Evaluating the Effectiveness of Cisco Packet Tracer for Teaching Networking Concepts at the Undergraduate Level

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ABSTRACT

This research aimed to examine whether Cisco Packet Tracer (CPT) leads to improved student achievement. Additionally, the study explored student's attitudes towards CPT during their networking learning experience. Employing a quasi-experimental quantitative research design, the study utilized a demonstrative and collaborative teaching approach based on Vygotsky's Social Constructivist learning theory. Twenty two students from Chitwan district of Nepal were purposively selected for the study. Multiple-choice questions for achievement test and five point likert scale for analyzing attitude towards CPT was used in the study. Pretest and posttest achievement test items were developed using scholarly and peer suggestions, followed by a pilot test. The data obtained from the achievement test and opinionnaire were analyzed using inferential and descriptive statistics. The finding of the study indicates that the student of experimental group has better performance than control group. In the Likert scale questionnaire conducted solely on the experimental group, students' attitudes toward Cisco Packet Tracer appeared positive, showing increased interest, engagement, and confidence when dealing with real physical devices.

Keywords: Networking, Cisco Packet Tracer, Zone of Proximal Development, Peer Collaboration

Introduction

The development and rapid growth of the Internet in combination with its increasing accessibility for the public have opened up for completely new digital world (Hohenwarter et al., 2008). With the growing demand of computer networks especially in enterprise, small organizations, and even in domestic applications, there is a need of professionals with sound knowledge and practical experience in computer network. This need is reflected in the curricula of bachelor's degrees in IT related courses, where computer networking is now a fundamental subject. Computer networking is crucial in

various undergraduate programs, including Electrical Engineering, Computer Engineering, Computer Science, Information and Communication Technology, Software Engineering, and others (Crichigno & Hurtado, 2012).

In the context of Nepal, different Universities have launched different IT courses. In a couple of years Tribhuvan University, Kathmandu University, Purbanchal University, Pokhara University came out with their own undergraduate programs in IT and have been conducting the IT courses by themselves or through their affiliated colleges (Shakya & Rauniar, 2002). Each degree program has a motive of producing skilled manpower related to IT field along with proficient knowledge and skill in computer network. To address this, colleges must emphasize providing ample practical knowledge alongside theoretical concepts in IT-related subjects. According to Prvan and Ozegovic (2020), the theoretical concepts in this field are quite abstract, making them appear too technical and challenging for students to grasp. This creates a significant challenge for teachers to enhance students' motivation and interest in learning computer networks. It reflects the need for both theoretical and practical knowledge. Considering this well-equipped laboratory is obligatory to enhance practical skills on computer network. However, their interest and motivation may diminish during theoretical session. Therefore, a tool is required during the teaching and learning of theoretical concepts on networking in order to maintain their interest in learning before their hands-on practical.

A simulator can be used to keep student's interest and motivation in learning networking. Liu (2019) emphasizes that simulation is used in computer networks to demonstrate the internal workings and protocols, as well as to emulate network scenarios without the need for dedicated hardware. Patel et al. (2018) also mentioned that "network simulation is a technique in which software program analyzes the behavior of a network by computing the association between different network devices such as the hub, switch, router, access points, links, etc." Hence, network simulator provides virtual environment where students can design, build and configure network model. Airi and Peter (2017) mentioned that "Simulation serves as an alternative approach, though it is not intended to completely replace hardware". Thus, network simulator can play role of supplementary tool to visualize and demonstrate the concept of computer networks, protocols, and applications.

From the above discussion, we can observe that integration of ICT tools in learning has significantly changed conventional classroom settings to drill and practice learning environments. In the case of computer network, simulation has provided a platform where students can learn in better-visualized form. Students can explore their ideas by looking, observing, manipulating things in the simulator which help them to maintain their curiosity on learning and moreover help them to create a visual form of content in their mind. The objective of this study is to compare the performance of students taught using the Cisco Packet Tracer (CPT) network simulator software with those taught using

conventional teaching methods in networking. The null and alternative hypothesis of the study are listed below. Additionally, the study aims to assess students' attitudes towards the use of CPT network simulator software in learning networking.

- H0: There is no significant difference between the achievement of students by using Cisco Packet Tracer simulation software and conventional method in teaching networking.
- H1: Students who participate in learning networking using Cisco Packet Tracer simulation software have higher achievement scores than students who participate in learning networking by conventional method.

Theoretical Framework

It is quiet challenging to teach students networking concept and related terminologies and master them on those concepts. That's why the researcher adopted demonstrative as well as collaborative method to teach networking. Vygotsky's Social Constructivists Theory of Learning was used as primary theoretical framework. Vygotsky's Social Constructivists Theory of Learning emphasized on social interaction for cognitive development. The main principles were anchor on the zone of proximal development (ZPD) and scaffolding.

Vygotsky defined the ZPD as "the gap between a learner's current level of independent problem-solving ability and their potential development level, which can be reached through problem-solving with adult guidance or collaboration with a more capable peer" (Shabani et al., 2010). In this research, instructor taught concept of networking by using Cisco Packet Tracer, after that learners have to work in peer to practice in Cisco Packet Tracer simulator to enhance their learning. Scaffolding refers to the guidance provided for one to reach the ZPD. The researcher encouraged learners to participate in collaborative creation of various networks using Cisco Packet Tracer during their peer activities for lesson learning. The learner may not reach actual level of attainment on concept by themselves because of difficulty level that's why teacher's clarification on concept is required. Moreover, every individual have different level of understanding as well as different interpretation of concept and when they have peer interaction while using Cisco Packet Tracer. It has supported them to gain a different perception and develop a different manner of understanding on learning networking which means the higher ability learner helped lower level learner to reach their ZPD. The higher ability learners also get benefited through insight gained from peer. Therefore, in this study, the Cisco Packet Tracer simulator software, along with guidance from instructors and the availability of peer support, serve as scaffolding. After participating in a learning process involving instructors and peers, each learner individually explores networking knowledge through both intra-psychological and inter-psychological perspectives. Vygotsky also emphasized the social aspect of learning stressing that knowledge is socially constructed as we interact with more knowledgeable others (Rampersad, 2011). In this study, the more knowledgeable individuals included instructors who introduced students to concepts, peers with whom collaboration occurred, and the Cisco Packet Tracer tool used to master these concepts. "All human action is regulated by tools and effective learning takes place as we interact with the tools and artifacts" (Vygotsky, 1978). In the current

society, technology is most effective tool with which students are getting influenced. Thus, the more students get a chance to interact with technology in a group the more they get interested in learning which supports them in constructing concept.

Literature Review

Diverse research has been conducted on use of simulation while teaching computer network to find out its effectiveness as well as attitude towards simulation implementation considering different variables, such as teacher, student, administration, gender, and so on. Marquardson and Gomillion (2019) investigated the effectiveness of simulations in transferring network skills from simulated to physical environments. Their study involved 17 students (3 females and 14 males) who performed networking exercises using Cisco Packet Tracer and subsequently completed tasks using physical cisco routers and switches. The result indicated that while simulations are effective, they do not completely eliminate the need for physical equipment.

Taher and Khan (2015) conducted a comparative study to evaluate simulation-based teaching against traditional hands-on-labs for circuit construction using Multisim-8. Based on findings it is suggested that students should be exposed to theoretical knowledge in traditional lecture mode first, followed by simulation-based lab activities, and finally required to do hands-on lab experiments. The study recommended a multi-phase approach to teach complex technical subjects.

Rashid et al. (2019) examined the impact of CPT on student learning and their attitude about the effectiveness and acceptance of CPT in teaching and learning computer network. Fifty-five students were exposed to CPT on which they developed Wide Area Network (WAN), servers and switches according to cisco standard. The study concluded that Cisco Packet Tracer as a simulation and visualization tool significantly enhanced students' practical knowledge of computer networking principles, facilitated learning of network technical concepts, and improved networking skills, particularly in learning routing protocol concepts which is considered as the toughest and essential topic in this course.

Delialioglu and Gullu (2018) explored the impact of computer network simulators on students' motivation and learning. The study revealed that computer simulations effectively help students to visualize network concepts and procedures that allow observation of underlying processes that may not be feasible in real laboratories, thereby improving their learning outcomes and motivation in the subject matter.

Bello et al. (2016) found through quasi-experimental research that the simulation game technique resulted in higher academic performance compared to the lecture method among students at the Basic education level in Mafoni Day Secondary School, Maiduguri, Nigeria.

Sulaiman (2020) implemented a one-group pretest-posttest quantitative research design to explore the effectiveness of incorporating realistic multi-user practices in networking classes using Cisco Packet Tracer. The study aimed to enhance student's learning of simple networking equipment while fostering creativity in teaching. The study revealed

that integrating such practices resulted in heightened student curiosity in technical subjects and offered lecturers a convenient means to track student success.

Despite these established benefits, there remains a lack of comprehensive understanding regarding its effectiveness within the Nepalese educational context. Factors like student demographics, curriculum structure, and access to resources may influence CPT's impact in Nepal. Thus, a thorough investigation into various aspects of learning, including Nepalese student's perceptions and engagement with CPT as a learning tool, is crucial for ensuring its effectiveness. By addressing these aspects through rigorous research, a more subtle understanding of CPT's effectiveness in Nepal can be achieved, thereby facilitating informed decision-making in educational policy and practice.

Methods

Conceptual Framework

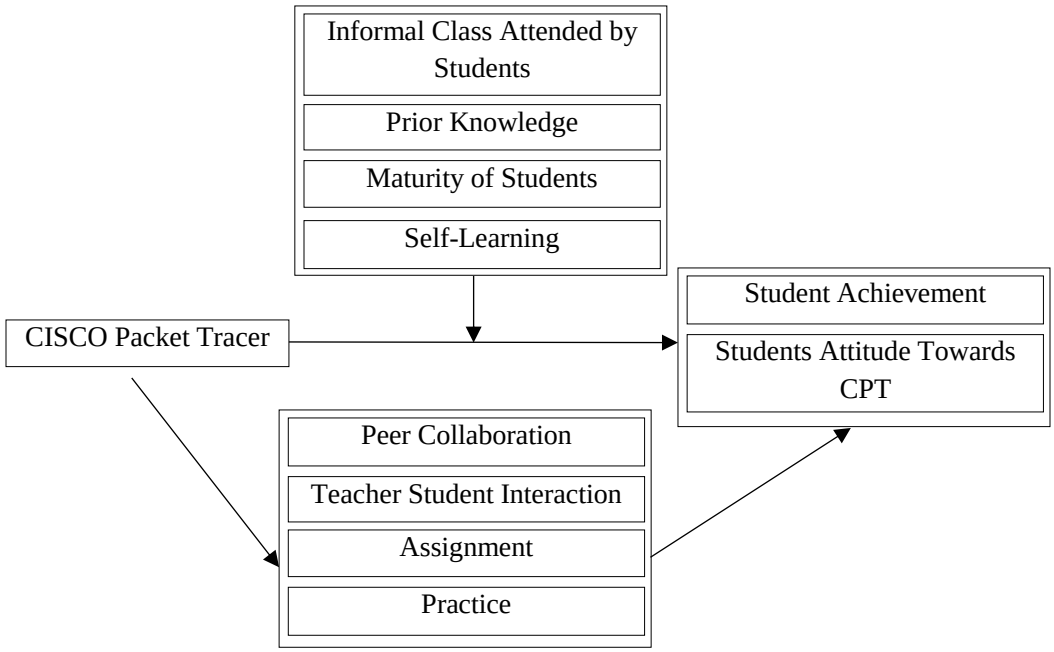

Figure 1. *Conceptual Framework*

The Figure 1 represent the conceptual framework of this study. Cisco packets tracer was considered as an independent variable. Student achievement and student attitude towards Cisco Packet Tracer was considered as a dependent variable. Peer collaboration, teacher student interaction, assignment and practice were considered as mediator variables. The mediator variable is influenced by the independent variable initially, and the dependent variable is afterwards influenced by the mediator. Student participation in informal

classes, prior knowledge, maturity of student and self-learning are considered as an extraneous variable of this study and its' influence was ignored by the researcher.

Research Design

This research study chosen quasi-experimental pretest-posttest nonequivalent groups design. Quasi-experimental design is frequently employed in classroom experiments because experimental and control groups often consist of naturally assembled groups, such as intact classes, which may be similar. The researcher elicited the students' attitude towards using Cisco Packet Tracer while learning networking using opinionnaire. This design is represented in a table as shown below.

Table 1. Design of the Study

Groups	Pretests	Treatment	Posttest
Experimental	P_1	X_1	P_2
Control	P_3	X_2	P_4

Where,

P_1=Pre-test held on the experimental group student's
P_3= Pre-test held on the control group student's
P_2=Post-test held on the experimental group student's
P_4= Post-test held on the control group student's
X_1=Teaching by using Cisco Packet Tracer simulation software
X_2=Teaching without using Cisco Packet Tracer simulation software

At first pretest was held on students of both control and experiment group. Then after, students of control group were taught networking by using conventional method in which multimedia tools such as projector and PowerPoint slide were used. They passively received the knowledge delivered by teacher whereas in the case of experimental group same multimedia tools were used while teaching networking, in addition, demonstrative and collaborative approach was carried out. They were facilitated with Cisco Packet Tracer simulator software to visualize the content to have clear understanding. Experimental group also collaborated with a peer to identify and implement the network scenario using Cisco Packet Tracer.

Subsequently, post achievement test was conducted on both experimental and control groups. Then students were explored in laboratory to have practical knowledge of networking concepts that were learned in previous sessions. The researcher conducted set of questionnaire using Likert scale on experimental group only to gather their attitude on use of Cisco Packet Tracer in learning concepts of networking devices.

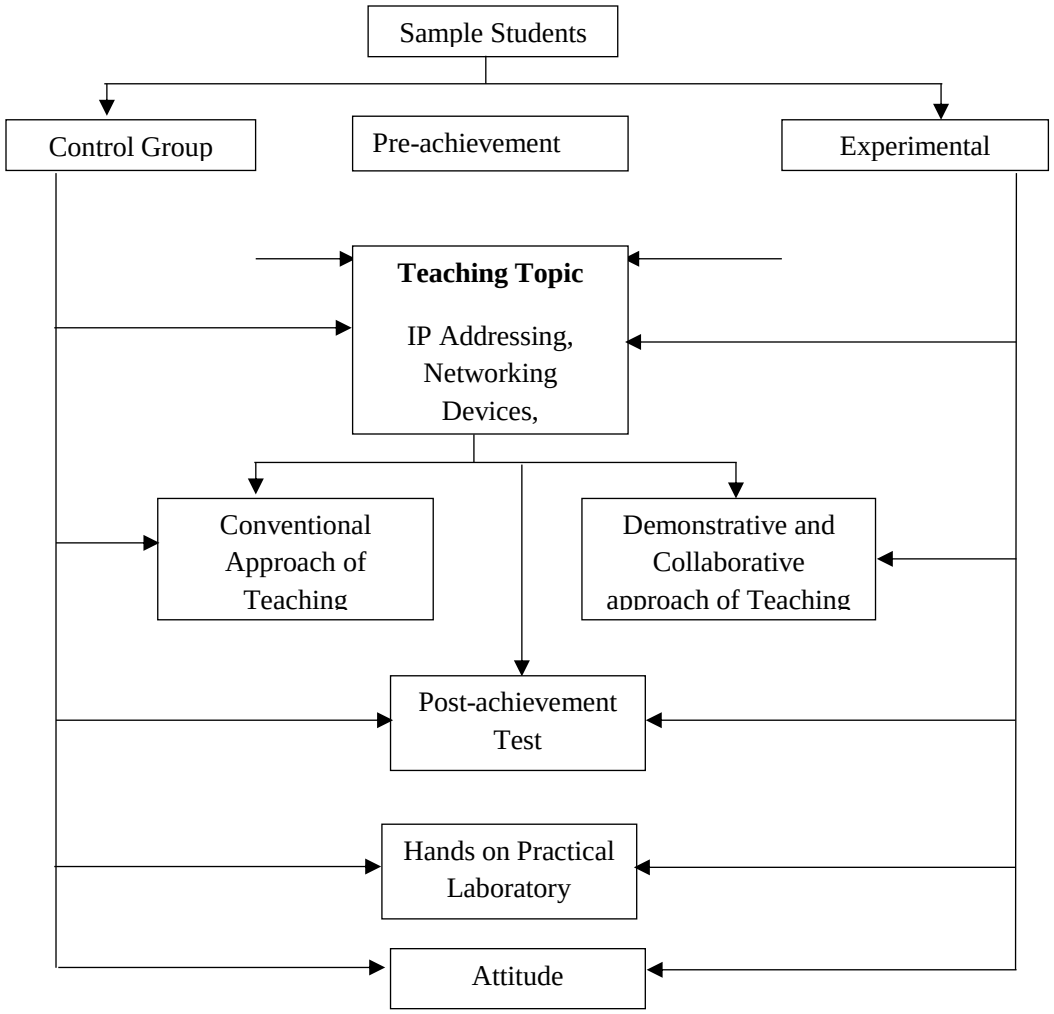

Figure 2. Visualization Map of Research Design

Data Collection

In this research, all the students of Bachelor in Information Management (BIM) program of Tribhuvan University were taken as the population of the study. The researcher focused only Chitwan district for sample. For the convenience of the researcher as well as due to having similar physical infrastructure required for learning networking, two colleges having BIM program were selected using purposive sampling. In particular, 10 students of Indreni College and 12 students of Saptagandaki Multiple Campus studying in BIM second semester were the sample of the study. Two groups were undergone homogeneity test before selecting them as sample. Experimental groups and control

groups were selected through lottery procedures. Indreni College students were assigned as experimental group and Saptagandaki College students were assigned as control group. The researcher conducted pre-achievement and post-achievement tests to acquire the major source of data. Additionally, an opinionnaire was administered to the experimental group participants to assess their attitude toward using Cisco Packet Tracer for understanding networking concepts.

The pre-achievement test consisted of twenty multiple-choice test items related to the fundamental concept of networking which enable the researcher to evaluate their prior knowledge in networking. Pre-achievement test items cover areas about basic concept of networking, data communication, network topology, network architecture, OSI reference model, networking devices and so on. The post-achievement test also included twenty multiple-choice questions. The post-achievement test items include questions on the working principles and configurations of classful IP addresses, CIDR, networking devices, routing protocols, and subnetting.

In this study, opinionnaire was divided into three parts which contained 16 items using five points Likert scale of "1-Strongly Disagree, 2-Disagree, 3-Undecided, 4-Agree, and 5-Strongly Agree". The mean from 1 to 1.8 signifies strongly disagree, from 1.81 to 2.60 signifies disagree, from 2.61 to 3.40 signifies undecided, from 3.41 to 4.20 signifies agree and from 4.21 to 5 signifies strongly agree.

Data Analysis

The data obtained from the achievement test was analyzed using inferential statistics and descriptive statistical analysis was applied in order to analyze opinionnaire. The control and experimental group's achievement levels were compared using the independent sample t-test, which focused on mean, standard deviation, p-value, and t-value. The null hypotheses were tested at a level of significance of 0.05. Descriptive statistics were utilized to analyze the data obtained from the opinionnaire to elicit students' attitudes about Cisco Packet Tracer software.

Results

Analysis of Pre-Achievement Test Scores

Table 2 shows the mean score and standard deviation for the control group, which were 13.33 and 5.694, respectively. The mean score for the experimental group was 13.40, with a standard deviation of 5.40. The mean score difference between the groups was 0.07, with a t-value of 0.28 and p-value of 0.978. This shows that there was no

statistically significant difference in mean scores of the two groups indicating that the control and experimental groups had equal levels of knowledge prior to treatment.

Table 2. Pre Achievement Test Results of an Independent T-Test

Group	N	Mean	SD	T-value	p-value	Remark
Experimental	10	13.40	5.40	0.28	0.978	Null hypothesis is
Control	12	13.33	5.694			accepted.

Analysis of Post Achievement Test Scores

Table 3 Shows that the control group obtained a mean score and standard deviation of 11.75 and 4.515 respectively and the experimental group obtained a mean score and standard deviation of 15.70 and 4.111 respectively. The mean score difference between the groups was 3.95 with a t-value of 2.703 and the p-value was 0.014. Moreover, to find out consistency of the data from post achievement test of control and experimental group, the coefficient of variation (CV) is calculated. The CV of experimental group was 0.26 and control group was 0.38. This reflect that experimental group seems to be more consistence than control group as CV of experimental group is less than CV of control group. Again, p-value<0.05 and mean scores of experimental group was higher than mean score of control group. This shows that null hypothesis on was rejected and eventually alternative hypothesis was accepted. Hence, the achievement of students taught by CPT-assisted teaching method have better outcomes than students taught by using conventional teaching method.

Table 3. Result of Independent T-Test on Post Achievement Test

Group	N	Mean	SD	T-value	p-value	Remark
Experimental	10	15.70	4.111	2.703	0.014	Null hypothesis is rejected
Control	12	11.75	4.515			

Attitude of Students on Cisco Packet Tracer Software in Learning Networking

The researcher has selected four items to collect student attitude about interest in learning networking while CPT-assisted teaching method was used.

Table 4. Student's Attitude about Interest in Learning Networking Using CPT

S.N	Items	Maximum	Minimum	Mean	Standard deviation
1	I am enthusiastic when the teacher introduced the Cisco Packet Tracer software in class to teach networking.	3	5	4.40	0.843
2	I prefer to use Cisco Packet Tracer software for learning networking.	3	5	4.40	0.699
3	I feel comfortable doing practical's using Cisco Packet Tracer.	2	5	3.80	1.033
4	The use of Cisco Packet Tracer in learning keeps me more focused.	3	5	4.30	0.823

From table 4, the mean of item 1 and item 2 was 4.40. This indicates that the majority of participants strongly agree that they were enthusiastic when teacher used CPT-assisted methodology. The mean of test item 3 was 3.80 which indicates that majority of participants agreed that they feel comfortable doing practical on CPT. The mean of test item 4 was 4.30 which indicates that majority of students strongly agree that use of Cisco Packet Tracer keeps them more focused in learning networking. This shows that integrating CPT into networking classes catches students' attention.

From table 5, the mean for item 1 was 4.10, indicating that majority of the participants agreed that CPT help them to note down important points during the session. The mean of item 2 was 4.20. This indicates that the majority of participants agreed that CPT keeps them engaged in subject matter discussion with the teacher. The test item 3 mean was 4.30. This shows that a majority of participants strongly agreed that CPT keeps them engaged in peer discussion on subject matter. The mean of test item 4 was 4.20 which indicates that majority of participants believed that using CPT assists them to complete their assignment in much easier way. The mean of test item 5 was 4.00 which shows that majority of students agreed that CPT assists them to submit their assignment regularly. The mean of test item 6 was 4.50 which indicates that majority of participant strongly agreed that CPT enhance self-learning of networking. In the study by Airi and Peter(2017), Cisco Packet Tracer supports self-paced learning outside the classroom. Similarly, (Liu, 2019) also stated that Cisco Packet Tracer encourage personalized learning in networking courses. Taher and Khan(2015)also supported that simulator provides instant and reliable feedback and, thus, gives students an opportunity to try out different options and evaluate their ideas for accuracy almost instantly. The item's average mean, as determined by table 5, was 4.22, indicating that integrating CPT while teaching networking had a positive impact on participants' engagement in learning both inside and outside of the classroom.

Table 5. *Student's Attitude towards Enhancement of Engagement in Learning Networking Using CPT*

S.N	Items	Maximum	Minimum	Mean	Standard deviation
1.	While learning with Cisco Packet Tracer software, I am able to take notes on the important points throughout the session.	2	5	4.10	1.101
2.	During the networking session, the Cisco Packet Tracer software keeps me engaged in subject matter discussion with the teacher.	3	5	4.20	0.789
3.	During the networking session, the Cisco Packet Tracer software keeps me engaged in a subject matter discussion with peers.	3	5	4.30	0.823
4.	Cisco Packet Tracer helps to complete my assignments in much easier way.	2	5	4.20	1.033
5.	Cisco Packet Tracer software assists to submit my assignment to the teacher regularly.	2	5	4.00	0.943
6.	Learning networking using Cisco Packet Tracer software enhances my self-learning/ independent research.	4	5	4.50	0.527

From table 6, the mean of item 1 was 4.40 which indicate that most of participants strongly agreed that CPT helps them in visualizing the concept of networking. Muniasamy et al.(2019)also stated that students can more easily understand and adapt the information from the subject, when they can visually see how it really works. The mean of item 2 and 3 was 4.20. This shows that the majority of participants agreed that CPT helps them to have clear concept on physical networking equipment's and also increase their confidence levels while dealing with physical networking devices. The mean of test item 4 was 4.00. This indicates that majority of participants agreed that CPT is a subsidiary tool for networking practice but not as a replacement to it. Raashid Javid (2014) also experienced that CISCO packet tracer is not a replacement of real equipment but it helps a student to do lot of practice and gain lot of confidence so that it's easy to work on a real network. The mean of test item 5 was 3.90 which indicates that majority of participants agreed that CPT software facilitates learning network technical concepts. The mean of test item 6 was 3.90 which indicates that majority of students agreed that CPT software assists in faster completion of content. The item's average mean was 4.1.

As a result, it can be stated that Cisco Packet Tracer is a supportive tool to enhance confidence level of students while dealing with real physical devices, but it is not a replacement for them.

Table 6. Student's Attitude towards Ease of CPT in Setting Real Networking Devices

S.N	Items	Maximum	Minimum	Mean	Standard deviation
1.	Cisco Packet Tracer helps me in visualizing the concept of networking devices.	2	5	4.40	1.075
2	Cisco Packet Tracer software helps me to have a clear concept of physical networking equipment.	2	5	4.20	0.919
3	Cisco Packet Tracer helps to increase my confidence levels while dealing with physical networking devices.	2	5	4.20	1.033
4.	Cisco Packet Tracer software might be a subsidiary tool for networking practice and not as a replacement to it.	2	5	4.00	1.054
5.	Cisco Packet Tracer software facilitates learning network technical concepts.	2	5	3.90	0.994
6.	Cisco Packet Tracer software assists in faster completion of content – can accelerate the pace of content delivery.	2	5	3.90	1.101

Conclusion

This study looks into whether using a simulator tool, specifically Cisco Packet Tracer, can help learners visualize and gain practical networking knowledge prior to actual lab experience. The research work utilized Vygotsky's Social Constructivist learning theory when teaching networking, facilitating a more interactive learning environment, particularly emphasizing peer collaboration. Additionally, teacher guidance and the utilization of Cisco Packet Tracer simulator served as scaffolding mechanisms, supporting students in reaching their Zone of Proximal Development (ZPD).

The results indicate that students taught using the CPT-assisted teaching method performed better than those taught using conventional teaching methods. Furthermore, most participants expressed positive attitudes regarding interest, engagement, and ease of hands-on practicals after learning networking with Cisco Packet Tracer. Integrating Cisco Packet Tracer into networking classes captures student’s attention and heightens their

curiosity, keeping them focused on learning. Additionally, using Cisco Packet Tracer in networking instruction positively impacted participants' engagement both inside and outside the classroom. It also enhances students' confidence in handling real physical devices. Consistent with Vygotsky's Social Constructivist learning theory, teaching networking with Cisco Packet Tracer appears to positively influence student achievement. Conclusively, using Cisco Packet Tracer for teaching and learning networking is an effective tool to enhance the student's achievement, their interest and engagement. Furthermore, Cisco Packet Tracer is a supplementary tool but not the replacement of hands on practice on laboratory.

Exploring teacher's perceptions of integrating simulators like Cisco Packet Tracer could provide invaluable insights into their instructional efficiency and the challenges faced during implementation. Moreover, examining the impact of simulator across diverse educational levels and IT programs could reveal subtle differences in learning outcomes and highlight best practices for implementation. By addressing these areas comprehensively, future studies have the opportunity to inform pedagogical strategies, optimize learning environments, and ultimately enhance student engagement and proficiency.

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