FLaSKU - A classroom experience with teaching computer networking: Is it useful to others in the field?

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Abstract:

In general, every educator has a classroom experience that he or she wants to share for the benefit of other educators and students in the field. This paper presents a classroom experience with teaching a computer networking course to both undergraduate and graduate students in Information Technology (IT) areas. This course uses conceptualization and summarization techniques coupled with standard teaching methods, such as independent learning, incremental learning, and out-of-class assignments. It also defines two terms: independent conceptualization and dependent conceptualization, and adopts them with a summarization technique to improve conceptualized computer networking. Two simple examples are presented to illustrate these definitions. The paper also presents a teaching philosophy and a flexible grading policy that help motivate learning over earning a grade. The experience and knowledge gained from the delivery of a computer networking course over eight years is shared in this paper. Course evaluations were conducted using a departmental questionnaire, peer evaluations, and an independent survey. The course evaluation results of over eight years demonstrate a significant improvement in the overall quality of the course delivery. The methods, results, and findings can deliver benefits to young university educators and students in the IT field.

Keywords: Conceptualized learning | incremental learning | independent learning | computer networking

Article:

1. INTRODUCTION

Educating information technology students is paramount in today's technologically advanced society. In particular, the delivery of a computer networking course is challenging due to rapidly changing technology, limitations in the usage of technology and industry demands. This paper provides an experience with teaching a computer networking course while addressing these challenges. Conceptualization and summarization techniques in teaching and learning combined with appropriate course structure, course delivery, assessment mechanisms of student work, and a course evaluation plan can help confront these challenges. The conceptualization and summarization have been used in the education arena to address general educational and psychological issues. For example, Friedman and Kass [4] studied the problems associated with how teachers perceive their own teaching competency and how that affects students' learning. They also studied the conceptualization of teacher efficacy, focusing on classroom organization and its effect on students' creativity, motivation, and participation.

In 2003, Manning [6] presented a master's thesis in which both conceptualization and summarization were addressed relating to reading comprehension in disabled students using visual tools in classrooms. Noah et al. [8] used conceptualization and summarization for the semantic annotation and searching of digital images with keyword tagging. They utilized conceptualization to disambiguate terms of keyword texts used for tagging images and summarization to extract knowledge from the surrounding text that provides description of the images. Recently Chubbuck [1] used conceptualization to build a framework that provides informed decisions to educators about the learning ability of students. Most recently, Hsieh et al. [5] utilized conceptualization for developing indicators that help investigate the quality of international mathematics education in different countries, and Mueller et al. [7] utilized it for demonstrating the importance of longhand note taking over laptop note taking. In general, the conceptualization and summarization have been used in the psychology aspects of education, but a detailed study on their contributions to improve computer networking courses is still needed.

This paper presents a Flexible Learning and Sequential Knowledge Update (FLaSKU) technique that can help instructors accomplish their teaching objectives and help students succeed in their learning outcomes. In FLaSKU, an improved version of conceptualization (independent conceptualization and dependent conceptualization) and summarization techniques are explored and combined with an effective teaching philosophy, an independent learning technique, an incremental learning technique, a motivational assessment mechanism of students' work, and a course evaluation plan and improvement strategy. The results and findings from eight years of course evaluations are also presented.

2. COURSE STRUCTURE

Structuring the course so the instructor and students can achieve their teaching and learning goals successfully is a highly thoughtful, resource-intensive, and time-consuming task. Tools such as the teaching philosophy, course outline, course objectives, student learning outcomes, assessment mechanisms, and grading policies, can help achieve these goals.

2.1 Teaching Philosophy

The author devised a teaching philosophy from his 30 years of teaching experience. It reflects the instructor's beliefs on teaching and learning, and how those beliefs could be integrated into the course structure and course delivery. A strong teaching philosophy is one of the key factors that help motivate both the instructor and students to be engaged in teaching and learning. A well-structured, meaningful, and feasible teaching philosophy was developed, adopted, and practiced strictly throughout the course. It reflected a genuine commitment and effort from the instructor, thus motivating the students. It helped promote students' own commitments and engagement in the course. The following teaching philosophy was developed and adopted in the computer networking course: SUCCESSFUL.

_ (S)tudious: Teaching must be studious. The commitments and efforts of the instructor can stimulate the same level of commitments and efforts among students. They must be presented to students.

_ (U)ltimate: Teaching must be ultimate. The perfection in teaching materials contributes to this philosophy. The course materials must be current, simple, challenging, and interactive. This is one of the contributors that encourage student participation.

_ (C)reative: Teaching must be creative. Interesting examples keep students engaged in learning new knowledge and developing skills to achieve more than what they think is possible.

_ (C)omplete: Teaching must be complete. Completeness in the networking course comes from the integration of the instructor's own research findings. The research techniques and deliverables must be incorporated in the delivery of instruction.

_ (E)ffective: Teaching must be effective. The instructor provides a friendly and comfortable atmosphere to students during the delivery of instruction in classroom, as well as during one-on-one advising in the office. Effective teaching is another contributor that helps motivate student participation.

_ (S)uperior: Teaching must be superior. This describes the genuine interest to deliver advanced knowledge. Difficult theories are simplified in the course with real world examples and applications. Superior teaching helps students visualize and understand theories and concepts.

_ (S)trong: Teaching must be strong. The instructor must display leadership qualities and bring energy and enthusiasm to the classroom to motivate students and increase their interest in the subject.

_ (F)ruitful: Teaching must be fruitful. When students' opinions are well received and respected, fruitfulness is achieved in class. Additionally, students' opinions and comments must be used as a mechanism to improve both course materials and mode of instruction.

_ (U)seful: Teaching must be useful. Well-structured, modern tools with state-of-the-art, technology-based resources should be used in the delivery of instruction, focusing on encouraging students toward lifelong learning. Lifelong learning is an important requirement for rapidly advancing fields like computer networking.

_ (L)uminous: Teaching must be luminous. The course must give brightness to students. The instructor must update knowledge through professional training, learn the latest advancements in the field, and transform this knowledge to students.

The keyword "SUCCESSFUL" imprinted the success in students' minds at the early stage of the course. As students saw a bright future, they engaged in the course and participated in class activities. The successful interaction in this course was reported in the peer evaluation. Class visits by professional peers, one of the effective course evaluation mechanisms used, stated:

"...lecture was an example of good interaction between the instructor and the students..." and "...the interaction style and student engagements and accessible levels to students ...".

2.2 Course Objectives

The main objective of the course was to educate students in computer networking, including hardware and software components of computer networks, and their organization and operations. In particular, the conceptualization and summarization aspects of computer networking, hop-to-hop mechanisms, host-to-host mechanisms, process-to-process mechanisms, and network simulator modeling were covered in the course. Another objective was to adopt a variety of teaching models, such as classroom instruction, independent learning, incremental learning, and out-of-class assignments in the structure and delivery of the course.

2.3 Course Outline

The course outline was sketched to include five sections: the conceptualization and summarization, hop-to-hop mechanisms, host-to-host mechanisms, process-to-process mechanisms, and simulator modeling so students can conceptualize the transmission of a packet over a network. Hence, the book chapters intended to be covered were grouped into five parts:

_ Conceptualization and summarization: Communications, Standards and protocols. Network models.

_ Hop-to-hop mechanisms: Data and signals. Digital transmission. Bandwidth utilization. Transmission media and switching. Error detection and correction.

_ Host-to-host mechanisms: Data link control and Multiple Access. Wired LAN and connecting LANs. Logical addressing and Internet protocol. Address mapping, error reporting and multicasting. Routing of IP packets and packet switching.

_ Process-to-process mechanisms: Congestion control and QoS. Network applications such as Email, telnet, and file transfer protocols (ftp and tftp).

_ Simulator Modeling: Network programming - simulation of computer networking concepts.

The course outline with course objectives, learning out- comes, prerequisite requirements, required textbooks and materials, grading policies, and instructor information was made available to students during the first week of classes and posted on the course website. The textbooks used for this course in different semesters were: Comer [2], Peterson and Davie [9], Forouzan [3], and Tanenbaum [10]. The last two textbooks were used in recent years.

2.4 Learning Outcomes

Learning outcomes were designed to specify what networking theory and applications students would familiarize and learn from the activities incorporated in the course and played an important role in the evaluation component of the course. The following learning outcomes were developed and announced to students during the first week of classes:

_ Ability to identify different types of data communication networks and different applications of computer communication networks;

_ Ability to implement seven layer computer network architecture and their corresponding protocols;

_ Ability to solve problems related to inter-networking and TCP/IP protocols;

_ Ability to understand and apply the packet-switched networks and routing strategies;

_ Ability to recognize and implement various ways of enforcing ow control, error detection, and error correction in practice;

_ Ability to integrate networking concepts and build computer network simulators.

These learning outcome are measurable and helped design questions in the assignments, class tests, and the final examination that adopted incremental learning and independent learning.

2.5 Assessment Mechanism

Assessment mechanism included three assignments, three class tests, and a final exam. The assignments were designed to support incremental learning and independent learning. The class tests had two sections: multiple choice questions and essay questions. In general, there were about 15 multiple choice questions and 3 essay questions in each test. They carried 40% and 60% weights toward the total grade of each test. Students were asked to answer all 15 multiple choice questions and 2 out of 3 essay questions. The final exam followed the same style, but there were 32 multiple choice questions and 4 essay questions. Students were asked to answer all multiple choice questions and 2 out of 4 essay questions. The essay questions in the final exam have more parts or sub questions than the class tests. Students needed the entire 3 hours to complete the final exam. Note that the class tests were 1 hour and 15 minutes long. To support students' success in the class tests and the exam, sample tests and a sample exam were provided for practice.

2.6 Grading Policy

The grading policy encourages learning more than earning a grade. Students earn grades through the demonstration of flexible learning and sequential knowledge updates. This course is an upper division course, and was attended by both undergraduate and graduate students. Therefore, the grading policies were different for undergraduate and graduate students. For undergraduate students, the scores were: Assignment 1: 5%; Test 1: 10%; Assignment 2: 15%; Test 2: 10%; Assignment 3: 15%; Test 3: 10%; and Final Exam: 35%. Graduate students were required to do a mini project thus their scores were: Assignment 1: 5%; Test 1: 10%; Assignment 2: 10%; Test 2: 10%; Assignment 3: 10%; Test 3: 10%; Project: 20%; and Final Exam: 25%.

To support the flexible learning and sequential knowledge updates, this grading policy was relaxed at the end of the semester. If the final assignment score was higher than the previous assignment scores, the final assignment score replaced the other two. Similarly if the final exam score was the highest, then it replaced the class tests grades. The assignments and the tests were designed to be cumulative so students were rewarded for knowing all topics covered in the course and demonstrating networking skills at the end of the semester.

3. COURSE DELIVERY

Course delivery included conceptualization, summarization, independent learning, incremental learning, and out-of-class assignments. These teaching mechanisms were adopted to ensure the actions described for each instrument of the teaching philosophy, "SUCCESSFUL", were emphasized and followed throughout the course delivery.

3.1 Summarization

Summarization uses visual aids to help the instructor teach the course and help students learn the topics. The key to computer networking is the transmission of packets from a source host to a destination host and the processes that packets undergo during their transmission through the intermediate network environment. Based on this, three phases of learning computer networks using the three figures (Figure 2 to 4) were taught to the students in the first week of classes. Students were required to use them as summarization to conceptualize the network model throughout the course.

3.2 Conceptualization

Conceptualization has been addressed in the education research, but its contribution to successful teaching and learning of computer networking has not been reported in the education arena. In the delivery of computer networking course, both textbooks and simulators play important roles. However, they directly address the hardware and software components and theory behind those tools. The concepts behind the techniques that form the network theory are not addressed to a level that the teaching and learning can be successful. The conceptualized learning helps students to understand difficult topics instantly and recall the topics later as needed without realizing the memorization. The goal of conceptualization developed in teaching our computer networking course is to help students understand and learn difficult techniques that are important to computer networking. One of the objectives of conceptualization is to develop simple examples (numerical or visual) for the networking concepts that form the network theory. These examples were grouped in two classes: *Independent Conceptualization* (IC) and *Dependent Conceptualization* (DC). IC helps students understand the concepts by using examples not directly related to the topic, whereas DC helps understand the concepts by using examples that are directly related to the topic. Two examples are presented below: Ant and Bubble Examples.

3.2.1 Independent Conceptualization

Ant Example. Figure 1 describes the Ant example which focuses on the signal representation that plays a major role in the physical layer protocols. It illustrates the relationship between the two main elements of a signal: Frequency (f) and Period (T), and thus helps students understand the meaning of high frequency. This example (i.e., Figure 1) uses a light source to create a shadow, a ring for ant to travel, an Ant to create sine waves for signals, a screen to show the shadow movement, and a paper for students to draw an imaginary sine wave. Students were told that the ant was a smart ant, and it would listen to you. You tell the ant to travel in a consistent speed and complete 1 cycle in 1 second. While ant travels on the ring, the shadow on the wall moves up and down. As the shadow moves, students had to draw its reflection on the paper using a pencil or pen. This effect is shown in Figure 1. Now the students were asked to tell the ant to double the speed (but maintain consistent speed) and draw the sine wave. They were able to see two sine waves in 1 second. Hence, they were able to see the relationship between f and T. Then the students were asked to tell the ant to increase the speed to 1 million cycles per second and observe the effect. Now they were able to define the term High Frequency.

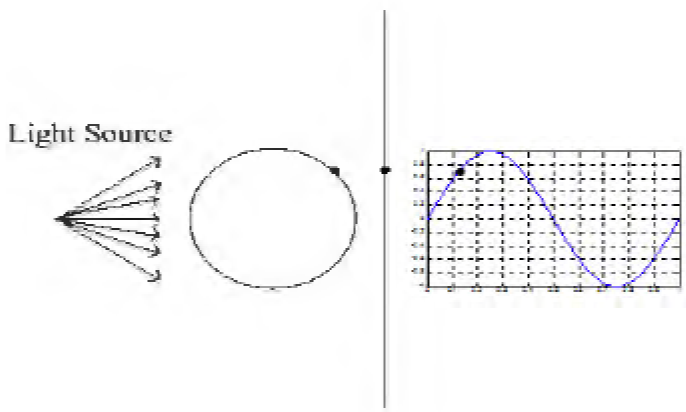

Figure 1. Ant example to conceptualize $f = 1/T$.

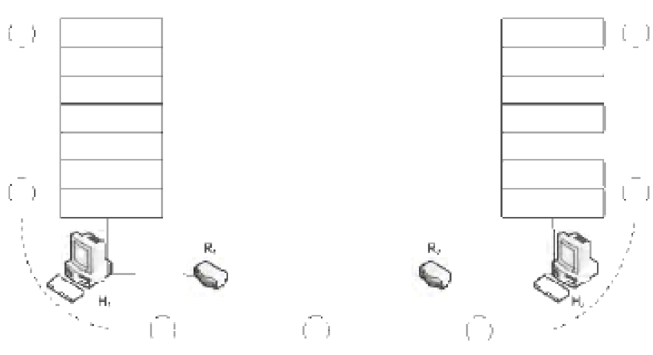

Figure 2. Conceptual model for assignment 1.

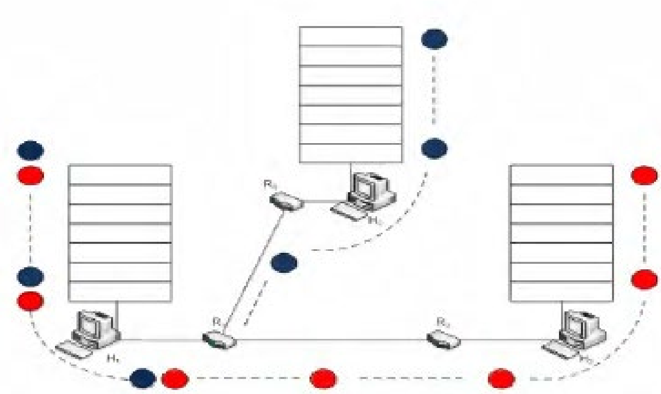

Figure 3. Conceptual model for assignment 2.

3.2.2 Dependent Conceptualization

Bubble Example. Figures 2 and 3 show the Bubble examples. The summarization in Figure 1 helped students conceptualize the transmission of a network packet (protocol) from source to destination via a simple link with two routers. With the understanding of this simple conceptualized model, the students were able to construct a large network virtually with a combination of many such simple links and conceptualize the transmission of a packet over a large network like the Internet (as shown in Figure 3). When the packet (i.e., the bubble) travels through the network, its transformation by the network theory was explained thoroughly at each step, then students had to implement that as part of the assignment. However, due to time limitations, students had to implement only some of the networking concepts. This example helped students to understand the topics of the networking course and stay abreast with the instructions and course requirements.

3.3 Independent Learning

Independent learning required students to independently learn certain sections designated by the instructor. This model was applied in the computer networking course, which helped students prepare and face the lifelong learning demand of the IT industry. IT graduates are required to update their knowledge frequently, while employed, by learning on their own from resources like textbooks and the Internet. The independent learning gave students a ground to train themselves to face such a demand.

3.4 Incremental Learning

Incremental learning is a technique that helps students observe connections between topics and motivates them to be enthusiastically engaged in the subject. To adopt incremental learning, the topic covered in a class was connected with the topics covered in the previous class, and that connection was clearly highlighted for the students. In addition, at the end of each class, students were informed of the topics that would be covered in the next class. The class tests were also designed to support the incremental learning by testing 20% of the previously tested topics in a test.

3.5 Out-of-class Assignments

Out-of-class assignments, in contrast to the instructor-led laboratory sessions, provided students a mode of flexible learning to work on their own time while accessing tutors, computer labs, and other classmates. In the out-of-class assignments, students had the opportunity to build a network simulator and learn the concepts of network protocols through visualization of packet transfer at various steps in a computer network. There were three out-of-class assignments designed to support incremental learning. Students had to demonstrate the network protocols they learned conceptually in the classroom or through independent learning. The goals of these assignments were: (i) understanding of the encoding, decoding, and modulation approaches; (ii) understanding of the error detection and correction techniques; and (iii) understanding of routing algorithms together with the shortest path algorithm called Dijkstra algorithm. End of these three assignments, students had to present an animated system (simulator) that simulates and illustrates some of the important protocols of TCP/IP-based computer networks. Each assignment stated its own network protocols so the students would develop a complete system by the end of the semester. Their simulator had to process and demonstrate the transmission of a message (long enough to show the intended protocols) from a source host to a destination host via a collection of routers with user interaction. The simulator had to incorporate the network diagrams presented in Figures 2, 3, and 4. Figure 2 illustrates a simple host-to-host transformation of a packet (bubble) with the locations where the students had to show the content of the packet and its transformations. Figure 3 shows two packets and there routing locations. Once again, students had to show the transformation of the packets at various locations. Figure 4 shows the network configuration (network graph is from [10]) with a set of random weights to demonstrate the influence of the Dijkstra algorithm to packet routing. All three assignments were posted during the first week of classes, the conceptualization and summarization of the figures were explained, and students were asked to familiarize themselves with these models, use them for learning concepts, and apply them in the simulator.

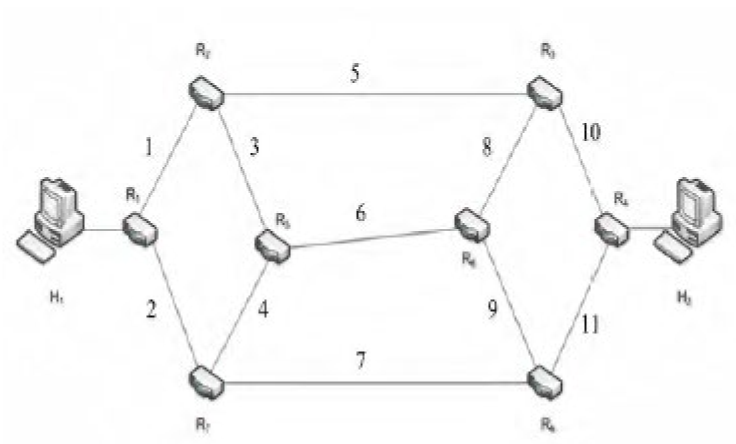

Figure 4. Conceptual model for assignment 3.

4. COURSE EVALUATION

Course evaluation is carried out using three different instruments: departmental questionnaire, peer evaluation, and an independent survey.

4.1 Departmental Questionnaire

A departmental questionnaire, used as the first evaluation tool, was circulated to students during the last few weeks of classes. This questionnaire allowed students to rate the course and provide comments. This questionnaire consisted of 16 questions to improve the course at different areas. The following areas were improved based on this evaluation: revision of teaching philosophy, balance of course workload, quality of instruction, adequacy of resources, quality of students, and effectiveness of teaching methods.

4.2 Peer Evaluation

The second tool used for course evaluation was the observations and comments provided by senior faculty members. In this process, senior faculty members visited the classroom and observed the teaching. The department provides a form for this peer evaluation. Senior faculty members completed the form based on their observations and provided feedback for improvements. Some areas were improved based on this evaluation: organization of materials, delivery of materials, teaching strategies, and contents of the materials.

4.3 Independent Survey

An independent survey was implemented outside the classroom based on students' availability. When students meet with the instructor, their opinions on the strengths and weaknesses of the course were noted and instantaneous improvements were integrated. This process helped both current and future students. Other evaluation strategies can only help future students, thus current students miss the benefits of improvements based on their own contributions. Therefore, the independent survey was considered a preferred mechanism. In addition, independent comments received from colleagues, staff, and other students were also considered for course improvements.

4.4 Course Improvement

Course improvement was carried out based on student evaluations, peer evaluations and independent surveys. These evaluations helped incorporate student-developed simulators in the course. Initially, the course was taught without any simulator, and students only learned the theory of networking. However, the evaluations indicated that students wanted to see the effect of computer networking in motion. Hence, the network simulator called NS-2 [11] was adopted subsequently. Although students enjoyed the animation part of NS-2, they had difficulties in understanding the functionalities of the software itself. This feedback led the instructor to select OPNET IT Guru (an academic version of OPNET) [12] for simulating various concepts of computer networking. However, students found that the use of this software was not challenging. They didn't see the connection between the concepts they learned and the simulation. As a result, the idea of student-developed simulators was proposed in which the students had to develop modules and integrate them into a full package. It provided significant success in both teaching and learning computer networking. One problem still remains how to accommodate all the requirements within one semester. Hence, the next level of improvement is to develop a framework for students, and students can add modules to this framework.

Table I. Final step classification accuracies

Type	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
Worst	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Actual	1.8	1.9	1.6	1.4	1.5	1.7	1.4	1.3
Best	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

5. RESULTS

Results obtained from the course evaluations are presented in Table I and Figure 5. Table I shows 8 years (Y1, Y2, ... Y8) of results; in each year 3 scores are shown. The first score, 5.0, represents the worst score, the second score shows the actual scores for the course, and the third score shows the best score. On average, the course evaluation shows 1.4, which is closer to the best score 1.0. This indicates satisfactory responses from the students for the overall course. Similarly, Figure 5 shows the actual scores received for the course are closer to the perfect score of 1 throughout. However, there are local variations in the course, while the trend of the curve approaches the best score of 1.0. The local fluctuations are somewhat reflective of the simulation softwares, such as NS-2 and OPNET used for the assignments. The last two years, the student-developed simulator assignments were used. This indicates the students like to implement concepts and understand the theory with an animated simulator of their own.

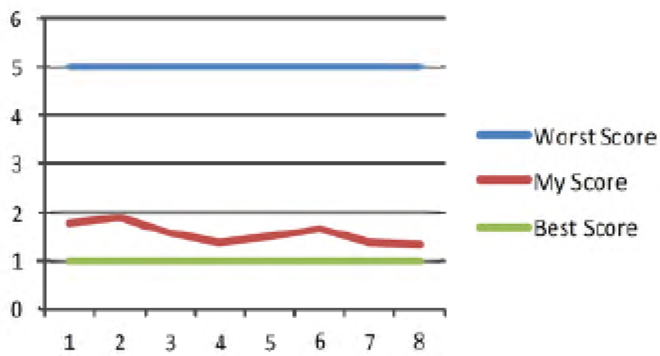

Figure 5. Course evaluation results.

6. CONCLUSION

The experience shows conceptualization and summarization coupled with the general teaching methodologies are effective mechanisms for improving teaching and learning a computer networking course when the class is a mix of undergraduate and graduate students. The examples with independent conceptualization and dependent conceptualization are added techniques that can support the goal of effective teaching and learning. The grading that encourages flexible learning and sequential knowledge updates can help motivate students' focus on learning more than earning a grade.

In this experience, students preferred to build simulators themselves by integrating concepts than simply using the off-the-shelf simulators. Additionally, the teaching methodology used the knowledge gained and reported, and the findings may be useful to young computer networking educators to adopt and deliver the course successfully, or revise based on their own experience. The framework proposed and practiced for more than 10 years is named FLaSKU (Flexible Learning and Sequential Knowledge Update) in this paper. FLaSKU will be adopted and evaluated for other courses (i.e., Is FLaSKU useful to others in the field?).

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8. REFERENCES

[1] S. M. Chubbuck. "Individual and structural orientations in socially just teaching: Conceptualization, implementation, and collaborative effort." Journal of Teacher Education, vol. 61, no. 3, pp. 197-210, 2010.

[2] D. E. Comer. *Computer Networks and Internets*. Pearson Education, Inc., 2009.

[3] B. A. Forouzan. *Data Communications and Networking*. McGraw-Hill Education, 2006.

[4] I. A. Friedman, and E. Kass. "Teacher self-efficacy: A classroom-organization conceptualization." Teaching and Teacher Education, vol. 18, no. 6, pp. 675-686, 2002.

[5] F. J. Hsieh, C. K. Law, H. Y. Shy, T. Y. Wang, C. J. Hsieh, and S. J. Tang. "A Conceptualization of Indicators for Mathematics Teacher Education Quality for International Studies. In International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn." Springer Netherlands, pp. 457-482, 2014.

[6] C. M. Manning. "Improving reading comprehension through visual tools." Division of Graduate Studies, Division of Teacher Education. Masters dissertation. Eastern Nazarene College. 2003.

[7] P. A. Mueller, and D. M. Oppenheimer. "The Pen Is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking." Psychological science, 0956797614524581, 2014.

[8] S. A. Noah, D. A. Ali, A. C. Alhadi, and J. M. Kassim. "Going beyond the surrounding text to semantically annotate and search digital images." In Intelligent Information and Database Systems, Springer Berlin Heidelberg, pp. 169-179, 2010.

[9] L. L. Peterson and B. S. Davie. *Computer Networks: A Systems Approach*. Elsevier, Inc. 2007.

[10] A. S. Tanenbaum. *Computer Networks*. Prentice-Hall, Englewood Cliffs, 1987.

[11] The Network Simulator - NS-2. Available online at http://www.isi.edu/nsnam/ns/.

[12] OPNET IT Guru (Academic Edition). Available online at http://www.opnet.com/university_program/itguru_academic_edition/.