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Comparing Traditional and Innovative Teaching Approaches in an Undergraduate Computer Networks Course: A Two-Cohort Study of Course-Outcome Attainment

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ABSTRACT

This study compares course outcome (CO) attainment under traditional and innovative teaching approaches in an undergraduate Computer Networks course. A single-institution, observational case study was conducted across two consecutive cohorts of 112 students each: the 2022–2023 cohort received predominantly lecture- and board-based instruction, whereas the 2023–2024 cohort experienced a package of active and technology-supported teaching interventions. The syllabus, unit structure, credit and contact hours, assessment scheme, CO definitions, attainment benchmark, and instructors were kept constant. Learning was evaluated through direct CO attainment derived from unit tests, preliminary examinations, practical examinations, and term-work, using a 50% target benchmark. Across 18 matched CO–assessment-component comparisons, mean attainment rose from 54.0% to 72.4%, an increase of 18.3 percentage points. The pooled difference was statistically significant (paired $t(17) = 5.31$, $p < 0.001$; Wilcoxon $p < 0.001$; Cohen's $d = 1.25$). Gains differed by assessment component: theory attainment increased by 36.4 percentage points and term-work attainment by 14.2 points, while the 4.4-point increase in practical attainment was not statistically significant ($p = 0.099$). These findings indicate an association between the introduction of the intervention package and higher CO attainment, particularly in theory and term-work. Because the comparison involved two non-randomized cohorts from one course at one institution, differences in student characteristics, prior knowledge, or year-specific conditions cannot be ruled out. The results should therefore be interpreted as context-specific evidence rather than proof of a causal effect.

1. INTRODUCTION

Computer Networks is a foundational course that covers protocols, applications, and various network topologies. Explaining these interconnected concepts clearly to students can be challenging.

Evolution of the course of computer networks teaching requires a sharp and keen balance between base knowledge and skills and practical achievements, as well. Achieving this can be started with new tools and techniques in engineering and sciences. From this point of view, effective teaching is, in reality, a set of tools and practical skills in networking, radio communication, and exchanging signals and data in local area networks (LANs) which, united, help students understand in practice. Advanced teaching tools and simulation environments are increasingly used to support practical learning in Computer Networks courses. In particular, network-simulation tools such as ns-3 and the BRITE topology generator, which are used as teaching aids in networking courses [1], provide students with opportunities to understand network behavior, topology design, and performance analysis through simulation. In addition, integrating Computer Networks with related areas such as programming and cybersecurity can provide a multidisciplinary learning environment and improve students' engagement with the concepts being studied [2].

Prior studies report that interactive and artificial intelligence (AI)-supported educational systems can improve personalized learning, teaching efficiency, and student engagement [3, 4]. Such systems have also been associated in the literature with gains in digital literacy and confidence.

Together, these strategies represent a complete framework for revolutionizing learning in computer networks [5]. This research highlights the integration of computer network technology into education, which enhances flexible and innovative teaching methods. When these methods combine with traditional, it fosters skilled professionals [5].

1.1 Traditional teaching techniques

At the same time, some of the concerns are related to the lack of student engagement and creativity in the classroom environment. The issue is linked to the traditional method of teaching that emphasizes rote learning and instructor-led lectures. While these teaching characteristics may be productive during foundational courses, integration of modern means is necessary, as traditional methods would not develop critical thinking or collaboration in a tech-savvy world. In this regard, an example can be presented of the situation in which "lecture-heavy teachers simply kill student initiative and creativity in thinking about a core concept. The students end up passively listening and taking notes." The approach does not promote student initiative and creativity, and the learners are less motivated to collaborate in various activities. Most notably, the quality is theoretical knowledge that does not prepare students for practical work in the field [6].

1.2 Innovative teaching approaches

Innovative teaching methodologies in computer networking increasingly incorporate simulation-based learning, virtual laboratories, and project-oriented activities. These student-centered approaches encourage active participation, practical problem-solving, and the application of theoretical networking concepts. The integration of virtual network simulation environments can further enhance students' practical skills and learning achievement by providing interactive and realistic networking experiences [7, 8]. Research findings indicate that innovative and interactive teaching methods can significantly improve students' academic achievement and attitudes toward computer networking compared with traditional approaches. However, traditional methods may still provide a stable foundation for basic knowledge acquisition before students engage in more complex and interactive learning practices [9].

The main difference between teaching the traditional and innovative technique is mostly in their approaches to teaching/pedagogical practices, and technology integration [10]. Talking about innovative techniques, it's focusing on student engagement, practical applications and interdisciplinary learning, while traditional methods often emphasize rote learning and instructor-led lectures. This trend reflects efforts to align education with employment needs in a changing labor market [11]. The traditional approach provides fundamental knowledge but may not be sufficient to develop the skills required for today's jobs. In contrast, creative teaching methods can engage students effectively; however, their successful implementation can be labor-intensive and require substantial teacher training [12].

This paper presents an empirical, course case study aimed at identifying, implementing, and evaluating a defined set of innovative teaching methods in a Computer Networks course. The effectiveness of these teaching methods/pedagogical practices is assessed by examining their association with student learning through course outcome (CO) attainment across two consecutive academic cohorts. The focused literature review included in this study is intended only to motivate and situate the proposed teaching interventions within the existing evidence on networking education and is not presented as a systematic review.

Accordingly, the study aims to identify, implement, and analyze the impact of modern teaching methods / pedagogical practices on student learning [13] by comparing COs across two consecutive academic years. The adopted teaching framework integrates selected innovative and adaptable instructional strategies designed to improve student engagement, conceptual understanding, and attainment of defined COs. Such teaching methods / pedagogical practices can support educators in strengthening computer networks education and preparing students with relevant knowledge and practical skills for a rapidly evolving technological landscape [14].

2. RELATED WORK

For this study on teaching computer networks, the investigation is organized around traditional teaching practices, innovative instructional tools, and multidisciplinary approaches. The following aspects are examined:

- Challenges and traditional approaches in teaching computer networks
- Innovative techniques and tools in teaching computer networks
- A multidisciplinary approach to teaching computer networks and cybersecurity

2.1 Challenges and traditional approaches in teaching computer networks

Table 1 highlights research on conventional approaches used to teach computer networks, which primarily focus on lectures, textbook instruction, and theoretical analysis. While these approaches provide essential conceptual understanding, they often fall short in addressing the fast-evolving nature of modern networking systems. The most significant disadvantage of all these conventional approaches is the restricted exposure to tangible, hands-on learning methods. It leads to a lack of opportunity for learners to effectively apply their knowledge gained from the classroom. This gap between academic theory and professional practice is still a major obstacle. In this case, learners most of the time still experience difficulty applying what they learned from the classroom in real life [14], even though teaching tools such as Computer-Aided Learning are being used. Despite the use of Computer-Aided Learning tools, concerns about learner participation and teaching effectiveness remain [15].

2.2 Innovative techniques and tools in teaching computer networks

Table 2 depicts that the modernized teaching methods, including simulations, virtual labs, and project-based learning, can also be innovative. The rate of these being implemented for students is much higher, which positively influences their immersion. Some, like software tools Delite, ns-3, and BRITE, make it easier for students to engage in activities like network design, simulation, and emulation that become beneficial to the student's ability to have a conceptual understanding and solve issues [16]. Other innovations, such as interactive ones, role-play exercises, and real-world problems to solve, also hold first place. As for the form of education, the Small Private Online Courses (SPOCs) imply many small private online courses. These have a high rate of satisfaction among students and yield better student results due to the improved ambiance they create. While the previously mentioned methods are effective, they can be developed in non-universal ways, thus requiring more from institutional staff. The consolidated summary is provided in Table 2.

Table 1. Tabular summary of challenges and traditional approaches in teaching computer networks

Teaching Method/Tool	Type	Purpose	Engagement Level	Hands-on Experience	Real-World Relevance	Effectiveness	Reference
Traditional networking teaching with a multidisciplinary approach	Traditional	To emphasize foundational networking knowledge while integrating cybersecurity into the curriculum	Low	Low		Moderate	Katonová et al. [12]
Computer-aided network technology in education	Traditional	To explore the role of computer-aided tools in enhancing traditional network technology education	Moderate	Moderate	Moderate	Moderate	Zhang [13]
Literature review on methods in teaching computer networks	Traditional	To evaluate existing methods for teaching computer networks and highlight their limitations	Low	Low	Low	Low	Prvan and Ožegović [16]
Traditional approaches in computer networks	Traditional	To provide foundational knowledge and theoretical understanding of computer networks	Low	Low	Moderate	Moderate	Zhou et al. [17]
Comparative analysis of traditional and modern teaching methods	Traditional	To compare the effectiveness of traditional methods with modern, technology-based approaches	Low	Low	Low	Moderate	Tian [18]

Table 2. Tabular summary of innovative techniques and tools in teaching computer networks

Description	Teaching Method/Tool	Type	Purpose	Engagement Level	Hands-on Experience	Real-World Relevance	Effectiveness	Limitations
Innovative network design and simulation tools	Delite, ns-3, BRITE	Innovative	To enhance the understanding of network design and simulation	Medium	Yes	High	High	Requires familiarity with complex tools and setups
Network education system using technology	Simulations, interactive tools	Innovative	To adopt new technologies for improving network education systems	High	Yes	High	High	Potentially costly and requires technological infrastructure
Project-based learning and simulations	Project-based learning, role-play, simulations	Innovative	To engage students in active, real-world problem-solving in network education	High	Yes	High	High	May be time-consuming for instructors to manage
Small private online courses (SPOCs)	SPOCs (Online courses)	Innovative	To offer personalized, flexible learning for students	Medium	Yes	Medium	Medium	May lack direct instructor interaction and peer collaboration
Innovative pedagogies for improved learning	Active learning techniques, collaborative learning	Innovative	To enhance student outcomes using innovative pedagogies	Medium	Yes	High	High	Can be challenging to implement in large classes
Network technology integration in computer-aided education	Computer-aided education tools	Innovative	To integrate network technology into computer-aided education tools for better learning	Medium	Yes	High	High	Requires technological support and skilled instructors
Comparison of traditional and innovative teaching methods	Traditional vs. innovative teaching methods	Hybrid	To compare and contrast traditional and innovative methods and improve curriculum development	Medium	No	Medium	Medium	May be biased towards one approach over the other

Table 3. Tabular summary of multidisciplinary approach to teaching computer networks and cybersecurity

Teaching Method/Tool	Effectiveness	Engagement	Skill Development	Student Satisfaction	Real-World Application	Reference
Multidisciplinary framework for computer networks and cybersecurity	High	High	Technical, critical thinking	High	High	Katonová et al. [12]
Innovative thinking approach to computer network education	High	High	Problem-solving, technical	High	High	Zhou et al. [17]
Cybersecurity integration in network education	High	High	Technical, problem-solving	Medium	High	Kainz et al. [15]

2.3 A multidisciplinary approach to teaching computer networks and cybersecurity

As shown in Table 3, a multidisciplinary approach like cybersecurity, data science, and system administration is considered altogether in teaching Computer Networks course or in other networking education.

Traditional approaches to teaching computer networks provide a strong theoretical foundation but may offer limited opportunities for practical skill development. Experiential, technology-supported, and interdisciplinary approaches involving areas such as cybersecurity and system administration can complement theoretical learning and better address real-world networking requirements. Prior studies on virtual laboratories, network testbeds, and Packet Tracer report improvements in networking knowledge, engagement, and practical understanding. However, outcomes may vary with instructional context and assessment design. Therefore, this study evaluates the implemented teaching interventions using direct CO attainment in an authentic Computer Networks course. Accordingly, the present study addresses the following research question.

RQ: How does the integration of modern and interdisciplinary teaching methods affect CO attainment in computer networks education?

3. METHODOLOGY

3.1 Study context and participants

The study was conducted for Computer Science and Engineering students, in the Computer Networks course (course code C302). Both offerings ran for one semester of 14 weeks. The traditional cohort (academic year 2022–2023) comprised 112 students, and the innovative cohort (academic year 2023–2024) comprised 112 students, drawn from the same program and admitted under the same criteria. To isolate the effect of teaching method as far as an observational design allows, the following were held constant across both years: the syllabus and unit structure, the credit and contact-hour pattern, the assessment scheme and marks distribution, the CO definitions and the 50% target benchmark, and the instructor(s) delivering the course. What changed between the two years was the teaching method: predominantly lecture- and board-based instruction in 2022–2023 versus the defined innovative interventions listed in 2023–2024.

Table 4 summarizes the factors that were held constant and the factor that was deliberately varied. Factors that a two-cohort design cannot fully control—for example, differences in incoming student ability and external learning conditions—are discussed in limitations.

Table 4. Factors held constant or varied across the two academic years

Factor	Academic Year 2022–2023 (Traditional)	Academic Year 2023–2024 (Innovative)
Syllabus and unit structure	Same	Same
Credits/contact hours	Same	Same
Assessment scheme and marks	Same	Same
CO definitions and 50% target	Same	Same
Cohort size	112	112
Teaching method	Lecture / board-based	Role-play, Packet Tracer, virtual labs, 50:10, OCW, quizzes and flipped classroom

Note: OCW = OpenCourseWare, CO = course outcome.

The methodology includes the comparison of traditional and innovative teaching methods in detail.

3.2 Traditional teaching techniques

The advantages of traditional ones include the following: lectures and direct instruction are instructor-centered approaches offered to the students; in turn, the disadvantage rests upon the limited engagement in terms of student initiative and approach to the learning process. Secondly, it is the emphasis on theory, and although this knowledge can provide a good basis for the practical procedures in the field, there might be challenges that were not predicted beforehand. Here are a few from the list of traditional ones and scenarios.

3.2.1 Scenario 1

In Table 5, the teacher attempted to explain the concept of a Computer Network using the conventional chalk-and-board method, aiming to provide students with a foundational understanding. Similarly, when teaching network topology, teachers relied on the traditional approach to explain the concept in detail. However, when students tried to apply these concepts to real-world problems, many found themselves confused, struggling to bridge the gap between theoretical knowledge and practical application.

Figure 1 illustrates the conventional chalk-and-board presentation of the seven-layer Open Systems Interconnection (OSI) model and bus topology.

Table 5. Conceptual scenarios illustrating challenges associated with traditional teaching in computer networks

Sr. No.	Traditional Teaching Scenario	Potential Learning Challenge	Evidence Considered in the Present Study
1	The teaching of Computer Networks concepts is mostly conducted in the traditional way of chalk and board.	Concepts that are abstract may need further visualization and reinforcement in practice.	Theory-based course outcome (CO) attainment
2	Students are expected to relate the theoretically discussed networking concepts to real-life or practical problems.	Guided practice could be necessary to transfer theoretical knowledge into practice.	Theory, Practical and Term-Work CO attainment
3	The conventional board-based diagrams are used to explain the network topology.	Static representations might offer limited opportunities for interactive exploration of network structures.	Theory-based CO attainment
4	Students try to use the concept of network topology to solve real problems.	Hands-on activities may be needed to reinforce conceptual understanding and application.	Practical and Term-Work CO attainment

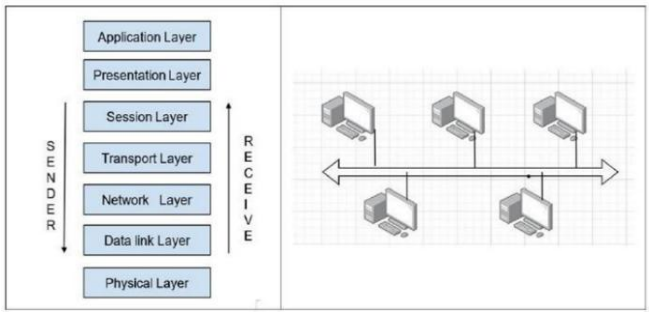

Figure 1. Open Systems Interconnection (OSI) seven-layer model and bus topology

3.2.2 Scenario 2

The scenario shown in Table 6 occurred during the teaching of the Dynamic Host Configuration Protocol (DHCP) concept using the traditional chalk-and-board method. Although the instructor used analogies and diagrams to simplify DHCP, learners continued to struggle with its practical functionality in real-world networking environments. The confusion was mainly due to the dynamic nature of IP address assignment and device-server communication. This scenario highlights the limitations of conventional teaching approaches and the importance of lab assignments and network simulations in bridging the gap between theory and practical application.

Figure 2 illustrates the DHCP server architecture used to explain address allocation in the traditional teaching scenario.

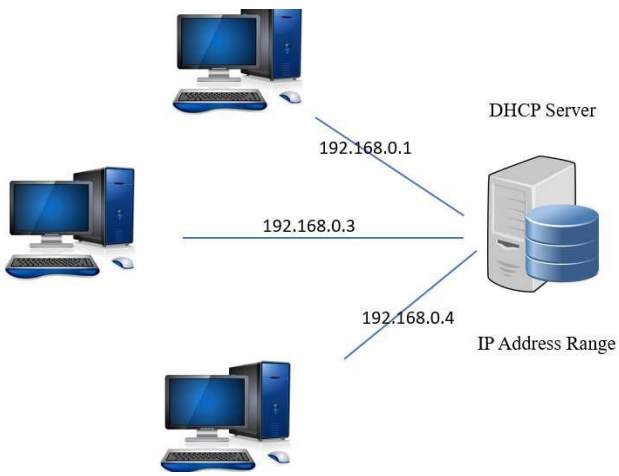

Figure 2. Dynamic Host Configuration Protocol (DHCP) server architecture

Table 6. Dynamic Host Configuration Protocol (DHCP) for traditional teaching method

Teacher: *"Alright, Dear students, today we're going to learn Dynamic Host Configuration Protocol. Let's start with the basics. Imagine a network as a room full of devices, and each device needs a unique address to communicate. The DHCP server assigns these addresses dynamically."*
Student 1: *"So, the server gives out addresses... but how does it know which device gets what?"*
Teacher: *"Good question! The server has a pool of addresses. When a device joins the network, it requests an address, and the server picks one from the pool."*
Student 2: *"I don't get it. What if two devices get the same address?"*
Teacher: *"That's the job of the DHCP server. It ensures no two devices get the same address by keeping track of what's assigned."*
Student 3: *"But what does this request look like? And how does the device even know to ask?"*
Teacher: *"Okay, let me try again. Think of it like borrowing a book from a library. The device asks for a book, and the server—like a librarian—hands it one that's available."*
Student 1: *"I think I get the library part, but what does that look like in a real network?"*
Teacher: *"Hmm, it seems the traditional method isn't enough. Maybe I need to show you a simulation or a hands-on example next time. That might help clarify the process."*
Student 2: *"Yes, a demonstration would really help. This is hard to visualize with just drawings."*

3.3 Innovative teaching techniques

A wide range of innovative tools and teaching techniques is available for computer networks education. In the present study, role-play, Cisco Packet Tracer, and virtual laboratory activities were implemented as part of the course delivery. Among these, Packet Tracer served as a network simulation tool for demonstrating, configuring, and troubleshooting virtual network environments, thereby providing students with practical learning experience without requiring extensive physical networking hardware.

The present study evaluates the overall effect of the implemented teaching interventions in the Computer Networks course. Therefore, the observed changes in CO attainment reflect the overall impact of the applied teaching approaches. The methods evaluated in this study are limited to those actually implemented during the 2023–2024 offering of the Computer Networks course. To clearly distinguish the evaluated interventions from the broader range of teaching methods and pedagogical practices discussed in the Related Work section, Table 7 identifies the methods implemented and

assessed in the present study and separately lists those discussed only as potential approaches for future adoption.

Table 7. Implementation and assessment status of innovative teaching methods in the Computer Networks course

Method	Status in 2023–2024 Course	Assessed in This Study?
Role-play	Implemented	Yes (via CO attainment)
Cisco Packet Tracer simulations	Implemented	Yes
Virtual laboratory	Implemented	Yes
50:10 presentation module	Implemented	Yes
OCW assignments	Implemented	Yes
Quizzes	Implemented	Yes
Flipped classroom	Implemented	Yes
MOOCs / SPOCs	Discussed only	No
Full multidisciplinary integration	Discussed only	No

Note: OCW = OpenCourseWare, CO = course outcome, MOOCs: massive open online courses, SPOCs: small private online courses.

3.3.1 Role-playing activities

Another innovative method that has been used to teach computer networks is role-play, which creates opportunities for students to engage in key complex networks. This approach creates a community-based learning environment for students who impersonate certain individuals in the network, thus gaining a better understanding of human-centric behavior within the system, which improves their vital skills. The methodology is summarized in Figure 3.

3.3.2 Enhanced participation and understanding

•Role-play encourages active participation, making difficult concepts in computer networks more accessible.

•Students engage in scenarios that mimic real-world challenges, which aids in mastering technical content through experiential learning.

3.3.3 Development of soft skills

•This method cultivates critical soft skills such as teamwork, decision-making, and problem- solving, which are highly valued in the job market.

•By dividing students into attacking and defending roles in network security exercises, they learn to collaborate and strategize effectively [12].

According to student feedback, learning becomes more enjoyable. Physical activity is transformed into conceptual knowledge, which is retained in memory for a longer time, leading to better exam results.

3.3.4 Teaching bus topology and DHCP server using innovative way

The animated illustrations in Figures 4 and 5 show how these concepts can be taught using innovative methods.

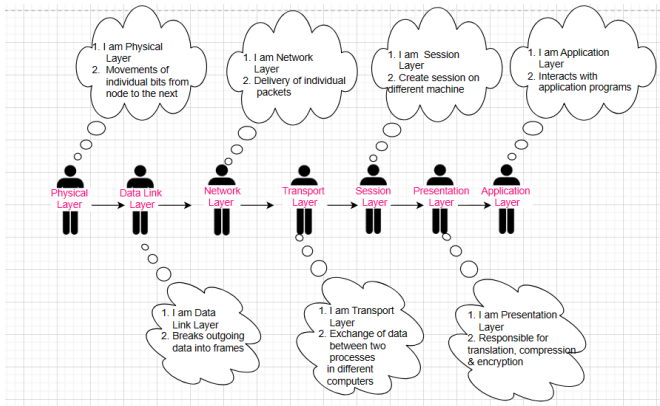

Figure 3. Innovative teaching methodology through role play

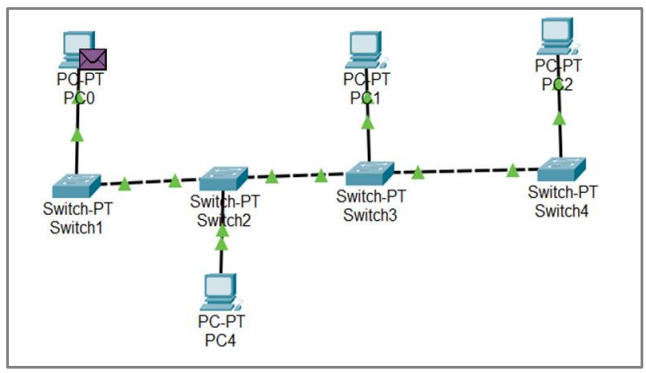

Figure 4. Innovative teaching methodology for bus topology

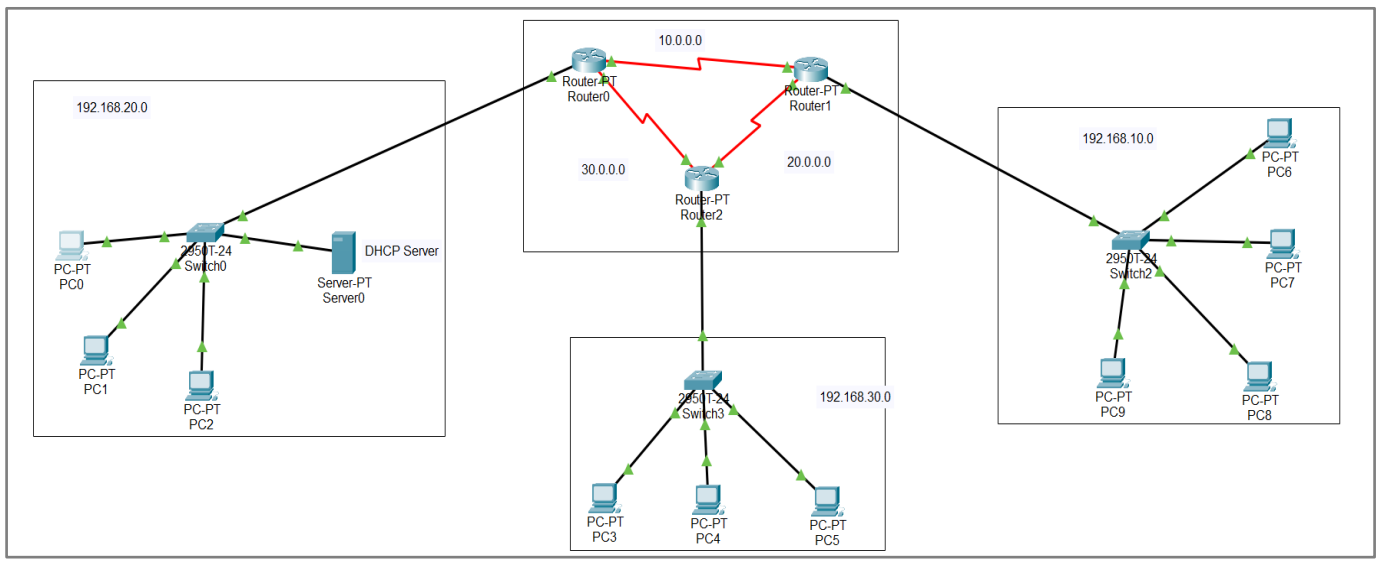

Figure 5. Innovative teaching methodology for Dynamic Host Configuration Protocol (DHCP) server

3.4 Other innovative techniques

The methods below are apart from the traditional way and can be taken into consideration for teaching subjects like computer networks to students.

•Multidisciplinary approach: Innovative methods integrate various fields such as programming

•Cybersecurity: Fostering a more holistic understanding of computer networks

•Active learning: Techniques like team-based projects and real-world case studies encourage collaboration, critical thinking, and problem-solving skills

•Use of technology: Incorporation of online courses and digital tools enhances accessibility and allows for personalized learning experiences.

3.4.1 50:10 module

The objective of developing this module is to imbibe critical thinking skills in learners, so that they can recapitulate knowledge gained in attended sessions or through self-learning. Many students in India come from vernacular backgrounds and may have average or poor English skills. So, Implementation of the 50:10 module in teaching improves the communication and presentation skills of students, as well as their subject knowledge. This practice helps in improving their verbal communication and presentation skills and also helps boost their confidence to face the audience.

The engineering faculty has a 60-minute lecture period. The 50:10 module involves the teacher giving a 50-minute lecture and a 10-minute presentation slot. The confidence of students has been boosted by this activity. This module allows learners to share their insights about the concept with other members of the class. At the end of every session, a random learner is selected as the presenter; he is expected to summarize the concepts taught by the instructor or the concepts understood through self-learning.

Benefits of 50:10 module:

•Improved scores and individual performance during technical presentations and exams.

•The level of confidence of students during job interviews and events is remarkable.

•Participation in other activities can be improved.

3.4.2 Virtual lab

It offers remote access to the laboratory for experiential learning and enables sharing of basic as well as state-of-the-art equipment and resources of remote labs. Virtual lab is a very useful and effective way compared to traditional teaching. Remote experimentation helps students learn basic and advanced concepts and provides an online platform for self-paced experiments. The provision of a lab facility overcomes the boundaries of physical distances and allows for exposure to state-of-the-art equipment and resources.

Benefits of using virtual labs:

•The significant improvement in conceptual knowledge.

•Learners' performance in practical and oral exams is enhanced.

•Critical thinking and problem-solving skills of learners can be improved.

•Quality of projects developed by learners is improved.

3.4.3 OpenCourseWare assignment

The implementation of the OpenCourseWare (OCW) assignment can be de facto in teaching computer network using innovative way. It encourages self-learning and raises awareness about the available open courseware resources. It enhances the abilities of listening, reading, and writing, and also enhances employability. In OCW, instructors allocate the topics to learners and provide the data regarding available OCW modules where learners refer to OCW videos/resources; further, they provide a brief summary of the contents in the prescribed format as an assignment. This method improves academic performance and bridges the gap between industry and academia, which helps in better placements.

3.4.4 Quiz

Innovative teaching methods, particularly through quizzes, can significantly enhance the learning experience in computer networks. By integrating quizzes into a multidisciplinary approach, educators can foster engagement and reinforce key concepts. This strategy not only motivates students but also connects various areas of informatics, such as programming and cybersecurity.

Multidisciplinary approaches:

•Quizzes can be designed to cover multiple disciplines, encouraging students to apply knowledge from computer networks, cybersecurity, and programming.

•This approach has shown positive feedback, with over 86% of students expressing interest in expanded content.

Innovative teaching methods:

•Incorporating quizzes within flipped classrooms and MOOC/SPOC frameworks can enhance student-centered learning, making the material more accessible and engaging.

•Quizzes can also be used to assess practical skills, fostering teamwork and innovation through collaborative problem-solving.

3.5 Assessment methodology

Student learning was measured by direct assessment of CO attainment. Each CO is assessed by one or more tools — Unit Test, Preliminary Examination, Practical Examination, and Term-Work — and every examination question is mapped to a single CO. For a given CO, attainment is the average fraction of the marks that students obtained on the questions mapped to that CO, expressed as a percentage (Eq. (1)):

$$\text{CO Attainment (\%)} = \frac{\text{Average marks obtained by students in CO} - \text{related questions}}{\text{maximum marks assigned to CO} - \text{related questions}} * 100 \quad (1)$$

where, the average marks obtained is the mean, over all students in the cohort, of the marks each student scored on the questions mapped to that CO, and the maximum marks assigned is the total marks allocated to those same questions. A CO assessed by more than one tool is combined as a weighted mean of the tool-level attainment values, using the marks distribution of Table 8 as weights (Eq. (2)):

$$CO \text{ Attainment} = \frac{\sum_k (w_k \times A_k)}{\sum_k (w_k)} \quad (2)$$

where, A_k is the attainment of the CO on tool k (Theory, Practical, or Term-Work) and w_k is that tool's weight. The final course attainment is the mean of the individual CO attainments. A CO meets the target when its attainment $\geq$50%; the attainment gap is defined as (target−achieved), so a positive gap indicates a shortfall against the 50% target and a

negative gap indicates attainment beyond target.

For example, if the questions mapped to CO C302.1 carry a total of 20 marks and the cohort's mean score on those questions is 10, the Theory attainment for C302.1 is calculated as follows:

$$\text{Attainment (C302.1} - \text{Theory)} = \frac{10}{20} \times 100 = 50\% \quad (3)$$

4. RESULTS AND DISCUSSION

The results of the Computer Networks course are analyzed, focusing on the effectiveness of traditional teaching methods compared to innovative techniques. The academic year 2022–2023 was taught in a traditional manner, as discussed in scenarios 1 and 2. Academic year 2023–2024 was taught in innovative ways, and attainment was calculated in the academic year 2022–2023. The detailed result analysis is discussed below.

4.1 Evaluation rubrics and criteria

To ensure transparency, attainment can be calculated using structured rubrics, and the criteria are decided based on overall observation and can be updated as per the requirement.

•Theory (Unit Test/Prelim): Knowledge & Understanding (40%), Application (40%), Presentation (20%).

•Practical (Labs/Simulations): Correctness (40%), Problem-Solving (30%), Documentation (20%), Innovation (10%).

•Term-Work: Completeness (30%), Accuracy (30%), Originality (20%), Presentation (20%).

Scores from these rubrics were mapped to COs, and attainment was computed using Eq. (1).

4.2 Assessment tools and marks distribution

Table 8 illustrates the assessment tools employed in the Computer Networks course and their respective weightage across the units. The evaluation framework consists of two major assessments: Unit Tests and Preliminary Exams, each covering specific units of the syllabus. The distribution of marks is designed to ensure a balanced evaluation of student understanding across different sections of the course.

Table 8. Assessment tools and marks distribution of Computer Networks course

Assessment Tool	Units Covered	Weight (%)
Unit Test	Unit I	Unit I: 50%
	Unit II	Unit II: 50%
Preliminary Exam	Unit III	Unit III: 25%
	Unit IV	Unit IV: 25%
	Unit V	Unit V: 25%
	Unit VI	Unit VI: 25%

•Unit Test: This test assesses Unit I and Unit II equally, with each unit contributing 50% of the total marks for this assessment. By focusing on these initial units, the test gauges students' foundational knowledge in the subject.

• Preliminary Exam: The exam covers evaluations of Unit III, Unit IV, Unit V, and Unit VI. Each unit is awarded 25%, ensuring thorough coverage of the second part of the course syllabus.

The distribution of marks across the assessments is well structured and allows for a fair system of testing. Testing in this way ensures that no unit is over-assessed and promptly addresses where more support should be accorded to students for better learning.

4.3 Statistical analysis

The statistical analysis was conducted using aggregated CO attainment values. For each assessment component (Theory, Practical, and Term-Work), the same six COs measured in 2022–2023 and 2023–2024 were matched, resulting in six paired observations per component. Each pair therefore represents the attainment percentage of the same CO across the two academic cohorts. Accordingly, the paired *t*-test and Wilcoxon signed-rank test were applied to these six matched CO-level differences. For the pooled analysis, the six COs across the three assessment components were combined, resulting in 18 matched CO-component observations. Cohen's d_z was calculated using the mean and standard deviation of these paired differences.

To test whether the difference in CO attainment between the two cohorts is larger than would be expected by chance, the attainment values for the matched COs were compared across the two years, separately for each assessment component. Because the same six COs are measured in both cohorts, a paired comparison is appropriate: for each CO i the paired difference is

$$d_i = A_i(2023 - 2024) - A_i(2023 - 2024) \quad (4)$$

We report the mean paired difference $\bar{d}$ with its 95% confidence interval (CI), a paired *t*-test, and the standardised effect size Cohen's $d_z = \frac{\bar{d}}{s_d}$, where s_d is the standard deviation of the differences. Because each component has only six matched COs, the non-parametric Wilcoxon signed-rank test is reported as a robustness check. All tests are two-tailed at $\alpha = 0.05$.

Across the 18 matched CO / component measures, mean attainment increased from 54.0% (2022–2023) to 72.4% (2023–2024): mean paired difference $\bar{d}$ = 18.3 percentage points, 95% CI [11.1, 25.6], paired $t(17) = 5.31$, $p < 0.001$, Cohen's $d_z = 1.25$ (Wilcoxon $p < 0.001$). The change was not uniform across components (Table 9): the improvement was large and significant for the Theory component (+36.4 pp, $p < 0.001$, $d_z = 6.44$) and moderate and significant for Term-Work (+14.2 pp, $p = 0.001$, $d_z = 2.80$), whereas the Practical component changed only modestly and the difference was not statistically significant (+4.4 pp, 95% CI [−1.2, 10.1], $p = 0.099$). This pattern suggests that the innovative methods were most strongly associated with gains in conceptual/theoretical outcomes, while Practical-component attainment—already comparatively high under traditional teaching—showed little additional change.

These results indicate a statistically detectable association between the change to innovative teaching and higher CO attainment, concentrated in the Theory and Term-Work components. They do not by themselves establish causation: the two cohorts differ in more than teaching method (see Limitations), and the design is observational rather than a randomized controlled comparison.

Table 9. Comparative statistical analysis of course outcome (CO) attainment across 2022–2023 and 2023–2024 academic cohorts

Component (n = 6 COs)	2022–2023 Mean	2023–2024 Mean	Mean Difference (pp)	95% Confidence Interval (CI)	$t(5)$	p	Cohen's d_z
Theory (Th)	45.2%	81.5%	+36.4	[30.4, 42.3]	15.77	<0.001	6.44
Practical (PR)	63.3%	67.8%	+4.4	[−1.2, 10.1]	2.02	0.099 (n.s.)	0.82
Term-Work (TW)	53.6%	67.8%	+14.2	[8.9, 19.5]	6.85	0.001	2.80
Pooled (n = 18)	54.0%	72.4%	+18.3	[11.1, 25.6]	5.31	<0.001	1.25

4.4 Results

Course attainment for the academic year 2022–2023, illustrated in Figure 6, indicates that the attainment percentages for Theory are highly variable between COs. Particularly, C302.2 and C302.3 results are achieved at 45.2%, which is lower than the target of 50%. As such, it can be assumed that students performed poorly on these outcomes due to certain theoretical miscomprehensions or problems. On the contrary, the attainment percentages for Practical are generally the highest among Theory and Term-Work. This finding means that students have used their gained knowledge better when it came to practical tasks. This can be explained by the hands-on learning principles, interest in the subject, or simply a higher degree of understanding of theoretical tasks. Lastly, the attainment percentages for Term-Work vary among outcomes. Few results reach the 50% limit, while others, again, are lower than 30%. This suggests that the complexity of Term-Work or its teaching might differ among COs.

The gap between the target set and target achieved, the negative %, shows that the overall attainment of the course is described in Figure 7.

The attainment of academic year 2023–2024, as elaborated in Figure 8, indicates a remarkable improvement, since more overall student performance is evidenced in the academic year 2023–2024 compared to the previous year, as is shown by higher attainment percentages in most of the assessment tools and COs.

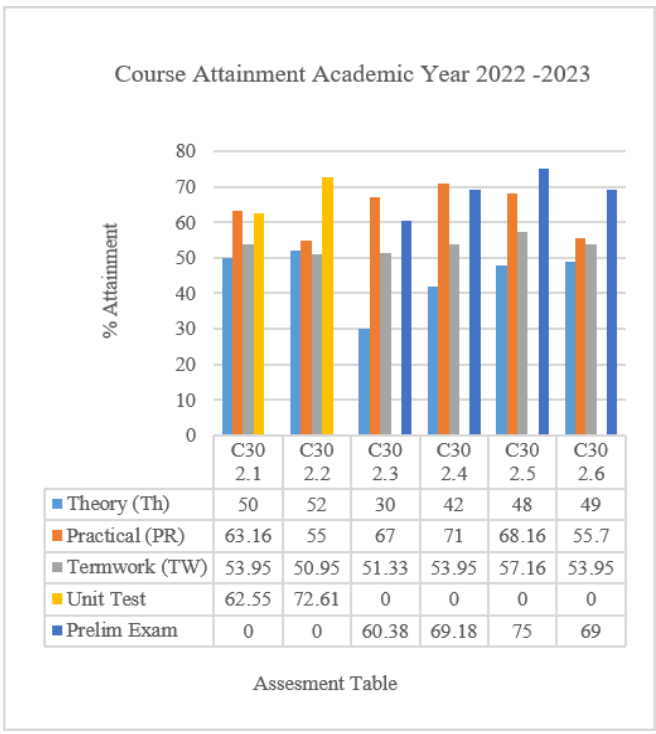

Figure 6. Course attainment for academic year 2022–2023



Figure 7. Target set vs attainment, academic year 2022–2023

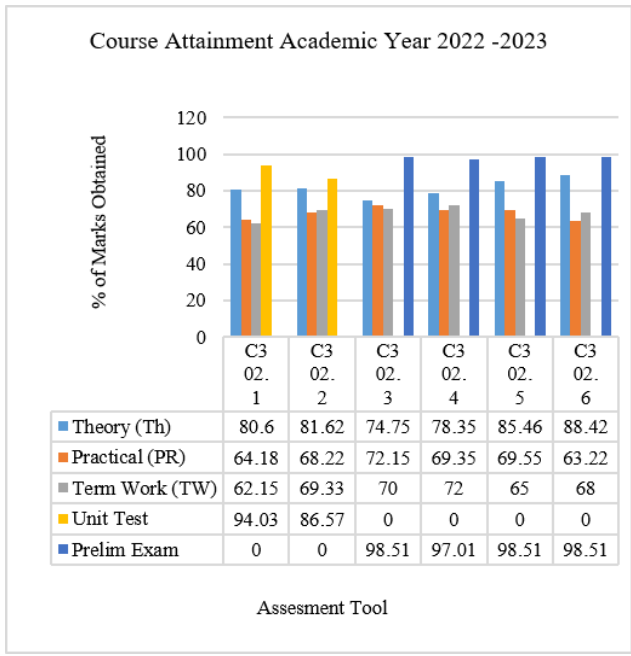

Figure 8. Course attainment for academic year 2023–2024

4.5 Specific assessment tools

4.5.1 Theory

•While both years showed variation in attainment percentages, the overall performance in 2023–2024 is notably higher.

•This suggests that students may have had a better understanding of theoretical concepts or that teaching methodologies were more effective in the 2023–2024 academic year.

4.5.2 Practical

•Both years showed similar trends in practical performance,

with variations across different COs.

•However, the overall performance in 2023–2024 seems slightly higher, indicating potential improvements in practical skills and application of knowledge.

4.5.3 Term-Work

•The attainment percentages for Term-Work in 2023–2024 are generally higher than those in 2022–2023.

•This suggests that students may have performed better in Term-Work assignments, possibly due to improved guidance, feedback, or student engagement.

4.5.4 Unit Test and Preliminary Exam

•Both years showed consistently high attainment percentages in Unit Tests and Preliminary Exams.

•This indicates strong performance in these specific assessment formats, likely due to effective preparation and exam strategies.

The gap between the target set and target achieved, publicized in Figure 9, shows the overall attainment of the course.

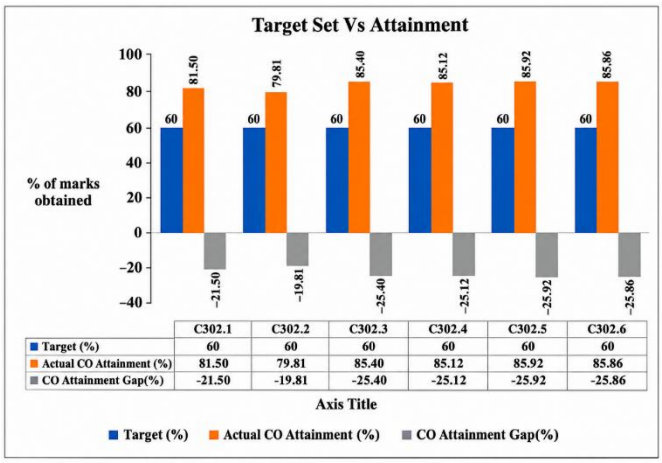

Figure 9. Target set vs. attainment, academic year 2023–2024

5. CONCLUSIONS

This study evaluates the relative effectiveness of traditional and innovative teaching methods / pedagogical practices in teaching the Computer Networks course through CO attainment. The comparison is based on two consecutive academic year: 2022–2023, during which the traditional teaching methodology was followed, and 2023–2024, during which innovative teaching methods were implemented. The results for 2022–2023 indicate comparatively lower attainment in some theoretical components, whereas practical COs showed relatively better performance. Term-Work attainment also suggested the need for improvements in teaching and student support. In contrast, the innovative teaching approach implemented during 2023–2024 was associated with improved attainment across Theory, Practical, and Term-Work components. The incorporation of Practical activities, guided learning, continuous feedback, and structured assessment appeared to support improved student engagement and learning outcomes. Unit-test and preliminary-examination performance also reflected the benefits of a more structured and activity-oriented instructional approach. Within the scope of one Computer Networks course and two consecutive cohorts, the adoption of innovative teaching methods was associated with measurably higher CO attainment across the Theory, Practical, and Term-Work components. These findings are encouraging but specific to this setting; whether the same association holds across other courses, institutions, and instructors remains a hypothesis for future multi-course and multi-instructor studies rather than a conclusion that can be drawn from the present data. Moreover, there was no systematic control over individual student characteristics and background differences between the two cohorts, and so these should be taken into account when interpreting the differences in CO attainment observed.

5.1 Limitations and future scope

This study is not a randomized or controlled experiment, but is an observational comparison of two sequential cohorts. The two groups were the same program and the same student selection criteria, but the effects of student individual-level characteristics and background factors were not systematically controlled for in the analysis. The observed differences in CO attainment may thus have been due to differences in academic ability when students enter the class, their prior exposure to the topic, the experience of the instructor over the years, and outside learning conditions. Thus, the observed improvement should be considered as related to the adopted innovative teaching approach, not as a cause of the approach. Second, the evidence base is a single course at one institution with cohort sizes of 112 and 112 students, which limits statistical power and generalizability. Third, only CO attainment was measured; affective outcomes such as motivation and confidence were not assessed with validated instruments. Future work should use larger, multi-course samples, ideally with a controlled or crossover design and pre-registered analysis, and add validated affective and skills measures.

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