



Developing and Implementing Practical Lessons for the “Computer Network Analysis and Design” Course Using EVE-NG Software for Information Technology Students

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ABSTRACT: Practical teaching in virtual environments using simulation software has become a crucial direction in higher education, particularly in the course Computer Network Analysis and Design within the Information Technology (IT) program. This approach aims to develop learners’ competencies and meet learning outcomes in the context of the Fourth Industrial Revolution. This paper discusses the role of practical teaching in virtual environments for IT students, thereby clarifying the principles and processes for developing and organizing practical lessons on network analysis and design using the EVE-NG software platform. Experimental practice is a typical instructional method in IT education and research, contributing to the comprehensive development of students’ professional competencies. To fulfill these requirements, instructors must be proficient in designing and implementing practical lessons on computer network analysis and design within virtual environments. The findings of this study serve as a valuable reference for higher education institutions offering Information Technology programs.

KEYWORDS: EVE-NG software, IT students, Instructional methods, Practical teaching, Practical lessons, Virtual environments

1. INTRODUCTION

In today’s information and knowledge society, where technology evolves rapidly and exponentially, it has penetrated deeply into all professions and areas of life and production. Building virtual learning environments through specialized software has become a prominent topic in contemporary education. Many educational institutions are transforming their learning environments, teaching methods, and instructional organizations to enable learners to not only acquire knowledge but also apply it effectively in practice, especially at the higher education level.

Practical instruction is an indispensable component of teaching and learning in Information Technology (IT) programs. Practical activities allow learners to apply the knowledge, skills, attitudes, and experiences they have accumulated to real-life situations [1]. Teaching through practice and experiential learning also fosters the development of learners’ organizational and management competencies, metacognitive awareness, self-regulation, and self-activation. It helps them identify their personal strengths and advantages, thereby cultivating professional competence and career adaptability [2]. This is particularly essential for IT students. Another study also proposed a practical teaching process for Information Technology students, implemented in the form of project-based learning with four steps [3]. Overall, existing research on practical teaching demonstrates that instructional processes are typically rigorous and promote creativity and active learning. However, establishing a virtual practice environment for certain IT courses is of great significance, as it minimizes potential risks and allows learners to experiment and make numerous errors safely before implementing solutions in real-world contexts.

In this spirit, IT students require extensive professional skills and practical competencies to meet the increasing demand for high-quality human resources in the field, while also enhancing educational quality and learning outcomes.

One of the most effective software tools currently available for creating virtual practice lessons or environments is EVE-NG. Integrating EVE-NG into the design of virtual practice exercises for IT students helps establish a diverse and active learning environment that contributes to the achievement of program learning outcomes. Therefore, this study aims to help instructors gain a deeper understanding of EVE-NG software, its role in constructing virtual practice lessons, and the process of designing and implementing such lessons for IT students. The results serve as a foundation for instructors to apply these approaches to other specialized subjects in IT education.

2. RESEARCH RESULTS

2.1 Overview of the Course “Computer Network Analysis and Design”

The Computer Network Analysis and Design course provides learners with an overview of computer network design, focusing on the fundamental concepts of small and medium-sized network systems, along with methods and approaches for interconnecting network devices. Additionally, the course equips students with practical skills to configure network operations based on specific requirements and to design applicable network systems for real-world contexts. It also fosters independent working habits, critical thinking, and the ability to apply technical knowledge in analyzing network solutions, intrusion detection, and defensive mechanisms in cybersecurity.

Half of the course duration, equivalent to 30 hours, is allocated to practical sessions. These practical components primarily focus on logical and physical network topology design, performance-oriented design, reliability-focused design, and ensuring network security and safety [4].

Computer network analysis refers to the process of collecting, examining, and evaluating data from a computer network to gain insights into its operation, performance, security, and potential issues. This process helps identify errors, optimize performance, ensure network security, and plan for system upgrades or expansion. Network analysis can be performed on various components, including network traffic, network devices (such as routers, switches, firewalls), communication protocols, and applications operating within the network infrastructure [5,6].

The process of computer network analysis typically includes the following steps:

Network Data Collection: This is the most critical phase, allowing learners to analyze the network system and propose design solutions. During this stage, students gather relevant information such as network traffic data, device logs, performance metrics, and protocol usage. Common tools used in this process include SolarWinds, PRTG Network Monitor, Wireshark, tcpdump, Splunk, and ELK Stack.

Data Classification and Organization: After collecting the necessary information, learners categorize and structure the data to facilitate effective analysis. This involves filtering out irrelevant data, grouping data by type, and organizing it chronologically or by device for easier monitoring.

Data Analysis: This is the central phase of network analysis. Through data analysis, learners evaluate the network system, identify issues, and propose performance improvements. Main tasks include traffic analysis, performance analysis, security analysis, and protocol analysis. Tools supporting this phase include Snort, Suricata, Zeek, NetFlow, Wireshark, Nagios, and Cacti.

Solution Recommendation: Based on analytical results, learners formulate conclusions and propose solutions to address network weaknesses and enhance overall performance and security. Network analysis can be conducted in two primary ways:

Manual Analysis: Conducted by hand, using standard tools and manual techniques.

Automated Analysis: Conducted using automated tools and algorithms, often enhanced with machine learning models. Benefits of network analysis include:

Improved performance: Identifying and resolving performance bottlenecks; **Enhanced reliability:** Detecting and fixing stability-related issues; **Increased security:** Identifying vulnerabilities and preventing cyberattacks; **Cost efficiency:** Optimizing network utilization and reducing operational costs.

Computer network design involves planning, constructing, and implementing a network infrastructure to meet specific requirements regarding connectivity, performance, security, and scalability. The primary objective is to create a network that operates efficiently, securely, and reliably, supporting the communication and data management needs of organizations or individuals. Network design extends beyond hardware and software selection must also account for data traffic, organizational scale, budget constraints, and future expansion. Within IT training programs, students are often required to design and upgrade networks based on enterprise requirements, install network services, and ensure both performance optimization and cybersecurity. The process of network design includes the following steps:

Requirement and Objective Analysis: The initial and most critical step is to identify organizational or individual requirements and objectives for the network. This includes factors such as the number of users and devices, types of services, data volume, applications, and expectations for performance, reliability, and security.

System Analysis and Component Identification: Based on the requirements, designers identify essential network components, including hardware (routers, switches, hubs, access points, modems, firewalls) and software (network operating systems, management



tools, and security programs). For existing systems, a detailed analysis of current infrastructure is necessary to propose upgrades or expansions.

Network Topology Design:

Network topology defines how components are interconnected. Common topologies include star, ring, and tree structures, each with its advantages and limitations. In this stage, learners select the appropriate topology, allocate IP addresses, and develop network security policies.

Functional Definition and Technology Selection: The main network functions - data transmission, access, resource sharing, and security are defined, and appropriate devices and technologies are chosen accordingly. This step also involves selecting cables, software, and other supporting components.

System Implementation and Configuration: This stage focuses on practical deployment, installing and configuring devices to ensure the system operates as planned.

Testing and Optimization: After deployment, learners conduct performance and security testing to ensure the network operates efficiently and securely. Optimization processes may include adjusting configurations to achieve higher throughput and reliability.

Design Considerations and Network Types

When designing a computer network, several factors must be considered:

Performance: The network must meet the performance demands of its applications; Reliability: It should operate stably and minimize downtime; Security: It must be well-protected against intrusion and attacks; Scalability: It should support future growth and expansion.

Common types of computer networks include:

LAN (Local Area Network): Connects devices within a limited area such as an office or school.

WAN (Wide Area Network): Connects devices across large geographical areas, such as cities or countries.

MAN (Metropolitan Area Network): Connects multiple local networks across a large urban area.

In summary, network design is a complex process requiring deep technical expertise and hands-on experience. To achieve an effective and sustainable network infrastructure, collaboration among skilled professionals is essential.

2.2. The process of developing practical exercises for the course Computer Network Analysis and Design on EVE-NG

2.2.1. Overview of the EVE-NG Software

EVE-NG (Emulated Virtual Environment – Next Generation) is a free and open-source virtual network emulation platform developed based on the Dynamips project. The software enables users to create, configure, and manage complex virtual network infrastructures that include various types of networking devices such as routers, switches, and firewalls.

EVE-NG provides a comprehensive set of features that support a wide range of virtualized network devices and environments. These include:

Multi-vendor device support, such as Cisco, Juniper, and MikroTik.

Compatibility with various network operating systems, including Linux, Windows, and FreeBSD.

Support for multiple network architectures, such as Local Area Networks (LANs), Wide Area Networks (WANs), and Metropolitan Area Networks (MANs).

Advanced functionalities, including penetration testing, network monitoring, and performance evaluation [7,8].

Due to its versatility, EVE-NG is widely utilized in network training and education, testing and deployment of network systems, research and development, and virtual network environment creation. It serves as an effective educational and professional tool for both network engineers and students, providing an interactive and flexible environment to design, analyze, and simulate network topologies with high realism and cost efficiency.

As an open-source platform, EVE-NG offers several advantages over other network simulation tools of similar types. It supports a broad range of devices and operating systems, allows for the creation of complex network topologies, and integrates numerous advanced features for practical network experimentation. However, EVE-NG also presents certain limitations: it requires relatively high system specifications to operate efficiently and may be challenging for beginners due to its configuration complexity [9,10].

Overall, EVE-NG stands out as a powerful and flexible virtual network emulator. Its extensive functionality and multi-platform compatibility make it an excellent solution for professionals, educators, and learners engaged in the analysis, design, and management of virtual networks.

2.2.2. The Process of Developing Practical Exercises for Computer Network Analysis and Design on EVE-NG

Developing practical exercises for computer network analysis and design is a process of creating realistic scenarios that allow students to apply their theoretical knowledge to authentic networking contexts. These exercises can be designed based on actual enterprise or organizational requirements, or they may be constructed as simulated cases that reflect real-world situations.

The primary purpose of developing such practical exercises is not only to help students master the core concepts and principles of network analysis and design but also to prepare them for real-world professional tasks. Through engaging in practice-based learning, students enhance their ability to analyze systems, design efficient network architectures, and implement solutions aligned with industry needs.

Organizing instructional activities for computer network analysis and design practice involves preparing and conducting teaching and learning processes that guide students to perform learning tasks effectively within the practical sessions. The objective of this organization is to enable students to consolidate essential knowledge and skills required to complete the exercises successfully. Moreover, it supports the development of analytical thinking, problem-solving competence, and adaptability to real-world network management tasks through experimentation in a virtual environment.

To fulfill the objectives of the course and ensure that students achieve the learning outcomes, particularly those related to installing and managing fundamental network administration services such as user management, device configuration, bandwidth and memory optimization, lecturers need to establish a systematic procedure for designing and organizing practical exercises within a virtual learning environment. This approach helps students practice and experiment safely, refine their network analysis and design skills, and gain hands-on experience before working directly with real enterprise-scale or individual systems.

Furthermore, the process aims to foster students' ability to analyze network systems, upgrade and optimize networks according to enterprise demands, and deploy advanced networking services to enhance performance and ensure cybersecurity.

The process of designing and implementing practical exercises for computer network analysis and design is carried out through six stages, as illustrated in Figure 1.

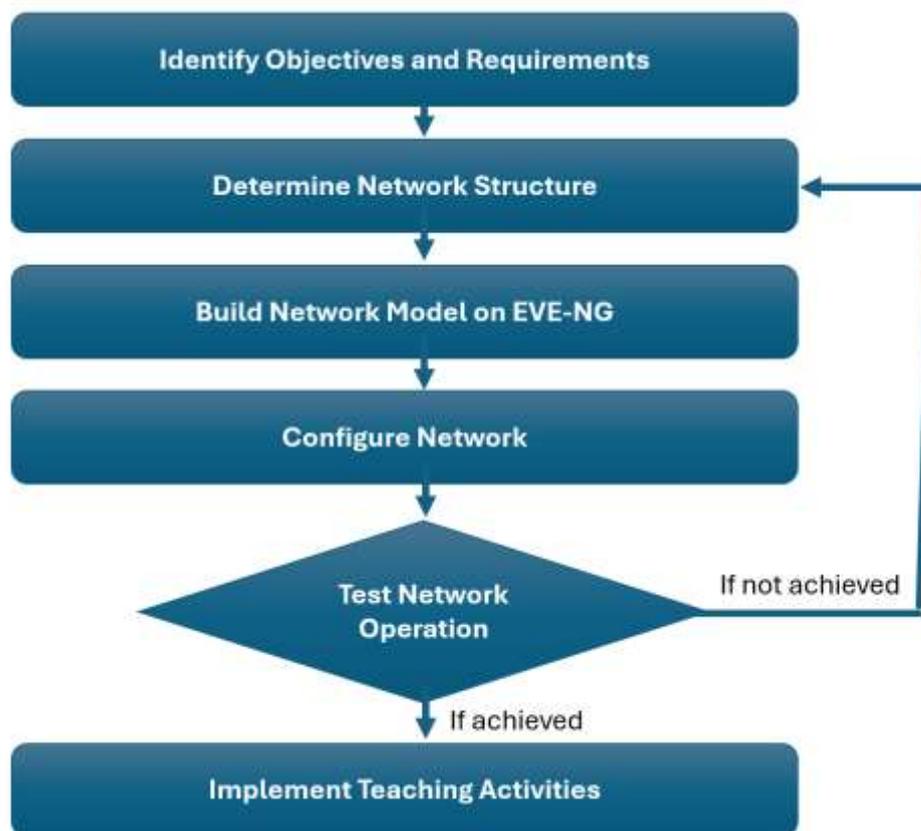


Figure 1: Process of Developing a Practical Lesson on Computer Network Analysis and Design Using EVE-NG



Step 1. Identifying the Objectives and Requirements of the Practical Exercise

The requirements of practical exercise encompass several key factors, including Hardware specifications (number and type of computers or devices); Applications and software tools to be utilized; Performance, reliability, and security requirements. This step ensures that the exercise objectives are aligned with the expected learning outcomes and technical constraints of the course.

Step 2. Defining the Network Topology

The network topology refers to the structural arrangement and interconnection of computers and devices within the network. Different types of topologies, such as star, ring, and tree structures, possess distinct advantages and disadvantages. In this step, the instructor determines the most appropriate network topology that best satisfies the instructional goals and technical requirements of the practical exercise.

Step 3. Building the Network Model on EVE-NG

Using the EVE-NG software, the instructor constructs the virtual network model according to the predefined topology established in Step 2. EVE-NG enables the creation of realistic network scenarios, allowing students to interact with virtualized routers, switches, and other network devices as if they were working in an actual environment.

Step 4. Configuring the Network

At this stage, network devices within the model, such as Cisco routers, Fortinet firewalls, and switches are configured with relevant parameters. Configuration tasks may include assigning IP addresses, subnet masks, gateways, and other network settings to ensure appropriate connectivity and data flow between devices.

Step 5. Testing Network Functionality

Network functionality is tested by executing diagnostic commands such as ping and traceroute to verify connectivity and routing accuracy. This is a critical step that allows the instructor to determine whether the exercise meets all instructional and technical requirements before implementation in teaching. If the test results meet the desired criteria, the exercise proceeds to the preparation stage for teaching. Conversely, if errors or issues are identified, the process returns to Step 2 for reevaluation and adjustment of the network topology.

Step 6. Preparing for the Teaching Implementation

In the final step, the instructor prepares all necessary instructional materials, equipment, and student prerequisites required for conducting the exercise effectively. This may include developing learning sheets, diagrams, video tutorials, or assigning preparatory tasks to students in advance. Such preparation ensures that learners have sufficient foundational knowledge and resources to successfully engage in and complete the practical exercise.

2.3. Organizing the Teaching of Practical Exercises in the Course “Computer Network Analysis and Design” on EVE-NG

After developing the practical exercises through the steps, the instructor proceeds to organize the teaching and learning activities for the Computer Network Analysis and Design course using the EVE-NG software. During this phase, students engage in hands-on learning activities, identify learning objectives, analyze assigned tasks, propose solutions, and conduct practice sessions within the virtual environment. Steps for Organizing the Teaching of Practical Exercises on EVE-NG:

Step 1. Assigning Learning Tasks

At this stage, the instructor acts as a facilitator and guide, proposing, supporting, and monitoring students as they carry out the assigned practical tasks.

Learning tasks are assigned to individuals or groups, ensuring that they are manageable, appropriate to students' competencies, and aligned with instructional objectives. Upon completing the assigned activities, students are expected to: Acquire the necessary conceptual and procedural knowledge, Develop and reinforce practical skills within the virtual environment, and build foundational competencies for solving real-world problems in computer network analysis and design. This step establishes a bridge between theoretical understanding and the development of applied professional capabilities.

Step 2. Guiding Students in Performing Practical Tasks

In this step, the instructor facilitates students' engagement in individual or group-based practical activities, depending on the specific requirements of the exercise. These activities are typically supported by learning sheets or worksheets that specify tasks and guide student actions. The instructor's role includes orienting students toward effective approaches, providing methodological guidance, and offering timely support when necessary. Through these activities, the instructor can assess each student's skills, competencies, experience, and prior knowledge, thereby identifying areas that require further reinforcement and development.

This step encourages active participation, self-regulated learning, and the integration of prior knowledge and technical skills in solving the assigned network design problems. It also promotes creativity, decision-making, and problem-solving abilities—key outcomes of experiential and practice-based learning in information technology education.

Step 3. Reporting and Presenting Results

In the final stage, students report and present the outcomes of their practical exercises, which should include: A description of the network topology; Network configuration details, and verification results of network operation and performance (e.g., connectivity tests). These reports allow both students and instructors to reflect on the effectiveness of the learning process, evaluate the accuracy of configurations, and identify any technical or conceptual issues for improvement in future sessions. To ensure that the practical exercises in Computer Network Analysis and Design meet the expected instructional standards while fostering students’ creativity and active engagement, several important considerations should be observed: Utilize virtual network devices that closely resemble real-world equipment in configuration and functionality; employ appropriate virtual operating systems that align with the intended applications and network services; adhere strictly to security principles when constructing and configuring virtual networks. Such practices not only enhance the authenticity of the virtual learning experience but also prepare students for real-world professional challenges in the field of computer networking.

2.4. Illustration of the Process of Developing and Organizing Practical Lessons for the Course

Practical Lesson: *Analysis and Design of Computer Networks Using EVE-NG Software*

Assignment: Create a model consisting of three Layer 2 switches and six cirros virtual machines as shown in Figure 2. Configure VTP to automatically synchronize VLAN information among the switches and configure VLAN functionality on the switches.

Requirements: Students are to complete the practical exercise in pairs using a computer, submit their work via the local network, and clearly include their full name, student ID, and major.

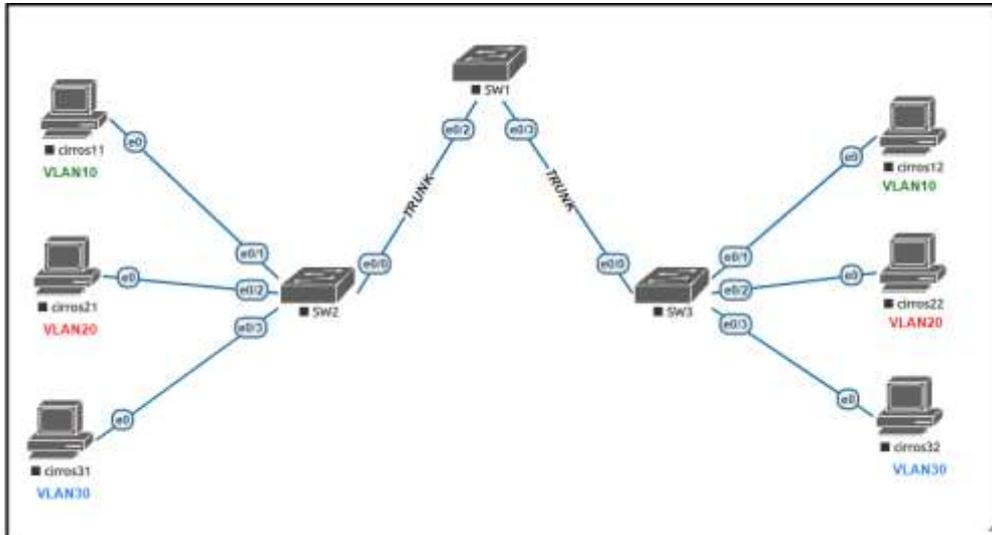


Figure 2. Model of three Layer 2 switches and six Cirros virtual machines built on the EVE-NG platform.

Step 1: Identifying the Requirements of the Practical Lesson

For this learning topic, the requirements of the practical lesson are as follows:

- Create a model consisting of three Layer 2 switches and six cirros virtual machines as shown in Figure 2.
- Configure VTP for automatic synchronization of VLAN information among the switches and configure VLAN functionality on the switches.

Step 2: Network Structure

Use a composite network structure.

Step 3: Network Modeling

Use the EVE-NG software to create six virtual computers and three virtual switches.



Step 4: Network Configuration

Configure the network devices as follows:

- Virtual switches: IP 192.168.1.1, subnet mask 255.255.255.0
- Six virtual computers: IP range 192.168.1.3–192.168.1.12, subnet mask 255.255.255.0

Step 5: Network Testing

Verify the network operation by performing the following tasks:

- Ping between computers in the network.
- Perform traceroute from one computer to another within the network.
- Access the Internet from a computer in the network.

Step 6: Preparation for Teaching Activities

The instructor identifies relevant materials, equipment, and prerequisite knowledge students need to complete the practical tasks.

- Materials: textbooks, course manuals, computers with EVE-NG software installed (for groups or individuals), and learning worksheets for task assignments.
- Student preparation: review knowledge related to building switch layer models and cirros virtual machines on EVE-NG, as well as LAN configuration techniques.

Based on the steps of Phase 1, the instructor develops the practical lesson with the following requirements: Create a model of three Layer 2 switches and six cirros virtual machines as shown in Figure 2; configure VTP for automatic VLAN synchronization among switches; and configure VLAN functionality on the switches, accompanied by Figure 2.

Organization of the Practical Lesson on EVE-NG Software:

Step 1: Assigning Tasks

The instructor assigns the practical task to the class, requiring students to work in pairs. Students receive the task, review available data, and identify the requirements and problems to be solved in the exercise.

Step 2: Organizing Student Practice Activities

After receiving the assignment and understanding the task requirements, students work in pairs, divide responsibilities, and plan the process of building models of switches, layers, and virtual machines. They configure the virtual devices according to the given requirements and diagram in Figure 2.

Step 3: Reporting Results

Students report the outcomes of the practical exercise, including:

- Network structure description
- Network configuration
- Results of network operation tests

This practical exercise helps students consolidate their knowledge of computer network analysis and design, apply theoretical concepts to solve practical problems, and develop the ability to address real-world networking challenges encountered in organizations, enterprises, or personal projects.

3. CONCLUSION

Organizing practical lessons for the Computer Network Analysis and Design course using the EVE-NG software represents an innovative and effective teaching approach, particularly for Information Technology (IT) students in the current era of rapid information and technological advancement. Practical teaching is a learner-centered methodology that emphasizes students' active participation in the learning process and fosters intrinsic learning motivation. During practical sessions, students are engaged in experiential learning activities—observing, exploring, experimenting, simulating, measuring, and applying their acquired knowledge to solve authentic, real-world problems. This process not only deepens their understanding of theoretical concepts but also enhances their analytical and problem-solving competencies. Based on teaching practices and the research findings obtained, it can be affirmed that EVE-NG, as an open-source and flexible software, provides robust support for the design, analysis, simulation, and monitoring of computer network parameters. It enables learners to interact directly with various network components and system parameters, thereby developing their ability to analyze, evaluate, and propose appropriate network design solutions that meet specific system requirements.



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Cite this Article: Giang, N.T., Giam, N.M. (2025). Developing and Implementing Practical Lessons for the “Computer Network Analysis and Design” Course Using EVE-NG Software for Information Technology Students. International Journal of Current Science Research and Review, 8(10), pp. 5335-5342. DOI: <https://doi.org/10.47191/ijcsrr/V8-i10-42>