



## Enhancing Network Security Skills using a Problem-Based Learning Approach in Cisco Packet Tracer Simulation Practices

Suti Mega Nur Azizah<sup>1\*</sup>; Hary Suswanto<sup>2</sup>; Syaifudin Ramadhani<sup>3</sup>

<sup>1\*</sup>Teacher Professional Education, Universitas Negeri Malang, Indonesia

<sup>2</sup>Electrical and Informatics, Universitas Negeri Malang, Indonesia

<sup>3</sup>Informatics, SMA Negeri 4 Malang, Indonesia

<sup>1\*</sup>Corresponding Email: [suti.mega.2431539@students.um.ac.id](mailto:suti.mega.2431539@students.um.ac.id)

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**Abstract:** The lack of understanding among students with kinesthetic learning styles regarding computer network concepts, particularly in digital security skills, requires a more practical and contextual learning approach. This study evaluates the efficacy of the Problem-Based Learning (PBL) approach, supported by Cisco Packet Tracer simulation, in enhancing student competencies in informatics subjects. This study used a pre-experimental design with a one-group pretest-posttest design approach. One experimental class was given learning using simulation-based PBL, and measurements were taken before and after treatment. The findings indicated that the implementation of PBL via Cisco Packet Tracer simulation markedly enhanced students' network security competencies and fostered critical thinking and problem-solving abilities. This study demonstrates that integrating PBL and digital simulation can be an effective strategy in informatics education. Recommendations for future research include the use of more robust experimental designs with comparison groups, as well as the exploration of immersive learning technologies such as augmented reality (AR) to create more interactive and industry-relevant learning experiences.

**Abstrak:** Kurangnya pemahaman pada siswa dengan gaya belajar kinestetik terhadap konsep jaringan komputer, khususnya dalam keterampilan keamanan digital, menuntut pendekatan pembelajaran yang lebih aplikatif dan kontekstual. Penelitian ini bertujuan untuk mengevaluasi efektivitas pendekatan Problem-Based Learning (PBL) yang didukung oleh simulasi Cisco Packet Tracer dalam meningkatkan kompetensi siswa pada mata pelajaran informatika. Penelitian ini menggunakan desain pra-eksperimental dengan pendekatan one-group pretest-posttest design. Satu kelas eksperimen diberikan pembelajaran dengan menggunakan PBL berbasis simulasi, dan dilakukan pengukuran sebelum dan sesudah perlakuan. Hasil penelitian menunjukkan bahwa implementasi PBL melalui simulasi Cisco Packet Tracer secara nyata meningkatkan kompetensi keamanan jaringan siswa dan menumbuhkan kemampuan berpikir kritis dan kemampuan pemecahan masalah. Penelitian ini menunjukkan bahwa integrasi PBL dan simulasi digital dapat menjadi strategi yang efektif dalam pendidikan informatika. Rekomendasi untuk penelitian di masa depan termasuk penggunaan desain eksperimen yang lebih kuat dengan kelompok pembanding, serta eksplorasi teknologi pembelajaran imersif seperti augmented reality (AR) untuk menciptakan pengalaman belajar yang lebih interaktif dan relevan dengan industri.

## A. Introduction

Network security is a critical component of information technology education, particularly in the context of high school-level Informatics. In the age of computing, it is highly essential to possess knowledge of network security to ensure that information is available, intact, and confidential (Kaur, 2020). However, with the rise in the sophistication level of cyberattackers, students are, in most instances, unable to gain knowledge of security fundamentals because they lack hands-on experience and adequate materials. This is a problem that is gradually on the rise because the youthful mind needs to be adequately prepared with competencies to address omnipresent digital security dangers (Setiadi et al., 2023). Research by Akbar et al (2021) has highlighted the need for adequate network security solutions capable of protecting valuable resources from the threat of future dangers. Wahyono (2019) also highlights the significance of training and education in network security, which is leading to the emergence of capable professionals in the field. As the digital world constantly evolves, it is essential to discuss awareness of security threats and countermeasures so that learners can, in addition to gaining knowledge of the theoretical concepts, apply them in practical terms.

Despite the importance of network security, high school students are often unable to learn these subjects, most notably due to the scarcity of resources and the lack of suitable exercises to work on (Permana et al., 2019). Most students struggle to comprehend network security, making it challenging for them to cope with the dynamic nature of cyber threats (Li & Liu, 2021). Earlier research has demonstrated that a proper learning approach can help students overcome existing problems in network security education (Alamsyah et al., 2020). Moreover, having an effective security system in schools is needed to safeguard classroom networks. Techniques such as firewalls and intrusion detection systems can be applied to enhance school security, providing a safer environment for acquiring IT skills (Suliman et al., 2021).

Based on observations in the Grade 11 Government Military Service (GMS) class at SMAN 4 Malang, it was found that students did not grasp practical concepts related to network security, primarily because most of them have a kinesthetic learning style. Students who prefer learning through kinesthetic methods are better served by physical exercise and face-to-face communication, rather than abstract or lecture-based learning (Gunawan et al., 2023). If taught in a theoretical manner, most students become bored and often fall asleep or play on their laptops. Nevertheless, students are highly interested if given practical problems, as when they were assigned to create a network map of the school, where they talk enthusiastically, cooperate, and come up with the network map using their imagination. This suggests that a more interactive, practice-based, or simulation-based learning approach would be more effective in helping students learn and understand concepts of network security (Allison, 2022).

Implementing the Problem-Based Learning (PBL) approach in the development of network security skills can be a suitable solution for enhancing students' understanding of this complex topic, particularly through simulation with Cisco Packet Tracer. This approach

places students in simulated real-life situations where they can solve network security-problem situations, thereby making learning more relevant and tangible (Susino et al., 2023). PBL enables students to break down complex concepts, work in groups, and gain increased comprehension of network security concepts through actual practice, which is confirmed by enhanced problem-solving skills (Ajid et al., 2025). Using the Cisco Packet Tracer tool, students can simulate various network security scenarios that bridge the gap between theory and practice, thereby increasing their comprehension of the technical application (Aleluia et al., 2020).

Besides that, the use of formative assessment in the PBL model significantly affects the quality of the learn process. Formative assessment enables constructive feedback during the learning process, allowing students to learn and progress continuously, and enhance their capacities (Fuadia et al., 2023). This is especially true when utilizing Cisco Packet Tracer network simulation, as students can detect errors or missing security settings and modify them immediately with the support of learned feedback (Sutrisno & Syukur, 2023). In addition to that, literature evidence seems to suggest that the incorporation of simulation systems such as Cisco Packet Tracer into PBL is capable of speeding up the process of acquiring the technical materials by the student, having greater engagement rates, and motivating the student's success in the field of learn (Mamahit et al., 2024). Among the technological innovation breakthroughs that can be incorporated, therefore, is the integration of more advanced network security scenario simulation in Cisco Packet Tracer, based on the latest threats and more advanced mitigation procedures. This will expand the simulation to make it more realistic, and students will be capable of performing real-world security scenarios in the field of networking.

The utilization of simulation software, such as Cisco Packet Tracer, which simulates networks, will further enhance the PBL process by allowing students to design and construct computer networks practically and safely. By utilizing simulation software, students can create multiple network security scenarios without relying on actual equipment, thereby enhancing the effectiveness of their learning in the field of network security (Akbar et al., 2021). Previous research by Kam & Katerattanakul (2019) confirms that simulation tools, such as Cisco Packet Tracer, have significantly enhanced students' hands-on skills in cybersecurity learning. While Akbar et al (2021) demonstrated that Cisco Packet Tracer enhances students' understanding of basic network security concepts, the application of PBL elements in the simulation tool remains to be explored. This research bridges the gap by incorporating the PBL technique with simulation tools to strengthen high school students' network security skills, offering both empirical and methodological contributions to the research.

This research addresses the need for youth to equip themselves to handle computer security challenges in the future. By providing a simulation-based, engaging learning experience that utilizes simulation media and the PBL approach, teachers can equip students with the network security skills they need and enable them to become highly capable of adapting to the dynamic information technology world (Agarwal et al., 2024). This approach

builds both a deeper understanding of network security fundamentals and the hands-on acquisition of skills, empowering students to be well-prepared to address real-world cybersecurity issues.

Based on the explanations of the problems and solutions above, this research aims to evaluate the efficacy of a Problem-Based Learning (PBL) approach, combined with Cisco Packet Tracer simulation tools, in improving the network security skills of high school students. This research contributes to the development of innovative learning methods in network security education by providing insights into how simulation-based learning, combined with PBL, can enhance students' practical and theoretical knowledge in this critical domain.

## B. Method

The research employed a pre-experimental design, which included a control group and a pretest-posttest methodology. The research flow used in this study is depicted in Figure.

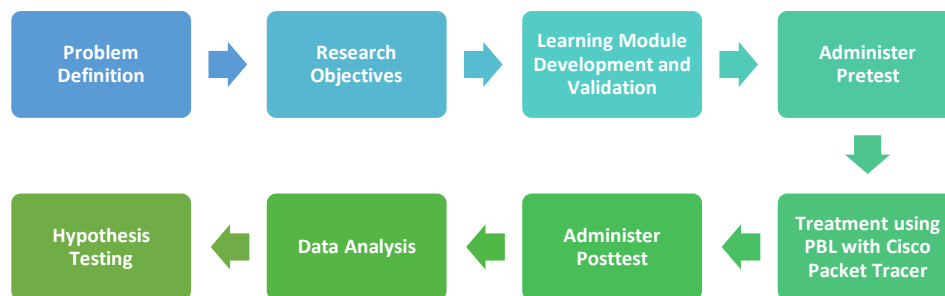


Figure 1. Research Flow

This study employed the Problem-Based Learning paradigm for the experimental class in Cisco Packet Tracer Simulation Practices. The employed design is depicted in Figure 2.

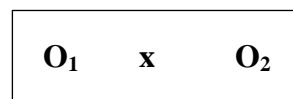


Figure 2. Research Design

Description:

O1 = Pre-test before PBL learning on Cisco Packet Tracer Simulation Practice

x = treatment during training

O2 = Post-test after PBL learning on Cisco Packet Tracer Simulation Practice

Students from Grade 11 GMS B at SMA Negeri 4 Malang were the subjects of this research. Students who have mastered the fundamentals of computer networks were used as a criterion to employ the purposive sampling technique in selecting the sample. Two groups, each consisting of 32 students, were created from the sample: the experimental group and the control group.

The instruments used in this study consisted of pre-test and post-test questions, which were used to evaluate the achievements before and after PBL learning in Cisco Packet Tracer Simulation Practice. The sub-materials contained in the pre-test and post-test questions include: 1) Understanding the concept of local networks and their connectivity; 2) Implementing local network implementation using Cisco Packet Tracer; 3) Configuring advanced security in local networks through simulation; 4) Developing solutions to network problems given; and 5) Summarizing the steps to solve network problems.

This research uses descriptive analysis where the tests applied include: (1) validity test with Kolmogorov-Smirnov, (2) reliability test with Cronbach's Alpha, (3) normality test using Shapiro-Wilk, and (4) paired sample t-test to test the average difference before and after treatment. According to the research design, the hypotheses assumed are as follows:

1. When the value of  $\alpha < 0.05$ , then  $H_1$  is accepted, indicating that there exists a significant difference between the students' pre-test and post-test scores following Problem-Based Learning (PBL) treatment with Cisco Packet Tracer simulation.
2. When the value of  $\alpha$  is greater than 0.05, then  $H_0$  is accepted, indicating that there is no significant difference between the students' pre-test and post-test scores following Problem-Based Learning (PBL) treatment with Cisco Packet Tracer simulation.

### C. Result

To determine the effectiveness of the Problem-Based Learning (PBL) technique in improving students' competency in network security, a pre-test and post-test series were given to students of SMAN 4 Malang's 11th-grade GMS B. The findings of the study are presented in the following sections, beginning with the comparison of validity and reliability test, data analysis, and testing of the hypothesis to determine whether there was any considerable difference in the competency of the students in network security after the implementation of the PBL technique in simulation practice using the Cisco Packet Tracer.

**Table 1.** Results of Validity and Reliability Test

Dimension	$I_{count}$	$I_{table}$	Description	Cronbach Alpha	Description
Understand the concept of local networks and their connectivity	1.000	0.355	Valid	0,703	Reliable
	0.425	0.355	Valid		
	0.410	0.355	Valid		
Implement a local network implementation using Cisco Packet Tracer	0.442	0.355	Valid		
	0.429	0.355	Valid		
	0.417	0.355	Valid		
Configure advanced security in a local network	0.381	0.355	Valid		
	0.396	0.355	Valid		

Dimension	r <sub>count</sub>	r <sub>table</sub>	Description	Cronbach Alpha	Description
through simulation					
Develop solutions	0.370	0.355	Valid		
to network problems given	0.442	0.355	Valid		
Summarize the steps to solve network problems	0.381	0.355	Valid		
	0.442	0.355	Valid		

Table 1 presents the results of validity and reliability tests conducted on the instruments used in this study, which encompass five dimensions of computer network ability. For understanding concepts and local network connectivity dimensions, three indicators have r-count values greater than the r-table value (0.355), and therefore they are declared to be valid. The same applies to the use of local networks with Cisco Packet Tracer, complex security configurations using simulation, designing solutions for network problems, and the design of steps to resolve network problems, wherein all the indicators have r-count values above the minimum mark. Additionally, the reliability of the instrument, as measured by Cronbach's Alpha coefficient of 0.703, indicates that it is reliable and consistent in measuring each of the studied dimensions.

**Table 2.** Results of Normality

	Statistic	df	Sig.
Pre-test	0.961	31	0.313
Posttest	0.946	31	0.124

Table 2 presents the results of the pre-test and post-test normality tests, as determined by the Shapiro-Wilk test. The Sig. of pre-test data is 0.313, and the Sig. of post-test data is 0.124. These are greater than the critical value of 0.05, indicating that the data distribution does not differ from the normal distribution. Thus, both pre-test and post-test data are typically distributed and satisfy the normality assumption for further statistical analysis.

**Table 3.** Results of Paired Sample Ttest

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig.
Pre-test - Post-test	-17.13	14.46	2.59	-6.59	30	.000

Table 3 presents the paired sample t-test results comparing students' knowledge of network security before and after incorporating the Cisco Packet Tracer simulation into problem-based learning (PBL). The analysis results showed a mean difference score of -17.13

with a standard deviation of 14.46 and a significance value of 0.000 (2-tailed). As per the rules of hypothesis testing used in this study, if the value of  $\alpha$  is  $< 0.05$ , then  $H_1$  will be accepted. Since the significance value of 0.000 is  $< 0.05$ ,  $H_1$  will be accepted and  $H_0$  will be rejected. Thus, it can be stated that the difference between the post-test and pre-test scores of the students is significant. In other words, PBL teaching supported by the Cisco Packet Tracer simulation has been successful in enhancing students' understanding of network security.

## D. Discussion

This study aims to evaluate the efficacy of a Problem-Based Learning (PBL) approach, combined with Cisco Packet Tracer simulation tools, in enhancing the network security skills of high school students. The results revealed that all the instruments used in the study proved to be valid and reliable. Since the data from the post-test and pre-test revealed a normal distribution, the methodology allowed for deeper analysis. In the Problem-Based Learning (PBL) activity in the Cisco Packet Tracer simulation, the post-test and pre-test results revealed a statistically significant difference, implying that the students' knowledge of the network security topic has been appropriately developed.

The research results indicate that the PBL approach, implemented in the Cisco Packet Tracer simulation laboratory activity, has effectively enhanced the students' network security capabilities. This outcome is consistent with past research, which shows that the PBL method in secondary education can help students develop their practical abilities in the IT field (Wahyudi et al., 2024). For students preparing to enter the rapidly expanding digital world of employment, knowledge and skills in this subject are also quite helpful (Siardizal, 2024). Furthermore, through a learning process that involves problem analysis, concept identification, and exploration of the relationships between various ideas, the adoption of PBL in many disciplines has been shown to enhance students' critical thinking skills (Wenno et al., 2021).

Simulation with Cisco Packet Tracer enhances interactive learning, thereby increasing student engagement and motivation. Several studies have demonstrated that the use of Cisco Packet Tracer simulation in the PBL process facilitates learners' development of network security skills. By enhancing skills in the challenging areas of network security, Ahmad (2022) found that the application of simulation in Virtual Private Networks (VPNs) improved students' academic performance. Thombre & Velankar (2022) reported similar findings, suggesting that the application of the simulation helps present an overview of its use and frees the learner to defend against cyberattacks on networks. The integration of network technology, cybersecurity, and simulation provides a better foundation for students to discuss and apply concepts in the workplace.

Particularly with the use of simulators like Cisco Packet Tracer, the PBL technique applied in learning network security has enormous potential in facilitating meaningful and deep learning in informatics. Through practical experience in constructing, configuring, and securing networks, this method enables students to actively acquire knowledge, making

them better equipped to address real-world issues in the technology sector (Allison, 2022). The use of simulation has been proven to not only accelerate the understanding of complex technical concepts but also improve students' independent and collaborative problem-solving skills (Rizkiawan & Kurniawan, 2024). Therefore, this learning model is highly suitable for application at the secondary education level as a strategy to strengthen the deep learning process, which fosters technical competence and readiness to face the challenges of a dynamic digital world (Setiawan et al., 2022). It is evident that the application of Cisco Packet Tracer in network security training is not theoretical; it is critical in the process of acquiring hands-on skills that aid in countering the constantly evolving security threats posed by the virtual environment.

### **E. Implication**

The findings in this study have important theoretical and practical implications. Theoretically, the success of the Problem-Based Learning (PBL) approach, combined with Cisco Packet Tracer simulation, reinforces constructivist theories that emphasize the importance of contextual learning experiences in building students' technical and critical thinking skills, especially in the field of network security. Practically, these results provide direction for teachers and curriculum developers to adopt more interactive and applicable simulation-based learning, in order to improve students' readiness to face cybersecurity challenges and the evolving needs of the digital industry.

### **F. Limitations and Suggestions for Further Research**

This study has several shortcomings that need to be considered accordingly. The first limitation is that the research design adopted a single control group without comparison to an experimental group, and therefore, the inferences made fail to comprehensively consider the usability of applying Cisco Packet Tracer to improve network security skills. The second issue is that learning media still primarily rely on simulations in Cisco Packet Tracer, and therefore, still fail to provide an experience that closely resembles real-world work environments. They may have an impact on students' state of knowledge and engagement in the learning process.

Future work should include a more extensive experimental process, incorporating control and experimental groups, so that the results can be compared and tested comparatively. The creation of learning media may be guided towards the implementation of more contextual and interactive technologies, such as immersive technology (e.g., Augmented Reality), to create a more immersive learning experience. The incorporation of technology goes hand in hand with a Problem-Based Learning (PBL) approach, so that students not only become technically skilled but are also capable of approaching real-world problems thoughtfully and collaboratively.

## G. Conclusion

Statistical studies revealing notable variations between pre-test and post-test scores indicate that the implementation of the Problem-Based Learning (PBL) paradigm supplemented by Cisco Packet Tracer simulation effectively improves students' skills in network security. Particularly in terms of developing technical competency and active, cooperative problem-solving abilities, this result helps inform the development of contextual and appropriate informatics learning methodologies. It is advised that the study employs an experimental design with a control group and investigates the integration of immersive learning technologies, such as augmented reality (AR), to generate a more immersive and interactive learning experience for future development. Along with increasing training in the use of digital technology to be more flexible in response to the needs of the dynamic digital workplace, teachers are expected to start implementing this method in the learning process.

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### Author's Biography



**Suti Mega Nur Azizah, S.Pd.**    Received a Bachelor of Education degree in the Informatics Engineering Education Study Programme at the Department of Electrical Engineering and Informatics, Faculty of Engineering, at the Universitas Negeri Malang (UM), graduated in 2022. The author is currently pursuing studies in the PPG Prajabatan Informatics Education at UM.  
Email: [sutimegana@gmail.com](mailto:sutimegana@gmail.com) or [suti.mega.2431539@students.um.ac.id](mailto:suti.mega.2431539@students.um.ac.id)

	<p><b>Dr. Hary Suswanto, S.T., M.T.</b>    Received a doctoral degree in Technology and Vocational Education at Universitas Negeri Yogyakarta (UNY). Currently a lecturer at the Department of Electrical Engineering and Informatics, Faculty of Engineering, at the Universitas Negeri Malang (UM), specializing in Technical and Vocational Education and Training (TVET). His research focuses on enhancing educational methodologies and student competencies in vocational settings. Email: <a href="mailto:hary.suswanto.ft@um.ac.id">hary.suswanto.ft@um.ac.id</a></p>
	<p><b>Syaifudin Ramadhani, M.Kom.</b>    Received a master's degree in Informatics at Universitas Islam Negeri Maulana Malik Ibrahim, Malang. Currently a teacher at the SMA Negeri 4 Malang in the Informatics Subject. Email: <a href="mailto:dhani@sman4malang.sch.id">dhani@sman4malang.sch.id</a></p>