice	3.29	8.79	1.27	.73	5.85	2.59	47	.006	.013

Based on Table 2, the paired sample t-test results show that there are three pairs of variables tested. In the pre-test and post-test pairs, the mean difference value is -17.729 with a standard deviation of 7.712. The calculated t value is -15.927 with a degree of freedom (df) of 47, and the significance value (two-sided p) is <0.001. Since this significance value is smaller than 0.05, it can be concluded that there is a significant difference

between the pre-test and post-test scores. The negative sign on the mean difference indicates that the post-test value is higher than the pre-test value, which indicates an increase in student learning outcomes after learning. Furthermore, for the pair of pre-test and practice scores, the mean difference value is -14.438 with a standard deviation of 7.901. The calculated t value is -12.660 with 47 degrees of freedom, and a significance value <0.001. These results indicate that there is a significant difference between the pre-test scores and the practical scores, where the practical scores are higher than the pre-test scores.

The pair of post-test and practice scores showed a mean difference of 3.292 with a standard deviation of 8.795. The calculated t value is 2.593 with 47 degrees of freedom, and a significance value of 0.013. Since this significance value is smaller than 0.05, it can be concluded that there is a significant difference between post-test scores and practical scores. A positive mean difference indicates that the post-test scores are higher than the practical scores. Overall, the paired sample t-test results showed significant changes in all three pairs of variables tested, indicating that the learning process has been effective in improving student learning outcomes in both knowledge (post-test) and skills (practical) aspects.

Effect Size Test Results

The Effect Size test was conducted to measure the magnitude of the influence or effect of the treatment given using the Cohen's d method. This analysis aims to determine the practical significance of changes that occur between pairs of variables tested, namely pre-test and post-test. In the interpretation of Cohen's d, the effect size is divided into three categories: small effect ($0.2 \leq d < 0.5$), medium effect ($0.5 \leq d < 0.8$), and large effect ($d \geq 0.8$). The results of the effect size test in this study can be seen in Table 3.

Table 3. Effect Size Test Results

		Paired Samples Effect Sizes			
		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Pre Test – Post Test	Cohen's d	7.712	-2.299	-2.838	-1.752
Pre Test – Practice		7.901	-1.827	-2.288	-1.359
Post Test – Practice		8.795	.374	.080	.665

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.

Based on Table 3, the effect size test results for pre-test and post-test pairs show a Cohen's d value of -2.299 with a 95% confidence interval between -2.838 and -1.752. The negative value of Cohen's d indicates that there is an increase in value from pre-test to post-test. The absolute value of 2.299 is included in the large effect category ($d \geq 0.8$), which indicates that the treatment provided has a very significant effect on improving student learning outcomes from pre-test to post-test. Furthermore, for the pair of pre-test and practice, the Cohen's d value was -1.827 with a 95% confidence interval ranging from -2.288 to -1.359. This negative value also indicates an increase from the pre-test score to the practice score. The absolute value of 1.827 also falls into the large effect category ($d \geq 0.8$), indicating that the treatment had a very significant effect on improving students' practical ability compared to their initial ability.

Finally, in the last pair, the Cohen's d value was 0.374 with a 95% confidence interval between 0.080 and 0.665. A positive value indicates a slight decrease from post-test to practice scores. The magnitude of 0.374 is included in the small effect category ($0.2 \leq d < 0.5$), which indicates that the difference between post-test scores and practical scores is not very significant. Overall, the results of the effect size test showed that the treatment given in this study had a very large effect on improving student learning outcomes, both from pre-test to post-test and from pre-test to practical scores. However, the effect was relatively small between the post-test and the practical score, indicating that the students' cognitive ability (as measured through the post-test) and their practical ability were at similar levels after the treatment.

Manova Test Results

Multivariate Test is a multivariate statistical analysis used to test the significance of differences between variables simultaneously. In this table, there are two main effects analysed, namely Intercept and Treatment, using four different test statistics: Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. The multivariate test results in this study can be seen in Table 4.

Based on Table 4, the Multivariate Test analysis results show the results of the simultaneous significance test of differences between variables. In the table, there are two main effects analysed, namely Intercept and Treatment (treatment/class), using four different test statistics: Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root. For the Intercept effect,

the Pillai's Trace value was 0.999 with F=16048.127, Wilks' Lambda was 0.001 with F=16048.127, Hotelling's Trace was 1094.190 with F=16048.127, and Roy's Largest Root was 1094.190 with F=16048.127. All test statistics showed a significance value of p<0.001, meaning the Intercept effect was statistically significant. Furthermore, for the Class (treatment) effect, the Pillai's Trace value is 0.726 with F=38.921, Wilks' Lambda is 0.274 with F=38.921, Hotelling's Trace is 2.654 with F=38.921, and Roy's Largest Root is 2.654 with F=38.921. All test statistics show a significance value of p<0.001, which means there is a statistically significant difference between the control class and the experimental class on all three dependent variables (pre-test, post-test, and practical value) simultaneously.

Table 4. Multivariate Test Results

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.999	16048.127[b]	3.000	44.000	<.001
	Wilks' Lambda	.001	16048.127[b]	3.000	44.000	<.001
	Hotelling's Trace	1094.190	16048.127[b]	3.000	44.000	<.001
	Roy's Largest Root	1094.190	16048.127[b]	3.000	44.000	<.001
Class	Pillai's Trace	.726	38.921[b]	3.000	44.000	<.001
	Wilks' Lambda	.274	38.921[b]	3.000	44.000	<.001
	Hotelling's Trace	2.654	38.921[b]	3.000	44.000	<.001
	Roy's Largest Root	2.654	38.921[b]	3.000	44.000	<.001

a. Design: Intercept + Class; b. Exact statistic

This result indicates that the treatment given to the experimental class had a significant effect on students' overall learning outcomes compared to the control class. This treatment effect is consistent and strong based on all four test statistics used in the MANOVA analysis, which strengthens the validity of the research results.

The results showed that the developed E-Module was effective in improving students' learning outcomes, as reflected by the significant increase between the pre-test and post-test scores in both groups. Data analysis showed that the experimental class using the E-Module consistently scored higher than the control class in all aspects of assessment. The experimental class recorded an average pre-test score of 69.25, post-test 85.83, and practice 86.04, while the control class obtained an average pre-test score of 63.29, post-test 82.16, and practice 75.37.

Discussion

The effectiveness test through paired sample t-test confirmed the significance of the changes with a p value <0.001 in all pairs of variables tested. The improvement from pre-test to post-test showed a mean difference of -17.729, indicating a significant increase in learning outcomes after learning. Furthermore, effect size analysis using Cohen's d yielded a value of -2.299 for the pre-test and post-test pairs, far exceeding the threshold of the large effect category (0.8). This finding reinforces the results of Delianti & Jalinus (2020) who also found a significant improvement in learning outcomes using e-modules.

The most significant difference between the control and experimental classes was seen in the practice score with a difference of 10.67 points, followed by the pre-test score (5.96 points), and post-test score (3.67 points). The MANOVA test results showed a multivariate significant difference between the control and experimental groups ($p < 0.001$), which was confirmed by all test statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root). This finding is consistent with the study of Jafnihirda et al. (2023) who reported significant improvement in learning outcomes and learning motivation of students using interactive e-modules.

The effectiveness of the E-Module in this study was supported by the instrument validation results which showed good convergent validity with loading factor values > 0.7 and AVE > 0.5 for all constructs (Pedagogical Feasibility, Self-Instruction, Self-Contained, Multimedia and Design, Technological Adaptability, and Evaluation and Feedback). The reliability test also showed excellent results with Cronbach's Alpha, rho_A, and Composite Reliability values all > 0.8 for all variables, indicating high internal consistency. These results are in line with the findings of Ramadhan et al. (2021) who noted high levels of validity and practicality (material validation 86.25%, media 84.38%, and student response 90.63%) for self-directed learning-based electronic modules. Similar results were also reported by Putri et al. (2023) who noted high validation from material experts (89.6%) and media experts (92.3%).

The most prominent advantage of using E-Modules is seen in the practical aspect, where the experimental class shows an average score of 86.04 compared to the control class which only reaches 75.37. This indicates that the stand alone interactive E-Module is very

effective in facilitating the development of students' practical skills in the Fundamentals of Network Engineering and Telecommunications material. This finding is in line with the research of Ermiyati et al. (2024) who found that a product-based approach in e-module development can improve students' understanding and practical skills.

Overall, the results of this study confirm that the development standalone interactive E-Modules has achieved its goal in producing valid and effective learning media. The E-Module is proven to not only improve student's theoretical knowledge, but also significantly improve their practical skills. The findings make a significant contribution to the body of knowledge of digital learning media development, particularly in the context of network and telecommunication engineering vocational education.

Conclusion

Based on the results of the e-module development research that has been carried out, the following conclusions are obtained, The stand alone interactive E-Module developed in the subject of Fundamentals of Network Engineering and Telecommunications has met the valid criteria based on the validation results of all aspects of the assessment with a loading factor value> 0.7 and AVE value> 0.5 in the convergent validity test, as well as Cronbach's Alpha, rho_A, and Composite Reliability reliability values that are consistently above 0.8 for all variables. Based on the results of the material validity test with an average value of 0.89 and media validation with an average of 0.88, it can be concluded that the material and media validation can be declared "valid". The developed stand alone interactive e-module is proven effective in improving student learning outcomes, as evidenced by the increase in the average value of the experimental class which is higher than the control class in the pre-test, post-test, and practice aspects, with the biggest difference being in the practice value (difference of 10.67 points). Significant paired sample t-test results ($p < 0.001$). The very large Cohen's d effect size values for the pairs of pre-test and post-test (-2.299) and pre-test and practice (-1.827) indicate that the E-Module has a very significant learning impact. Finally, the MANOVA test results proved multivariate significant differences ($p < 0.001$) between the control and experimental groups on all dependent variables simultaneously, indicating the effectiveness of the stand alone interactive E-Module in improving students' learning outcomes.

Acknowledgments
Thank you to the supervisors and discussants who have provided knowledge related to this writing.

Author Contributions
Conceptualization, M.N, N.J; methodology, M.N, M,G.M,; validation, D.I. and T. R.; formal analysis, M.N, N.J, L.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

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