Journal of Theoretical and Applied Information Technology
28th February 2022. Vol.100. No 4
2022 Little Lion Scientific
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

THE EFFECTIVENESS OF TRAINING FUTURE COMPUTER SCIENCE TEACHERS IN COMPUTER NETWORKS BASED ON NETWORK MODELLING

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The study covers and substantiates the effectiveness of training future computer science teachers in computer networks based on network modelling. The analysis of academic and methodological literature has shown that in the training of computer science teachers, computer networks are studied in the aspect of information modelling of their structures, while modelling the processes of their functioning is not given due attention, despite the possibility of its use in the organisation of training. The purpose of the study was to provide practical confirmation of the effectiveness of training future computer science teachers in computer networks based on network modelling. Training in computer networks based on network modelling can play a significant role in improving the effectiveness of training students in the specialisation "Computer Science". A pedagogical study was conducted based on the formation of control (40 people) and experimental (39 people) groups from among third-year students. In the experimental group, training in the discipline "Computer Networks and Web technologies" was carried out using the same means of informatisation, selected taking into account the specifics of methodological training systems. Comparative diagnostics of the students' knowledge level was carried out using methods of mathematical statistics and specially developed test tasks. The study established that the development and implementation of the proposed teaching methodology provides an opportunity for full and high-quality training of future computer science teachers in the field of computer networks, allowing them to solve professional problems in the design, maintenance, configuration, and administration of computer networks, and contributes to the development of specialised competences in this field. The effectiveness of training future computer science teachers in computer networks based on network modelling has been experimentally confirmed.

Keywords: *Software environment, Computer science teacher, Network technologies, Teaching methods, Informatisation*.

1. INTRODUCTION

The informatisation of society is inextricably linked with the development and spread of corporate and global computer networks, which allow for the rapid and efficient exchange of various information using modern digital devices. Any computer network is a set of hardware (personal computers, digital devices, servers, communication equipment, etc.) and software components that ensure the creation, storage, transmission, and exchange of information between users. The development of computer networks leads to an increase in the volume and complexity of work related to their design, implementation, configuration, and exploitation. This, in turn, makes it necessary to carry out purposeful professionally-oriented training of qualified specialists, including future teachers of

computer science, who are able to successfully solve the problems of professional activity in the process of teaching computer science at the university [1].

Let us consider the issues of teaching computer networks in a school computer science course from the point of view of training future computer science teachers. The updated content of basic secondary education sets students the following learning goals in the field of computer networks [2]: the ability to place, modify, download shared files; explain the advantages of wireless communication; classify computer networks; determine network capacity; carry out collaborative work with documents using cloud technologies, etc. [3]. The updated content of the level of general secondary education of the mathematical and natural field includes the section "Computer networks and information security", which contains subsections: organisation of computer networks, security measures when working in the network. In the first section, the following topics are offered for study: network components (hosts, routers, switches), IP addresses, DNS (Domain Name System), private virtual networks. The second section deals with the issues of information security, confidentiality, integrity, and availability of data.

The expected results at the end of the general secondary education in the subjects of the advanced level of mathematical and natural field suggest that in the field of computer network technologies, the student: knows the network protocols and principles of the Internet; security measures designed to ensure the security of data and computer systems; understands the basic principles of computer networks; the advantages and disadvantages of the client-server model; applies software tools for modelling computer networks and cloud technologies when editing and storing documents; knows and understands the rules of personal security in the network and network etiquette.

2. LITERATURE REVIEW

Previous studies discussed methods that used emulations and simulation approaches, given current conditions authors have chosen to simulate the network equipment of computer networks. For a better understanding of the methods associated with structuring an effective methodology of the educational process, the works of both foreign and domestic researchers, such as V. Olifer and N. Olifer [4], S.K. Damekova [5], P.V. Nikitin, A.I. Melnikova, R.I. Gorokhova [6], A.V. Mogilev, N.I. Pak, E.K Hönner [7], A. Sergeev [8] and others are being considered. They devoted to the issues of teaching computer networks to IT specialists, including computer science teachers. The work of V. Olifer and N. Olifer covers the principles of building computer networks, the features of conventional and prospective technologies of local and global networks, as well as ways to create large composite networks and manage such networks [4]. S.K. Damekova considers the improvement of the methodology for teaching future computer science teachers with the basics of telecommunications networks using an educational site, approaches to the use of electronic publications in teaching courses related to telecommunications networks, defines the purposes and content of the course "Fundamentals of Telecommunications Networks", focused on the use of an educational site [5].

A. Sergeev in his textbook "Basics of local computer networks" examines the theoretical foundations and technologies for local computer networks and their construction [8]. The questions are enunciated: 1) basic concepts, models, and methods of building computer networks; 2) organisation of the TCP/IP protocol stack (IPv4 and IPv6); 3) creation of public access servers and services for IP networks (DNS, email, web, etc.). Special attention is paid to the organisation of local networks on Windows (working group and domain), the physical construction of cable and wireless local networks.

Most educational institutions face organisational, technical, and material difficulties in organising training in computer networks on real equipment, related to the following:

– firstly, to configure and administer the operating systems of computers that are part of a computer network, the authority of a system administrator is required, which is not provided to students based on the need to ensure the security a computer network functioning of the whole educational institution;

– secondly, experimenting with real communication equipment can lead to failures or temporary termination of its functioning, breakage, which can be financially costly due to its relatively high cost [9].

The analysis of academic and methodological literature has shown that educational institutions cannot fully provide the practical orientation of training in the field of computer networks, due to various difficulties while using real equipment and insufficient hardware resources of computers when using virtual machines [10; 11]. There can be several

of them, with different operating systems. The use of virtual machines provides simulation of the hardware components of the model; installation and operation of various software; connection to the local network and the Internet in the conditions of information security, their network interaction, etc. [12]. The issues of using virtual machines in teaching computer networks in universities were investigated by O.I. Lyash [13], O.Yu. Lyaginova [14], O.A. Shestopalova [15] and others. O.I. Lyash [13] considered methods of teaching network technologies to future computer science teachers through the use of virtual machines and environments in the logic of the competency-based approach. O.Yu. Lyaginova [14] in her research considered theoretical aspects and methodological approaches to training computer science teachers in the field of modelling the structure and functioning of computer hardware and software based on specialised software environments. O.A. Shestopalova [15] considered methodological approaches to teaching network technologies to high school students in a specialised computer science course, focused on the study of the design, construction, and use of hardware and software based on the simulation of their functioning. But the use of virtual machines in training computer networks has its drawbacks: the need to have sufficient hardware resources for the operation of several systems at the same time. According to O. A. Shestopalova [15] and other researchers studying the direction chosen by the authors – imitating the functioning of information networks and effective learning, provides a conscious choice of an individual learning path that corresponds to inclination, individual characteristics and interests.

3. MATHERIALS AND METHODS

The developed by the authors methodology is based on the conditions provided by educational institution at the moment, that is, on limited capabilities, which in turn can be used as a benefit, given that in realistic conditions, full access to certain equipment or software may not be possible. Using the observation and analysis, it is possible to teach students on practical examples in conditions close to those with which they may face in the future. So, for more effective results and development of teaching process, at the control stage, the results of the experimental methods of teaching computer networks based on network modelling were summarised and worked out.

The network model is created based on a certain structure and topology of a computer network as a fixed ordered set of components that make it up, and the relationships between them [16; 17]. So, network modelling implies the reproduction of a dynamic image of the main components of the network (network cables, switches, hubs, routers, etc.) and the visualisation of the processes of their configuration and operation on the computer screen.

There are two main approaches to modelling computer networks: emulation and simulation. Emulation is a set of software, hardware, or a combination of them, designed to copy the functions of one computer system to another, different from the first so that the emulated behaviour corresponds to the behaviour of the original system. Simulation, on the other hand, does not aim to accurately match the behaviour of one system to the behaviour of another, but focuses on recreating or reproducing any of its key features or parameters [18; 19]

Based on this, it was concluded that when teaching future computer science teachers in computer networks, it is necessary to use network modelling with the help of software environments that simulate the structure and functioning of computer networks (Figure 1). To solve these problems and achieve the corresponding purposes, the described study attempts to improve the methodological systems of teaching and conducting training sessions with students of a pedagogical university in the discipline “Computer Networks and web technologies” based on network modelling and subsequent measurement of the degree of influence of such a pedagogical approach on the effectiveness of training future teachers of computer science.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

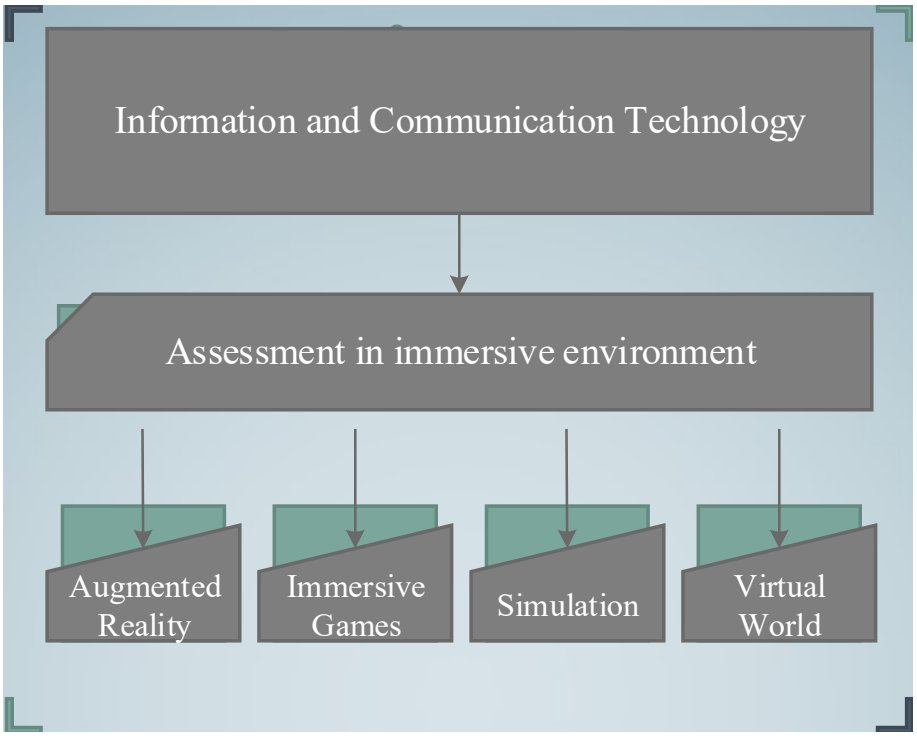

Figure 1. Available methods for building a new methodology

Abai KazNPU provides the discipline "Computer networks and Web technologies" in the cycle of profile disciplines for the training of computer science teachers in the field of computer networks and information security according to the university component in accordance with the state mandatory standard of education. The expected results in this subject suggest that future computer science teachers should know and be able to apply in their professional activities:

– the principles of building networks;

– network topology;

– the purpose and basic principles of operation and configuration of network devices;

– levels of network device interface;

– addressing in computer networks;

– routing in computer networks;

– using web, DNS, and DHCP servers;

– issues of computer networks information security;

– principles of operation of wireless networks, etc.

This will make it possible for future computer science teachers to form knowledge about the forms and methods of information interaction, the importance of considering information security issues in the development of information culture.

The following software environments that emulate or simulate the structure and functioning of computer networks were selected for the study: HP Network Simulator, eNSP, NetEmul, Cisco Packet Tracer. The capabilities of such software environments allow creating networks of various topologies and structures by emulating network components (network cables, switches, routers, workstations, servers, etc.) and visualise on the computer screen: the processes of configuring components and their interaction; the processes of various network protocols; configuring the connection of a local network and a global network to the Internet; the functioning of a computer network as a whole. This ensures: determining the optimal topology, an adequate choice of network equipment, determining the performance characteristics of the network; the impact of hits of broadcast requests on the network functioning and determining the limit beyond which its "destruction" will go; possible stages of future development of the network.

From the analysis of the functional capabilities of the above software environments, it follows that they fully provide the opportunity for full and high-quality training of future computer science teachers in the field of computer networks,

allowing them to solve professional problems in the design, maintenance, configuration, and administration of computer networks. And the system of training in computer networks based on their modelling built in this way contributes to the development of specialised competences in this area.

The experimental study analysed the need to teach computer networks and the capabilities of software environments based on network modelling to future computer science teachers, and the problems of teaching computer networks in the training of future computer science teachers in domestic and foreign studies. Students of Abai Kazakh National Pedagogical University, Kazakh State Women's Pedagogical University, and M.Kh. Dulati Taraz Regional University took part in the pedagogical experiment. The experimental group included third-year students studying in the specialisations of "Computer Science" (a total of 39 people). The control group consisted of 40 people – students studying in the specialisation "Computer Science". Methods of mathematical statistics were used to process the results of the experimental part of the study. Multi-criteria decision-making method was used to evaluate available options. Cost efficiency of developed methods was main criteria, so measuring quality of teaching and cost of the equipment was primary task of this analysis.

4. RESULTS AND DISCUSSION

At the Abai Kazakh National Pedagogical University, in accordance with the state mandatory standard of education in the field of training future computer science teachers in the educational programme of the specialisation, the discipline "Computer Networks and Web Technologies" was acquired in the profiling cycle, the group on the university component as a control group, and the group studying the course "Computer Networks and Web Technologies" using the proposed methodology, as an experimental group. The volume of topics studied in both control and experimental group, in accordance with the volume of the state standard, formed the basis of the experiment. During the practical classes, the main nuances of working with computer networks selected for the study and the quality of their development were reviewed. The proposed material was to be assimilated by future computer science teachers in the course of the following practical classes using the developed methodological guidelines.

No. 1. Preliminary preparation of the PC for building a network. Installing and initialising the network adapter, connecting the station to the network. As a result of laboratory work No.1, students will learn how to create a local network, set IP addresses, and check how well the local network functions.

No. 2. Addressing and routing in TCP/IP networks. During the course of laboratory work No.2, students must learn how to configure data transfer protocols, but the limited rights of both students and teachers do not give them full access to the equipment and software. The results of the experiment justified the fundamental implementation of the presented methodological materials and allowed outlining ways to their further improvement. A methodology for teaching computer networks based on network modelling has also been developed.

The study of the effectiveness of training future computer science teachers in computer networks based on network modelling was conducted from 2018-2020.

The initial stage of the research (2018) studied and analysed the conditions for teaching computer networks to future computer science teachers studying computer science at the Abai Kazakh National Pedagogical University, students of the Kazakh State Women's Pedagogical University, M.Kh. Dulati Taraz Regional University. Software tools and educational practices used in many pedagogical universities that participated in the experiment showed that future computer science teachers are not ready to teach topics that include computer networks and to work with computer networks in laboratory classes. In the course of the study, it was found that the conventionally used methodology does not allow solving the problems of training future computer science teachers in the practice of working with computer networks. After analysing and summarising the observations made, the authors came to the conclusion that it is necessary to teach computer networks based on network modelling to future computer science teachers who conduct training based on network modelling. The next stage of the research considered the ways of teaching computer networks to future computer science teachers and the ways of effective work with computer networks in practical classes. This stage of the experiment identified a group of students whose level of work with computer networks coincided with the level set in the theoretical part of the study, which was conducted at the Abai Kazakh National Pedagogical University, Kazakh State Women's Pedagogical University, and the M.Kh. Dulati Taraz Regional University.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The second stage of the study clarified the work on the implementation of the methodology of teaching computer networks based on network modelling, and carried out the involvement of future computer science teachers in the learning process.

The control experiment was conducted in 2019-2020. During the organisation, the possibilities of mastering software tools for working with computer networks by students of control and experimental groups were identified, the effectiveness of software environments for network modelling was studied, which forms the basis of the proposed methodology. The students of the experimental and the control group had the same training in computer science, and the experiment took place in these groups in the same way. The experimental groups were trained according to the proposed method of working with computer networks, and the control groups were trained according to the conventional method. To test the effectiveness of the proposed training method, the authors present a table comparing the results of laboratory work No.1 in the experimental group and laboratory work No.1 in the control group (Table 1).

TABLE 1: The results of laboratory work

Groups	Grades				Average arithmetic grade	"satisfactory", "unsatisfactory" grades (%)	"excellent", "good" grades (%)
	5	4	3	2			
Experimental group (20 students)	6	7	6	1	3.9	35	65
Control group (20 students)	2	6	10	2	3.4	60	40

It was established that the average arithmetic grade in comparison with the results of the control and the experimental group is 0.5 (3.9-3.4) higher than in the control group. At the same time, it was noted that the quality of task performance and the depth of material understanding in the experimental group exceeded these indicators in the control group by 25% (65-40). Similarly, a table comparing the results of laboratory work No.2 in the experimental group and laboratory work No.2 in the control group, is as follows (Table 2).

TABLE 2. The results of laboratory work

Groups	Grades				Average arithmetic grade	"satisfactory", "unsatisfactory" grades (%)	"excellent", "good" grades (%)
	5	4	3	2			
Experimental group (20 students)	7	10	3		4.2	15	85
Control group (20 students)	3	7	9	1	3.6	50	50

Results of laboratory work No. 2. show that the average arithmetic grade in comparison with the results of the control and experimental groups is 0.6 (4.2-3.6) higher than in the control group. At the same time, the quality of task performance, the depth of material understanding in the experimental group is 35% of these indicators in the control group (85-50). Figure 2 demonstrates the indicator of the quality of academic performance in the control group the experimental group according to the grades "excellent" and "good" for laboratory work.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

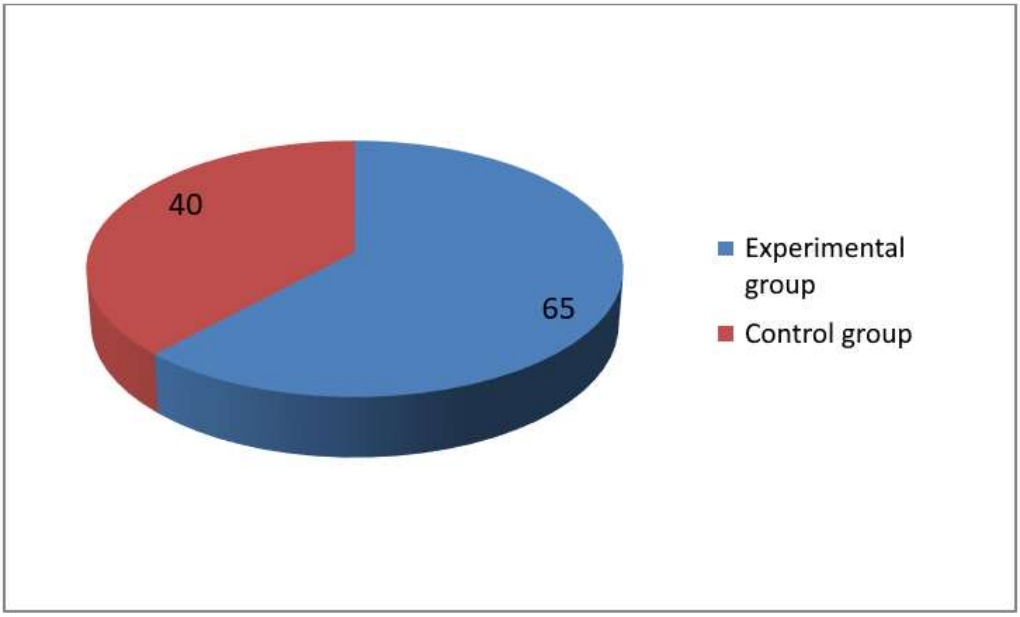

Figure 2. An indicator of the quality of academic performance

For the first laboratory work, the grades of the experimental and control groups are shown in the following figure (Figure 3).

Quality of performed tasks in the experimental and control group for the 2nd laboratory work demonstrated in the next figure (Figure 4).

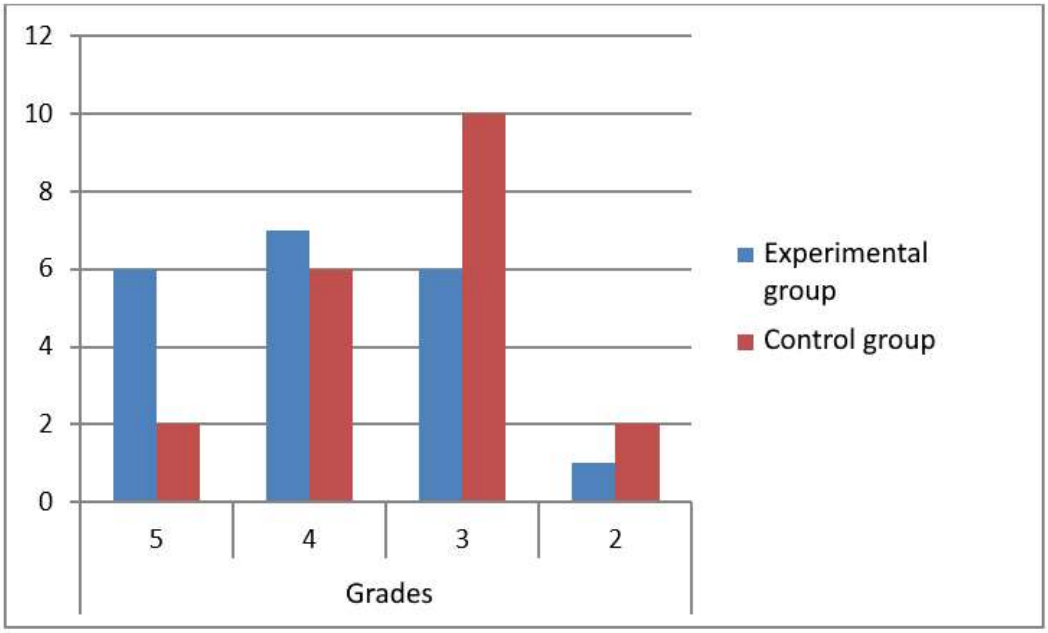

Figure 3. Grade indicator for the 1st laboratory work

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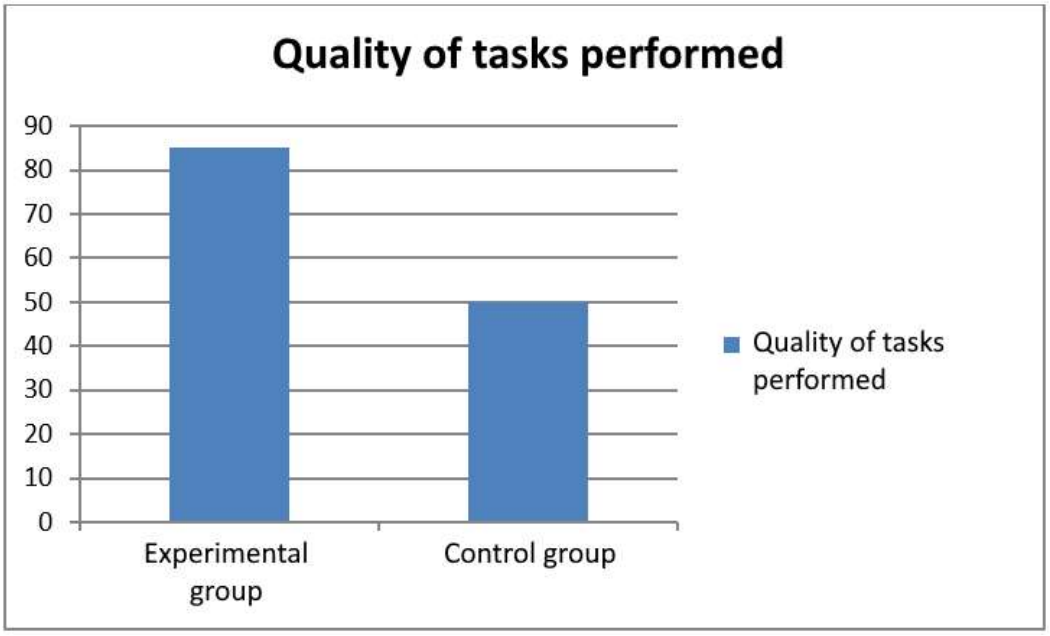

Figure 4. An indicator of the quality of tasks performed for the 2nd laboratory work

The results of all other laboratory work on quality indicators in the experimental group were also 30%-32.5% higher than the corresponding indicators of the control group. To test the students' knowledge, a test method was used for the section computer networks of the discipline "Computer networks and Web technologies". The advantage of the test method over the control methods is that there is a possibility of systematic, complete control of the student's knowledge in a certain section, which in turn allows determining what knowledge he has about the basic concepts and conclusions, and also develops the students' thinking. In this method, the correct answer to each question is considered one point, the sum of these points is obtained as the only indicator of the student's knowledge. The relative indicator of the test results was determined by the formula:

$$K = \frac{N1}{N} 100\% \quad (1)$$

where N is the total number of test questions asked; N1 is the number of correct answers; K is the points scored by the student.

The assessment method was evaluated according to the following indicator, assigned based on the universal method of testing the student's knowledge and skills – the statistical method [20]:

– 81%≤K≤100% – "excellent";

– 61%≤K≤80% – "good";

– 41%≤K≤60% – "satisfactory";

– K≤40% – "unsatisfactory".

The levels of students' mastery of the topic were determined based on the results of knowledge testing tasks and calculated using the formula (1). The results of the experiment show that the quality of knowledge of the experimental group is higher than of the control group.

Thus, it could be seen that the methodology used will achieve the desired efficiency despite some individual differences. Researchers P.V. Nikitin, A.I. Melnikova, R.I. Gorokhova in teaching students in the discipline "Computer networks, the Internet and multimedia technologies", suggest using modular technology with the help of a differentiated approach and a set of competency-based tasks and describe the following structure of the learning model: multimedia technologies, HTML, JavaScript, registration and administration of a web site on the Internet, local area networks, wireless networks [21]. This structure covers a fairly large area of students' knowledge, but in authors opinion luck in peculiar areas of virtual network deployment will eventually lead to decrease in overall efficiency. On the other hand, in the training manual of A.V. Mogilev, N.I. Pak, E. K Hönner, in the section computer networks and telecommunications, the following topics are considered: local area networks, local area network operating systems, global networks, and the use of computer networks in education [7], so this material could be a great basis for developing a specialised methodology on the local instances.

It was established that the development and implementation of the proposed teaching methodology provides an opportunity for full and high-quality training of future computer science teachers in the field of computer networks, allowing them to solve professional tasks in the design, maintenance, configuration, and administration of computer networks, and contributes to the development of specialised competences in this field. Placing the learning environment within university control – both administratively and physically, has the benefits of providing a safe environment where educational quality can be ensured, but with enough realism for participants. The experience of using the proposed methodology confirms its positive impact on the effectiveness of training future computer science teachers in computer networks based on network modelling.

5. CONCLUSIONS

Based on the pedagogical purposes of using software environments to simulate the network equipment of computer networks, it can be concluded that with the help of such software environments, one can create various topologies and structures by emulating network components (network cables, switches, routers, workstations, servers, etc.). In addition, visualisation on the computer screen allows performing the following processes: configuring components and their interaction; the operation of various network protocols; the local network and the Internet; as well as determining the functioning of the computer network as a whole, the optimal topology, the appropriate choice of network equipment, determining network performance characteristics; possible options for building a network in the future.

In the course of the study authors identified that the training using the methodology developed by the authors has reached a high level. The advantage of the test method over the control methods of verification was proved, which consists in the possibility of systematic, complete control of the student's knowledge in a certain section, which, in turn, allows determining what knowledge he has about the basic concepts and conclusions. The results of the experiment show that the quality of knowledge of the experimental group is higher than of the control group. Current research has its limitations, as the number of students in the groups and number of available equipment could be increased, and access rights extended, so in authors opinion these improvements can be helpful for further research on this topic.

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