Moving Data, Moving Students: Involving students in learning about Internet data traffic

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Abstract

Undergraduate students often have difficulty understanding the way in which data moves across a TCP/IP network, such as the Internet. From the initial data request, to larger files being packetized and transmitted via multiple routes, the students can become lost in the details. These are important concepts for both introductory Management Information Systems courses and telecommunications courses in the business school. This article describes the results of an in class exercise that involves the students in the process of data transmission and aids their understanding of this topic.

Keywords: information systems education, Internet data routing, IS pedagogy, teaching telecommunications, data packets, active learning

1. INTRODUCTION

The process by which data is transmitted over the Internet is an important concept for students to grasp in introductory Management Information Systems (MIS) or data communications courses, but is frequently one that leaves them confused. Even though the majority of students use the Internet daily for academic, entertainment and e-business purposes, they often have trouble understanding the basics of the technology involved (Anderson, 2004; Gross, 2004). In most cases, the students have a hard time comprehending how the data they request gets to their browsers and can become easily lost in the technical details of data transmission, such as the process of "breaking" a file into smaller pieces, moving data packets across the network, and reassembling the pieces on the receiving side.

While business students don't need to understand the details of more technical topics (such as routing tables, sub-netting, etc) in telecommunications, understanding the basics is important. As businesses continue to integrate technology into their operations, it is important for the future managers of those organizations to understand the basics of how technology works so that they can make better decisions for the organization. The importance of this topic for general business education can be seen in the fact that telecommunications, and the basics of Internet data traffic, are covered in many of the textbooks available for Introductory IS courses (Baltzan and Phillips, 2008; Stair and Reynolds, 2008).

One popular and commonly used method in improving learning of a complex concept is the use of games and simulations. The theory of active learning suggests that engaging students with games during the learning process increases student understanding (Massey, Brown, and Johnston, 2005; Minch and Tabor, 2007), and there is evidence to suggest that simulations aid in student understanding of complex concepts (Holzinger, Kickmeier-Rust, Wassertheurer, and Hessinger, 2009; Selman and Selman, 1999). Even though many of the simulations are quite complex and computerized, there are studies demonstrating that the use of simple and non-technical tools are actually better methods of introducing technology (Pollard and Duvall, 2006). There have also been studies showing that concrete examples can help students learn abstract concepts, particularly in the area of technology (Astrachan, 1998; Poon, 2000).

Given the importance of the topical area, and student difficulty in grasping it, the authors endeavored to develop an activity to assist the students in understanding the material. The purpose of the exercise described in this paper is to clearly demonstrate the process of data exchange over the Internet by involving the students in a simulation game in which they act as the computer requesting a file, the server hosting the file, the routing nodes on the Internet, and the data itself.

To determine if an active learning exercise would improve student learning in data communications area, the authors conducted a study on general business students. This paper describes the exercise in detail and presents the results of this experiment comparing the student comprehension of the introduced concepts prior to and following the activity.

2. THE ACTIVITY

The scenario for this exercise is that two roommates, located in Wilmington, NC, are looking at graduate schools. The first student is considering one program in Los Angeles and one at the school they are attending, while the second is looking at only one institution in his home town New York City, via the web. In the scenario, these students are sitting next to each other in the same room, using the Internet, and yet the websites from the respective programs reach the appropriate browser windows - how does this happen?

To answer this question, the students are divided into groups to represent the students requesting the data, the servers they are requesting the data from, the various pieces of networking equipment involved and the data packets that will move across the network. The students then work their way through the process of requesting the data from the various servers, moving the data packets across the network and reassembling the web pages once they arrive at the requesting computers. The students themselves are spread across the classroom to represent the geographic dispersion of the various servers involved in this process. This means that to request the web pages and have them delivered, various students are moving around the room interacting with the other students who are representing the networking equipment. The details on the exercise are given in section 2.1. The handout given to students with job descriptions and diagram of the network layout for this activity are given in Appendix 1.

Activity Details

The students asked to volunteer to participate in a game simulating a data network with the needed functions, such as acting as a switch, router, server, data packet, etc. The instructors administrating the game used the below tools to facilitate the game:

• Gold ribbon: representing copper cables within a LAN
• Blue ribbon: representing fiber cables in between networks
• Mini candy bars: representing data packages. E.g. a bunch of mini almond joy bars can be used to represent UCLAs webpage and mini twix bars can be used to represent NYUs webpage.
• Sign cards for each device: For different devices (e.g. router, switch, server, etc.) a sign card was prepared to direct packet traffic. Behind each sign card, the duties of the corresponding device was printed.

Administrator notes:

The students require a complete description of the scenario prior to being arranged to support the network. The description should include the details on their handout sheet, but should also include details about each device on the network diagram, and a description of the process of transmitting data across the network. A brief example narrative is found below:

When a webpage is requested it's generally done by *URL* (like www.youtube.com), because we don't know the actual *IP address* for every computer on the Internet! Once a URL is typed in, the requesting computer puts that request into a *data packet* and sends it out on the network.

The following steps are recommended to be followed by the administrator for the illustration of network traffic. In order to simulate the data packets, different types of candy packages could be used. In this example we will use almond joy for data packets to and from UCLA, Twix for data packets to and from NYU, and snickers for data packets to and from the UNCW web server.

1. Student A types www.ucla.edu on his/her web browser and hits enter. One student representing the request carries an almond job and leaves Student A.

2. The first stop for the request is the *LAN switch*. The switch looks at the IP addresses or URL on every incoming data packet within a network to determine where it should be sent – another computer connected to the switch, or out to the *Router* to be connected to the Internet. If the switch doesn't know the URL or IP address on a given request, then it will ask the *Domain Name Server (DNS)*.

The first time a switch sees a request for a given web server, it won't know the address, so it will ask the DNS. It's the DNS's job to keep track of the IP address associated with the URLs for WebPages. The DNS will look up the address in its database and give the switch the IP address for a URL, so that the switch can determine where to send the data. It's possible that the DNS won't know the URL either (there are a lot of them after all). If one DNS doesn't know the IP address for a URL, it will just ask another DNS! In our case the DNS knew that address (UCLA is a popular school!), so it can give the switch the IP Address. Since the request was made for a webpage from UCLA, the switch will send the request to the router.

3. While the switch controls information inside the LAN, the routers control traffic on the Internet. The router at UNCW will take the request for data from UCLA, now with an IP address supplied by the DNS, and pass it on to the router in Atlanta.

4. The router in Atlanta will look at the request and then determine the best way to get it to LA. The data will make the trip to Atlanta over a *fiber optic cable*, which is capable of carrying much more data than the typical copper cable found in a LAN.

Remember, this isn't the only request on the Internet right now! So the router in Atlanta will look to see which route to LA is the quickest at the moment, and then put the data packet with our request in with the many other requests flowing to LA. This process is called *interleaving*, because the router will place data packets from many different requests next to each other on the line to LA. The advantage to this type of *packet switching* network is that the routers can choose the fastest routes, and handle many (in the case of the Internet, millions) of requests at the same time!

5. Once our request for data reaches the router in LA, it is passed on to the web server at UCLA. The server at UCLA will look at the request to see which web page it should pass back. It will then take the data from that webpage and break it up into many data packets to be sent back to the requesting computer. This can be represented by a small bucket full of almond joy bars. Administrator can assign 5-10 students to this server to carry the almond joy bars to the requesting computer (Student A at UNCW).

6. Getting all of those data packets back to the requesting computer will follow the same process at getting the request to LA in the first place. LA router takes sends the almond joy bars to either DFW or ATL router depending on the traffic.

7. The administrator would take the line between LA and ATL routers and use the advantage of packet switching networks by having the LA router route the traffic around the problem area using only the path through DFW router to reach ATL router.

8. The administrator can put the data transmission on hold for a short period to start the data traffic demo for Student B's request of NYU website using Twix bars.

9. A student carrying the Twix bar would go through the switch (assuming the address is known by the switch this time) to UNCW router. UNCW router would send the packet to NY router via ATL router.

10. Once our request for data reaches the router in NY, it is passed on to the web server at NYU. The server at NYU will look at the request to see which web page it should pass back. It will then take the data from that webpage and break it up into many data packets to be sent back to the requesting computer. This can be represented by a small bucket full of Twix bars. Administrator can assign 5-10 students to this server to carry the Twix bars to the requesting computer (Student B at UNCW).

11. The administrator can resume the data traffic from UCLA at this point to demonstrate the interleaving of different data packages at the ATL router. Interleaving of the data packages would help timely delivery of data requests.

12. In order to demonstrate that the requests within the network do not leave the borders of the network, Student A also requests a webpage from the local web server using snickers bars this time.

13. The switch would directly send the request to the UNCW web server.

14. The server at UNCW will look at the request to see which web page it should pass back. It will then take the data from that webpage and break it up into many data packets to be sent back to the requesting computer. This can be represented by a small bucket full of snickers bars. Administrator can assign 5-10 students to this server to carry the snickers bars to the requesting computer (Student A at UNCW).

15. Once all the data packets get to the requesting computer, it's up to that computer to put all the pieces of the web page back together again!

3. THE STUDY

In order to measure whether active learning would have an impact on student comprehension and retention of new concepts, we conducted a study on introductory management information course (MIS) students at a midsized public university. The introductory MIS course is one of the required courses to be admitted to the business school and is taken by all business students. For this experiment, a larger section with approximately 90 students was used. Data on the demographics for the class can be seen in Table 1.

		Responses	
Gender		**(percent)**	**(count)**
	Female	40.26%	31
	Male	59.74%	46
	Totals	100%	77
		Responses	
Age		**(percent)**	**(count)**
	18-21	72.73%	56
	22-24	14.29%	11
	25-28	6.49%	5
	29-32	0%	0
	32+	6.49%	5
	Totals	100%	77
Reported Major		**Responses**	
		(percent)	**(count)**
	Accounting	14.47%	11
	Finance	26.32%	20
	IS	3.95%	3
	Management	28.95%	22
	Marketing	26.32%	20
	Totals	100%	76

Table 1 - Class Demographics

The authors used a pre and post test design to determine if the exercise had an impact on the student understanding of the material. Four weeks prior to the lecture covering the data communications concepts, the students were given a pre-concepts test in class to assess their understanding of data communications details. Data was collected using Interactive Student Response Pads from Turning Point, which are also referred to as clickers. Instructors of these introduction to MIS courses regularly used the clickers throughout the whole semester to take attendance, administer quizzes and collect anonymous feedback on the student comprehension of the subjects covered. For this experiment, data was collected anonymously. Results from this set of questions can be seen in Table 2 (located in Appendix 3), and the questions themselves can be found in Appendix 2. As can be seen in the Table, the students did not know the answers to most of the questions. This result was not unexpected.

Roughly one month after the pre test, the concepts for the telecommunications portion of the course were delivered via a lecture accompanied by Power Point slides developed by one of the authors. Following the lecture, students were asked the same multiple choice questions to measure their understanding of the material presented. The results from this are shown in Table 3 (located in Appendix 3). As expected, the students were more likely to know the answers to the questions following the lecture than they were prior to the lecture. We observed an increase in the correct answer percentage in all questions except, question 3 on routers and question 7 on switches.

Following another break of roughly one month, the students participated in the interactive game described above (and described in more detail in the Appendix), and were then asked the questions again. A survey with the same set of questions was again administered following the game to gauge how helpful the interactive exercise was in learning complex concepts. The results from this are discussed in the next section.

It is worth to note at this point that the answers to the survey questions were only provided after the administration of the post-activity test. In the previous administrations of the test, the answers were not provided to students in order to capture learning and avoid recall.

4. DATA AND ANALYSIS

The question the authors sought to answer with this study was: Would this style of learning help the students better comprehend the more complex and technical details of data transfer? In order to answer this question, the authors compared the data collected from pre-lecture, pre-activity and post-activity results to determine if there were significant differences between them. This comparison is shown in Figure 2 and Table 4.

In this experiment authors used "I don't know" as one of the answer options of the survey questions in order to capture the knowledge level of the students and eliminate the 20% chance of randomly guessing the right answer. When the significance analysis is done to compare the means of pre and post activity results, "I don't know" answers were included in the incorrect answer group.

The Table indicates that, overall, students showed a marked improvement in their understanding of the telecommunications concepts following the interactive activity the students participated in. For most questions, a sharp increase in the student comprehension is observed between the lecture and then following the activity. This observation can likely be attributed to enhanced learning stimulated by first "hearing" and then "doing". It is interesting to note that this is particularly true for some of the most complex concepts, like packets. It can also be observed that the students felt more confident about their knowledge on the subject covered by the significant decrease in the percentage of "I don't know" responses.

Table 4 shows that in some cases, the exercise was helpful in the students learning of the concepts involved, but not in every case. The students clearly had a better understanding of the concepts of packets and routers following the activity than they did prior to the activity. They also had a better understanding of how the data was routed on the Internet, as shown in question 7. While their knowledge did not increase in every area, it did increase in these areas, which are difficult for students to learn and understand.

The comparison of means for student test scores prior and following the activity was conducted using a one-tailed t-test. The success rate following the activity was significantly higher ($p\text{-value}<0.001$) than the success rate before the activity. This data shows that the activity does help to increase student learning.

It is especially interesting to note that this exercise helped with those more technical issues, such as the concept of packets and how they move, which students have a hard time understanding in lecture. This could be because they were forced to play the role of the packets and routers, and thus had a direct connection to those concepts that are difficult to get across in lecture.

5. CONCLUSIONS

This research has presented a method for teaching students how data is moved across the Internet and a study to determine if it was effective. The results suggest that this exercise was effective at increasing student learning. While this indicates that the exercise is effective for increasing student learning, another informal result was noted by the authors. The students indicated that they enjoyed the activity, and would recommend it to other students. This is not the response the authors have noted from students generally when discussing telecommunications in class, and may indicate that even when the activity doesn't directly increase student learning, that it does increase their enjoyment in learning the subject.

Even though this study in conducted at a business school, the use of this activity can be easily adapted and be beneficiary in explaining introductory networking topics by many other programs in other types of colleges or units.

There are areas in which this research could be extended in the future. For instance, would this type of activity be useful when teaching more advanced data communications concepts to upper level IS students? Could this exercise be used to replace the lecture on the subject, so that the topics are covered via an extended version of the activity, rather than by lecture and by the game? Would this be as effective? These are areas that future research will explore.

6. REFERENCES

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Appendix 1: The details of the interactive game

I. Handout given to students with job descriptions:

Switch: A switch looks at the addresses on every incoming data packet within a network to determine where it should be sent.

Your job will be to determine where each incoming packet should be sent – to one of the computers on your network, or out to the Router. This is how switches work in a **packet switched network**.

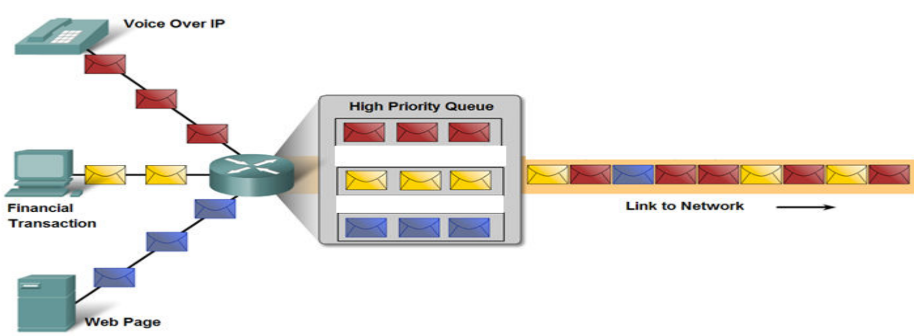
Switching Table

Destination Address	**What to do?**
Web request with unknown IP address	Send to DNS directly
Student A	Send to Student A directly
Student B	Send to Student B directly
UNCW Web Server	Send to UNCW Web Server directly
Any other address	Send to LAN router directly

Router: Routers work much like switches do, but where a switch works *within* a network, routers work *across* networks. These are the devices that forward data across the Internet.

You are the navigator. Your job will be to look at each incoming packet and determine which network it should go to. You may also need to look at **multiple** routes to get the information to its destination. If you have multiple routes, choose the route with the **least** traffic to send the packets.

When packets from multiple sources arrive you can ***interleave*** the packets.



DNS: A Domain Name Server translates the URL you type in (www.uncw.edu) into an IP address for that computer. Every ISP has a DNS that keeps track of common addresses (the registered domain names that get used the most, like cnn.com, facebook.com, youtube.com etc) in a database. If a local DNS doesn't know the address you've typed in, then it checks with one of the Internet DNSs.

Your job is to translate the URL into an IP address and give that address to the router asking for it. If you don't know it, you need to ask the other DNS.

Packets: When data is moved between computers over a network, it has to be broken down into pieces. These pieces are called packets. When a sending *server* or *computer* gets a request for a file, it will break that file into thousands of pieces to send across the network. The *receiving computer* then takes those pieces and puts them back together again.

Your job is to move across the network to get the data to the computers that need it.

Server: Servers are the computers on the network that hold files and give them to other computers on request. Every webpage everywhere is housed on a server.

Your job is to take the request for information and then pass that information back to the requesting computer in *packets*.

Web Server: A web server stored files related to the organization's web page. When a request comes for one or more of those files, the server breaks the page down to small packets and send it to the requesting computer.

Requesting Computer: Through the web browser (Firefox, Internet Explorer, etc) computers request files from *servers* via the network. These files could be located anywhere in the world, and are transmitted back to the requesting computer.

You will request a file from one or more servers. Once you have made the request(s), you will then have to take the data that is passed back to you and put the file together. You will do this by grouping the data that is the same, so that the web pages you are requesting don't get mixed up!

II. The layout of the data network

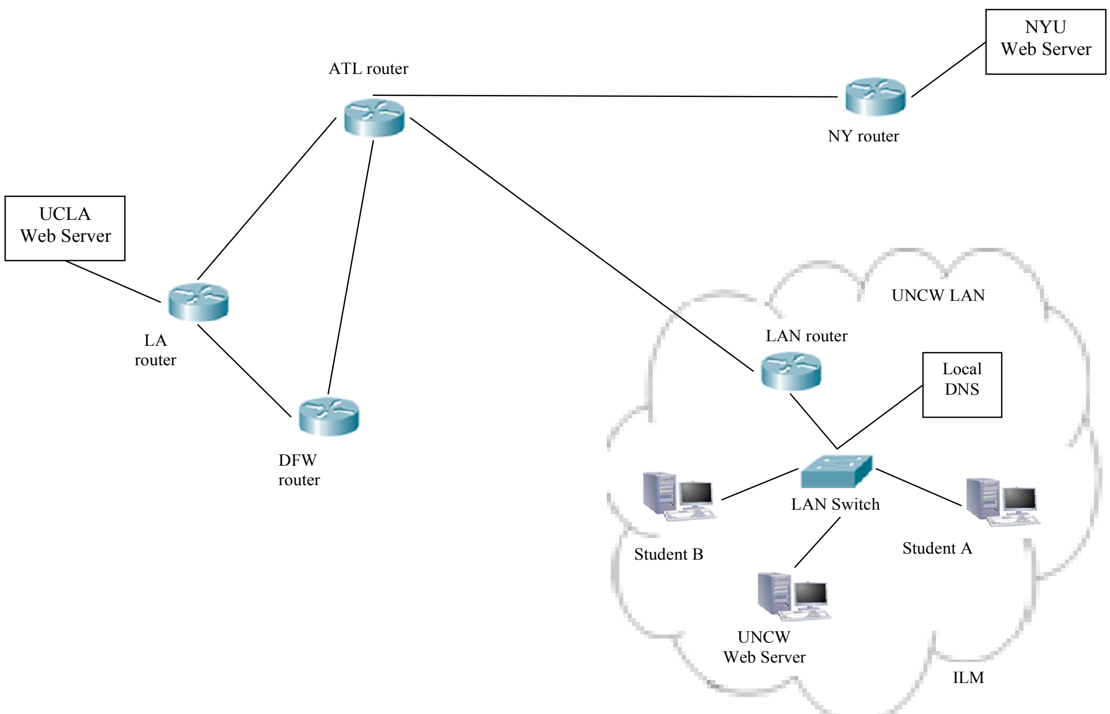


Figure 1 The layout of the data network

Appendix 2: Survey questions

1. What is your gender
    a. Female
    b. Male
2. What is your age group
    a. 18-21
    b. 22-24
    c. 25-28
    d. 29-32
    e. 32+
3. What is your major?
    a. Accounting
    b. Finance
    c. Information Systems
    d. Management
    e. Marketing
4. _________ is a collection of many separate networks.
    a. A WAN
    b. An Internet
    c. A LAN
    d. None of the above
    e. I don't know
5. What are packets?
    a. Protocols routers follow to determine where information needs to go
    b. Smaller packages of information routers shovel around the Internet
    c. Large bundles of data grouped into chunks for delivery
    d. None of the above
    e. I don't know
6. What does a router do?
    a. Makes sure data sent over the Internet goes where it needs to go -- and not where it isn't needed
    b. Acts like a traffic controller, working to cut down on congestion and keep everything flowing smoothly along the best possible path
    c. Both
    d. Neither
    e. I don't know
7. What are the pros of a packet-switching network?
    a. Packets can easily be routed around problems, and the overall load of information can be balanced across different Internet paths.
    b. Since packets are small, they don't get jammed up in the Internet's series of tubes.
    c. Packet-switching decreases the memory needed on each individual computer.
    d. All of the above.
    e. I don't know
8. Data packet interleaving helps with which of the below?
    a. Timely transmission of data packets
    b. Breaking messages into small data packages
    c. Locating best path destination
    d. All of the above
    e. I don't know
9. Which of the below is ***not*** true about fiber optic cables?
    a. The signals transmitted in fiber optic are light signals, not electrical signals.
    b. It is preferable to use fiber optic to carry data over longer distances due to price and bandwidth advantages.
    c. An optical cable weighs less than a comparable copper wire or coaxial cable.
    d. The diameter of fiber-optic cable is larger than that of coaxial cable.

e. I don't know.

10. A _____ is a place of convergence where data arrives from one or more directions and is forwarded out in one or more directions.
    a. Hub
    b. Gateway
    c. Bridge
    d. Switch
    e. I don't know
11. Which of the below is ***not*** true about Domain Name Servers (DNS)?
    a. DNS translates the human-readable domain name into the machine-readable IP address.
    b. DNS is a database.
    c. Each DNS carries all the registered domain names on the Internet.
    d. All of the above.
    e. I don't know
12. There are _______________ Internet service providers.
    a. local
    b. regional
    c. national and international
    d. All of the above
    e. I don't know

Appendix 3: Figures and Tables

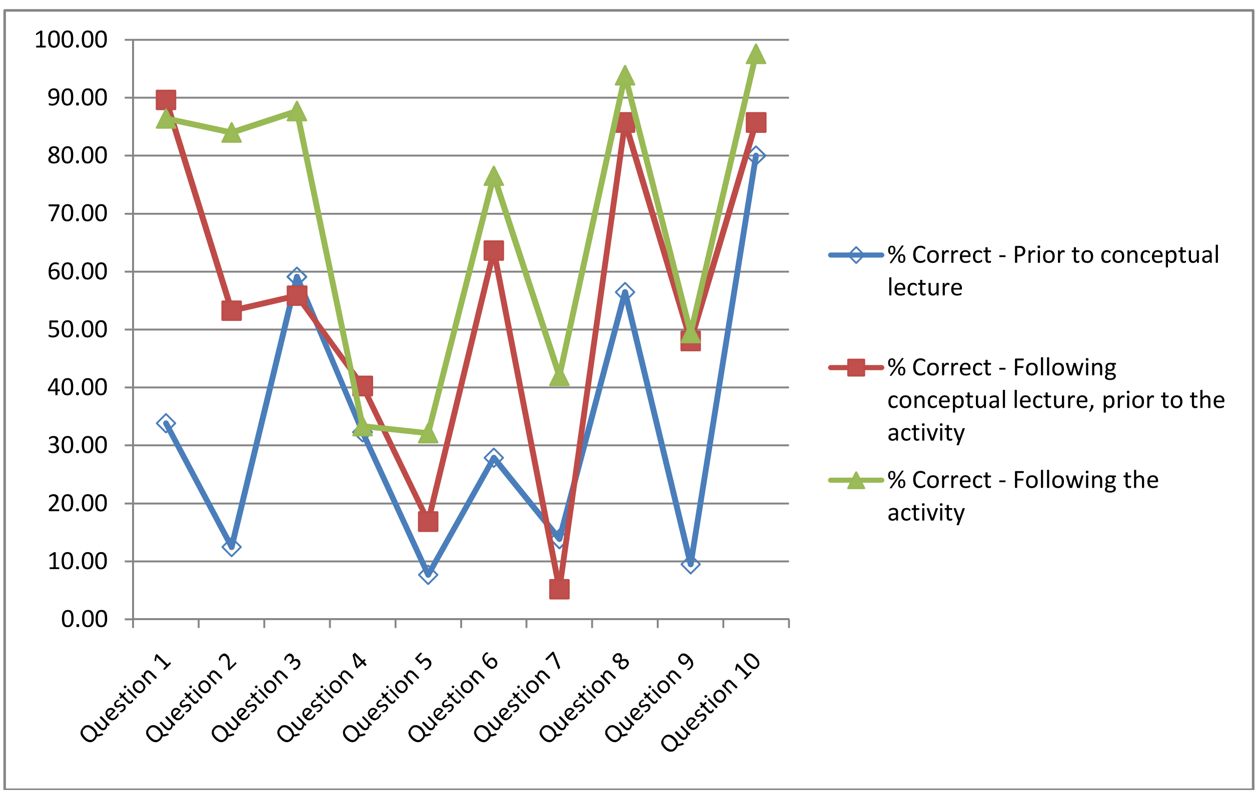


Figure 2 - Pre-Lecture, Pre-Activity and Post Activity Responses

		Responses	
		(percent)	(count)
1.) ________ is a collection of many separate networks.	Correct	33.85%	22
	Incorrect	55.38%	36
	I don't know	10.77%	7
2.) What are packets?	Correct	12.50%	8
	Incorrect	58.46%	38
	I don't know	29.69%	19
3.) What does a router do?	Correct	59.09%	39
	Incorrect	36.92%	24
	I don't know	3.03%	2
4.) What are the pros of a packet-switching network?	Correct	32.31%	21
	Incorrect	40.00%	26
	I don't know	27.69%	18
5.) Data packet interleaving helps with which of the below?	Correct	7.69%	5
	Incorrect	61.54%	40
	I don't know	30.77%	20
6.) Which of the below is not true about fiber optic cables?	Correct	27.87%	17
	Incorrect	47.69%	31
	I don't know.	27.87%	17
7.) A ____ is a place of convergence where data arrives from one or more directions and is forwarded out in one or more directions.	Correct	13.85%	9
	Incorrect	76.92%	50
	I don't know	9.23%	6
8.) _______ is a data communication system within a building, plant, or between nearby buildings.	Correct	56.45%	35
	Incorrect	26.15%	17
	I don't know	20.97%	13
9.) Which of the below is not true about Domain Name Servers (DNS)?	Correct	9.52%	6
	Incorrect	58.46%	38
	I don't know	33.33%	21
10.) There are ______ Internet service providers.	Correct	80%	48
	Incorrect	23.08%	15
	I don't know	3.33%	2

Table 2 – Student Baseline Knowledge

		Responses	
		(percent)	(count)
1.) ________ is a collection of many separate networks.	Correct	89.61%	69
	Incorrect		8
	I don't know	0%	0
2.) What are packets?	Correct	53.95%	41
	Incorrect		30
	I don't know	3.95%	3
3.) What does a router do?	Correct	55.84%	43
	Incorrect		33
	I don't know	1.30%	1
4.) What are the pros of a packet-switching network?	Correct	41.89%	31
	Incorrect		43
	I don't know	4.05%	3
5.) Data packet interleaving helps with which of the below?	Correct	17.33%	13
	Incorrect		57
	I don't know	9.33%	7
6.) Which of the below is not true about fiber optic cables?	Correct	63.64%	49
	Incorrect		25
	I don't know.	3.90%	3
7.) A ____ is a place of convergence where data arrives from one or more directions and is forwarded out in one	Correct	5.26%	4
	Incorrect		72
	I don't know	1.32%	1
8.) _______ is a data communication system within a building, plant, or between nearby buildings.	Correct	86.84%	66
	Incorrect		11
	I don't know	0%	0
9.) Which of the below is not true about Domain Name Servers (DNS)?	Correct	48.68%	37
	Incorrect		34
	I don't know	7.89%	6
10.) There are ______ Internet service providers.	Correct	88%	66
	Incorrect		9
	I don't know	2.67%	2

Table 3 - Post Lecture Responses

		Pre-Lecture	Pre-Exercise	Post-Exercise
		Responses		
1.) ________ is a collection of many separate networks.	Correct	33.85%	89.61%	86.42%
	I don't know	10.77%	0%	0%
2.) What are packets?	Correct	12.50%	53.95%	83.95%
	I don't know	29.69%	3.95%	0%
3.) What does a router do?	Correct	59.09%	55.84%	86.59%
	I don't know	3.03%	1.30%	0%
4.) What are the pros of a packet-switching network?	Correct	32.31%	41.89%	32.93%
	I don't know	27.69%	4.05%	0%
5.) Data packet interleaving helps with which of the below?	Correct	7.69%	17.33%	32.10%
	I don't know	30.77%	9.33%	0%
6.) Which of the below is not true about fiber optic cables?	Correct	27.87%	63.64%	76.54%
	I don't know.	27.87%	3.90%	0%
7.) A ____ is a place of convergence where data arrives from one or more directions and is forwarded out in one or more directions.	Correct	13.85%	5.26%	41.98%
	I don't know	9.23%	1.32%	0%
8.) _______ is a data communication system within a building, plant, or between nearby buildings.	Correct	56.45%	86.84%	95%
	I don't know	20.97%	0%	0%
9.) Which of the below is not true about Domain Name Servers (DNS)?	Correct	9.52%	48.68%	50%
	I don't know	33.33%	7.89%	1.25%
10.) There are ______ Internet service providers.	Correct	80%	88%	97.53%
	I don't know	3.33%	2.67%	1.23%

Table 4 - Pre-Lecture, Pre-Activity and Post Activity Responses