Web-based Hybrid Virtualization Laboratory to Facilitate Network Learning: HVLab

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***Abstract*— Teaching computer networks is one of the core topics in computer science curricula for undergraduate students. Recently, a network emulator has been used for teaching students to configure network devices, such as routers and switches, to practice in real network configuration scenarios without purchasing network hardware. Previous studies usually used standalone emulators to facilitate individual network learning. However, few studies applied collaboration in network learning. In this study, we proposed a web-based Hybrid Virtualization Laboratory (HVLab), which integrates network emulators and virtualization technology. The HVLab can support multiple network configuration scenarios (network emulators) for students to practice. Meanwhile, HVLab also implement collaborative mechanism to facilitate discussion among the experimental students. After experiment, the statistical results showed that the post-test scores of experimental group were higher than the control group. In addition, they outperform the control groups in homework and in-class assignment, especially when experimental students become more familiar with HVLab and know how to get benefit from collaboration using HVlab. Furthermore, the experimental students perceived that was easy to use the HVLab and useful for accomplishing assignment and homework. Most of the students also expressed they were highly motivated to use HVLab as learning tool in the future. Finally, the observation and questionnaire with experimental group showed that collaboration in HVLab was potentially helpful during the experiment.**

Keywords—hybrid virtualization; web-based virtualization laboratories; teaching computer network

I. INTRODUCTION

In computer science courses, computer networks need special laboratories for facilitating students to practice what they learned in class. These laboratories provide chances for students to learn how to set up, and troubleshoot the configuration of network devices, thereby verifying their network knowledge. Conversely, due to hardware availability limitation on campus for teaching network lab several studies used standalone network emulators to teach computer network course [1-3]. They mentioned that emulators can emulate different network behaviors (i.e. packet flow) [1], provide hands-on experience, realistic network environment and in teaching computer networks [3]. In addition, network emulator also inexpensive, flexible real code and provide network device software (i.e. router, switch). However, such emulators has limitation, while the students' work individually using standalone emulators they became less confident and unable to accomplish their laboratory activity on time and hard to support collaborative activities among the students. Furthermore, it is also difficult to manage peer interaction activities and analyze learning behavior and performance of the students.

Moreover, some studies [4-6] used virtualization with collaborative laboratory environment and resource sharing with help of server access control. According to [5] and [4] mentioned that collaborative learning among students in network labs is helpful to improve their network configuration skill and share their knowledge.

To address the above limitations like the complex collaborative mechanism [6] and focusing individual task using standalone network emulator. This study, we used virtualization technology and network emulator together to propose a web-based Hybrid Virtualization Laboratory (HVLab), which is a collaborative environment for learning and practicing to design network topology and configure multiple network devices controlled by server.

This study investigated the effect of HVLab to students' behavior, perception, and learning achievement for learning computer networks. In the experimental procedure were divided into two groups, control and experimental group; both groups perform their laboratory using HVLab. In addition, the experimental group performs their laboratories assignment and homework using HVLab with collaboration mechanism, while the control group used HVLab individually.

II. RELATED WORK

A. Hybrid virtualization technology

In earlier, the hybrid virtualization was proposed to combine the advantages of software and hardware virtualization [7], in which the software virtualization can provide more ability to manage the virtualization and the hardware virtualization can make the virtualization has more performance and scalability. For instance the CPU and memory virtualization are the leading solution to increase the performance of hardware assisted virtual machines [8].

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The hybrid virtualization was used to extend a number of operations with easy management. Recently, hardware has been powerful and more complex to configuration and management, the hardware virtualization was less used.

Several studies show software virtualization with modern hardware can support more operating tasks [9]. Therefore, this study showed an alternative way to create a hybrid of software virtualization by designing a virtual machine (VM) to organize with application that running on it. Then, the proposed system of hybrid virtualization was established, in which the proposed system consists of VMs with running simulators. With the capability of the simulator, which can emulate many operations. Thus, this proposed system also can facilitate a large number of operations.

B. Online collaborative learning

Several studies have demonstrated the benefits of online collaborative learning [10-12]. For example, [13] proposed the online collaborative learning (OCL) theory, which focused on three components, namely: collaborative learning, knowledge building which was mediated through internet to facilitate for formal and informal education, and working online to solve problems together; the application of OCL usually employed web-based technologies to provide multimedia, synchronous and asynchronous tools. OCL motivates students to undertake programs and courses via the internet and encourages them to help each other and foster lifelong learning online which alter traditional education.

Collaborative learning through interaction peoples have learned informally in groups for thousands of years. However, lots of formal learning today, particularly at university level, still take place in an environment in which students were expected to learn individually. Despite this, students sometimes try to form their informal groups and study together to assist learning. Collaborative learning helps students to establish their learning community, showing social presence, talking some issue related to learning [11].

Moreover, collaborative learning represents a good approach to achieve common teaching and learning goals, which involves groups of learners working together for solving a problem [10]. OCL provides a strong fundamental that strengthens the importance of interaction for learning anytime and anywhere and can facilitate practice laboratory through discussion. Therefore, OCL has an important role in deep understanding of knowledge through peer interaction.

C. Research questions

This study purpose was to assess how beneficial HVLab for students learning and to answer the following research questions.

1. Does HVLab collaborative mechanism beneficial for learning Computer Networking course and had a positive impact on student learning performance?
2. Does learning behavior and system usage of students in the hybrid virtual laboratory such as homework, the number of command count and practice significantly influence their learning performance during learning computer-networking courses?
3. How students perceive HVLab and their attitude towards HVLab?

III. METHODOLOGY

A. Participant and Procedure

To test the fundamental functionality of the system and how is advantageous it can be, we conducted an experiment during the second semester academic year of 2016 at National Central University, Taiwan. The participants were 54 undergraduate student's majoring computer science and information engineering department. Course of introduction to computer networking and its practice. The participants were divided into two groups. The first group with 27 students as the experimental group (separated into five groups, each group consists of five-members) and the second group with 27 students as a control group to perform their laboratory group and individually, respectively.

The procedure of this experiment was based on the following five steps. 1) Pretest, laboratory training, one router configuration in class assignment and homework assignment (lab 1); 2) Static routing, in class assignment 1 and homework 1; 3) Router information protocols (RIP), 4) Open Shortest Path First (OSPF) and Enhanced Interior Gateway Routing Protocols (EIGRP) and 5) Post-test and questionnaire. The experiment was managed 2 hours per week during in class assignment practice.

B. Learning task design

To cover concepts of basic and advance network configuration, connectivity check and routing, Instructor prepared the laboratory materials and assignments for both groups of students. In the first class, the instructor provided the students a brief content and objective of the experiment, offered them one router configuration and assignments; which were completed within 2 hours class period. In addition, we proposed a sample task for the students to complete. These are listed as follows:

- Individual laboratory assignment: Includes both static and dynamic routing Labs, control group students were accomplished all labs individually
- Group Laboratory assignment: The students were divided into six groups and each group members were helping each other to accomplish the laboratory assignments within the given class period. In addition, the experimental students had an online synchronous discussion with their group members and the instructor using the HVLab chatting window feature. In week 2 to 4 (refer Figure 1) each experimental students configured three routers. At the beginning of the assignment, one student configures one router and explains how to configure router to the group members.
- Homework: The teacher prepared same homework assignments for the control and experimental groups, which includes 5 laboratory questions. The experimental students were allowed to use HVLab to determine the answers from the command manual document issued in class and repeat the assignments to approve their answers.

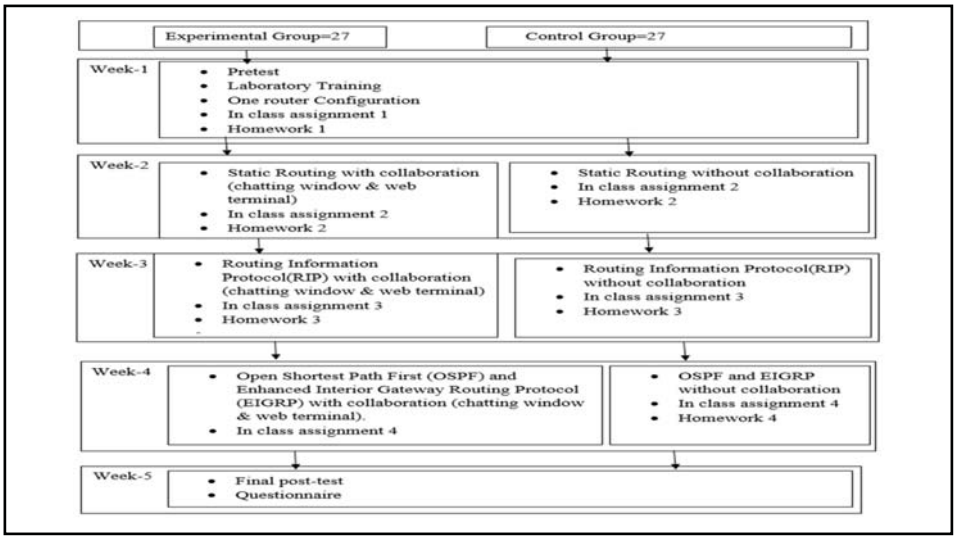

Fig. 1. Flow chart of the experiment

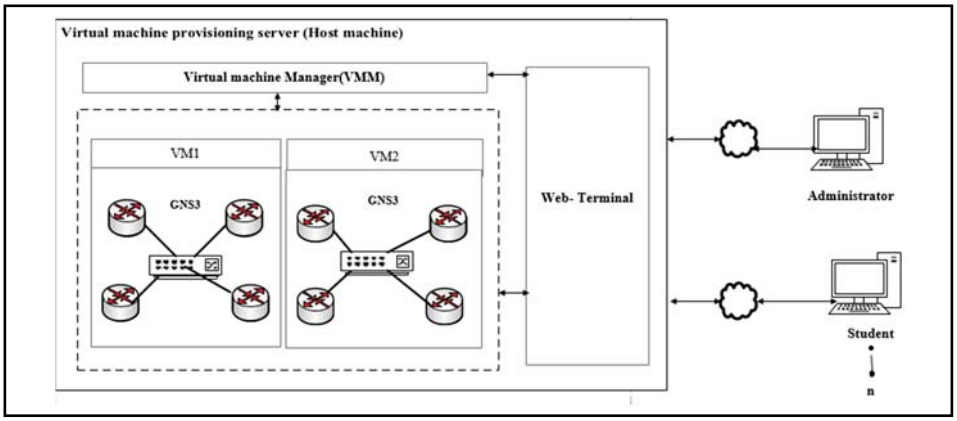

Fig. 2. HVLab Architecture

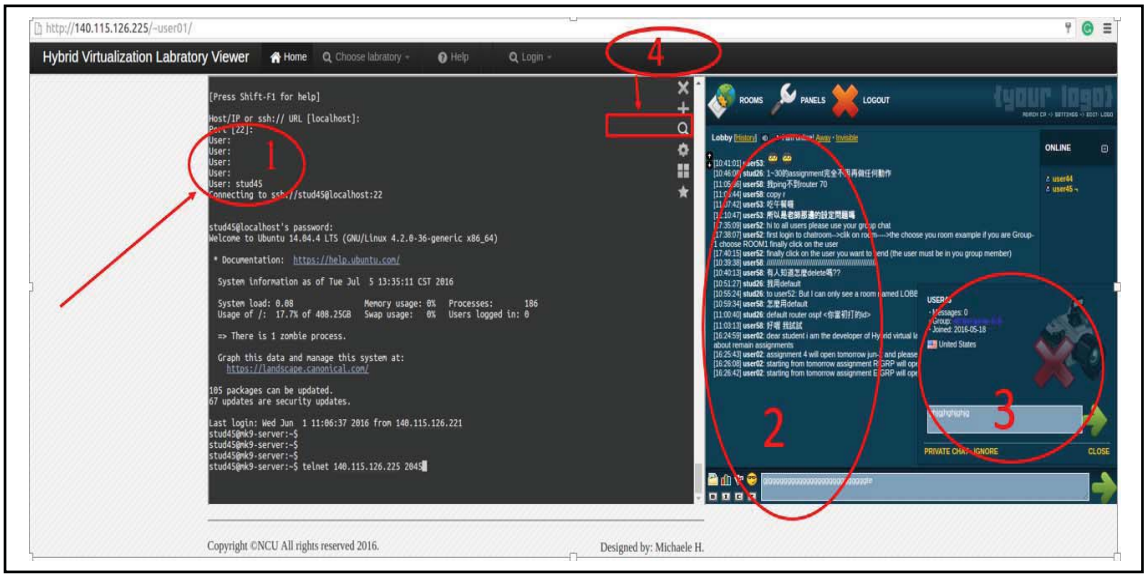

Fig. 3. Graphical user Interface 1) Gate-One Command terminal, 2) Group chatting window 3) Private chatting window 4) Log file viewer

C. Research variables

In this experiment, we define the following variables related to correct command count, incorrect command count, homework scores, pretest, and post-test. Moreover, an evaluation of these variables was made between one another likewise with overall learning achievement.

- Correct command count: The total number of correct network commands coded during Cisco IOS virtual router configuration by the students using HVLab for all Labs (week-1 to week-4).
- Incorrect command: the total number of incorrect network commands coded during Cisco IOS virtual router configuration by the students using HVLab from all Labs (week-1 to week-4).
- Homework Score: Homework scores for all Labs (Week-1to week-4).
- Pre-test & Post-test: Pre-test after the lab training prior knowledge exam scores of the students before the actual lab begin and post-test is the final exam score after all lab activities finished.

D. A Hybrid Virtualization Laboratory: HVLab

Figure 2 shows the architecture of HVLab which includes: Virtual Machine Manger (VMM), two GNS3 network emulator installed Virtual Machines (VMs) virtualized installed on it and other programming tools (Web terminal).

E. HVLab tools

In Figure 3, the web based Graphical User Interface (GUI), which includes the following major features that can help students to practice network configuration.

- Web terminal: This is a command terminal, which provides chance students to access virtual Ethernet or serial interfaces of network devices.
- Group and Private chat window: The chatting window enables the experimental students to exchange network command with their group members
- Log file viewer: Is a file, which useful to view the students' configuration command steps recorded by HVLab. Also, helped the teacher to evaluate students' performance accuracy.

IV. Data Analysis, Results and Discissions

In this section, we present the different results related to research questions, all data collected using a questionnaire and observation during the lab activities.

A. Learning and activity outcomes

1) T-test results of the pre-test and post-test

The pre-test designed to make sure that both group of students had same basic knowledge required for learning in the course. According, the pretest test result shows that no significant difference (t=-0.747, p=0.458) between the experimental group and control group .This indicated that these two groups had similar prior knowledge to take the course.

Additionally, the analysis of post-test shows no significant difference, but the experimental group students score higher (t=-1.431, p=0.159) than the control group. The insignificant difference in post-test result between the two groups is due to paper-based exam. However, as we have seen in Table 1 and Table 2 as the experimental student get a more correct command count and practice in class assignment improves their homework scores. In addition, the activity of the experimental group was with collaboration and they had more interaction to exchange network commands with their peers (See in Figure 3). We have discussion in details in next section

2) T-test results of in class assignment and homework scores

Table 1 illustrates the t-test result of both in-class assignment and homework scores. T-test result in-class assignment scores shows that the experiment group had significantly higher scores on in-class assignment 3 (t=-2.171, p<0.05) and in-class assignment 4 (t=-3.241, p<0.01) than control group; further, the average score of in-class assignment 1 and 2 for the experimental group was higher than for the control group. The main reason for this difference is that the experimental group students divided in two to six groups, each group had five members. As a result, each group members had a collaborative discussion using the chatting window to share network commands with their members.

Moreover, t-test result of homework scores also shows that the experimental group students had significantly higher score on homework 3 (t=-2.244, p<0.05) and homework 4 (t=-2.868, p<0.01) than the control group; additional, average score of homework 1 and 2 for the experimental group was higher than that of control group. The primary reason for this difference is the experimental students had long time to discuss collaboratively with their group members as well as the chatting window feature.

Based on these finding, we can conclude that week 1 to week 4 laboratory activities, the experimental group students perform better than that control group students who worked individually. We trust this is due to they worked with collaboration with their peers to share their network knowledge and improved their network configuration skill.

3) T-test result of the correct command count and incorrect command count

Table 3 shows that t-test result of both correct command count and incorrect command. There are statistical significant difference regarding correct command count on Lab 4 (t=-2.598, p<0.05) between the experimental group and control group. Likewise, there was a statistically significant difference regarding incorrect command count in lab 4 (t=2.785, p<0.05) between experimental and control group. As indicated in Table 3, in the first three labs (1, 2 and 3), there is no significant difference in terms of correct command and incorrect command count between the two groups. However, the mean of the correct command count of the experimental group was higher than the control group and the mean of the incorrect command count of the experimental group is less than the control group. Therefore, this implies that HVLab with collaboration help the experimental students to complete their assignment and homework. This shows that the experimental students can get quick help from their peers through the interaction when they have learning question.

Pearson correlation among homework, in class assignment and post-test

The results of the Pearson correlation analysis of the experimental group indicate significant correlation among assignment, homework, with post-test scores. In terms of correlation of homework with post-test, it was found that homework 2 (r=0.290, p<0.05), 3 (r=0.371, p<0.05), and 4 (r=0.338, p<0.05) had a significant correlation with post-test. Meanwhile assignment 3 (r=0.279, p<0.05) and 4 (r=0.275, p<0.05) also had significant correlation with post-test. The significant correlation of both homework and assignment with posttest imply that after the experimental students became familiar with system, they practiced well in laboratory activities particularly, Lab 3 and Lab 4. As a result, the students improved their final posttest score. This finding shows that assignment and homework lab practice are vital to improve students' concept and skill related knowledge. In terms of the learning behaviors like assignment, homework, correct command and incorrect command, there is a significant correlation between assignment and homework score in Lab 1 (r=0.892, p<0.01), Lab 2 (r=0.598, p<0.01), lab 3 (r=0.801, p<0.01), and lab 4 (r=0.395, p<0.05). The significant correlation between assignment and homework scores (Lab1-Lab4) shows that when the experimental students do more in class assignment helped them to improve their homework score. Furthermore, it was also found that a significant correlation correct commands with homework and posttest. In terms of the correlation of homework and posttest with correct command, it was found that correct command count had significant correlation with homework 1 (r=0.551, p<0.01), 2 (r=0.398, p<0.05), 3 (r=0.406, p<0.05), and 4 (r=0.471, p<0.05). Furthermore, correct command in Lab 2 (r=0.472, p<0.05), 3 (r=0.552, p<0.01), and 4 (r=0.598, p<0.01) had significant correlation with posttest. Even though the command count not related learning achievement, but the result reveals that, command count is possibly an indicator affecting students' learning. Furthermore, the significance difference in lab 1, 2, 3, and 4 with homework and lab 2, 3 and 4 with posttest shows that using chatting window helped the experimental students to do their homework and assignments collaboratively in the web-based HVLab. This leads the experimental students' to make commands that are more correct [6]. However, there is no significant correlation incorrect command count with a homework and post-test scores of all Labs (Lab1-Lab4). The reason is, incorrect commands are negatively significant correlated to the assignment, homework and posttest scores. This indicated that, experimental students improve their command writing because of the chatting window helped them to careful and corrects their work easily. Therefore, experimental students minimize their typing error commands.

B. Implications and Suggestions

Based on obtaining finding, this study makes the following implications and recommendations for instructors who plan to teach an advance computer network course using HVLab. First, we recommend that students use HVLab in a web-based environment to enhance their networking practical skill as well as take advantage of using HVLab during and after lectures. Second, HVLab is a collaborative learning environment in which instructors and students can have direct and indirect conversation through a chat feature. Furthermore, instructors can concurrently monitor student in class and help them correct certain configurations by sending messages. Therefore, this collaborative chat feature increases students' attention to perform assignment during laboratory class. Thirdly, the students' behavior during the dynamic routing Labs (group assignments), the students had many discussions with their group members. Thus, instructors should use online discussions to communicate with their class via the chat feature. Particularly for providing guideline commands. Fourthly, the experiment recommends the instructors should prepare lab manual in order to help the students to accomplish their assignments during class period.

Finally, this experiment shows that HVLab can be a low cost laboratory solution compared to the cost of buying high-profile networking equipment directly from the manufactures. Furthermore, our server performance result was satisfactory and enables all students to access the server remotely at the same time. As a result, all students' were accomplished their in-class assignment and homework using HVLab successfully.

TABLE I. T-TEST RESULTS OF IN CLASS ASSIGNMENT AND HOMEWORK SCORES

Assessment	Control Group			Experimental Group			F	t	Sig.(2-tailed)
	N=27			N=27					
	Mean	SD	SE	Mean	SD	SE			
Homework-1	3.935	0.649	0.125	4.056	0.590	0.113	0.048	-0.713	0.479
Homework-2	4.389	0.467	0.090	4.500	0.398	0.077	3.037	-0.941	0.351
Homework-3	4.482	0.510	0.096	4.769	0.438	0.084	2.290	-2.244	0.029*
Homework-4	4.389	0.467	0.090	4.685	0.265	0.051	11.465	-2..868	0.006**
Assignment 1	4.009	0.652	0.126	4.056	0.590	0.113	0.129	-0.274	0.785
Assignment 2	4.444	0.382	0.073	4.452	0.423	0.081	0.502	-0.068	0.946
Assignment 3	4.500	0.470	0.091	4.768	0.438	0.084	0.921	-2.171	0.035*
Assignment 4	4.343	0.450	0.087	4.667	0.259	0.050	12.602	-3.241	0.002**

*P<0.05 **P <0.01

TABLE II. T-TEST RESULTS OF THE CORRECT COMMAND COUNT AND INCORRECT COMMAND COUNT

Assessment	Control Group			Experimental Group			F	T	Sig.(2-tailed)
	N=27			N=27					
	Mean	SD	SE	Mean	SD	SE			
Correct command count of Lab-1	7.148	0.907	0.175	6.741	1.023	0.197	1.377	1.549	0.128
Correct command count of Lab-2	7.222	0.847	0.163	7.519	0.643	0.124	1.811	-1.448	0.154
Correct command count of Lab-3	7.519	1.051	0.202	7.815	0.879	0.169	1.451	-1.124	0.266
Correct command count of Lab-4	7.407	0.800	0.153	8.000	0.877	0.169	0.323	-2.598	0.012**
Incorrect command count of Lab-1	2.370	0.967	0.186	2.111	0.751	0.145	2.906	1.100	0.276
Incorrect command count of Lab-2	1.963	0.808	0.155	1.963	0.649	0.125	0.238	0.000	1.000
Incorrect command count of Lab-3	2.074	0.675	0.130	1.852	0.602	0.116	0.106	1.277	0.207
Incorrect command count of Lab-4	2.407	0.797	0.153	1.852	0.662	0.127	1.086	2.785	0.007**

*P<0.05, **P<0.01

V. CONCLUSIONS AND FUTURE WORK

In this paper, we presented our approach to building a web-based hybrid virtualization Laboratory (HVLab) where students can freely practice on configuration, troubleshooting a network scenario. In our experiment, we used HVLab to determine its effectiveness on learning performance. In addition, we investigate the students' perception and behavioral intentions towards HVLab. To build HVLab, we used virtualization and network emulator tool as a core technology enables the instructor to create a variety of virtual networking topology and enable the student to access virtual network topology and practice real network laboratory using web-based environment. Moreover, HVLab system was server based and enables the instructor to manage students' activities and designing network topologies for the practical laboratory period. Accordingly, the students accepted HVLab for performing their assignments and homework. Furthermore, group assignments with the help of chatting window HVLab feature. This feature helps the students interact with their group members and facilitates to complete the laboratory tasks within a given time in class. In general, this virtualization laboratory can handle large number of students logging at the same time and prove to a best method for virtual networking laboratory. There is one limitation needs to be acknowledged and addressed regarding this study.

The limitation is the consequences of unable the students to create network topology by themselves. For the next experiment should consider to allow students can create their own network topology in advance lab.

REFERENCES

[1] Carniani, E. and R. Davoli. The NetWire emulator: a tool for teaching and understanding networks. in ACM SIGCSE Bulletin. 2001. ACM.

[2] Huang, T.-Y., et al. Teaching computer networking with mininet. in ACM SIGCOMM. 2014.

[3] Pizzonia, M. and M. Rimondini. Netkit: easy emulation of complex networks on inexpensive hardware. in Proceedings of the 4th International Conference on Testbeds and research infrastructures for the development of networks & communities. 2008. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[4] Aravena, M. and A. Ramos, Use of a remote network lab as an aid to support teaching computer. CLEI electronic journal, 2009. 12(1): p. 1-8.

[5] Krichen, J.P. and H. Lahoud. Remote labs in the online environment: indicators for success. in Proceedings of the 9th ACM SIGITE conference on Information technology education. 2008. ACM.

[6] Xu, L., D. Huang, and W.-T. Tsai, Cloud-based virtual laboratory for network security education. IEEE Transactions on Education, 2014. 57(3): p. 145-150.

[7] Dong, Y., et al., HYVI: a hybrid virtualization solution balancing performance and manageability. IEEE Transactions on Parallel and Distributed Systems, 2014. 25(9): p. 2332-2341.

[8] Nakajima, J., et al. Optimizing virtual machines using hybrid virtualization. in Proceedings of the 2011 ACM Symposium on Applied Computing. 2011. ACM.

[9] Lin, Q., et al., Optimizing virtual machines using hybrid virtualization. Journal of Systems and Software, 2012. 85(11): p. 2593-2603.

[10] Gorghiu, L.M., et al., Implementing virtual experiments in Sciences education-challenges and experiences achieved in the frame of VccSSe Comenius 2.1. project. Procedia-Social and Behavioral Sciences, 2010. 2(2): p. 2952-2956.

[11] Hastie, M., et al., A blended synchronous learning model for educational international collaboration. Innovations in Education and Teaching International, 2010. 47(1): p. 9-24.

[12] Moore, J.L., C. Dickson-Deane, and K. Galyen, e-Learning, online learning, and distance learning environments: Are they the same? The Internet and Higher Education, 2011. 14(2): p. 129-135.

[13] Harasim, L., Learning theory and online technologies. 2017: Taylor & Francis.

[14] Xakaza-Kumalo, S. Using the internet communication tools to facilitate learning. in Education and Management Technology (ICEMT), 2010 International Conference on. 2010. IEEE.

[15] Hwang, W.-Y., C. Kongcharoen, and G. Ghinea, To enhance collaborative learning and practice network knowledge with a virtualization laboratory and online synchronous discussion. The International Review of Research in Open and Distributed Learning, 2014. 15(4).