Enhancing Learning Experiences in Data Networking Education

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Abstract

Instructors of data networking face the challenge of providing students with lab experiences to apply their learning. This often is accomplished through the use of actual hardware lab environments, remote lab environments, and simulated lab environments. The high cost and access limitations of hardware and remote lab environments can serve as obstacles to achieving student learning outcomes. These limitations can be overcome through the use of simulation software such as Packet Tracer. There are concerns that simulation software does not provide the "presence" or realism offered by physical and remote labs. This article will address several of these concerns and offer strategies for creating more realistic user experiences for students using the Packet Tracer network simulation software.

Introduction

Data networking provides the foundation upon which all other information technologies are built. Students learning these technologies need strong theoretical and applied understanding of how networking infrastructures are designed, built, and maintained. Instructors have long provided the theoretical framework for data communications through lecture and case study. The difficulty is in providing the resources required by students to learn the applied aspects of data networking. Hands-on lab activities are recognized as an essential component in fulfilling this aspect of their education(Comer, 2003; Guo, Xiang, & Wang, 2007; Hua, 2013; Lahoud & Krichen, 2010; Stohr-Hunt, 1996). Students need to be able to design, install, configure, and troubleshoot a networking environment (Zhang, Liang, & Ma, 2012). These applied experiences also reinforce the theoretical framework provided in the classroom (Sarkar, 2006; Zhang et al., 2012).

Providing network lab experiences

To provide this experiential learning, there are three options that an institution can adopt (Adams, 2004; Brown & Lahoud, 2005; Hua, 2013; Lahoud & Tang, 2006). The first option is to provide a physical lab where students can build and configure their network topologies. The next option is to utilize a remote lab solution in which students connect to network equipment over the Internet. The final option is to utilize simulation software that provides a virtual environment that allows students to design and configure network topologies without physical equipment.

Physical Labs
The challenge has been providing students with the lab environment in which students can apply concepts and theories. Such a lab would require an assortment of equipment such as routers, switches, network cables, and computers. Students are able to manually connect the equipment based on a given network topology. The cost for providing a physical lab can be quite prohibitive (Hua, 2013; Lawson & Stackpole, 2006; Wong, Wolf, Gorinsky, & Turner, 2007). The financial burden is increased when student access is considered. One of the factors that affect student engagement is the accessibility of lab equipment (Ma & Nickerson, 2006). A lab environment with insufficient equipment can create situations in which students are competing with each other for access to the equipment needed to complete their lab assignments (Hua, 2013).

Remote Labs
Remote labs allow students to connect to hardware devices without the requirement of physical proximity (Lindsay & Good, 2005). The Cisco Networking Academy offers the NetLab Academy Edition in support of its networking curriculum (Cisco Networking Academy, 2007). Like a physical lab, NetLab requires a set of network hardware as well as NetLab control equipment to allow students to access those resources from anywhere over the Internet. The advantage of such a remote lab offering is that it provides students with lab experiences that have nearly the same authenticity as sitting in front of the actual equipment in a physical lab. This remote access to physical equipment allows instructors to create academically meaningful activities (Kuh, 2001) that engage students by providing them with the configuration capabilities at a distance (Border, 2007; Rigby & Dark, 2006).

NetLab is not without costs or limitations. As with physical labs, there is a significant financial cost for the initial deployment of a NetLab system. The system requires the network hardware associated with the physical lab as well as a NetLab Academy Edition device and annual maintenance plan. In addition to the financial costs, there is a significant limitation with remote labs. Accessibility continues to be an issue as it is with physical labs. Only one student or team of students can access the hardware at a given point in time. This necessitates a scheduling system for which instructors grant access to preconfigured topologies for set time blocks.

Simulation Software
The simulation software available for data networking typically provides a virtual sandbox in which students can create and configure network topologies (Lahoud & Krichen, 2010). Simulation software overcomes the problems of availability associated with physical and remote labs. Students are able to install the software on their own computers allowing them to work on labs at any time. Boson NetSim, GNS3, and Packet Tracer are examples of network simulation applications. Boson NetSim offers a feature rich simulator available for students to purchase that aligns with the Cisco CCNA certification. Packet Tracer is offered at no charge to students enrolled in the Cisco Networking Academy. These simulators do not offer the full feature set found in the operating systems of Cisco network hardware. They are limited to the configurations

enabled by the programmers of the simulators. GNS3 differs in that it is an open source simulator that allows students to load actual Cisco operating systems into the virtual devices. This gives them access to the full range of commands available on actual hardware. The problem is getting the Cisco operating system files. Typically this requires one to download the operating system from physical hardware and then upload it into the virtual device in GNS3.

An exploratory study by Lahoud and Krichen (2010) found that in most situations, students preferred simulation software over physical and remote lab experiences. While it was found that physical labs were desirable among students, accessibility issues made simulation software the more preferred source for lab experiences. These findings suggest that students would like the authentic experience of working on actual hardware but are frustrated by gaining access to those limited resources.

If this holds true, the key to engaging students while using simulation software is to create "real" experiences (Sauter, Uttal, Rapp, Downing, & Jona, 2013). Studies have defined this realism or "presence" as the degree to which the user experience with the simulation software matches the experience working on physical hardware (Witmer & Singer, 1998). As the user experience of simulation software replicates what the student would experience on actual hardware, students are more likely to perceive it as an educationally authentic experience (Lahoud & Krichen, 2010; Lindsay & Good, 2005; Ma & Nickerson, 2006).

Creating Realism in a Simulated Environment
The Cisco Networking Academy is one of the most broadly adopted networking education curricula available. There are hundreds of thousands of students enrolled in over 9000 academies located in over 170 countries (Cisco Networking Academy, 2014). Packet Tracer is a network simulation application available to all instructors and students participating in the Cisco Networking Academy.

Configuring Realism
Despite the robustness of its capabilities as an educational tool for data networking, there are default configurations that detract from the realism of the user experience. Presented below are a series of modifications to the Packet Tracer environment that will provide students with a user experience that more closely aligns with what they will experience on actual hardware.

Activity Wizard Password
An instructor choosing to use a Cisco Networking Academy lab as a graded assignment or quiz should do so with trepidation. Embedded in the labs provided by the Cisco Networking Academy is the answer key for the lab activity. This answer key includes a list of assessment items that are used by Packet Tracer's assessment features. Access to the answer key is password protected. The problem is that a simple Internet search will reveal a thriving community of individuals finding ways to bypass this password security.

An instructor should change the default password on Academy labs before assigning them to students for a grade.

Changing Activity Wizard Password
1. Open the Packet Tracer lab.
2. Select the Activity Wizard in the Extensions menu.
3. Enter the default password.
4. Select Password within the Activity Wizard (See Figure 1).
5. Enter and confirm a new password for the lab.
6. Select Save and then Exit.
7. Re-open the Packet Tracer lab
8. Verify that the new password is required to enter the Activity Wizard by repeating steps 2 and 3.
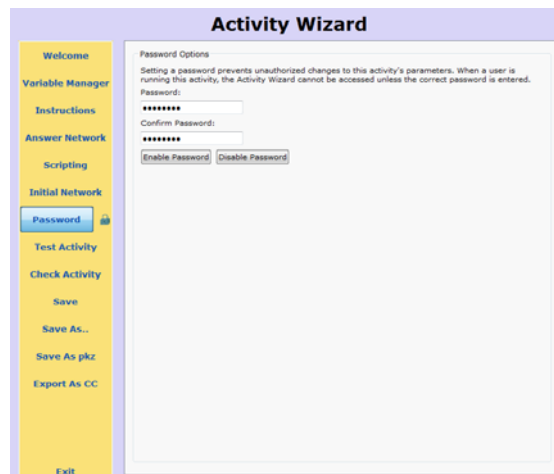

Figure 1

This modified copy of the Cisco Networking Academy lab is what should be assigned to the students. This procedure can also be used to secure the Activity Wizard on instructor created labs within Packet Tracer. Passwords are disabled by default when an instructor creates a custom lab. The Enable Password option would need to be selected after entering and confirming a password as seen in Figure 1.

Self-Assessment
Feedback is a key requirement in the early stages of network education. Packet Tracer incorporates self-assessment features that allow students to monitor their progress as they work through the labs. These features include individual assessment items and an overall completion percentage. These self- assessment features when combined with detailed instructions provide a supportive learning environment for novice networking education students. As the students develop their networking skills, this level of feedback can be counter-productive. These features can foster a dependence on feedback mechanisms that will not be present as students transition to physical hardware. Instructors need to know how to change Packet Tracer configurations to scale back these self-assessment features as students develop in their networking skills.

Completion Percentage

One of the self-assessment features on the PT Activity window is the completion percentage. The percentage found in the bottom, right corner of the window indicates the amount of configurations that are successfully completed (See Figure 2). This provides students with feedback on their overall progress during a formative, skill-acquisition lab.
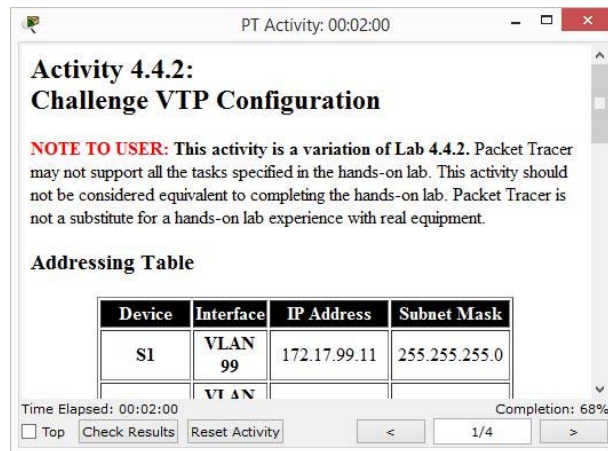

Figure 2

The presence of the completion percentage becomes counter-productive once an instructor chooses to assign a lab to assess skill comprehension and retention. The completion percentage feature does a line item monitoring of the configurations on the devices in the network topology. The completion percentage increases each time a configuration item has been entered correctly. The fallacy is that a completion percentage of 100% does not indicate an accurate configuration. Packet Tracer does not monitor extra lines of configuration that are unneeded or incorrect. A student with a completion percentage of 100% may find that the lab does not work properly because extra configurations have been added that counter-act the intent of the correct configurations. A student may choose to go beyond the stated instructions and independently add a misconfigured firewall that does not allow network traffic to flow through the topology as expected. The completion percentage will show 100% if the monitored configuration items are correct even though the intended outcome of the lab has not been accomplished properly.

The following set of procedures will remove the completion percentage from the PT Activity window for a given lab.

Disabling Dynamic Feedback
1. Inside the Activity Wizard, click on Answer Network (See Figure 3).
2. Click on the Settings tab.
3. Select No Dynamic Feedback to disable the completion percentage feedback. Selecting Show Item Count Percentage will re-enable the completion percentage feedback.
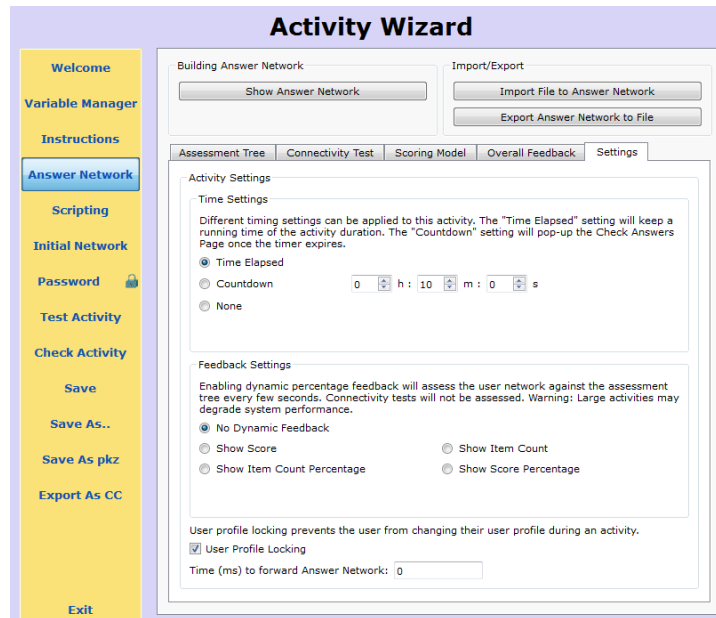
4. Click Save.
5. Click Exit.

Figure 3

Assessment Items

Selecting the Check Results button on the instructions window will allow students to view the list of configuration items being assessed and whether they have correctly configured those items (See Figure 4). A red X next to an assessment item indicates that it has either not been configured yet or that it has been configured incorrectly.
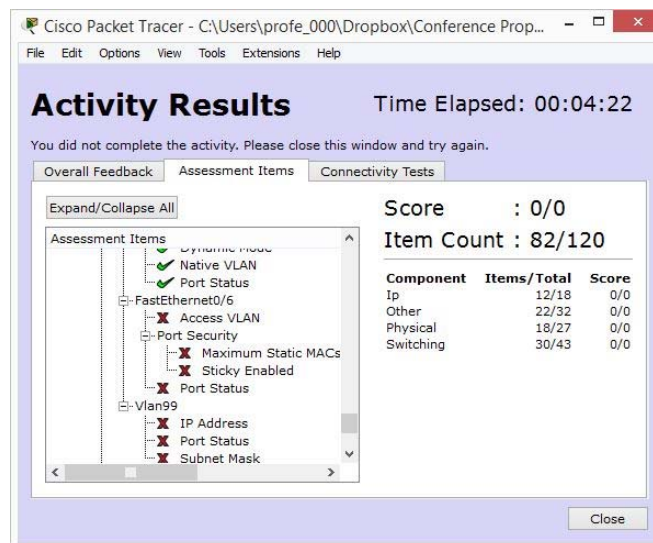

Figure 4

If the lab is being used as an in-class exercise for skill acquisition, self-assessment is beneficial. It becomes a liability once an instructor decides to use a lab to assess retention or comprehension. Students should not be able to view these assessment items as they are working on a lab for these purposes. Students need to become more self-reliant as they develop in their networking skills. Disabling assessment items allows an instructor to assess whether students can transfer the skills developed during the acquisition stage to a more realistic networking environment.

Disabling Assessment Items
1. Select Initial Network within the Activity Wizard.
2. Expand the folder directory to Locking/Interface/Activity (See Figure 5).
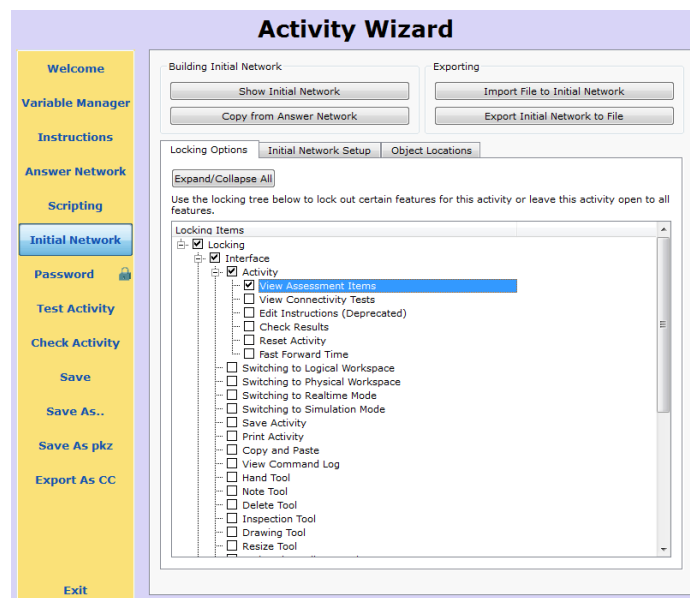3. Place a check mark in the box next to View Assessment Items.
4. Click Save.

Figure 5

Config Tab

The Config tab in Packet Tracer presents students with a graphical configuration interface that is unique to the software. The purpose of the Config tab is to provide the user with a quick method of entering basic configurations. The problem is that the Config tab bears no resemblance to the interfaces students will use when configuring Cisco networking devices. Students using this interface do not have to learn the syntax needed to configure Cisco routers and switches. Instructors can enhance the realism of the simulation software by disabling the Config tab. This will require students to use the command line interface that is present on actual physical hardware.

Disabling the Config Tab
1. Inside the Activity Wizard, click on Initial Network.
2. Expand the folder directory to Locking/ Topology/Global (See Figure 6).
3. Place a check mark in the box next to Use Config Tab.
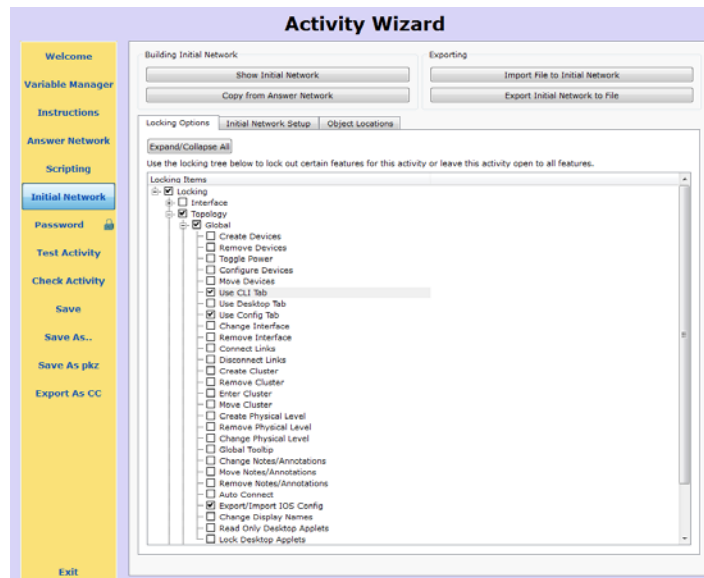4. Click Save

Figure 6

Requiring Console Port connectivity
The initial configuration of network devices is typically accomplished through the device's Console port. A student in a hardware lab environment would accomplish this by connecting a console or rollover cable from a computer to the Console port on the network device. The student would then use a terminal emulation program, such as Putty, to configure the device.

Within the Packet Tracer logical topology, students can configure the devices in the CLI tab after selecting the device. The user interface in the CLI tab is the same as what the student would experience using a terminal emulation program. The problem is that this does not reflect what a student would have to do with actual hardware. An instructor can require students to manually connect a computer to the console port by disabling the CLI tab. Students will then have to establish a console connection between the RS232 port on a computer and the console port of the network device within the topology. At that point, the student would open the computer and use the Terminal program in the Desktop tab (See Figure 7).
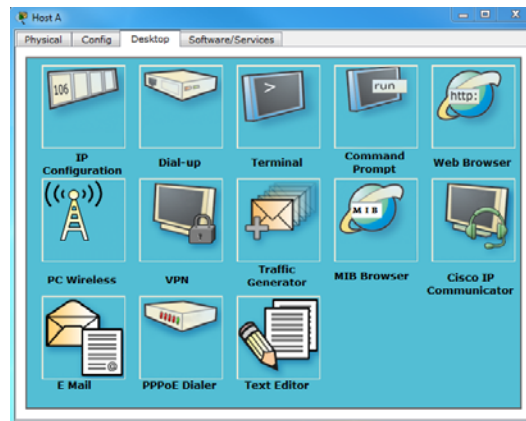
Figure 7

Disabling the CLI Tab
1. Inside the Activity Wizard, click on Initial Network.
2. Expand the folder directory to Locking/ Topology/Global (See Figure 6).
3. Place a check mark in the box next to Use CLI Tab.
4. Click Save

Maintaining Academic Honesty
A student's work is stored in an electronic file when working with the Packet Tracer application. In a physical lab, an instructor is able to actively monitor student participation in the lab. This is not the case when using Packet Tracer. By default, there is nothing to uniquely identify the work to a particular student. This creates the opportunity for a student who has completed the lab to share the file with other students. If the student who initially completed the lab did it correctly, there may be no way for the instructor to identify whether the student work is original or a copy of someone else's file. This only becomes apparent when the source file was not configured properly and the identical error manifests in multiple student submissions.

One method of forcing student participation is through the use of profile locking. Profile locking requires students to embed their name into the file. The author of the file becomes readily apparent with profile locking. The question then becomes, "Why not just change the user name in the file?" When profile locking is engaged, any change to the user name results in all the configurations to be returned to the default original settings.

Enabling Profile Locking
1. Inside the Activity Wizard click on Answer Network
2. Click on the Settings tab.
3. Place a check mark in the box for User Profile Locking (See Figure 3).
4. Click Save.

Students will have to create a user profile for their assignment once profile locking has been enabled. If they do not create a profile, the profile for the lab will default to "Guest". Instructors should require that students create a user profile for each Packet Tracer lab.

This should be done before the student does any configurations as the process will return the lab to its initial state.

Creating a User Profile in Packet Tracer
1. Click on Options on the Menu Bar
2. Select User Profile from the list of options.
3. Enter your name in the Name field and click OK (See Figure 8).
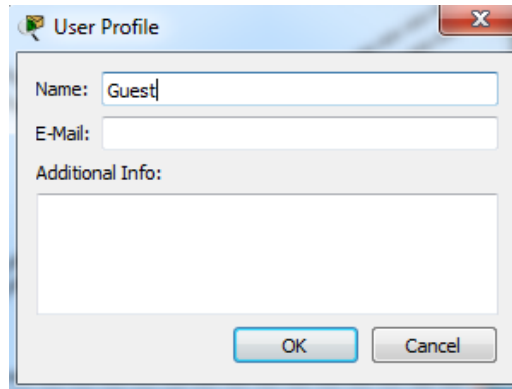

Figure 8

Another potential problem is sharing of configuration files. This is an issue for both physical labs and simulation software. One of the features of Cisco networking devices is the ability to export the configuration file. In an actual production environment, it is critical that a network administrator restore network connectivity as quickly as possible. Having an exported configuration file allows the network administrator to restore the network device quickly.

In an educational environment, this ability provides an opportunity for academic dishonesty. User Profiles will prevent students from making copies of a lab and submitting it as their own work. It will not, however, prevent a student from exporting the configuration files from a completed lab. Nor will it prevent that student from importing that configuration file into the Packet Tracer file using their own user profile. This can be prevented by disabling the ability to export or import configuration files within the Packet Tracer lab.

Disabling Import and Export of Configuration Files
1. Inside the Activity Wizard click on Initial Network.
2. Expand the folder directory for Locking/ Topology/Global (See Figure 6).
3. Place a check mark in the box for "Export/Import IOS Config".
4. Click Save

Conclusion
Instructors of data networking courses have several options for providing students with hands-on learning experiences. They can provide their students with physical labs,

remote labs, and labs through simulation software. Each option has its own set of strengths and weaknesses. The most significant obstacle to offering students access to physical and remote labs is cost. This is where simulation software provides a low to no cost alternative. It also provides unrestricted and portable access to the lab experiences.

Packet Tracer is a freely distributed network simulation application offered through the Cisco Networking Academy. It is what students use to complete the lab assignments available through the Cisco Networking Academy. Instructors may also use the program to create their own topologies and lab scenarios.

There are, however, aspects of the Packet Tracer interface that do not align with what students will experience on actual networking hardware. Several strategies were presented to help an instructor to improve the realism of the user experience. Studies have found that students are more engaged as the lab experience more closely reflects what they will experience on actual hardware.

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