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Enhancing Computer Network Education in Higher Education Through Network Simulation: A Case Study Using Cisco Packet Tracer

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Abstract
The rapid development of computer network technology highlights the importance of understanding computer networks, especially for students in higher education. Informatics engineering and computer science programs at universities focus on teaching networking concepts, with Cisco Packet Tracer emerging as an effective tool for network simulation. This research aims to explore the use of Cisco Packet Tracer in the computer network learning process, emphasizing its impact on students' understanding of network design and configuration. The study employs a quantitative research approach, using simple random sampling to select participants from computer network courses. Research instruments include pre- and post-tests to measure knowledge gain and a survey questionnaire to assess students' learning experiences. Data analysis, using descriptive statistics, reveals that students showed a significant improvement in their understanding of network concepts after using Cisco Packet Tracer. The findings indicate that simulations enhanced student engagement, simplified the learning process, and provided a cost-effective alternative to hardware-based network labs. In conclusion, Cisco Packet Tracer is an effective tool for improving the learning experience in computer network education, offering both educational and economic benefits.

Keywords: Cisco Packet Tracer, network simulation, interactive learning, networking education, educational technology.

Introduction

In higher education, learning computer networks requires both theoretical knowledge and practical skills (Asadi et al., 2024; Kurose, 2005; Mwansa et al., 2024). While theoretical understanding is crucial, it is practical experience that enables students to grasp advanced concepts in network management. However, the high cost of hardware required for hands-on practice often presents a challenge for educational institutions. This issue emphasizes the importance of finding cost-effective solutions that still provide valuable learning experiences. Network simulation software, such as Cisco Packet Tracer, offers a solution by allowing students to create, configure, and test network scenarios without the need for expensive physical hardware (Allison, 2022; Dustmirzayevich &

Ashirkulovich, 2023). Cisco Packet Tracer has gained widespread use in educational settings due to its realistic simulation capabilities and accessibility, making it an ideal tool for teaching networking concepts. Through this research, we aim to investigate how the use of Cisco Packet Tracer can enhance students' understanding of computer networks while addressing the practical limitations of traditional lab environments (Ariawal & Purbo, 2016; Čabarkapa, 2015; Drajana & Bode, 2021).

The urgency of this research stems from the growing need for educational institutions to adopt innovative teaching methods that are both cost-effective and impactful in preparing students for the demands of the rapidly evolving IT industry. This study is novel in its approach to examining the effectiveness of Cisco Packet Tracer not only in basic network setup but also in more complex network design and management scenarios, providing a deeper insight into its educational potential compared to previous studies that primarily focused on simple network simulations.Network simulation using Cisco Packet Tracer allows students to directly practice network concepts that have been learned theoretically. Thus, students' understanding of network concepts can be significantly improved.

This research aims to examine the effectiveness of using Cisco Packet Tracer in learning computer networks in higher education (Tanenbaum & Wetherall, 2011; Upadhyay et al., 2024). Through this simulation, students can gain hands-on experience in understanding how networks operate, designing and configuring network topologies, and troubleshooting common issues that may arise in real-world networks. The use of Cisco Packet Tracer is particularly valuable as it allows students to explore network scenarios interactively without the need for expensive physical hardware (Maulana et al., 2021; Rozi, 2021).

Previous studies have shown that network simulations, such as those conducted with Cisco Packet Tracer, significantly improve students' practical knowledge and understanding of complex networking concepts. For example, a study by Mukazi, (2022) demonstrated that network simulations enhanced student engagement and allowed them to practice network configuration tasks in a risk-free environment. Similarly, research by Laksito & Wibowo, (2022) highlighted the effectiveness of using simulation tools in bridging the gap between theoretical knowledge and real-world application in network education. Furthermore, this research is built on earlier findings that suggest using simulation software not only increases student retention of network concepts but also improves their problem-solving and critical thinking skills.

The current study aims to build upon these previous works by exploring the impact of Cisco Packet Tracer in a more comprehensive learning environment, considering both the advantages of simulation in networking education and the challenges students face when utilizing such tools in an academic setting. By expanding on prior research, this study provides deeper insights into the educational potential of network simulations and their role in improving learning outcomes in computer network courses.

Research Methods

This study adopts an experimental research design to investigate the effectiveness of Cisco Packet Tracer in improving students' understanding of computer networks. The study involves students from the Informatics Engineering program at one of the universities in Indonesia. The experimental approach includes a treatment group using Cisco Packet Tracer and a **control group** to compare the results effectively.

The research is divided into the following stages:

1. **Learning Design**
   In this phase, a learning module is developed to guide students through the use of Cisco Packet Tracer. The module will include theoretical explanations of networking concepts and practical exercises on how to configure network devices, troubleshoot, and design network topologies using the software.
1. **LearningImplementation**
   Students will be divided into two groups: a **treatment group** and a **control group**. The treatment group will use Cisco Packet Tracer during the learning process, while the control group will use traditional methods (e.g., textbook learning or classroom-based practicals without the simulation tool). The students will be provided with theoretical explanations on how to use Cisco Packet Tracer and will engage in network simulations based on the topics covered.
2. **Measurement and Data Collection**
   After the learning session, all students (both in the treatment and control groups) will take a **post-test** designed to measure their understanding of key concepts such as network configuration, design, and troubleshooting. The post-test will assess their knowledge of computer network fundamentals, the ability to apply this knowledge in designing networks, and their problem-solving skills related to troubleshooting.
3. **Sampling Techniques**
   The sample will consist of students from the Informatics Engineering study program at the university. The sampling technique used will be **random sampling** to ensure that each student has an equal chance of being assigned to either the treatment or control group. The sample size will be determined based on the university's student population for the course.
4. **Data Analysis**
   The data from the post-test results will be analyzed using **statistical analysis techniques** to compare the performance of the two groups. A **t-test** will be employed to determine if there are statistically significant differences between the scores of the treatment group (using Cisco Packet Tracer) and the control group. This will help determine whether the use of Cisco Packet Tracer has a measurable impact on students' understanding of computer network concepts and practical skills.
5. **Research Instruments**
   The primary research instrument used in this study is the **post-test** designed to assess the students' understanding and practical abilities in computer networking. The test will consist of both theoretical and practical questions, including network design and troubleshooting scenarios. Additionally, an observation checklist may be used to record how students interact with the Cisco Packet Tracer simulation tool during the learning process.

Results and Discussion

This research aimed to assess the effectiveness of using Cisco Packet Tracer in enhancing students' understanding of computer network concepts in higher education. The study was conducted with students from the Informatics Engineering program at a university in Indonesia. The effectiveness was evaluated through both quantitative and qualitative data collection, including pre- and post-test assessments, and feedback from students regarding their learning experiences.

Quantitative Results

To measure the improvement in students' understanding, pre-tests were administered before the students engaged in the Cisco Packet Tracer-based learning sessions, and post-tests were given at the end of the simulation-based learning (Anwar, 2020). The results of the pre- and post-tests were compared to analyze the improvement in students' knowledge of networking concepts, network design, and troubleshooting (Maleke et al., 2022).

The statistical analysis of the pre- and post-test results showed a significant improvement in student performance. Using paired t-tests, the average score of students increased by 35%, indicating a substantial enhancement in their understanding of networking concepts and their ability to troubleshoot network configurations. The data are summarized in the table below:

Test Type	Average Score (%)	Standard Deviation
Pre-Test	55%	7.8
Post-Test	90%	5.4

This substantial increase in average test scores reflects the effectiveness of Cisco Packet Tracer in enhancing students' understanding and practical skills.

Qualitative Results

In addition to the quantitative data, qualitative feedback was gathered through surveys and interviews with students. The responses provided valuable insights into students' experiences with Cisco Packet Tracer as a learning tool. The key findings include:

a. **Increased Engagement:** Students reported greater engagement in the learning process due to the interactive and visual nature of Cisco Packet Tracer simulations. They appreciated being able to simulate real-world network configurations and troubleshoot issues without needing physical hardware.
b. **Enhanced Practical Skills:** Many students expressed that the hands-on experience provided by the simulations helped them develop practical skills in configuring network devices and solving network issues. They highlighted the practical application of theoretical knowledge, especially in areas like IP configuration and device connectivity.
c. **Improved Troubleshooting Skills:** A significant portion of students mentioned that Cisco Packet Tracer facilitated the development of their troubleshooting skills. The tool enabled them to identify network problems, such as incorrect configurations or connectivity issues, and practice resolving them, thereby strengthening their analytical abilities.

d. Flexibility and Accessibility: Students valued the flexibility of being able to experiment with a wide range of network configurations, from routing and switching to wireless network setups. The accessibility of Cisco Packet Tracer allowed them to engage in learning activities outside the traditional classroom environment, providing more opportunities for practice.

Discussion

This research investigates the effectiveness of using Cisco Packet Tracer in the learning of computer networks in higher education, particularly within the context of informatics engineering programs. The increasing complexity of computer networks and the high cost of physical hardware have made network simulation tools like Cisco Packet Tracer invaluable in educational settings (Wanda et al., 2023). This study demonstrates how Cisco Packet Tracer can bridge the gap between theory and practice, providing students with an accessible platform to design, simulate, and troubleshoot networks in a virtual environment. By using this simulation tool, students gain hands-on experience that enhances their understanding of networking concepts without the need for costly physical equipment. This is particularly important for educational institutions, as it allows them to deliver high-quality network education without a significant financial burden.

The novelty of this research lies in its focus on assessing the real-world effectiveness of Cisco Packet Tracer within the context of higher education, specifically for students in Indonesia. Previous studies have acknowledged the importance of network simulation tools but have often focused on theoretical aspects or conducted research in different educational settings, which may not fully represent the unique challenges faced in other regions or educational systems. By providing a detailed analysis of Cisco Packet Tracer's impact on student learning, this research contributes to a more comprehensive understanding of how simulation tools can be integrated effectively into computer network education.

Our findings suggest that Cisco Packet Tracer significantly improves students' understanding of computer networks, including network configuration, troubleshooting, and design. After engaging with the tool, students demonstrated a substantial improvement in their ability to design and configure various network topologies, such as LAN and WAN, and troubleshoot common network issues. These improvements were supported by quantitative data, showing an average score increase of 35% on post-tests related to network design and configuration skills. Qualitative feedback from students further confirmed the positive impact of Cisco Packet Tracer, with many students expressing greater confidence in their ability to apply theoretical concepts to real-world network scenarios.

One of the key findings of this study is that Cisco Packet Tracer provides an effective platform for troubleshooting practice. Students were able to identify and resolve configuration errors, such as incorrect IP address assignments or misconfigured routing protocols, in a controlled virtual environment. This not only reinforced their theoretical understanding but also improved their practical troubleshooting skills, a crucial competency for aspiring network engineers. The simulation mode allowed students to visualize data flows and identify bottlenecks, helping them understand how various components of a network interact in real-time.

However, it is important to note that while Cisco Packet Tracer provides a realistic and interactive environment for learning, it does have certain limitations. For example, the simulation does not fully replicate the performance of physical network devices,

particularly under high-traffic or complex scenarios. Advanced network protocols, such as MPLS and BGP, are not supported, which can limit the depth of simulation for students studying more advanced networking topics. Additionally, while the tool offers a high degree of interactivity, it does not replace the practical experience gained from working with physical hardware, which remains crucial for comprehensive networking education.

In comparison to previous research, this study emphasizes the importance of integrating network simulation tools into the curriculum to enhance both theoretical and practical knowledge. While earlier studies have demonstrated the potential of simulation tools, this research adds value by focusing on the effectiveness of Cisco Packet Tracer in a specific educational context and providing concrete evidence of its impact on student learning outcomes.

Overall, this research highlights the urgency and importance of adopting simulation-based tools like Cisco Packet Tracer in higher education to address the increasing demand for skilled network professionals. It underscores the value of providing students with the opportunity to engage with real-world network scenarios in a safe, low-cost virtual environment, ultimately equipping them with the skills needed to succeed in the rapidly evolving field of computer networking.

Conclusion

This research demonstrates that Cisco Packet Tracer is an effective tool for improving students' understanding of computer network design, configuration, and troubleshooting in higher education. The findings from the data analysis reveal a significant improvement in students' practical skills and theoretical knowledge after using the tool, as reflected in the 35% increase in post-test scores. Cisco Packet Tracer facilitates an interactive learning experience, allowing students to simulate real-world network scenarios without the need for costly hardware. This study supports the conclusion that integrating simulation tools like Cisco Packet Tracer into the curriculum enhances the learning experience, making it more engaging and cost-effective. Furthermore, the tool helps prepare students for the challenges of network management in the professional world, contributing to their readiness for employment in the field of computer networking

This research highlights the effectiveness of Cisco Packet Tracer in enhancing students' understanding of computer network concepts in higher education. The analysis showed a significant improvement in students' ability to design, configure, and troubleshoot networks, as evidenced by the increase in post-test scores. Cisco Packet Tracer provides a cost-effective, interactive learning environment that simulates real-world networking scenarios without the need for expensive hardware. The results support the conclusion that Cisco Packet Tracer is not only a valuable educational tool but also an essential platform that enhances practical network skills, bridging the gap between theoretical knowledge and real-world applications. By integrating this simulation into the curriculum, universities can better prepare students for careers in IT, offering a hands-on learning experience that is both scalable and accessible. Furthermore, the ability to simulate and test various network configurations without physical infrastructure allows for more flexible, personalized learning experiences for students. Overall, this research

demonstrates that the use of Cisco Packet Tracer can play a significant role in improving the quality of computer network education and making it more inclusive and effective.

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