An Experimental Study on the Comparison of Learning Outcomes in VLAN Configuration Using Graphical Network Simulator 3 and Cisco Packet Tracer

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ABSTRACT

Selecting an appropriate network simulator for advanced VLAN instruction in higher education remains an unresolved pedagogical challenge, as empirical comparisons of GNS3 and Cisco Packet Tracer at university level are scarce. This study aimed to examine (1) whether a significant difference in VLAN configuration learning outcomes exists between students using GNS3 and those using Cisco Packet Tracer, and (2) the relative effectiveness of each simulator for students of the Informatics and Computer Engineering Education Program (PTIK) at Universitas Sebelas Maret. A quasi-experimental pre-test–post-test design was employed with two intact classes ($N = 30$) from the 2023 cohort, randomly assigned to the GNS3 condition ($n = 15$) and the Cisco Packet Tracer condition ($n = 15$). Learning outcomes were measured using ten validated essay items ($\alpha = 0.673$) and analysed via an independent-samples t-test and normalised gain (N-gain) index. Results revealed that GNS3 users outperformed Packet Tracer users on the post-test (mean 79.33 vs. 72.80), with a statistically significant difference ($t(28) = 2.224$, $p = 0.034$). N-gain analysis further showed that the GNS3 group achieved moderate learning effectiveness ($g = 0.452$), compared to the low category recorded for the Cisco Packet Tracer group ($g = 0.277$). These findings suggest that GNS3's authentic Cisco IOS emulation fosters deeper cognitive engagement with advanced VLAN tasks—including inter-VLAN routing and native CLI syntax—than the abstracted environment of Packet Tracer. GNS3 is therefore recommended as the primary simulator for advanced networking courses in higher education, while Packet Tracer remains appropriate for introductory-level instruction. Future research should replicate this design with larger, multi-institutional samples to strengthen external validity.

Keywords: VLAN, GNS3, Cisco Packet Tracer, learning outcomes, network simulation

1. INTRODUCTION

The development of information and communication technology (ICT) encourages the education sector to continuously innovate, particularly in developing adaptive and contextual learning methods. The configuration of Virtual Local Area Networks (VLANs) represents one of the essential competencies in computer networking education, playing a strategic role in network segmentation, data traffic efficiency, and system security in large-scale institutions or organizations. VLANs are also critical in enhancing the performance, security, and scalability of networks through effective segmentation (Shaik, 2024). In response to the demands of technological advancements and the requirements of the 21st-century workforce, higher education, especially in informatics engineering, is required to adapt to innovations in learning media. Patikasari et al. (2022) emphasize that in order to follow the rapid progress of technology and information in education, instructors must utilize appropriate learning media. Several challenges in teaching computer networks include the limitation of physical devices, the complexity of materials, and the difficulty in understanding highly technical configuration processes. To bridge these challenges, simulation-based learning media emerge as a highly relevant alternative. Network simulators allow students to explore concepts and practice configurations independently and safely, without being fully dependent on expensive or limited hardware resources (Runtuwene et al., 2024). With such support, the learning process is expected to become more effective, efficient, and capable of significantly improving students' learning outcomes.

Two of the most widely used software tools are Cisco Packet Tracer and Graphical Network Simulator 3 (GNS3). Cisco Packet Tracer is known for its user-friendly interface, making it suitable for beginner-level learning, while GNS3 offers more realistic and complex networking simulations (Putra, 2020; Okhrimchuk & Okhrimchuk, 2024). Both provide positive impacts on learning; however, GNS3 delivers more in-depth VLAN configuration capabilities compared to Packet Tracer. GNS3 provides full support for VLAN configuration on Cisco IOS devices that can be integrated with real physical equipment (Vesel et al., 2016). Furthermore, according to Podsanikov (2021), GNS3 enables complex VLAN configuration, including Inter-VLAN routing and Private VLAN (PVLAN) configuration in a realistic manner. In contrast, Packet Tracer lacks integration with physical devices and provides less comprehensive support for advanced VLAN commands. On the other hand, GNS3 is recognized for its flexibility and capability to simulate real networking devices. Siregar et al. (2023), in their study at SMK Negeri 1 Marancar, demonstrated that using GNS3 resulted in a better conceptual understanding compared to Packet Tracer, especially for advanced networking topics such as wide-area network configurations. Other studies, such as Apriliansyah & Ariyadi (2025) and Sholid et al. (2025), also highlighted the effectiveness of Packet Tracer in VLAN practices, but few have directly compared the performance of both simulators in the context of VLAN configuration in higher education.

A research gap exists since the majority of prior studies were conducted at the vocational high school (SMK) level, with limited experimental studies focusing specifically on comparing the effectiveness of GNS3 and Cisco Packet Tracer in higher education contexts, particularly within PTIK UNS. Therefore, this study aims to compare students' learning outcomes in VLAN configuration assessments using the two different simulators: GNS3 and Cisco Packet Tracer. The findings are expected to contribute to the development of simulation-based learning strategies and serve as a basis for selecting appropriate learning media in network-related courses, supporting the achievement of computer networking competencies in PTIK UNS. More specifically, the novelty of this study lies in its focus on university-level competencies that go beyond introductory VLAN concepts typically taught at the SMK level. At the higher education level, students are expected to master advanced VLAN skills, including: (1) complex CLI-based command sequences such as trunking, VTP configuration, and access port assignment on Cisco IOS; (2) Inter-VLAN routing using router-on-a-stick or Layer-3 switch configurations; and (3) integration with physical or near-physical networking environments. These competencies are more authentically assessed through GNS3, which runs actual Cisco IOS images and supports the full command syntax encountered in real-world and industry-certification scenarios (e.g., CCNA). Cisco Packet Tracer, by contrast, uses a simplified command set that omits certain IOS behaviors, potentially limiting students' exposure to authentic network administration tasks at the university leve.

2. RESEARCH METHOD

This study employs a **quantitative approach**, grounded in the philosophy of positivism, which emphasizes objective phenomena analyzed using numerical data, statistical processing, structured design, and controlled experimentation (Sukmadinata, 2010). The research design applied is a **quasi-experimental design**, involving two different classes, namely the control class and the experimental class, each receiving different treatments. According to Arikunto (2000), experimental research is intended to determine whether or not there is an effect of a treatment on the investigated subjects. In this study, the quasi-experimental design was implemented using **pre-test** and **post-test** instruments to measure learning outcomes.

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Experimental	O_1	X_1 (Simulation using GNS3)	O_2
Control	O_2	X_2 (Simulation using Packet Tracer)	O_4

Population and Sampling: The sampling technique used in this study was **total sampling**, in which the entire population was included as the research sample. The population consisted of students enrolled in the Computer Network Technology practice class of PTIK, batch 2023. The rationale for applying total sampling was that the available population was naturally divided into two intact classes (Class A and Class B), with each class comprising exactly 15 students. Because the total population size was already small and the two classes presented a ready-made quasi-experimental structure, drawing a further sub-sample would have been neither practical nor statistically beneficial. Nevertheless, the authors acknowledge that a sample of N=30 (15 per group) is a limitation of this study: the small sample size reduces statistical power and limits the generalizability of the findings beyond the PTIK 2023 cohort at UNS. Future studies are encouraged to replicate this design with larger and more diverse samples across multiple institutions to strengthen external validity. Regarding the treatment conditions: X1 (experimental group) received instruction and practical exercises using GNS3 integrated with Cisco IOS images, while X2 (control group) undertook the same exercises using Cisco Packet Tracer. Both groups were taught by the same instructor, used identical learning objectives and task sheets covering VLAN creation, trunk configuration, and inter-VLAN routing, and completed the intervention over two weekly 2-hour sessions. Standardizing the instructional materials and duration across both groups was essential to ensure that any observed difference in learning outcomes could be attributed to the simulator used rather than to differences in content or instructional time.

Research Instruments: The research instrument was a test consisting of 10 essay questions, accompanied by a scoring guideline. According to Arikunto (2010:193), a test is a series of questions, exercises, or other tools used to measure skills, knowledge, intelligence, abilities, or talents of individuals or groups.

Instrument Testing, the test instrument underwent several stages of validation, including: 1). Validity Test,2). Reliability Test,3). Item difficulty analysis,4). Discrimination index analysis.

Data Analysis Technique, the collected data were analyzed using several statistical tests, namely:1). Normality Test,2). Homogeneity Test,3). Balance test,4). Hypothesis testing (t-test),5). N-gain index analysis.

3. RESULT AND ANALYSIS

The research subjects were students of the PTIK 2023 cohort, Class B, consisting of 30 students, who were divided into two groups: 1). 15 students using the GNS3 network simulator, 2). 15 students are using the Cisco Packet Tracer network simulator. The item analysis test was conducted by students of PTIK 2023, Class A, who had equivalent abilities to the research respondents and had already completed the basic competencies. This served as the basis for determining the validity of test items and the reliability of the test instruments.

3.1. RESULT

The results of the test analysis were then processed and presented in Table 1.2

Table 1.2. Instrument Testing Validation

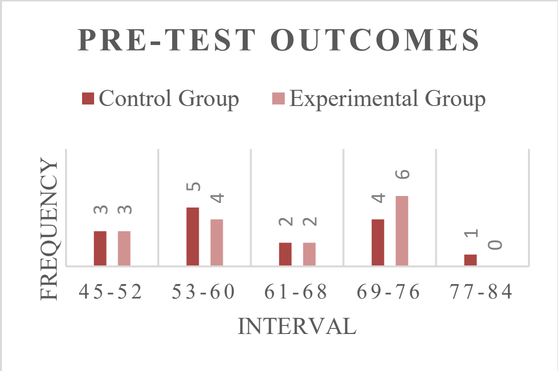
Test	Item Validation	Difficulty Level (P)	Discrimination Index (D)	Conclusion	Reliability
Learning Outcomes	1,2,3,4,5,6,7,8,9,10	Difficult: item 5, Moderate: item 1,2,3,4,6,8,9 Easy: item 7,10	Good: items 1, 7, 9, 10 Fair: items 2, 3, 4, 5, 6, 8 Poor: -	All items were used (1-10)	0,673

The pre-test was obtained from the learning outcomes prior to conducting the experiment in this study. The pre-test results were calculated using SPSS 25. The data used in this calculation were the pre-test scores from both the control class and the experimental class, with detailed results presented in Table 1.3 and Figure 1.1

Table 1.3. Pre-test outcomes: Control and Experimental Group

Learning Outcomes Statistic	Mean	Lowest Score	Highest Score	Standard Deviation	Variance
Control Group	62,4	48	78	10,03	100,69
Experimental Group	62,27	46	74	9,82	96,5

Figure 1.1. Pre-Test Outcomes

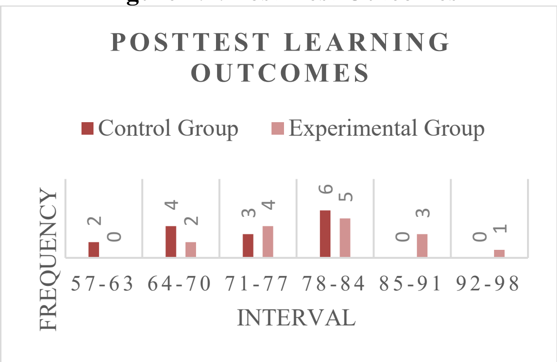


Based on Figure 1.1, it can be observed that the learning outcomes of the control class were the lowest in the score interval of 77–84, with a frequency of 1 student and a percentage of 6.7% of the total data. The highest results in the control class were found in the interval of 55–60, with a frequency of 5 students and a percentage of 33.3%. Meanwhile, the lowest learning outcomes of the experimental class were in the interval of 61–68, with a frequency of 2 students and a percentage of 13.3% of the total data. The highest outcomes in the experimental class were in the interval of 69–76, with a frequency of 6 students and a percentage of 40% of the total data. These data were obtained from the post-test results of both the control and experimental classes using SPSS 25, and are presented in detail in Table 1.4

Table 1.4. Post-test outcomes: Control and Experimental Group

Learning Outcomes Statistic	Mean	Lowest Score	Highest Score	Standard Deviation	Variance
Control Group	72,8	58	84	7,78	60,5
Experimental Group	79,33	64	94	8,3	68,95

Figure 1.2. Post-Test Outcomes



Based on Figure 1.2, it can be observed that the learning outcomes of the control class were the lowest in the score interval of 85–91 and 92–98, with a frequency of 0 students and a percentage of 0% of the total data. The highest results in the control class were found in the interval of 78–84, with a frequency of 6 students and a percentage of 40%. Meanwhile, the lowest outcomes in the experimental class were in the interval of 57–63, with a frequency of 0 students and a percentage of 0% of the total data. The highest outcomes in the experimental class were in the interval of 78–84, with a frequency of 5 students and a percentage of 33.3% of the total data.

3.2. ANALYSIS

Based on the results of the pre-test and post-test, there was an improvement in learning outcomes. The following presents the distribution of learning outcome improvements in the form of gain index values for the control and experimental classes, as shown in Table 1.5.

Table 1.5. Improvement in learning outcomes (Gain Index)

Classes	Pre-test Mean	Post-test Mean	Gain Index	Description
Control Group	62,4	72,8	0,277	Low
Experimental Group	62,27	79,33	0,452	Moderate

Hypothesis testing in this study was conducted using a parametric inferential statistical approach with an independent-samples t-test. The pre-test data were analyzed to determine the equivalence of students' initial abilities, whereas the post-test data were examined to identify significant differences in the final learning outcomes. The results of the hypothesis testing are presented in Table 1.6.

Table 1.6. Result of hypothesis testing

Classes	N	sig	α=5%	Criteria	Description
Experimental Group	15	0,034	0,05	0,034 < 0,05	H_0 rejected & H_1 accepted
Control Group	15				

Based on the results shown in Table 1.6, the initial hypothesis test with a significance level of sig < 0.05 obtained a value of 0.034 < 0.05, with *t*-calculated < *t*-table (0.034 < 0.05). Therefore, the null hypothesis (H_0) was rejected, and the alternative hypothesis (H_1) was accepted, indicating a significant difference in learning outcomes between the use of GNS3 and Cisco Packet Tracer network simulators.

Furthermore, the results of the second hypothesis test revealed that the gain index in the control class was 0.277, which indicates that the effectiveness of using Cisco Packet Tracer was categorized as low. Meanwhile, the gain index in the experimental class was 0.452, which signifies that the effectiveness of using GNS3 was in the moderate category. Therefore, it can be concluded that the improvement in learning effectiveness through the application of GNS3 is higher compared to Cisco Packet Tracer. These statistical findings can be explained from both a pedagogical and technical standpoint. From a technical perspective, GNS3 operates by emulating actual Cisco IOS images, which means students interact with the same command-line interface (CLI) syntax, error messages, and device behaviors they would encounter on real Cisco hardware. This is particularly significant for VLAN configuration, where advanced commands such as "switchport trunk encapsulation dot1q", VTP domain configuration, and Layer-3 inter-VLAN routing via Switched Virtual Interfaces (SVIs) are fully supported in GNS3 but either absent or simplified in Packet Tracer. When students in the experimental group successfully configured inter-VLAN routing and observed actual routing table entries in the IOS output, they were engaging with authentic network behavior rather than a simulated abstraction.

From a pedagogical standpoint, this authenticity aligns with cognitive load theory and situated learning principles. Cisco Packet Tracer provides a scaffolded, icon-driven environment with limited command sets, which is appropriate for novice learners at the SMK level who need to reduce extraneous cognitive load.

However, for university-level students in PTIK who are expected to develop professional-grade competencies, this same simplification becomes a ceiling rather than a scaffold. The abstraction offered by Packet Tracer may prevent students from developing a schema for how real IOS devices behave, whereas the realistic environment of GNS3 forces students to engage with genuine problem-solving – interpreting actual IOS error outputs, troubleshooting spanning-tree port states, and verifying VLAN databases – which promotes deeper cognitive processing and schema construction (Chernikova et al., 2022). The higher gain index of the GNS3 group (g = 0.452, moderate) compared to the Packet Tracer group (g = 0.277, low) is therefore consistent with the expectation that higher cognitive engagement produces greater learning gains, even within a short intervention period.

4. CONCLUSION

Addressing the gap identified in prior literature — wherein experimental comparisons of GNS3 and Cisco Packet Tracer at the higher education level were absent — this study confirms that GNS3's authentic Cisco IOS emulation yields measurably superior learning outcomes over Packet Tracer's abstracted environment in the context of advanced VLAN configuration instruction. The results of the independent sample *t*-test indicated a significant difference in students' learning outcomes between the use of GNS3 and Cisco Packet Tracer simulators in the VLAN module, with a significance value of $0.034 < 0.05$ and *t*-calculated > *t*-table ($2.224 > 2.0484$) at the 0.05 significance level. Furthermore, the analysis of the gain index revealed that the improvement in learning outcomes in the experimental class was greater than that in the control class. The experimental class, which used the GNS3 simulator, achieved a gain index of 0.452, categorized as moderate, whereas the control class, which used the Cisco Packet Tracer simulator, obtained a gain index of 0.277, categorized as low.

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