Experience on a course using Packet Tracer and Cisco real devices for practices IP Routing and IP addressing

Daniel Arias Figueroa[2], Loraine Gimson[2], Ernesto Sánchez[1], Álvaro Gamarra[1], Gustavo Gil[2]

[1]Facultad de Ingeniería – Universidad Católica de Salta

[2]C.I.D.I.A. – Centro de Investigación y Desarrollo en Informática Aplicada

Facultad de Ciencias Exactas – Universidad Nacional de Salta

{daaf, loraine, esanchez, alvaroig}@cidia.unsa.edu.ar, gdgil@unsa.edu.ar

Abstract: *The use of simulation software tools has demonstrated to be very useful in computer network teaching and learning processes for so long. Many advantages can be enumerated, but the outstanding one is a significant reduction in network devices acquisition cost such as routers, switches, wiring. Moreover, there is a time reduction on conventional physics laboratories launch (start-up). This article describes a study done in a Networking course context. It was organized by the Engineering Faculty at the Salta Catholic University (UCASal) in Argentina. The main study goal was to compare and contrast learning between students using laboratories with Packet Tracer simulation software tool and those with Cisco real equipment. Parametric tests led to the conclusion that students considerer that simulation simplifies the learning process.*

Resumo: *Desde hace un tiempo ya, el uso de herramientas de software de simulación ha demostrado ser de gran utilidad en los procesos de enseñanza y aprendizaje de redes de computadoras. Son muchas las ventajas que pueden enumerarse, entre las que se destacan, la reducción significativa en costos de adquisición de dispositivos de red tales como routers, switchs, cableado, entre otros. Así mismo, se reducen los tiempos para la puesta en marcha de los laboratorios físicos convencionales. Este trabajo presenta un estudio realizado en el contexto de una asignatura de Redes de Computadoras de la Facultad de Ingeniería de la Universidad Católica de Salta en Argentina. El objetivo fue contrastar el aprendizaje de los estudiantes con laboratorios con la herramienta de simulación Packet Tracer y laboratorios con equipo real Cisco. Las pruebas paramétricas permitieron concluir que los estudiantes consideran que la simulación simplifica el proceso de aprendizaje.*

1. Introduction

Network concepts and fundaments are difficult to assimilate. That is because of the complexity of the involved processes that are not always visible [1], [2], [3] and [4]. Specific equipment required to stand up a network laboratory are very expensive.

Besides, scarce resources are a common reality in most argentine national universities located in provinces. In this context, simulation software tools emerge as a possible solution to make the most of the students' practices by making, also, possible the use of these tools out of classes' schedule (Virtual laboratory).

According to what has been stated before, the difficulties can be summarized as follows:

- The teacher has to adequate work practices to the characteristics of the equipment available. Equipments are generally scarce.
- The number of students is normally high.
- Network devices (routers, switches, wiring, etc) are expensive. Their updating and maintenance involve high costs. That is the reason why there is usually only one or at least two devices per students group. This makes real equipment laboratories unviable.
- Not all topics can be tackled with a real environment practice
- The learning curve to manage devices in real laboratories is high. The same occurs with physical links in order to define a certain topology because there are available different kinds of interfaces such as Ethernet, FastEthernet, Serials and Consol Ports. This makes impossible the access to the network hardware difficult for many groups.

2. Contextual frame

The experience was carried out with all the students that were taking "Networking I" course. This course was part of the telecommunications engineering degree curriculum at the Engineering Faculty at the Salta Catholic University. Students performed simulation practices using Packet Tracer tool. Later, for the same topic, a 3600 series Cisco real equipment practice was carried out IP Routing and IP addressing corresponding to the TCP-IP model network layer. Even though the practice was the same that the one performed with the Packet tracer tool simulator, a guide had to be prepared providing explanation of the specifics commands necessary to go ahead with the practice. While working with the simulator, the entire configuration needed to achieve the requested IP routing was made practically from the general configuration tab. That made students independent from the need to know specific syntaxes related to IOS Cisco. Students were separated in groups and each group made the configuration asked in the statement sheet distributed in the simulation practice laboratory.

The main objective of this studio was to compare and contrast the same practice activity working with real Cisco equipment and with Packet Tracer simulator. A survey divided in three parts was given to the students. The first part inquired about the simulator use and its ease to configure a topology, configure devices, check functionality and track events. The second part presented the same questions but related to a real devices laboratory. The last part examined the possibility of replacing real equipment laboratory with simulators when the objective is teaching network concepts and fundaments. Clearly, computer network teaching in environments such as

universities is different from the specific training that network technicians need because for them it is crucial to work with real equipment from different providers.

3. Simulation Software

A variety of simulation tools are available. They allow easy network systems implementation and analysis. Those simulators offer a range of possibilities to the user; they allow simulations with standard protocols and models but also programming their own protocols and models. Because of that, it is very important to make an assessment of the existing options in order to select the most suitable tool for each particular case.

Packet Tracer was chosen for these experiences because of the following reasons:

- Concepts and fundaments form the application layer, transport layer, network layer and link layer can be analyzed with only one tool.
- Complex simulations are allowed
- It is multiplatform (Linux, Windows y Android) with minimum hardware requirements.
- Simulation models can be visualized and their functionality can be verified in a virtual environment.
- The data packets behavior in the computer network can be observed and analyzed (the same way as with a protocol analyzer).
- A huge user community, a variety of documentation, examples and practices are available.
- It is in continuous development, new functionalities are constantly added
- The development can be seen by data tracker transmion and reception process layer (OSI reference model).
- Relative rapid and intuitive development of the model.
- Scenarios recreation, whose reproduction would be very complex in real equipments labs, is possible.
- Model variables can be manipulated, which promotes the learning by discovery.
- Topics of all the network subjects from the curriculum can be addressed with the same tool.

4. Simulators for training

One of the most important jobs that communications networks designers have is the study of the computer networks performance. This is because bad design decision cans strongly affect the network performance and provoke economics loss for the company.

Communications computer networking simulators are learning active elements in a context of education. They make easier the study and comprehension of theoretical

concepts and fundaments. The difficulty related with practices in real equipments laboratories is the number and variety of equipments, that provides few possibilities to vary the design and many times students have to work with only one existing topology. Furthermore, inherent difficulties of laboratories, such as coordination with other people that share the use, maintenance and amount of people that can contain, are present.

Although a simulator can't substitute the direct work with the equipment, it can provide: easy access, various topologies, equipments and protocols handling, promptness in assembling, working with different scenarios, some scenarios can be mistakenly or incompletely configured to be corrected, and, a key issue, graphic visualization. Though they are not real, the closely imitate the reality. An additional benefit is that home practices are possible for students at any time and at their own rhythm.

One of the key functions of the teacher is to promote a context that encourage the use of the tool, generating questions or problems that students have to answer or solve. A notable effect of the use of these kinds of tools is that the teacher has to adopt a new profile. The teacher assumes a facilitator and counselor role, and understands that the student is the protagonist f the learning process, Garcia & Gil (2006). In this respect, the following teacher's functions in his new role can be mention:

- Resource provider
- Organizer
- Tutor
- Researcher
- Facilitator

Activities development using simulation tools involve diverse abstraction levels that are used in an instructional strategy, in this respect. The development of a study guide that motivates the student to search what happens when parameters change is very important. The challenge in our research was to use the tool to teach concepts and fundaments in systems careers, and not to train technicians in computer networking.

5. Data Statistic Analysis of IP routing experience

The arithmetic average for these data exceeds, in all cases, at least the scale medium value (3,00). That confirms the content validity of all items included in the survey.

The Cronbach's alpha coefficient calculated is 0.863. This value surpasses the 0.7 value therefore questionnaire reliability grade can be confirmed. Consequently, high polarization in reliable answers from students can be appreciated.

Bellow, data statistic analysis for each part of the survey is presented.

5.1. Using Packet Tracer simulation tool.

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Config. topología sencilla	-	-	1x	10,00	-	-	1x	10,00	8x	80,00	4,60	0,97
Config. dispositivos senc...	-	-	1x	10,00	1x	10,00	4x	40,00	4x	40,00	4,10	0,99
Herramienta adecuada p...	-	-	1x	10,00	-	-	5x	50,00	4x	40,00	4,20	0,92
Verif. funcionalidad senc...	-	-	1x	10,00	-	-	2x	20,00	7x	70,00	4,50	0,97
Seguimiento de eventos...	-	-	1x	10,00	-	-	3x	30,00	6x	60,00	4,40	0,97

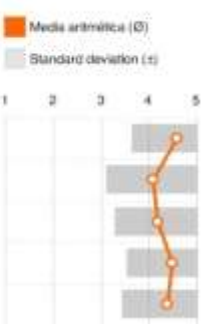

Figure 1: Analysis working with Packet Tracer simulation tool

Here, 90% of the students considered that topology configuration was simple with simulators, 80% considered that devices configuration was simple, and, 90% considered that functionality verification and events tracking were simple with the simulator.

5.2. Working with Cisco real equipment.

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Config. topología simple	1x	10,00	6x	60,00	1x	10,00	1x	10,00	1x	10,00	2,50	1,18
Config. dispositivos simp...	6x	60,00	1x	10,00	1x	10,00	-	-	2x	20,00	2,10	1,66
Lab. adecuado para fund...	-	-	6x	60,00	1x	10,00	1x	10,00	2x	20,00	2,90	1,29
Verif. funcionalidad simp...	4x	40,00	3x	30,00	-	-	1x	10,00	2x	20,00	2,40	1,65
Seguimiento de eventos...	5x	50,00	1x	10,00	1x	10,00	3x	30,00	-	-	2,20	1,40

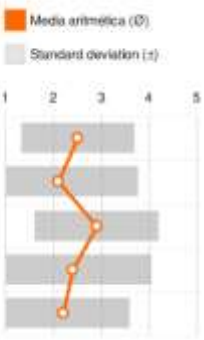

Figure 2: Analysis working with Cisco real equipment

In this situation, 20% of the students considered that topology configuration was simple using real equipment. 20% considered that devices configuration were simple. 30% considered that functionality verification and events tracking were.

5.3. When the objective is teaching network concepts and fundaments, Do you consider that simulation can replace the real equipment practice?

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Simulación reemplaza eq...	-	-	-	-	2x	20,00	6x	60,00	2x	20,00	4,00	0,67

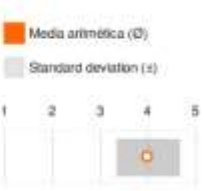

Figure 3: Simulation vs. Real equipment analysis

80% of the students considered that simulation can replace real equipment laboratory when the main goal is teaching fundamentals.

5.4. Students comments and suggestions

Bellow, there are the opinions made by students related to the experience they had while working with simulation.

- *The inconvenient that I can see in real equipment laboratories is the lack of equipments and some of them do not work properly. That is why connectivity takes too long. Other than that, it is a good experience, because it is similar to reality.*
- *Real equipment laboratory allows direct contact with equipments and their configuration. It would be desirable to have more real equipment laboratories.*
- *Using simulators lots of details can be appreciated that in real equipment laboratories wouldn't be easy.*
- *It was a good experience. Personally I think it is necessary, considering that Networking 1 and Networking 2 are the only subjects in our career where we can see that kind of equipment. It is a good workshop because it allows us to be able to defend ourselves if tomorrow we have to work with them*
- *What we made with the simulator could be checked in real equipment laboratory. It was almost the same but with real equipments. Also real equipments laboratory gives a better experience.*

6. Data Statistic Analysis of IP addressing experience

The arithmetic average for these data exceeds, in all cases, the scale medium value (3,00). That confirms the content validity of all items included in the survey.

The Cronbach's alpha coefficient calculated is 0.68. This value does not surpass the 0.7 value however questionnaire reliability grade can yet be confirmed. Consequently, a minor polarization in reliable answers from students can be appreciated.

Bellow, data statistic analysis for each part of the survey is presented

6.1. Using Packet Tracer simulation tool.

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Config. topología sencilla	-	-	1x	9,09	-	-	7x	63,64	3x	27,27	4,09	0,83
Config. dispositivos senc...	-	-	1x	9,09	1x	9,09	6x	54,55	3x	27,27	4,00	0,89
Herramienta adecuada p...	-	-	-	-	3x	27,27	4x	36,36	4x	36,36	4,09	0,83
Verif. funcionalidad senc...	-	-	-	-	3x	27,27	5x	45,45	3x	27,27	4,00	0,77
Seguimiento de eventos...	-	-	-	-	3x	27,27	4x	36,36	4x	36,36	4,09	0,83

Figure 4: Analysis working with Packet Tracer simulation tool

As shown in Figure 4, 90,91% of the students considered that topology configuration was simple with simulators, 81,82% considered that devices configuration was simple, 72.72% considered that functionality verification and events tracking were simple with the simulator and also 72,72% considered that the tool was appropriate to teach computer networking fundaments.

6.2. Working with Cisco real equipment.

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Config. topología simple	2x	18,18	2x	18,18	3x	27,27	2x	18,18	2x	18,18	3,00	1,41
Config. dispositivos simp...	1x	9,09	3x	27,27	2x	18,18	5x	45,45	-	-	3,00	1,10
Lab. adecuado para fund...	-	-	4x	36,36	2x	18,18	-	-	5x	45,45	3,55	1,44
Verif. funcionalidad simp...	-	-	4x	36,36	2x	18,18	4x	36,36	1x	9,09	3,18	1,08
Seguimiento de eventos...	3x	27,27	2x	18,18	3x	27,27	2x	18,18	1x	9,09	2,64	1,36

Figure 5: Analysis working with Cisco real equipment

In this situation, 36.36% of the students considered that topology configuration was simple using real equipment. 45.45% considered that devices configuration were simple. 45.45% considered that functionality verification was simple and 36.36% considered that events' tracking was simple. 45.45% considered that real equipment laboratories are appropriate to learn computer networking fundaments.

6.3. When the objective is teaching network concepts and fundaments, Do you consider that simulation can replace the real equipment practice?

	Prácticamente Nada (1)		Poco (2)		Lo Suficiente (3)		En Buen Medida (4)		En Gran Medida (5)			
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Ø	±
Simulación reemplaza eq...	-	-	2x	18,18	4x	36,36	4x	36,36	1x	9,09	3,36	0,92

Figure 6: Simulation vs. Real equipment analysis

45.45% of the students considered that simulation can replace real equipment laboratory when the main goal is teaching fundamentals. 36.36% of the students didn't have a defined answer and opted for a neutral value.

6.4. Students comments and suggestions

Bellow, there are the opinions made by students related to the experience they had while working with simulation.

- *It would be convenient to implement various real equipments labs, because that would help to supplement understanding of the concepts*

- *Real equipment provides an experience nearer to the commands necessary to configure routers, because there is no friendly interface available to do it as it is available in simulator tools.*
- *The detection of causes of errors in real equipment labs is not as easy as when using simulator tools*
- *Real equipment laboratory allowed us to physically see some equipments that we weren't able to physically know before and also to be able to do some configurations on those equipments. This work didn't turn to be complex for me because those practices were performed before on a Packet Tracer simulator, that is perceived in a similar way. It was a very good experience and very fruitful one.*
- *Several details can be observed in a simulator tool, those details are hard to see in a real equipment lab. Until you experience with real equipment, you can't fix the exact knowledge. People do not work with simulators, real equipment labs are really necessary because they bring to light doubts that simulators don't, they let you solve problems that are not contemplated in simulators such as software incompatibility, accesses, permissions, etc.*

7. Conclusions

Considering that the addressee of this course were network engineers and technicians that perform network configurations, it could evince in the analysis made, that students understood that simulation simplified the topology and devices configuration process, as well as the functional verification and event tracking. Also, they have considered that practices with simulation can replace practices with real equipment when the objective is to learn network concepts and fundamentals. It should be pointed out that the results obtained in this research study present similarities with others studies made by the same research group on network subjects at the Salta National University.

It is worth noting that results obtained in this work present similarity to other studies performed by the same research group in a Mickrotik Certification course in 2018[14]. That course was organized by CIDIA a research and development center that belongs to the Salta National University.

Additionally, this study presents similarity with others made by teachers of network subjects from different universities of Argentina in 2016 [13]. In that work, teachers considered that the topology and devices configuration learning curve is short working simulation software; but it is long when working with real equipment. Most of them considered that it is possible to replace real equipment practice with simulation practice when the objective is teaching network fundamentals.

8. Future work

As future researches, studies related about the impact of software simulation in other network scopes are suggested. Also, it is important to value the influence of this tool in other educational levels. Other quantitative and qualitative researches that lead to know

with grater profoundness the conceptualization level gained by students because of the simulation software use and also that lead to a wider vision of the theme, are recommended.

Regarding the study weakness, it should be kept the small sample size in mind, so research conclusions can not be extrapolated to other contexts.

9. References

[1] SAKAR, N. I. (2006) Teaching TCP/IP Networking Using Practical Laboratory Exercises, *International Journal of Information and Communication Technology Education*, Vol. 2, No. 4, pp. 39-50.

[2] GOLDSTEIN, G., M LEISTEN, S, STARK, K.,& TICKLE, A. (2005) Using a Network Simulation Tool to Engage Students in Active Learning Enhances Their Understanding of Complex Data Communications Concepts, Proceedings of the *7th Australasian conference on Computing Education*, pp. 223-228.

[3] JAVIDI, G. & SHEYBANI, E. (2008) Content-Based Computer Simulation of a Networking Course: An Assessment, *Journal of Computers*, Vol. 3, No. 3, pp. 64-72.

[4] DIXON, M. W., MCGILL, T. J. & KARISOON, J. M (1997) Using a Network Simulation Package to Teach the Client-server Model. *Proceedings of the 2nd Conference on Integrating Technology into Computer Science Education*, pp. 71-73.

[5] ARIAS FIGUEROA, D. (2015) "Redes de Computadoras I con Packet Tracer", *Editorial de la Universidad Nacional de Salta – Argentina, EUNSa.* ISBN 978-987-633-132-6-1; 1a ed. Salta - E-Book - CDD 004.68.

[6] CAMERON, B. (2003): Effectiveness of simulation in a hybrid online networking course. *Quarterly Review of Distance Education*, 4(1), 51.

[7] GATTO, D. (1993): The use of interactive computer simulations in training. *Australian Journal of Educational Technology*, 9(2), 144-156.

[8] YAVERBAUM, G., & NADARAJAN, U. (1996): Learning basic concepts of telecommunications: an experiment in multimedia and learning. *Computers & Education*, 26(4), 215-224.

[9] ZHU, S. Y. (2011).Teaching Computer Networks through Network Simulation Programs. Faculty of Business, Computing and Law – School of Computing. University of Derby. *Learning Teaching & Assessment Conference*.

[10] ARIAS FIGUEROA, D., GIL, G., GIMSON, L. (2016). "Estudio de la influencia del uso del simulador KIVA-NS en la enseñanza de redes IP". *Décima Quinta Conferencia Iberoamericana en Sistemas, Cibernética e Informática (CISCI 2016) Orlando, Florida, EE.UU*.

[11] KUROSE, J.F. & ROSS, K.W. (2015). Computer Networking: A Top-Down Approach. 6th Edition. Pearson Education. ISBN: 9780132856201.

[12] AVILA BLAS, Orlando José (2003). Probabilidad y estadística inferencial: teoría y aplicaciones. ISBN: 978-987-9381-23-6. *Editorial: Universidad Nacional de Salta.*

[13] ARIAS FIGUEROA, D., RODRIGUEZ, NELSON Y OTROS (2016). "Simulación en la enseñanza de redes de computadoras: visión de docentes". *CoNaIISi 2016. Universidad Católica de Salta. 17 y 18 de Noviembre de 2016.*

[14] ARIAS FIGUEROA, D., GIMSON, L., SANCHEZ, E. Y OTROS (2018). "Experience on a Mikrotik certification course using GNS3 and real devices for practices". Journal of Modern Education Review (ISSN 2155-7993), USA. Academic Star Publishing Company.

[15] ARIAS FIGUEROA, D., SANCHEZ, E. (2018) "Redes de Computadoras II con Packet Tracer", Editorial de la Universidad Nacional de Salta – Argentina, EUNSa. ISBN 978-987-633-527-0; 1a ed. Salta - E-Book - CDD 004.678.

[16] ARIAS FIGUEROA, D., GIMSON, L., SANCHEZ, E. Y OTROS (2019). "Research project final results: simulation software influence study in networking teaching at University Level". 1er. Encuentro de la Red Internacional de Investigación ERII, en el Marco de la X Jornada de Investigación Institucional, los días 11 al 13 del mes de septiembre del año 2019. Universidad Católica de Colombia. Bogotá D.C., 30 del mes de septiembre del año 2019. Registro No. IEIRII-PON-2019090022.

[17] ARIAS FIGUEROA, D., GIMSON, L., SANCHEZ, E. Y OTROS (2019). "Simulación en asignaturas de redes de computadoras en el nivel universitario". REABTIC Vol.1.N.11 (2019). ISSN: 2446-7634 – Revista Eletrônica Argentina-Brasil de Tecnologias da Informacão e da Comunicacão.