Deepen Students' Understanding of Computer Networking via a Project-oriented Cooperative Learning Strategy

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Abstract

This paper introduces an effective project-oriented cooperative learning strategy that is applied to computer networking class. Computer networking is a critical class for students majored in Computer Science (CS) and Electrical and Computer Engineering (ECE). To significantly improve students' learning experiences and outcomes, we integrate cooperative learning and project-oriented teaching strategy into the computer networking class. In this paper, a specific project, e.g., Network Address Translation, serves as an example to illustrate the cooperative learning strategy. The traditional instructional methods are adopted in one class while the cooperative instruction strategy is applied in another class. The learning outcomes of students from two classes are compared. We observe that students using the cooperative learning strategy gain a remarkably deeper understanding on the topics of networking and develop more interests in studying.

I. Introduction

Computer networking class introduces the basic principles of computer networks design and analysis. This is a critical class for students majored in Computer Science (CS) and Electrical and Computer Engineering (ECE). It requires students to thoroughly study protocol layers and service models, TCP and UDP semantics, principles of routing and switching, basics of error detection, access control, socket programming, network protocols in different layers and their interactions. It also requires certain mathematical backgrounds, including probability theory, binomial distribution, graph theory, and number theory. Those requirements make computer networking tough and challenging for first-time learners.

To improve students' learning experiences and outcomes, we integrate cooperative learning and project-oriented teaching strategy into computer networking class. Cooperative learning [1] is defined as forming a small group of students to maximize group members' learning. Studies [2] have revealed that cooperative learning produces a positive impact on achievement, retention, and attitudes toward learning for both male and female students in the fields of STEM. Group Investigation (GI) is one major model of cooperative learning. The GI cooperative learning model emphasizes learning to solve problems and encourage students' involvement [3], which is applied to our computer networking class. Specifically, students are divided into groups and get involved in the planning phase of learning from the beginning, which includes selections of topic and approaches to conducting their investigation. After selecting a topic or project, students complete it via active-study, e.g., reading textbooks, searching for technical papers, programming, trouble shooting, evaluation, etc.

The significance of project-oriented cooperative learning strategy has been explored in electrical power systems classes [4] [5], but it has not reported any project-oriented instructions in computer networking. In this paper, a specific project: Network Address Translation (NAT) [6] for a private network, serves as an example to illustrate cooperative learning strategy. As a popular and essential tool in conserving global address space in the face of IPv4 address exhaustion, NAT is used widely in academia and industry, but it remains a challenge for students to fully understand how it works and how to configure a NAT server. In this project, the objective is straightforward: set up NAT servers for private networks.

To evaluate the effectiveness of the project-oriented cooperative learning strategy, both formative assessment and summative assessment are adopted in this paper. In particular, the traditional instructional methods are adopted in one class while cooperative learning strategy is applied in another class. Students' learning outcomes are recorded and compared between these two classes. The formative assessment methods include observations, in-class activities, and self-evaluation. We find that students under the cooperative learning strategy have deeper understanding and stronger problem-solving capabilities on the same topics, which verifies the effectiveness of cooperative leaning.

II. Project-oriented Cooperative Instruction Design

In this section, we illustrate how to apply project-oriented cooperative instruction into our class using the NAT configuration project as an example. This project is to set up two NAT servers for two private networks.

After assigning the project, students are divided into two groups. They work as a team to read textbooks and relevant documents. If they have any questions, they discuss and look for potential solutions by themselves. When they assess they have mastered sufficient knowledge on NAT, they can start working on the project. The first step is to estimate the required devices and components for the project. Table I is an example, which lists the required devices and components for this project.

Table I. Devices and components used in the project

Devices/Materials	Numbers	Comments
Servers	2	Each server needs two NICs.
Clients	10	Each client needs one NIC.
Network Cables	14	Each server needs two cables. Each PC needs one cable.
Switches	2	At least 8 ports for each switch
Network Interface Cards (NICs)	14	Each server needs two NICs. Each client needs one NIC.
Operating System	9	Ubuntu
	3	Windows

In this project, two computers work as servers and 10 computers work as clients. Each client needs at least 1 network interface card (NIC), while each server needs at least two NICs. For the servers, one of the NICs is connected to the private network and the other is connected to the Internet. Note that the Internet can be accessed through public IP address or private network address, depending on the available resources and configurations of the campus network. For example, we use NAT IPs in our campus, so the servers are configured to NAT addresses that are provided by the campus network. That means the NAT network achieved by our NAT server is the second NAT network, which is nested in our campus NAT network.

Another important device is the switch. Switches should provide enough ports to connect those clients. In this project, two switches are needed and each one possesses 8 ports. Enough network cables are also needed to connect the servers, clients and switches. The Ubuntu OS is used, which can be downloaded online and installed to our servers and clients using USB flash discs. This is also a valuable opportunity for our students to learn how to install an OS through USB flash discs. The servers, clients and switches are depicted in Fig. 1.

Fig. 1 Layout of the servers, clients and switches.

After obtaining the required devices and components, students can get started. In order to facilitate students' study, the whole project is divided into steps, so that they are able to manage and complete the project successfully step by step. Those steps for this project are listed in Table II.

Table II. Objective and Steps of the project

Objective	Steps	
Set up NAT servers for private networks	1	Distinguish private IP address from public IP address
	2	Calculate appropriate subnet mask for a subnetwork
	3	Allocate and assign appropriate IP addresses for private networks
	4	Configure Firewalls to achieve IP masquerading and NAT server
	5	Test, trouble shooting and verification

Specifically, in order to configure a private network using NAT technology, the first step is to distinguish private IP addresses from public IP address. Students are encouraged to do research and figure out why private IP address is needed in the Internet and how it is distinguished from public IP address. The second step is to calculate appropriate subnet mask for a subnetwork. This is a challenge for students, so a brief lecture is offered to them. In this lecture, a general subnetting method is introduced and examples are examined to help them understand the process of subnetting. After calculating subnet masks, students allocate and assign IP addresses to those computers. We use both Linux and Windows in our clients, so it is an excellent opportunity for students to learn how to use Linux OS, in particular how to configure IP address for a Linux platform. In this project, the most important step is to configure Firewalls [7] to achieve IP masquerading. Sufficient resources, e.g., Official Ubuntu Documentation [8], are provided to students to help them familiarize Iptables and the process of IP masquerading. In this step, students are encouraged to discuss with their team members and test different methods to achieve IP masquerading, e.g., using Iptables or using Uncomplicated Firewall (UFW) [9]. They are also encouraged to compare and contrast these two methods in terms of efficiency and effectiveness. The last step of the project is testing, trouble shooting and verification. In this step, students may ask questions, especially when they have problems with their configuration. Students gain hands-on experiences and trouble-shooting skills throughout the project.

III. Teaching Result Evaluation

In this section, we assess students' learning performance in two classes that adopted different teaching strategies. We adopt the project-oriented cooperative instruction in Network Design & Configuration. In this class, students design basic networks, configure IP address for different operating systems, set up Local Area Networks (LAN), configure FTP, Web, Database and NAT servers, configure wireless routers, analyze network traffic and network protocols, etc. This is a 3-credit course. We meet twice a week and each lasts 75 minutes.

Table III. Selected Student Learning Outcome Description

Outcomes	Scale (1-10)
1. Be able to design basic networks, including calculating and assigning valid IP addresses.	
2. Be able to construct and administer a basic local area network.	
3. Understand and build the skills of subnetting and routing mechanisms.	
4. Be able to design basic networks, including calculating and assigning valid IP addresses.	
5. Understand network configuration for both Linux and Windows OS.	
6. Be able to configure static IP addresses for both Linux and Windows OS.	
7. Understand how Network Address Translation (NAT) works.	
8. Understand how firewall works and its main functions.	
9. Understand how to use firewall (e.g., UFW) to create and change policies.	
10. Feel more capable of solving computer networking problems independently.	
11. Understand basic computer network technology	
12. Construct and administer a basic local area network	
13. Configure computers with different OS (Linux and Windows) for connection to a network and the Internet	
14. Understand and describe the process by which data is transmitted over the Internet	

As a comparison, we offer another class named Networking Theory and Admin. Traditional instruction is adopted in this class and students mainly study from lectures. The lectures include Internet architecture, different layers in the Internet protocol stack, analysis and correction basic network issues, threats to network security, network configuration, e.g., subnetting and assigning valid IP addresses, the process by which data is transmitted over the Internet, etc. This is also a 3-credit course. We meet three times a week and each lasts 50 minutes.

The students' learning performance for all outcomes (0-10 scale) is evaluated based on students' self-assessment, homework/lab assignment and exams. Table III summarizes several selected outcomes. Each outcome is tested by carefully designed homework/lab assignment and exams.

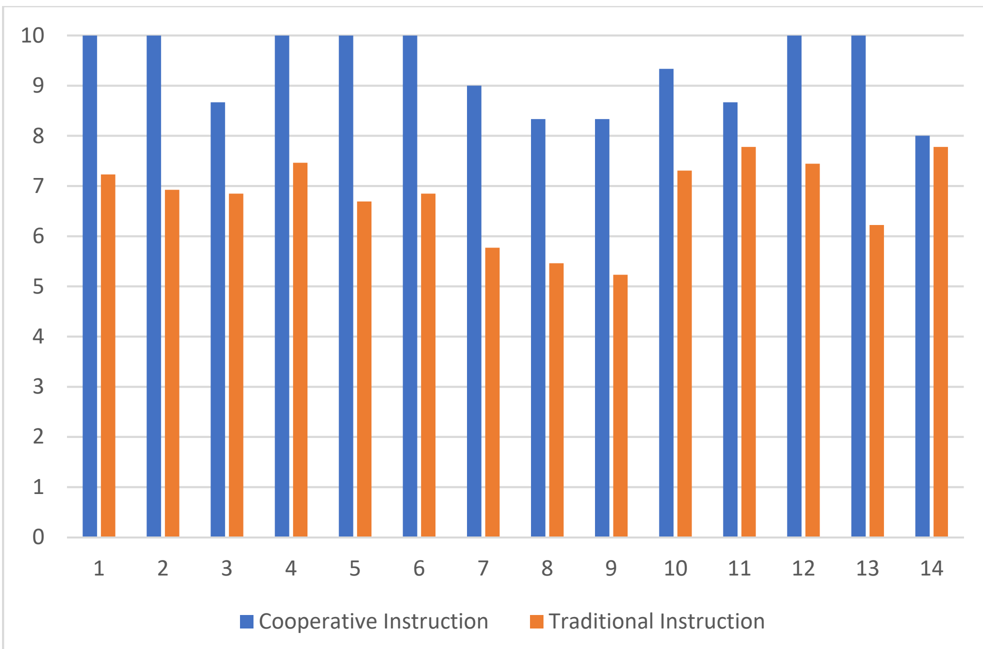

Fig. 2 Students' learning outcome in two classes with 0-10 scale

Fig. 2 compares the students' learning outcomes in these two classes. It can be seen that students under cooperative instruction had deeper understanding on most of topics than those under the traditional instruction. In particular, subnetting is one of the most challenging parts for our students. The cooperative instruction is able to significantly improve teaching and learning performance on this topic. Second, students under traditional instruction usually do not have enough opportunities to practically use Firewalls, e.g., creating and changing policies for a server. The cooperative instruction has strengthened their ability in this field. Third, since students have worked thoroughly on NAT servers, they have comprehensive understanding on how NAT works than students in the class adopted the traditional instruction. Most importantly, students under cooperative instruction have earned more hands-on experiences from the projects, so they are capable of applying their knowledge to solve practical problems. In contrast, students under traditional construction need more practices in network configuration, e.g., constructing and administering basic networks.

Some students' comments on the cooperative instruction are copied as follows.

I enjoyed the class overall quite a bit.

I enjoyed learning choice on what projects we did.

I enjoyed the professor's style of teaching as well as the professor himself.

I enjoyed this class and even though I was slow at some of the projects.

I feel like I learned a lot.

From those comments, we conclude that the cooperative learning has cultivated students' interests in learning, even for those who are slow at some of the projects.

We have also received suggestions from students who study under the cooperative instruction. "I wish there were a bit more lectures, that is the only negative I can mention." "I think a bit more instruction on how to start a project would be very helpful." From those comments, we learn that for some projects, a clear instruction on how to start a project can speed up students' learning process when adopting cooperative learning strategy in the future.

IV. Conclusion

We have integrated cooperative learning and project-oriented teaching strategy into computer networking class. This paper selects a specific project as an example to demonstrate how we teach the class using project-oriented cooperative instruction. Students' learning outcomes and engagement are improved after adopting this strategy in class. Consequently, students have gained deeper knowledge on the topics. It verifies the effectiveness of cooperative learning approach. We have also received valuable and constructive feedbacks from our students. These feedbacks are helpful for us to polish the projected-oriented cooperative learning strategy. In the future, we will continually improve our teaching by enriching cooperative learning methods while integrating other novel learning strategies as well.

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