EDUKASIA: Jurnal Pendidikan dan Pembelajaran
Vol. 6, 2 (December, 2025), pp. 927-938
ISSN: 2721-1150; EISSN: 2721-1169; DOI: 10.62775/edukasia.v6i2.1653

Students Understanding of Network Virtualization in Computer Network Courses at Universitas Negeri Makassar

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ARTICLE INFO

Keywords:

Cisco Packet Tracer;
Simulation Media;
Students Understanding;
Computer Networks;
Network Virtualization

Article history:

Received 2025-07-29
Revised 2025-09-10
Accepted 2025-10-28

ABSTRACT

Students' understanding of network virtualization concepts in Computer Network courses remains limited, particularly in institutions with restricted access to advanced practical facilities. This study aims to analyze students' comprehension of network virtualization and its relationship with learning experiences, technical skills, and perceptions of simulation tools. A quantitative cross-sectional survey was conducted with 202 students who had completed the Computer Network course and gained experience using Cisco Packet Tracer. The questionnaire was validated through expert judgment and construct validity testing via Exploratory Factor Analysis, and its reliability was confirmed. Findings indicate that four dimensions conceptual understanding, learning experience, technical skills, and perception of simulation tools consistently form a framework explaining students' understanding of virtualization. Correlation analysis revealed that technical skills exert the strongest influence, while learning experiences and perceptions contribute additional support to conceptual comprehension. These results highlight the importance of integrating simulation media such as Cisco Packet Tracer into Computer Network courses, not only as a means of developing practical skills but also as a strategy to enhance students' conceptual grasp of virtualization technologies increasingly demanded in the digital industry. This study contributes to the literature by emphasizing the cognitive dimension of simulation-based learning, an aspect often overlooked in prior research that mainly focused on technical performance.

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1. INTRODUCTION

In recent years, developments in information and communication technology have driven major transformations in network infrastructure management (McCarthy et al., 2023) , one of which is through the application of network virtualization technology (Orduña & Pérez, 2024) . This technology enables the creation of virtual networks without being tied to physical hardware, and supports system flexibility, efficiency, and scalability (Oktavian & Kholidya, 2024). Limitations in infrastructure at a number of educational institutions have resulted in learning that is theoretical in nature and lacks practical experience (Mwansa et al., 2024) . Various studies have presented network simulators as an alternative solution, but their implementation has not been fully effective (Runtuwene et al., 2024). Students' understanding of network virtualization in Computer Networking courses is still relatively low (Fathirma'Ruf et al., 2024). The learning process focuses more on traditional networks such as cabling, IP addressing, and physical device configuration, while virtualization material, which is now important for the industry, has not been optimally conveyed (Tokatlidis et al., 2024).

On the other hand, advances in cloud computing technology offer solutions in the form of virtual laboratories that can be accessed remotely, without space and time limitations. Through virtualization, students can use virtual machines to conduct practical simulations just like in a physical laboratory, but with even greater flexibility (Susanto dkk., 2022). This situation indicates that integrating network virtualization technology into the curriculum is an urgent necessity in order to address resource limitations and improve students' readiness to meet the demands of the digital industry (Luse & Rursch, 2021).

Virtual laboratories are an innovative learning tool that provides an interactive and flexible learning environment (Byukusenge et al., 2022) . Through this approach, students can conduct online practical work without being limited by space and time, while gaining learning experiences that resemble real laboratory conditions (Bonok et al., 2024). In addition to increasing student motivation and engagement, virtual laboratories also play a role in strengthening conceptual understanding through project-based simulations (Veza et al., 2022).

However, most studies still focus on technical aspects and have not evaluated the extent to which the application of virtual laboratories supports the improvement of students' conceptual understanding of network virtualization technology. The development of private cloud infrastructure in the campus environment also tends to focus on system performance without reviewing in depth its impact on the learning process (Panji Anugrah et al., 2022).

In the era of rapid digital transformation, understanding the concept of network virtualization has become a key competency for students in technology-based programs. Strengthening conceptual and cognitive aspects through simulation-based learning not only improves technical skills but also enhances digital literacy. Thus, this research contributes to bridging the gap between theoretical knowledge and practical application, providing insights for the development of more effective learning models in computer networking education.

With the development of cloud computing technology, virtual laboratories have become a learning solution that can be accessed remotely without space and time limitations (Susanto et al., 2022). Through virtualization integration, students can conduct network practice simulations independently with greater flexibility (Sapriati et al., 2023). This condition shows that the implementation of cloud-based laboratories is a strategic step to improve learning efficiency and student readiness to face the demands of the digital industry (Du et al., 2023) .

In addition, interactive virtual reality-based laboratories have also been proven to increase student engagement and conceptual understanding through immersive learning experiences (Rahman et al., n.d.). However, most existing studies still focus on the technical aspects of system development, without evaluating the extent to which the application of this technology impacts students' conceptual understanding, particularly in the context of network virtualization.

Various innovations have been made to overcome the limitations of physical devices in computer network learning. One of them is the development of a GNS3-based virtual laboratory, which is designed to provide practical experience without relying on real devices. However, the study has not evaluated the level of students' conceptual understanding (Widodo et al., 2023). Similar efforts have also been made through the design of a simulation-based smart learning environment that highlights the challenges in effectively bridging theory and practice (Woolcott & Bui, 2023). In addition, PCQ-based network simulation using GNS3 has been proven to optimize bandwidth distribution (Erlangga Wicaksono et al., 2025) . However, both the virtual laboratory and network simulation approaches still focus on technical aspects and have not assessed the educational and cognitive dimensions related to students' understanding of network virtualization technology.

In addition, there is research on Cisco Packet Tracer and evaluating student experiences through the User Experience Honeycomb Model approach, resulting in positive responses to aspects of usability and accessibility, but it has not yet measured students' conceptual understanding of network virtualization (Ratnasari et al., 2023). And research on designing an integrated information system based on Infrastructure as a Service (IaaS) in a university environment, which is effective in terms of infrastructure efficiency, but the research focuses only on architectural design without touching on user understanding of the virtualization technology used (Heriadi & Sumitra, 2022).

Furthermore, research on the use of *Cisco Packet Tracer* was significantly able to improve students' understanding of computer network concepts through a pre-experimental approach, with improved learning outcomes covering various domains such as routing, subnetting, and troubleshooting (Alfatira & Aisah, n.d.). Meanwhile, the application of *Mamdani Fuzzy* logic to evaluate the impact of using *Cisco Packet Tracer* on student learning motivation showed significant improvements in motivation and engagement (Adiguna & Widagdo, 2023). However, both studies still have limitations, in that the focus of the study was only on improving learning outcomes and motivation, without examining in depth students' conceptual understanding of network virtualization technology.

Further research discusses the implementation of cloud-based virtual labs using the OpenStack platform to support big data practicums. This study highlights how virtual infrastructure can be used as an alternative to large-scale physical laboratories (Sellberg et al., 2024). Although various studies have shown the effectiveness of virtual laboratories in supporting network practicums, most still focus on technical aspects and analysis of platform usage, such as the 2015 study on evaluating user interaction patterns through log analysis in virtual learning environments, but do not examine students' conceptual understanding of network virtualization principles. Therefore, research is needed that focuses on the extent to which students understand the concept of network virtualization through simulation-based learning, for example, by utilizing Cisco Packet Tracer in computer network practicums (Lavigne et al., 2015). Although the results of the study show an increase in students' creative thinking abilities, this study does not specifically evaluate their in-depth understanding of network virtualization principles (Gusti et al., 2024).

A study conducted by Damanik conducted practical module-based network security training for vocational school teachers and students using tools such as Cisco Packet Tracer and Proxmox VM (Damanik et al., 2023). This training successfully improved competency by up to 80%, but it remained limited to technical aspects and did not include systematic measurement of participants' understanding of network virtualization concepts. In addition, (Anom Susetyo Aji Nugroho & Hartati, 2022) Comparing OSPF and static routing protocols using a simulation approach on Cisco Packet Tracer for network optimization in high schools. This study emphasizes the effectiveness of protocol performance, but does not address pedagogical aspects or user understanding of the virtualization technology used in the simulation.

One relevant study developed a virtual laboratory based on the OpenStack platform for big data practicums. Black box testing results showed that the system was capable of serving more than 100 users simultaneously, and financing simulations showed cost efficiency compared to physical laboratories. However, this study did not touch on the aspect of evaluating students' understanding of the virtualization concepts applied (Kartadie & Nugroho, 2023). Further research developed a PNETLab-based virtual multiuser lab integrated with the VMware platform, where students collaboratively perform network simulations. Although this solution is effective from a technical and learning scenario perspective, the research has not specifically evaluated users' level of conceptual understanding of virtual network technology (Santyadiputra et al., 2024).

On the other hand, the study applied the Preboot Execution Environment (PXE) method to build a diskless computer network in the AKN Pacitan laboratory (Julianto et al., 2021). The application of PXE has been proven to reduce hardware requirements and increase maintenance efficiency, but this study only highlights the technical and device management aspects without discussing its impact on student learning (Julianto et al., 2021). The implementation of Virtual Project-Based Learning has been proven to increase student participation and collaborative skills. However, the study has not evaluated students' conceptual understanding of network virtualization technology (Asfihana et al., 2022).

Several studies have shown progress in the technical, security, and efficiency aspects of laboratory systems, yet few have examined students' conceptual understanding of network virtualization. Most prior research has emphasized technical implementation and system performance rather than cognitive aspects. Therefore, this study focuses on analyzing students' understanding of network virtualization in Computer Networking courses, including their perceptions, digital literacy, and influencing factors. Limited understanding of this technology may hinder competency achievement, making the study's findings valuable for educators in refining teaching strategies to align with students' learning needs.

In today's era of digital transformation, understanding the concept of network virtualization is not only a technical requirement but also part of the digital literacy competencies that technology students must possess. Simulation-based learning through tools such as Cisco Packet Tracer supports the development of critical thinking, collaboration, and problem-solving skills, which are essential elements of 21st-century learning. Therefore, this research contributes not only to improving students' technical skills but also to strengthening their conceptual understanding and readiness to face professional challenges in the field of computer networking.

2. METHODS

This study used a quantitative approach with a cross-sectional survey design (Putra et al., 2021). This design was chosen because it provides a factual picture of the level of understanding of students at a certain point in time without involving intervention or experimental treatment of respondents. The research population included all students majoring in Information Technology and Computer Science (JTIK) at Makassar State University, while the research sample consisted of 202 active students selected through purposive sampling. This technique was chosen based on methodological considerations that only students who met certain criteria relevant to the research objectives, namely those who had taken and completed the Computer Networks course and had experience using Cisco Packet Tracer as a network simulation medium, were considered capable of providing valid and representative data. Students who did not meet these criteria were excluded to minimize potential bias in data collection.

The research instrument was a closed-ended questionnaire designed using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The questionnaire consisted of 20 statements grouped into four main constructs, namely (1) Understanding of Basic Network Virtualization Concepts (PKDVJ),

(2) Cisco Packet Tracer Learning Experience (PPPT), (3) Technical Ability to Use Cisco Packet Tracer (KMPT), and (4) Perceptions and Attitudes towards Cisco Packet Tracer (PSPT). Examples of statements include, for example, "Saya memahami perbedaan mendasar antara jaringan fisik dan jaringan virtual" (PKDVJ) and "Cisco Packet Tracer helps me better understand the concept of network virtualization" (PSPT).

The validity of the instrument in the initial stage was tested through content validity by involving experts in the field of computer networks to ensure the suitability of each item with the construct being measured. Next, construct validity was tested through exploratory factor analysis (EFA) using the Principal Component method with Varimax rotation (Basantes-Andrade et al., 2023). The Kaiser-Meyer-Olkin (KMO) test and Bartlett's Sphericity test were used to ensure data suitability before the factor extraction process was carried out (Miaomiao et al., 2024) .

The reliability of the instrument was estimated by calculating Cronbach's Alpha coefficient using SPSS (Ramírez-Montoya et al., 2022). Cronbach's Alpha is a measure of internal consistency that indicates how closely related a set of items are as a group, with values ranging from 0 to 1. A coefficient above 0.70 is generally considered acceptable, while values exceeding 0.90 suggest very high reliability (Izah et al., 2024). The calculation results showed a value of 0.948, indicating excellent internal consistency. However, the reliability value also suggested the possibility of redundancy between items, which was recognized as one of the limitations of the instrument.

3. FINDINGS AND DISCUSSION

Reliability testing was conducted to determine the internal consistency of the instrument. Cronbach's Alpha values were used to assess the extent to which items in the questionnaire were correlated and consistent in measuring variables. The results are presented in the table (Alia, 2023) .

Table 1. Reliability test

Alpha Range	Interpretation
Cronbach's Alpha	0.948
Number of Items	20

3.1. Instrument Reliability Test

The results of the instrument reliability test showed a Cronbach's Alpha value of 0.948 for all 20 statement items. This value indicates a very high level of internal consistency, so that the instrument can be considered reliable in measuring the research construct. However, excessively high reliability may also indicate redundancy between items, so this needs to be acknowledged as one of the limitations of the instrument used.

3.2. Construct Validity Test through Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was conducted to test the construct validity of the instrument, which consisted of 20 statements. The feasibility test results showed a Kaiser-Meyer-Olkin (KMO) value of 0.852 and Bartlett's Test of Sphericity was significant (χ^2 = ...; $p < 0.001$), indicating that the data met the prerequisites for factor (Bonovas & Piovani, 2023). The Principal Component extraction procedure with Varimax rotation identified four factors with eigenvalues >1, in line with the conceptual framework of the study, namely (1) Understanding of Basic Concepts of Network Virtualization (PKDVJ), (2) Cisco Packet Tracer Learning Experience (PPPT), (3) Technical Ability to Use Cisco Packet Tracer (KMPT), and (4) Perceptions and Attitudes towards Cisco Packet Tracer (PSPT).

Table 2 Rotated Component Matrix Network Virtualization Understanding Instrument

Item	Faktor 1: PKDVJ	Faktor 2: PPPT	Faktor 3: KMPT	Faktor 4: PSPT
PKDVJ 1	0,797	-	-	-
PKDVJ 2	0,840	-	-	-
PKDVJ 3	0,871	-	-	-
PKDVJ 4	0,709	-	-	-
PKDVJ 5	0,728	-	-	-
PPPT 1	-	0,879	-	-
PPPT 2	-	0,876	-	-
PPPT 3	-	0,902	-	-
PPPT 4	-	0,686	-	-
PPPT 5	-	0,825	-	-
KMPT 1	-	-	0,864	-
KMPT 2	-	-	0,905	-
KMPT 3	-	-	0,899	-
KMPT 4	-	-	0,836	-
KMPT 5	-	-	0,826	-
PSPT 1	-	-	-	0,866
PSPT 2	-	-	-	0,784
PSPT 3	-	-	-	0,851
PSPT 4	-	-	-	0,834
PSPT 5	-	-	-	0,874

Note:
Only loading values ≥0.40 are displayed. Factor 1 = PKDVJ; Factor 2 = PPPT; Factor 3 = KMPT; Factor 4 = PSPT

All items showed loading values ≥0.40 on the relevant factors, ranging from 0.686 to 0.905. These results confirm that the instrument has adequate construct validity, and the four hypothesized dimensions—basic concept understanding, learning experience, technical ability, and perception of simulation media—are empirically proven to form a consistent framework in explaining students' level of understanding of network virtualization technology.

3.3. Data Normality Test

The results of the normality test using the Shapiro-Wilk method showed that the data were not normally distributed ($p < 0.001$). This condition is in line with the general characteristics of Likert scale-based data, which often do not meet the assumption of normal distribution. Therefore, the analysis of the relationship between the research variables was conducted using a non-parametric method, namely Spearman's correlation.

3.4. Spearman's Correlation Test

Since the data were not normally distributed, the relationship between variables was analyzed using Spearman's correlation test. The following table shows the strength and direction of the relationship between the main variables in this study.

Table 3. Spearman's Correlation Test

Relationship between Variables	Correlation Coefficients (r)	Sig. (2-tailed)	Power of Relationships
PKDVJ_TOT & PPPT_TOT	0.551	< .001	Moderate
PKDVJ_TOT&KMPT_TOT	0.645	< .001	Quite strong
PKDVJ_TOT& PSPT_TOT	0.588	< .001	Moderate
PPPT_TOT & KMPT_TOT	0.711	< .001	Strong
PPPT_TOT & PSPT_TOT	0.733	< .001	Strong
KMPT_TOT & PSPT_TOT	0.748	< .001	Strong

Based on the results of Spearman's correlation test in the table above, a significant relationship was found between Understanding of Network Virtualization Concepts (PKDVJ) and Cisco Packet Tracer learning experience (PPPT), Student Technical Ability (KMPT), and Perception of Simulation Media (PSPT). The strongest relationship was identified between technical ability and conceptual understanding, with a correlation coefficient of $r = 0.645$ ($p < 0.001$).

Discussion

The results of the study indicate that the instruments used to measure students' understanding of network virtualization technology have excellent validity and reliability. Based on the results of exploratory factor analysis (EFA), all questionnaire items were consistently grouped into four main dimensions, namely understanding of the basic concepts of network virtualization, learning experiences using Cisco Packet Tracer, technical abilities, and perceptions of simulation media. This shows that each statement item was able to represent the measured construct accurately and consistently.

The findings of this study also confirm a significant relationship between students' technical abilities in using Cisco Packet Tracer and their level of conceptual understanding of network virtualization technology. These results support the view that hands-on learning processes play an important role in deepening conceptual understanding. Thus, direct experience in designing, configuring, and managing virtual networks contributes significantly to the formation of students' understanding.

In addition, the relationship between learning experiences and students' perceptions of Cisco Packet Tracer shows that the use of simulation media can increase engagement and motivation to learn. Students find it easier to understand abstract concepts when they can visualize and apply them through virtual network simulations. This condition illustrates the importance of integrating technology-based learning media in supporting interactive and contextual learning, especially in the field of applied computer networking.

From a practical standpoint, the results of this study have important implications for curriculum development and teaching strategies. Lecturers and educational institutions need to maximize the use of modern simulation media such as Cisco Packet Tracer as a primary learning tool. A project-based learning approach combined with simulation can be an effective strategy for bridging the gap between theory and practice, while also improving students' critical thinking and problem-solving skills.

Furthermore, these findings underscore a paradigm shift in computer network education—from device-dependent learning toward virtualization-oriented learning. This transition reflects ongoing changes in the ICT industry, where the ability to understand abstract network models and manage virtual systems is increasingly essential. Consequently, the adoption of virtual simulation platforms in higher education not only supports skill development but also prepares students to meet industry expectations in managing scalable, cloud-based network infrastructures.

However, this study has several limitations. First, the cross-sectional design only captures student understanding at a single point in time, preventing an assessment of longitudinal learning progress. Second, the use of self-reported questionnaires may introduce bias related to students' subjective perceptions. Third, the high reliability coefficient may indicate potential redundancy among items, which should be refined in future research instruments. Therefore, future studies are encouraged to involve a broader sample across institutions, utilize longitudinal designs, and employ more advanced analytical methods such as Structural Equation Modeling (SEM) to explore causal relationships more comprehensively..

Based on these findings, further research is recommended to use a longitudinal approach in order to observe the development of students' understanding over a certain period of time. In addition, the development of more comprehensive analysis methods, such as Structural Equation Modeling (SEM), can be used to evaluate the causal relationship between technical factors, perceptions, and students' conceptual understanding in greater depth.

4. CONCLUSION

Based on the results of the research conducted, it can be concluded that the instruments used have good construct validity and reliability, as indicated by exploratory factor analysis (EFA) and high Cronbach's Alpha values. The four hypothesized dimensions, namely Understanding of Basic Network Virtualization Concepts (PKDVJ), Cisco Packet Tracer Learning Experience (PPPT), Technical Ability (KMPT), and Perceptions and Attitudes towards Simulation Media (PSPT), were empirically proven to form a consistent framework in explaining students' level of understanding of network virtualization technology.

In addition, the results of the correlation analysis show a significant relationship between students' conceptual understanding and learning experiences, technical abilities, and perceptions of simulation media, with technical abilities being the most dominant factor influencing the level of understanding. Students' positive perceptions of the use of Cisco Packet Tracer are also closely related to their learning experiences and technical skills.

These findings confirm that the use of Cisco Packet Tracer in computer networking education not only supports practical mastery of technical aspects, but also contributes significantly to improving students' conceptual understanding of network virtualization technology, which is currently in high demand in the digital industry.

Based on the findings, it is recommended that lecturers and educational institutions optimize the use of simulation media such as Cisco Packet Tracer in Computer Networking learning. Simulation-based approaches and Project Based Learning models have been proven to improve conceptual understanding and strengthen students' technical skills.

In addition, future research needs to expand the scope of respondents across study programs or institutions to improve the generalization of findings, use longitudinal designs to monitor the development of student understanding over time, and apply more comprehensive analytical approaches, such as Structural Equation Modeling (SEM), to explore causal relationships between variables in greater depth.

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