Assessment of the Results from Conducted Experimental Training in Computer Networks and Communications in the Laboratory Exercises

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Abstract – **This article describes a conducted educational research, related to the use of virtual models and appropriate software in order to acquire practical knowledge and skills in laboratory work in the subject "Computer Networks and Communications" (CNC) at the FMI at PU "Paisii Hilendarski".**

Keywords – **Computer Networks, Communications, simulation, GNS3, Education, LAN, VLAN.**

1. Introduction

This study is part of a larger project to create a new methodological set of tools for teaching this discipline. The initial steps aimed to develop dynamic models to illustrate the theoretical content [14].

It is commonly believed that visualization in its varieties (pictures, three-dimensional models, schematic diagrams, geometrical illustrations, computer-generated displays, simulations, animations, videos and so on [18]) is useful for training in various degrees and taught disciplines. It occupies an important place in teaching and learning, as visualization of models from theoretical computer science [5], building finite automata from regular expressions [1], visualization of simulation results from the development of the modelled biological structures [10], using virtual models in teaching chemistry [6], physics [3] and others.

The analysis in [18] of a significant number of scientific publications relating to the use of visualization in various forms, notes a varying influence in the learning process. Animations and other computer visualizations (with recommendations to them) qualify as a useful material for engaging the attention of students and for increasing their motivation to learn.

During the 2010/2011 and 2011/2012 academic years, with students from the Faculty of Mathematics and Informatics at PU "Paisii Hilendarski", doing the CNC course, a pedagogical research was held. It was consistent with the methodology described in [2], stated problems in the methodology of teaching computer sciences and information technologies in [7] and basic rules for creating tests from [17], proving the working hypothesis that visualization of the theoretical content in CNC through provisional visual and dynamic models, enhances the quality of learning and helps the process of formation of students' knowledge and skills [11].

The present study aims to define the role of virtual topologies and appropriate software to improve the practical level of training in the discipline, in the absence of specific hardware. Its purpose is to prove the working hypothesis that the use of simulation software [13] with the included appropriate virtual topologies (simple network topologies [15], VLAN topologies [16] and other exemplary topologies, published in [12]) during practice in laboratory exercises in CNC enhances the quality of education and improves the process of learning a specific content.

2. Toolkit

On a practical level, the focus is on the physical parameters for establishing networks of the type IEEE 802.3 and IEEE 802.11, network commands for diagnostics, learning the basic options for administration, included in the firmware of the widespread regional routing devices and others. The

expected results are associated with the acquisition of permanent knowledge and skills for building and managing small local home and office networks. The toolkit used is:

- GNS3 simulation environment, which provides the ability to design, configure and test virtual topologies. The use of a similar simulation training software is discussed in [4] about Virtual Network System (VNS), [8] about Velnet, [9] about GINI and others;
- An appropriately selected graphic editor to make a drawing for determining the length of the cable system at a specific placement of the devices;
- Methodological developments of tasks, including the implementation of virtual topologies;
- A project for building a local area network (LAN), including: an overview of the used components; virtual presentation by GNS3; a drawing for determining the length of the cable system at the selected location of the devices and valuation (price) of the project;
- Emulators of widespread regional routing low-class devices.

3. Learning objectives

The methodological developments of tasks [12] aim at achieving the following learning objectives:

1. Use of a central device L2 switch;
2. Configure subnets, gateways and IP addresses to appoint;
3. Use and administration of the router;
4. Use of a VLAN to separate a given network into logically independent segments;
5. Use of static routing and IGP routing protocols RIP, OSPF;
6. Knowledge and use of specific network commands and their configuration parameters;
7. Knowing and configuring basic options, related to the organization and communication, from the menu for administration of widespread regional routing devices.

4. Criteria and indicators for assessing the results

To assess the results of the final experiment, five main criteria are used:

1. Criterion 1 - Skills for the realization of virtual topology of the star type with a central unit L2 switch;
   1.1. Selection of a suitable device with the required number of physical ports;
   1.2. Connecting the end devices to the switch;
   1.3. Expanding the realized topology with an additional switch (extended star);

2. Criterion 2 – Configuring subnets, gateways and IP addresses for appointing;
   2.1. Determining the IP address of the subnet;
   2.2. Determining IP addresses for appointing;
   2.3. Static assignment of IP addresses to end devices;

3. Criterion 3 – Use and administration of a Cisco router;
   3.1. Selecting a device and modules to it;
   3.2. Knowing the operating modes of the selected device;
   3.3. Access to the device and use of its interfaces:
      3.3.1. Showing statistics for all/specified interface;
      3.3.2. Setting up the interface in up/down state;
      3.3.3. Assigning the IP address of the interface;
   3.4. Defining the name of a segment of consecutive IP addresses for distribution by the DHCP server;
      3.4.1. Setting the address of the network for the defined pool;
      3.4.2. Setting the default router;
      3.4.3. Setting the DNS server;
      3.4.4. Setting the leasing time for an address for the DHCP clients;
      3.4.5. Setting the domain name for the DHCP clients;
   3.5. Setting the range of IP addresses that cannot be distributed by the DHCP server;
   3.6. Include servicing of the zero subnet;
   3.7. Recording the changes in the memory;
   3.8. Save the current configuration as starting;

4. Criterion 4 – Use of VLAN to separate a given network into logically independent segments;
   4.1. Providing access to the database of VLANs;
   4.2. Creating a VLAN number vlan-id and a name vlan-name;
   4.3. Specifying the operating mode of a port;

5. Criterion 5 – Use of routing;
   5.1. Include the routing function of the router between the interfaces;
   5.2. Use of static routing;
   5.3. Use of RIP;
   5.4. Use of OSPF;

6. Criterion 6 – Using network commands to diagnose a network (e.g. for Windows);
   6.1. Programs for testing physical connectivity – ping, pathping;
   6.2. Programs for tracing the route – tracert;
   6.3. Programs for visualizing the configuration parameters of network adapters – ipconfig;
   6.4. Other TCP / IP utility programs:
      6.4.1. netstat and nbtstat – for visualizing TCP/IP and NetBIOS statistical information;
      6.4.2. arp - for visualization and management of the cache Protocol Address Resolution Protocol (ARP);
      6.4.3. route - for a review and correction of the elements entered into the routing tables.

      The included commands may be replaced with their equivalents from another operating system

7. Criterion 7 – Description of the main options related to the organization and communication, from the menu for administration of a low-class router. Options for examination (including their sub-options):
   7.1. Network – settings for local and global network;
   7.2. Wireless – configuring the wireless network;
   7.3. DHCP – settings and a way to configure the DHCP server;
   7.4. Forwarding – port forwarding;
   7.5. A concrete proposal for solving a problem.

5. Analysis of the results of the final experiment

The study involved a sample of 289 students from various computer specialties. An ascertaining experiment was conducted, whose results allow the conclusion that the training starts at equal opportunities of the participating students.

The final experiment was conducted after a three-month training course. To prove the main hypothesis, two separate groups are formed - a control group and an experimental group. The distribution of the sample into groups is as follows (Table 1.):

- control – the training in laboratory exercises in CNC is conducted without the use of simulation software and specialized hardware equipment. The traditional teaching method is used with explanatory diagrams and drawings;

- experimental – simulation software is included in the training, with the appropriate virtual topologies.

Table 1. Distribution of the sample in groups

Type of group	Number of students	Percentage (%)
Control group	48	16.61%
Experimental group	241	83.39%
Total	289	100%

The students are given three tasks to perform (Table 2.), covering the above criteria and indicators.

Table 2. Distribution of criteria to tasks

Task	Citerion number	MAX points
Task 1	1-5	29
Task 2	6	16
Task 3	7	12

6. Processing the results of the final experiment

Results of task 1

The frequency distribution of the score results of the two groups is presented in Table 3.

Table 3. Frequency distribution of the points in groups for task 1

points	3	6	9	10	21	24
Control group	3	2	12	2	5	10

27	29	Number	Mean	Successful
4	10	48	18.58	60%

points	3	6	9	10	14	21	24
Experimental group	5	10	7	9	12	15	81

25	28	29	Number	Mean	Successful
7	10	85	241	23.13	82%

The table shows that the difference in the average score is 4.55, and the difference in the percentage of successful students is 22% (the criterion for a successfully solved task 1 is min. 15 points out of 29) in favour of the experimental group. It remains to verify whether this difference is a result of the improved methodological tools or if it is random.
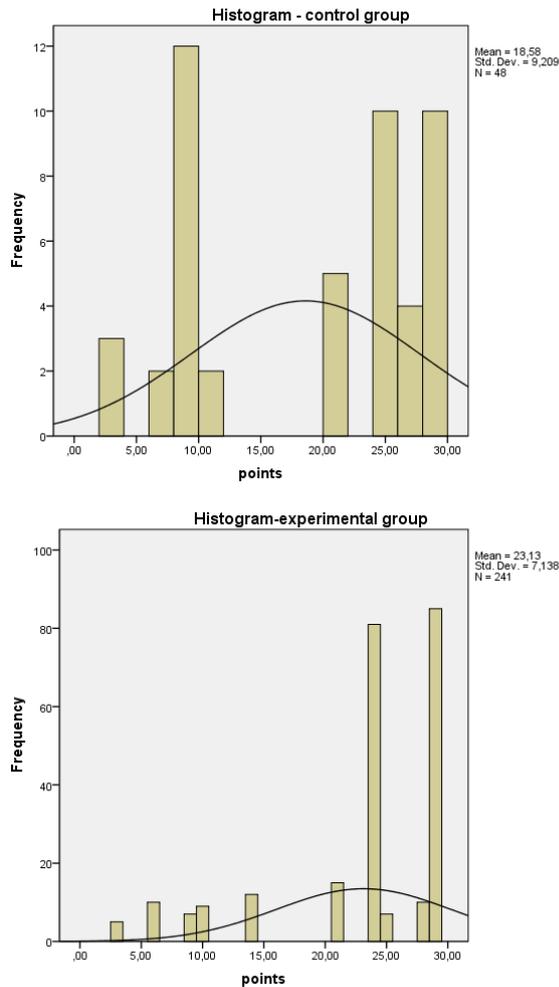
Figure 1. Histograms of a control and an experimental group for task 1

This requires verification of normal distribution of empirical data of the two formed groups that will allow the choice of a method of comparison. When processing the results with the program SPSS, we established the following:

- The Shapiro-Wilk test (Table 4.) applied to the control group and designed for small samples, returns a value for Sig. (Degree of significance) below 0.05 (0.000), which is sufficient to reject the null hypothesis (for a normally distributed sample -the null hypothesis is that the data is normally distributed) in favour of the alternative hypothesis (the alternative hypothesis is that the data is not normally distributed) for the abnormal distribution of the test results.

Table 4. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Control group	,222	48	,000	,835	48	,000

a. Lilliefors Significance Correction

- The tests of Kolmogorov-Smirnov and Shapiro-Wilk (Table 5.) applied to the experimental group, returning a value .000 for Sig., which is sufficient to conclude about the abnormal distribution of the test results.

Table 5. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Exp. group	,308	241	,000	,757	241	,000

a. Lilliefors Significance Correction

From the conclusions for both groups, it becomes necessary to use a non-parametric method to compare the results of the two independent sets. For this purpose, the comparative analysis was made with a U-test of Mann-Whitney (Mann-Whitney Test), which returns a result ,001 for Asymp.Sig. (2-tailed) (Table 6.).

Table 6. Mann-Whitney test

Ranks

	Groups	N	Mean Rank	Sum of Ranks
points	control	48	110,10	5285,00
	Exp.	241	151,95	36620,00
	Total	289		

Test Statistics[a]

	points
Mann-Whitney U	4109,000
Wilcoxon W	5285,000
Z	-3,281
Asymp. Sig. (2-tailed)	,001

a. Grouping Variable: Groups

Based on this result, (significance level <0.05) it can be concluded that the difference between the two measurements is not due to chance but is the result of

our actions. In other words, the confirmation of our hypothesis has no random character.

Results of task 2

The frequency distribution of the score results of the two groups is presented in Table 7.

Table 7. Frequency distribution of the points in groups for task 2

points		9	10	12	14	15
Control group		3	7	13	7	5

16	Number	Mean	Successful
13	**48**	**13.21**	**90%**

points	6	7	8	9	10	12	13
Exp. group	3	4	9	13	15	79	7

14	15	16	Number	Mean	Successful
24	29	58	**241**	**12.96**	**88%**

The difference in the average score is 0.25, and in the percentage of the successful students is 2% (the criterion for a successfully solved task 2 is min. 10 points out of 16) in favour of the control group.
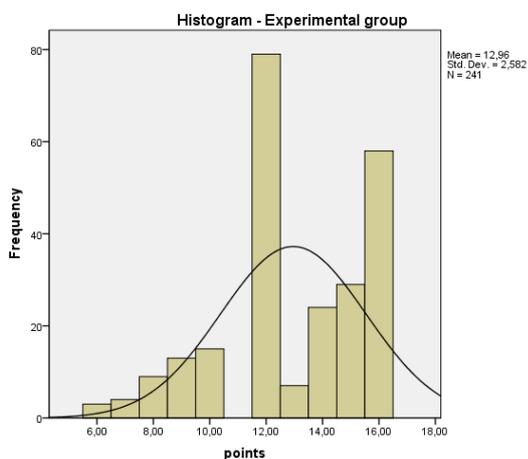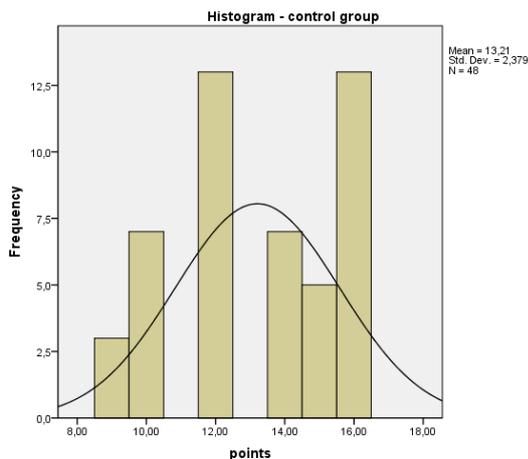

Figure 2. Histograms of a control and an experimental group for task 2

The results of the verification of normal distribution of the empirical data (Table 8. and Table 9.) of the two formed groups prove their abnormal distribution.

Table 8. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Control group	,173	48	,001	,878	48	,000

a. Lilliefors Significance Correction

Table 9. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Exp. group	,173	241	,000	,896	241	,000

a. Lilliefors Significance Correction

After the application of the U-Mann Whitney test (table 10.), the obtained value of Asymp.Sig. (2-tailed) is ,674. Based on this result, it can be concluded that there was no significant difference in the results of the two groups on task 2.

Table 10. Mann-Whitney test

Ranks

	Groups	N	Mean Rank	Sum of Ranks
points	control	48	149,52	7177,00
	Exp.	241	144,10	34728,00
	Total	289		

Test Statistics[a]

	points
Mann-Whitney U	5567,000
Wilcoxon W	34728,000
Z	-,421
Asymp. Sig. (2-tailed)	,674

a. Grouping Variable: Groups

Results of task 3

The frequency distribution of the score results of the two groups is presented in Table 11.

Table 11. Frequency distribution of the points in groups for task 3

points	6	8	9	10	12
Control group	2	11	14	12	9

Number	Mean	Successful
48	9.46	73%

points	0	6	8	9	10
Experimental group	3	3	28	51	65

12	Number	Mean	Successful
91	241	10.14	86%

The difference in the average score is 0.68, and in the percentage of the successful students is 13% (the criterion for a successfully solved task 3 is min. 9 points out of 12) in favour of the experimental group.
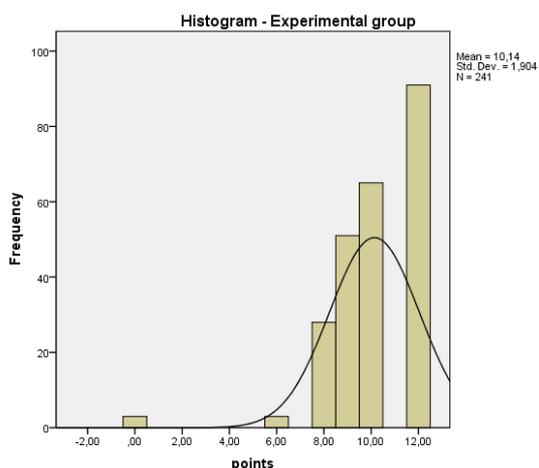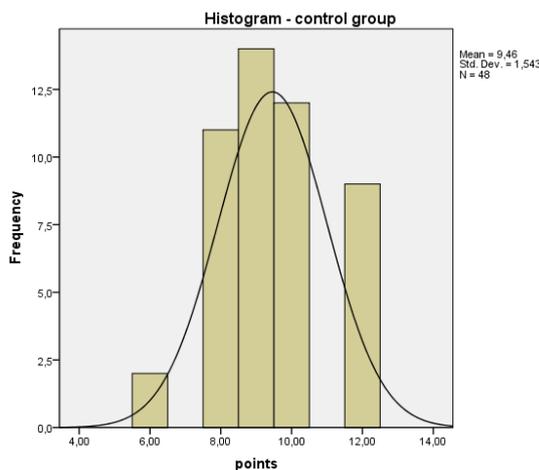

Figure 3. Histograms of a control and an experimental group for task 3

Verification of the type of distribution of empirical data (Table 12. and Table 13.) for the two formed groups proves their abnormal distribution.

Table 12. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Control group	,179	48	,001	,895	48	,000

a. Lilliefors Significance Correction

Table 13. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Exp. group	,214	241	,000	,769	241	,000

a. Lilliefors Significance Correction

After the implementation of the U-test of Mann Whitney, the obtained value of Asymp.Sig. (2-tailed) is ,002. Based on this result, it can be concluded that there is a significant difference in the results of the two groups regarding task 3.

Table 14. Mann-Whitney test

Ranks

	Groups	N	Mean Rank	Sum of Ranks
Points	control	48	112,66	5407,50
	Exp.	241	151,44	36497,50
	Total	289		

Test Statistics[a]

	points
Mann-Whitney U	4231,500
Wilcoxon W	5407,500
Z	-3,052
Asymp. Sig. (2-tailed)	,002

a. Grouping Variable: Groups

7. Conclusions and assessments

1. An educational study was conducted on 289 students, divided into two groups (control and experimental);
2. The obtained results were assessed by the SPSS software of IBM, for analysis of test results using the U-test of Mann Whitney for two independent samples to reject the assumption of a random nature of the outcome;
3. On the basis of the above measures and the obtained results, the following conclusions can be made:
   3.1. The results of task 1 and task 3 show the difference between the two groups, which is

not the result of a chance but is the result of the inclusion of simulation software with appropriate virtual topologies in training laboratory exercises in CNC;

3.2. The results of task 2 are not affected by the above action, because it does not require a specialized simulation tool for studying the included network commands;

3.3. The analysis confirms the working hypothesis that the use of simulation software with included appropriate virtual topologies in training laboratory exercises in CNC enhances the quality of education and improves the process of learning a specific content.

8. Conclusion

The objective information, obtained from processing the results of the pedagogical research, is just one example which confirms the assumption that the use of innovative approaches in education has a beneficial impact on the quality of education and helps to improve the comprehension of certain learning content.

Acknowledgements

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