Cloud Labs as a Tool for Learning Cisco CyberSecurity Operations and DevNet Associate Fundamentals Courses

Nadiia R. Balyk[1][a], Yaroslav Ph. Vasylenko[1][b], Vasyl P. Oleksiuk[1,2][c], Olesia R. Oleksiuk[3][d] and Galina P. Shmyger[1][e]

[1]*Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 M. Kryvonosa Str., Ternopil, 46027, Ukraine*

[2]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[3]*Ternopil Regional Municipal Institute of Postgraduate Education, 1 V. Hromnytskogo Str., Ternopil, 46027, Ukraine*

Keywords: ICT-Competence, Cloud Lab, Apache CloudStack, Computer Science Trainee Teachers, Rasch Model, Cisco Network Academy.

Abstract: The article is devoted to the study of the problem of using the corporate cloud of the university in the process of studying some courses of the Cisco Network Academy. Today, many universities have similar academies, while others can open them. Based on the free software platforms Apache CloudStack and EVE-NG Community Edition, the authors have developed and implemented 2 cloud labs. One of them is designed to teach the course “CCNA CyberOperations”, and other is “DevNet Associate Fundamentals Courses”. Both laboratories work on the IaaS model. Thanks to the technology of built-in virtualization, the work of many virtual machines, storage of their state, traffic analysis and visualization of network topologies is supported. The article describes the experience of teaching students majoring in “Secondary Education. Computer Science”. The authors conducted a survey of students who studied in the courses. The purpose of the survey was to determine how satisfied the learners were with the course. Statistical processing of the results was performed based on the Rasch model using MiniSteps software and R language. Students highly rated on-line curriculum materials, access to virtual machines, clear and easy to understand lessons, presenting information in multiple ways.

1 INTRODUCTION

Currently, the problem of intensifying the training of future professionals is relevant. This problem is especially relevant for the process of teaching computer science teachers (Ponomareva, 2021). This is because the effectiveness of this process is the basis for preparing future generations for life in the global digital world.

Various studies prove that the improvement of learning is possible through the use of e-learning systems (Kuzminska et al., 2019; Vlasenko et al., 2020). However, these tools alone are not enough. Among the factors influencing the low effectiveness of the introduction of e-learning is the lack of independent work of students.

Today, the development of computer systems and networks provides universal access to educational resources. This led to the emergence of the concept of open education (Kukharenko and Oleinik, 2019). One of its modern tools is massive open online courses (MOOC – Massive Open Online Cources) (Zinovieva et al., 2021).

One way to solve this problem is to study open courses by students. Their advantages are as follows: the opportunity to study at a convenient time; the ability to compare teaching styles and materials of different courses; the experience in discussing and peer assessment; improving the skills of listening, reading and writing English (or other); reflection of their own pedagogical activity in the light of new ideas, the digital creativity and collaboration with other participants (Markova et al., 2018).

Cisco offers similar courses within Cisco Network

[a] https://orcid.org/0000-0002-3121-7005
[b] https://orcid.org/0000-0002-2520-4515
[c] https://orcid.org/0000-0003-2206-8447
[d] https://orcid.org/0000-0002-1454-0046
[e] https://orcid.org/0000-0003-1578-0700

Balyk, N., Vasylenko, Y., Oleksiuk, V., Oleksiuk, O. and Shmyger, G.
Cloud Labs as a Tool for Learning Cisco CyberSecurity Operations and DevNet Associate Fundamentals Courses.
DOI: 10.5220/0010924000003364
In *Proceedings of the 1st Symposium on Advances in Educational Technology (AET 2020) - Volume 1*, pages 308-318
ISBN: 978-989-758-558-6

Academy. Although these courses do not fully correspond to the ideology of the MOOC, Cisco Network Academy can be organized at any education institute. Cisco Networking Academy, a Cisco Corporate Social Responsibility Program, is an IT skills and career building program available to educational institutions and individuals worldwide. Today, the company is professing a paradigm for providing free access to some courses to a wide range of users.

For example, scientists at The Open University of the United Kingdom have integrated some Cisco Network Academy courses into the training process of computer science bachelors. The researchers substantiated the effectiveness of the developed environment and identified the key role of the instructor in teaching students. A constructivist approach and blended learning model were applied during the design and testing of the course. It has proven to be an effective way to conduct Cisco courses. Such conclusions of authors are confirmed by the positive feedback of students and their academic achievements (Moss and Smith, 2010).

These and other studies confirm that Cisco Network Academy courses can be used effectively in the study of computer sciences. This raises the problem of giving students access to the objects of study. This problem is especially relevant in courses on cybersecurity and network applications development. The solution to this problem is possible through the introduction of cloud technologies for virtualization of objects of study in the courses of the Cisco Network Academy.

The goal of this article is to describe the model of cloud labs as learning tools in Cisco CyberSecurity Operations and DevNet Courses and to research the feedbacks of students about such labs.

2 RESULTS

As the experience of a secondary school shows, a teacher of informatics is the leading ICT specialist (Kuzminska et al., 2019). In the context of providing information security (Savchenko et al., 2020), he must be able to balance the advantages and disadvantages of using digital technologies in the learning process. We suggest using Cisco Network Academy Courses to improve the training process for future computer science teachers. At the same time there are problems with the provision of learning tools. Cisco Network Academy offers several solutions to the problem, such as:

- Use simulators like Cisco Packet Tracer. This approach is usually offered in courses related to the study of computer networks. The simulator is quite a powerful and affordable tool, but it simulates only the basic functionality of network devices.
- Work with online and cloud services. For example, this approach is used in programming courses to access API functions. However, these services may change. As a result, course authors need to constantly monitor changes and adjust learning objectives.
- Deployment virtual machines. In this case, the training takes place in an artificially created environment, which is created specifically for this course and contains all the necessary tools.

It should be noted that the Cisco Network Academy courses use each of the approaches. In the context of our study, we will examine the latter approach. We used virtual machines in CCNA Cyber Operations and DevNet courses. Having analyzed the available free courses, we chose CCNA Cyber Operations (Cisco, 2019) as a basic course for formation teachers' cybersecurity competences. By the end of this course, the students will be able to:

- Install virtual machines to analyzing cybersecurity threat events.
- Explain the role of the Cybersecurity Operations Analyst in the enterprise.
- Explain the Windows and Linux OS features to support cybersecurity analyses.
- Analyze the operation of network protocols and services.
- Classify the various types of network attacks and identify network security alerts.
- Use network monitoring tools to identify attacks against network protocols.
- Use various methods to prevent malicious access to computer networks.
- Analyze network intrusion data to verify potential exploits.
- Apply incident response models to manage network security incidents.

The course contains the following chapters: Cybersecurity and the Security Operation Center, Windows OS, Linux OS, Network Protocol and Services; Network Infrastructure, Principles of Network Security, Network Attacks: A Deep Look, Protection the network, Cryptography and the Public Key Infrastructure, Endpoint Security and Analysis, Security Monitoring, Intrusion Data Analysis, Incident.

To our opinion, the material of some chapters can be considered in other courses (Operation Systems, Computer Networks, Cryptography, etc.). Another approach is to include these chapters in the content of mentioned courses.

Each chapter contains terms and concepts review, quiz, labs and exam. In the process of teaching the course, we met with the problem of organizing laboratory works. Cisco Network Academy offers to run them on virtual student machines. This approach is justified, but it limits the universal and everywhere access of students to study. The use of separate virtual machines does not ensure the cooperation of students between themselves and with the teacher.

An effective way to overcome these limitations is to use the cloud technologies. Bykov and Shyshkina (Bykov and Shyshkina, 2018) note that the development of cloud computing technologies, adaptive information and communication networks services, virtual and mobile learning facilities are the important step towards solving the problems of accessibility and quality of training. Application of cloud technologies in professional activities should correspond the requirements of fundamentalization of learning through the inclusion in the content general both the theoretical and the technological provisions, with demonstration of them on the concrete examples (Merzlykin et al., 2017; Bondarenko et al., 2019; Lovianova et al., 2019; Spirin et al., 2019). Glazunova and Shyshkina (Glazunova and Shyshkina, 2018) distinguishes the following levels of the University Cloud-based Learning and Research Environment: physical, level of the virtualization and virtual resource management, as well as platforms and software levels.

We deployed a cloud-based environment according to the IaaS model. In the environment, the public and private cloud platforms are integrated. Since the corporate cloud platforms are widely using the virtualization technology, we see as possible the deployment of cloud laboratories on their basis.

After analyzing the interpretation of Bykov et al. (Bykov et al., 2020), we note that the cloud laboratory is an information system in which network virtual ICT objects are formed thanks to a special user interface, which is supported by the system software of the network setting. Such objects are an integral part of a logical network infrastructure with a flexible architecture that, according to its structure and time, corresponds to the personality needs of the user.

Cornetta et al. (Cornetta et al., 2019) have investigated how digital fabrication laboratories can leverage cloud technologies to enable resource sharing and provide remote access to distributed expensive fabrication resources over the Internet. They deployed a cloud lab according to the new Fabrication as a Service (FaaS) model. Researchers have developed firmware and software for monitoring equipment and providing real-time communications.

Gillet and Li (Gillet and Li, 2015) explore the concept of cloud laboratories as common spaces that integrate applications. Researchers are also studying the problem of integrating MOOC into the learning environment. They note that cloud labs can enable the implementation of connectivist MOOCs, allowing teachers or students to collect and monitor the use of openly available learning resources.

Typically, in a cloud laboratory, information from a subject field is based on some facts, and therefore limited by a set of predicted experiments. Another approach suggests that a pupil or student is able to carry out any experiments, not limited to a previously prepared set of results. It is thanks to the use of the virtualization technology of operating systems, the last approach should be tried to implement in the designed laboratory. Cloud virtualization technologies provide unique opportunities for the learning organization of the Cisco CyberSecurity Operations course.

The designed virtual laboratory was implemented in the cloud-based learning environment of Volodymyr Hnatiuk Ternopil National Pedagogical University. Based on the comparative analysis [8], as the program basis of the laboratory, we have chosen the Apache CloudStack platform. Then we modified the Cloud-based Learning Environment so that students could create virtual networks. This networks should not require changes in the topology of physical networks in the academic cloud. We divided the traffic transmitted between students' virtual computers among 100 VLANs. So each student has an opportunity to store their virtual computers and other devices in their personal or several guest networks.

As Apache CloudStack does not provide tools for visualization of network structure, students often have difficulty in designing and configuring networks in a cloud infrastructure. That fact prompted us to integrate into a virtual cloud laboratory a system that makes it possible to visualize the process of network design. It was vital that such system could work with networks on Apache CloudStack virtual machines. We analyzed relevant publications and compared several platforms – Cisco packet tracer, Graphical Network Simulator (GNS), Unetlab (EVE-NG). Despite the benefits of Cisco packet tracer, it did not provide the performance of all tasks of the laboratory works. Among the platforms of GNS and EVE-NG, we have chosen the last.

Every student's copy of ENE-NG platform is a separate virtual machine in Apache CloudStack cloud. As each node of EVE-NG is itself a virtual machine, hosts integrated in Apache CloudStack infrastructure have to support nested virtualization.

The laboratory works involves the use of such virtual machines: CyberOps WorkStation (based on Arch Linux); Kali Linux; Security Onion (based on Ubuntu Linux); Metasploitable; Windows Client.

The students used a virtual cloud laboratory when performing the following laboratory works:

1. Chapter 2: Windows Operating System. 2.0.1.2 Lab – Identify Running Processes; 2.1.2.10 Lab – Exploring Processes, Threads, Handles, and Windows Registry; 2.2.1.10 Lab – Create User Accounts; 2.2.1.11 Lab – Using Windows PowerShell; 2.2.1.12 Lab – Windows Task Manager; 2.2.1.13 Lab – Monitor and Manage System Resources in Windows.
2. Chapter 3: Linux Operating System. 3.1.2.6 Lab – Working with Text Files in the CLI; 3.1.2.7 Lab – Getting Familiar with the Linux Shell; 3.1.3.4 Lab – Linux Servers; 3.2.1.4 Lab – Locating Log Files; 3.2.2.4 Lab – Navigating the Linux Filesystem and Permission Settings.
3. Chapter 4: Network Protocols and Services. 4.1.1.7 Lab – Tracing a Route; 4.1.2.10 Lab – Introduction to Wireshark; 4.4.2.8 Lab – Using Wireshark to Examine Ethernet Frames; 4.5.2.4 Lab – Using Wireshark to Observe the TCP 3-Way Handshake; 4.5.2.10 Lab – Exploring Nmap; 4.6.2.7 Lab – Using Wireshark to Examine a UDP DNS Capture; 4.6.4.3 Lab – Using Wireshark to Examine TCP and UDP Captures; 4.6.6.5 Lab – Using Wireshark to Examine HTTP and HTTPS;
4. Chapter 7: Network Attacks. 7.0.1.2 Lab – What is Going On? 7.3.1.6 Lab – Exploring DNS Traffic; 7.3.2.4 Lab – Attacking a MySQL Database; 7.3.2.5 Lab – Reading Server Logs; Chapter 9: Cryptography and the Public Key Infrastructure; 9.0.1.2 Lab – Creating Codes; 9.1.1.6 Lab – Encrypting and Decrypting Data Using OpenSSL; 9.1.1.7 Lab – Encrypting and Decrypting Data using a Hacker Tool; 9.1.1.8 Lab – Examining Telnet and SSH in Wireshark; 9.1.2.5 Lab – Hashing Things Out; 9.2.2.7 Lab – Certificate Authority Stores;
5. Chapter 12: Intrusion Data Analysis. 12.1.1.7 Lab – Snort and Firewall Rules; 12.2.1.5 Lab – Convert Data into a Universal Format; 12.2.2.9 Lab – Regular Expression Tutorial; 12.2.2.10 Lab – Extract an Executable from a PCAP; 12.4.1.1 Lab – Interpret HTTP and DNS Data to Isolate Threat Actor; 12.4.1.2 Lab – Isolated Compromised Host Using 5-Tuple.

A typical topology of the network for the laboratory works is showed in figure 1.

Each of these machines was available in a cloud-based infrastructure. As a result, students could work with virtual machines in the university's local network or through VPN. The course was taught in a mixed methodology. It was dominated by independent distance work of students. The teacher's consultations were carried out at the classroom and online.

We have deployed a cloud lab for the Cisco DevNet Associate Fundamentals course. The course is dedicated to the development of competencies for a IT professionals, empowering organizations to embrace the potential of applications, infrastructure for the network, Internet of Things (IoT), Webex, etc. The course is also good because it can be completed by students with low levels of programming skills The DevNet course has the following modules:

1. Introduction. The module is devoted to the organization of the learning environment. Since students will be working in a cloud lab, we have modified this section a bit. In particular, they explained how to deploy a VM, what its parameters should be specified, how to connect to it remotely.
2. The DevNet developer environment. There are opportunities to learn more through such features as: learning labs, sandboxes, developers' documentation and support.
3. Software Development and Design Content. The software development life cycle is the main concept of this module. A phases of this process are also discussed in the module.
4. Understanding and Using APIs. In this module, students study API Design and Architectural Styles. The REST API is presented in more detail
5. Introduction to Network Fundamentals. The basic concepts of computer networks based on models OSI and TCP/IP are considered in this module.
6. Application Deployment and Security. Students are introduced to application deployment models such as virtual machines, containers, and serverless computing.
7. Infrastructure and Automation. In this topic students use a code to configure, deploy, and manage applications together with the compute, storage, and network infrastructures and services.
8. Cisco Platforms and Development. The module will be useful for students to further their career development. The topic describes Cisco Dev Centers. Those Dev Centers are a convenient way of grouping technologies together.

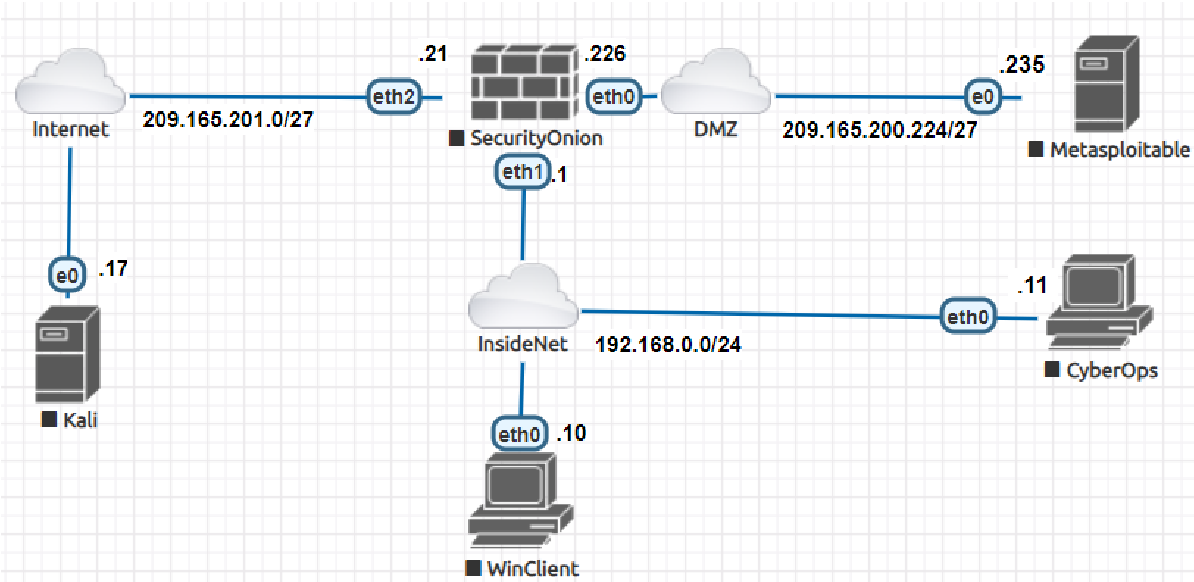

Figure 1: The network topology for labs.

The course offers to use a virtual machine based on free VirtualBox software. However, we modified it and created a VM template for the Apache CloudStack platform.

The VM runs on Ubuntu Linux and includes the following learning tools: interpreter of Python programming language, Visual Studio Code IDE, Postman (The Collaboration Platform for API Development), command-line utility Git, Cisco Packet Tracer, etc.

For example, VM was used to create a chatbot in the laboratory work "Integrating a REST API with Python". Students used the REST-API to work with MapQuest, ISS Location and Webex Teams. Chatbot read messages from the Webex Teams room in JSON format, performed their parsing, found messages with the name of the city. In the next step, the script called the API of the MapQuest service to determine the geographical coordinates of the city. Another step was to determine the nearest time for observation of the International Space Station in this city. In the last step, the chatbot sent a reply message to the Webex Teams room.

After learning this courses, students completed the final exam. He contained 60 questions from all the topics of the course, as well as the fragments of laboratory works. 56 students majoring in "Secondary education. Computer Science" passed the exam. Of these, only 24 passed the exam successfully. This indicator can be explained by the fact that the course "Cyber Operations" was studied as optional and did not affect the student's rating at the university.

In addition to the final exam students responded to the questionnaire "Cyber Operations Course Feedback". Questionnaire questions were formulated according to the principle of the Likert scale (five response categories) and grouped in 5 blocks (table 1).

3 STATISTICAL ANALYSIS OF RESEARCH DATA

To evaluate the efficiency of the designed and deployed cloud-based labs, a model with equally distributed responses of all indicators on the scale of the latent variable was used. This is one of the models of the Rasch's family, which is used in the case of polithomus indicators.

In the modern Item Response Theory (IRT), Rasch's model allows us to assess the meaning of latent variables, to investigate the relationship between them, and to identify factors that influence the behavior of latent variables. IRT is based on the theory of latent-structural analysis: the final score is considered as a result of the combined interaction of latent parameters – the true level of preparation of students and the complexity of the questions (tasks). This approach to the evaluation of the studied features in IRT theory differs significantly from the classical test theory, in which the result is the final score in a particular survey, corrected for error.

The Rasch's model is interpreted as a model of "objective measurements" that do not depend from the respondents and measuring instruments. The Rasch's model is based on three assumptions (Bond

Table 1: List of distractors (items) in questionnaire.

Distractor	Code	Description
Please rate your level of satisfaction with the following aspects of this course (Course Satisfaction)	CS1	On-line Curriculum Materials
	CS2	Labs
	CS3	Access to Equipment/Software
	CS4	Classroom Instruction
	CS5	Assessments
Please rate how confident you feel in your ability to do each of the following (Confident Ability)	CA1	Explain the role of the Cybersecurity Operations Analyst
	CA2	Explain the Windows and Linux OS features and characteristics needed to support cybersecurity analyses
	CA3	Explain the operation of the network infrastructure and various types of network attacks
	CA4	Analyze the operation of network protocols and services, and identify attacks against them
	CA5	Use various methods to prevent malicious access to computer networks, hosts, and data
	CA6	Explain how to investigate endpoint vulnerabilities
	CA7	Evaluate network security alerts and identify compromised hosts and vulnerabilities
Compare your instructor to other instructors you have had in terms of: (Compare instructor)	CI1	Preparedness to teach the course
	CI2	Clear and easy to understand lessons
	CI3	Approachability with questions and ideas
	CI4	Presenting information in multiple ways
	CI5	Making the topic interesting
Please rate how much you agree with the next statements (Course Content)	CC1	The lab activities helped me to achieve the stated course objectives
	CC2	The exam scores reflected my understanding of the curriculum
	CC3	Having access to equipment helped me learn
	CC4	The course curriculum was technically accurate
To what extent did this course help you (Course Purpose)	CP1	Prepare for Certification exam(s)
	CP2	Learn skills that can be used in a future job
	CP3	Increase your value in the job market
	CP4	Obtain a new job or advance in your current job

et al., 2021):

1. The level of difficulty of tasks and the level of preparedness of persons being tested can be measured in one scale, with a common standard unit of measurement.
2. In the presence of such a scale the probability of the correct answer of the tested person depends on the difference between his level of preparedness and the level of complexity of the test task.
3. The outcome of the confrontation of the tested person with the test tasks can be predicted. If the level of preparedness of the tested person is higher, than the probability of his correct answer to the task of a fixed level of complexity should be higher.

To measure the complexity of tasks and level of knowledge, the unit of measurement, called logit, is used. In our research, we used the WINSTEPS program. The program is commercial, but its free version called MINISTEP. It allows you to use all the capabilities of WINSTEPS, but has a limit on the number of questions in the test (25) and the number of people (75) (WINSTEPS, 2019).

Standardized Residuals in the Rasch's model are modeled for normal distribution. Therefore, significant deviations from the value of "0" for the Mean and the value "1" for the Standard Deviation (SD) signal that the primary data do not correspond to the Rasch's model, which should correspond exactly to the normal distribution. In our study, the values Mean = -0.02 and SD = 1.03 are sufficiently satisfactory.

The classic indicator of reliability of the survey scale is alpha Kronbach. Reliability is the consistency of the results within a single test. Alpha Kronbach points to the degree to which all items actually measure the same property (quality). It should be noted that the high value of the coefficient indicates the existence of a general basis in the formulated set of questions. Professionally designed tests must have an internal consistency of at least 0.90. In our survey, the Cronbach coefficient α=0.96.

As can be seen from figures 2 and 3, informational and characteristic functions are acceptable for IRT analysis.

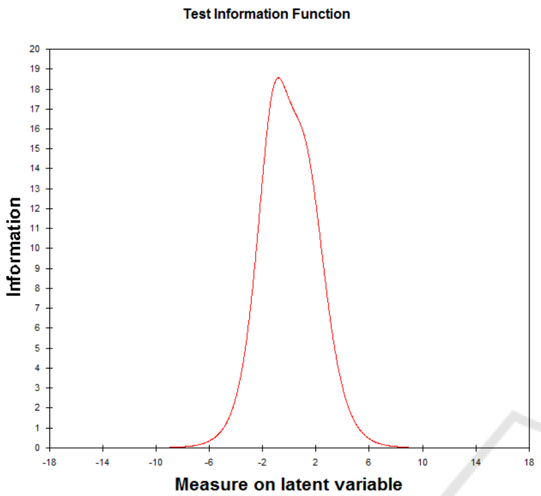

Figure 2: Information function.

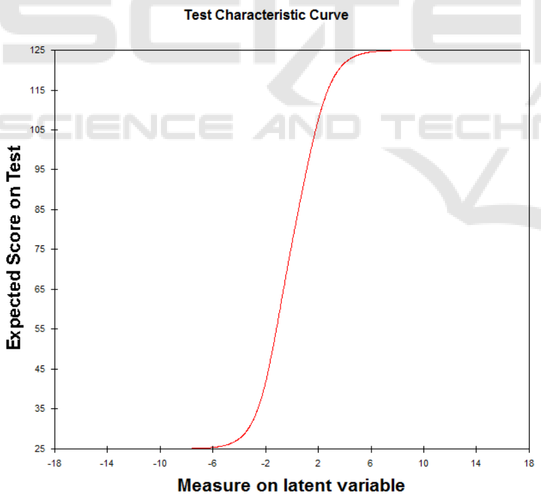

Figure 3: Characteristic function.

Person raw score-to-measure correlation = 1.00.

Cronbach Alpha (kr-20) person raw score "test" reliability = 0.96, sem = 4.07.

Item raw score-to-measure correlation = -1.00.

In columns INFIT and OUTFIT of tables 2 and 3 specified parameters that characterize the correspondence of the data to Rasch's model. In the field MNSQ (mean-square statistic) the statistics of the correspondence of the output data to the measuring model are showed, obtained on the base of the average sums of the squares of the deviations of the theoretical values from the empirical ones. The MNSQ values characterize the degree of "randomness" of the results or the discrepancy of the data to the used measurement model. Expected MNSQ values are near 1. The high MNSQ OUTFIT values can be associated with the "casual" respondents' responses. The high values of MNSQ INTFIT are usually interpreted as an indicator of the low validity of the tool, that is, the low suitability of the tool for the tasks for which it was developed. The most qualitative and significant (productive) measurements are those for which the MNSQ values lie in the range of 0.5 to 1.5. Higher values ($>$ 1.5) indicate uncertainty and "noise" in input data. Too low values ($<$0.5) are also not very desirable because they indicate excessive, "information overload" of the instrument. In the ZSTD field, the standardized MNSQ values are showed (with an average of 0 and a standard deviation of 1). Valid value is $-2.0 \leq$ ZSTD $\leq +2.0$.

For this survey, the match statistics for the measurements of all items are in this range, so they can all be used for further analysis.

Figure 4 shows the distribution of respondents and their judgments on the same interval scale (efficiency of the designed and deployed cloud-based environment). The content and composition of the questions in the survey is satisfactory – this is evident from the second bar graph on Figure 4. However, respondents' answers to the questions posed are not balanced. This means that some respondents answered randomly or could not orient themselves with the choice of an adequate response.

By analyzing table 4 in terms of the distractors included in the poll, the following conclusions can be drawn. Distractors with the lowest estimate of the efficiency of the proposed medium (Measure = -1.08, Item = CC3) and with the highest estimate of the efficiency (Measure = 0.75, Item = CA6) are not presentational for this study, since, as noted above, on the responses had an impact the factor of randomness and the factor of reluctance of respondents to understand the content of the questions deeply. The rest of the distractors can be divided into three groups according to the degree of influence on the overall efficiency: 1) with a small degree of influence on the overall efficiency (Measure from -0.43 to -0.12, Items = CP1, CP3, CP2, CS5, CA3, CP4, CI5); 2) with a mediocre degree (Measure from -0.09 to 0.07, Items = CS2, CS4, CI1, CC1, CI3, CA4, CA1, CA5); 2) with a large degree of impact on overall efficiency (Measure from 0.13 to 0.41, Items = CA2, CC4, CI2, CC2, CI4, CA7, CS3, CS1). The analysis of these distrac-

Table 2: Output table "Summary Statistics" (summary of 56 measured person).

	Total Score	Count	Measure	Model S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	72.1	25.0	-0.20	0.25	1.06	-0.13	1.07	-0.14
SEM	2.9	0	0.18	0.00	0.08	0.29	0.09	0.29
P.SD	21.5	0	1.30	0.03	0.62	2.27	0.65	2.14
S.SD	21.6	0	1.31	0.03	0.63	2.19	0.66	2.16

Table 3: Output table "Summary Statistics" (summary of 25 measured item).

	Total Score	Count	Measure	Model S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	161.6	56.0	0.00	0.17	0.98	-1.13	1.07	-0.80
SEM	2.5	0	0.07	0.00	0.17	0.83	0.19	0.88
P.SD	12.2	0	0.34	0.00	0.84	4.08	0.95	4.32
S.SD	12.4	0	0.35	0.00	0.85	4.16	0.97	4.41

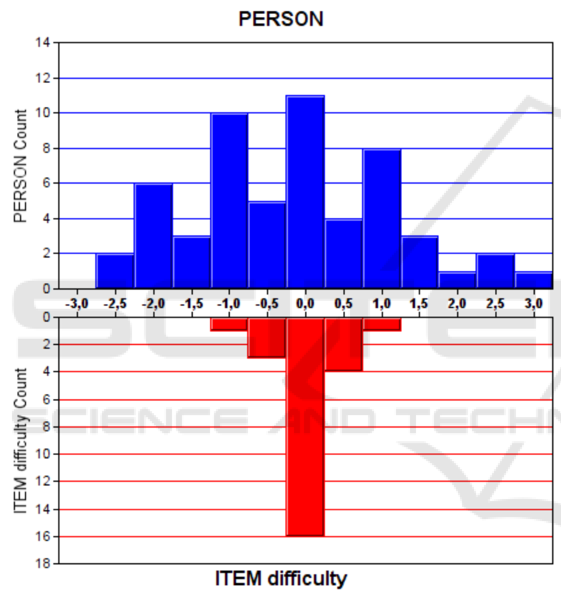

Figure 4: The relationship between the level of efficiency of the designed and deployed cloud-based virtual lab and the indicator variables.

tors at the content level will allow for the adjustment of the structure, some components in design of virtual cloud labs for the learning Cisco CyberSecurity Operations.

To further analyze the study data, we used the means of the R language in the RStudio environment. Currently, the MIRT package (Full-Information Item Factor Analysis (Multidimensional Item Response Theory)) is one of the most effective means of the R language to work with the Rasch model (Liu and Chalmers, 2018). This is open-source software, useful for real data analysis and research and provides a didactic tool for teaching IRT. It has no limits on the number of respondents or answers to questions. We used the mirt function to process and visualize the data. Here is the function call:

```
mod <- mirt(data = expdata,
       itemtype = "Rasch",model=1)
```

where

- expdata is a data frame with students' grades (link was provided above).
- itemtype is a type of items to be modeled. A value of 'Rasch' means that a credit model will be built by constraining slopes to 1 and freely estimating the variance parameters.
- model is a model to be built. A value of "1" means a unidimensional model.

To estimate the frequency of students' grades on all distractors, we constructed a histogram of response frequencies (figure 5). To do this, we used the P-function such as:

```
hist(d, breaks=c(0:5), freq=TRUE,
col= "blue",
xlab="Responses",
ylab="Frequency",
main="Frequency diagram")
```

The vector d is obtained from the full dataframe by extracting the header. That is, it contains columns of data without distractors.

Figure 5 shows that the answers at levels 4 and 5 were given the least. We can explain this by the fact that the proposed approach to the study of disciplines is innovative. Therefore, there is vigilance and caution of students to use it in the learning process.

To assess how clear the content of the distractors was for the respondents, we constructed a diagram using the next function.

```
plot(mod1, type = 'info',
xlim = c(-4, 4), ylim=c(0,40))
```

Table 4: Item statistics: measure order.

Entry number	Total Score	Total Count	Measure	Model S.E.	Item
11	135	56	0.75	0.17	CA6
1	147	56	0.41	0.17	CS1
3	149	56	0.35	0.17	CS3
12	151	56	0.29	0.17	CA7
16	151	56	0.29	0.17	CI4
19	154	56	0.21	0.17	CC2
14	155	56	0.18	0.17	CI2
21	156	56	0.15	0.17	CC4
7	157	56	0.13	0.17	CA2
10	159	56	0.07	0.17	CA5
6	160	56	0.04	0.17	CA1
9	160	56	0.04	0.17	CA4
15	160	56	0.04	0.17	CI3
18	160	56	0.04	0.17	CC1
13	161	56	0.02	0.17	CI1
4	162	56	-0.01	0.17	CS4
2	165	56	-0.09	0.17	CS2
17	166	56	-0.12	0.17	CI5
25	168	56	-0.18	0.17	CP4
8	169	56	-0.20	0.17	CA3
5	170	56	-0.23	0.17	CS5
23	172	56	-0.29	0.17	CP2
24	176	56	-0.40	0.17	CP3
22	177	56	-0.43	0.17	CP1
20	200	56	-1.08	0.17	CC3
Mean	161.60	56.00	0.00	0.17	
P.SD	12.20	0.00	0.34	0.00	

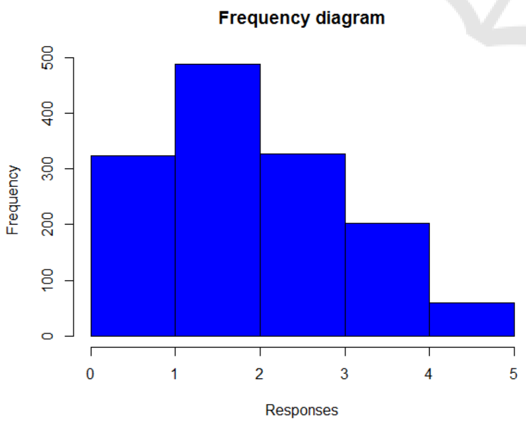

Figure 5: Histogram of response frequencies.

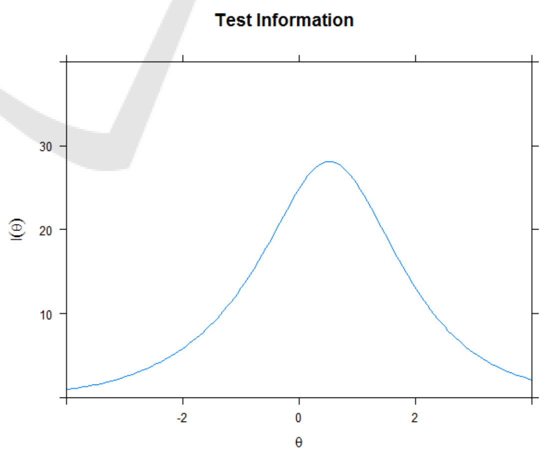

Figure 6: Graph of the information function of the questionnaire.

From the graph 6 of the information function we can conclude that the tasks of the polytomy type are the most informative for respondents with a level of training from -1 to 2 logs. This suggests that for students with an average level of preparation or slightly higher, the formulated questions were the most informative. The shape of the information curve (bell-shaped) indicates that the distractors were selected correctly and their description was made correctly.

The figure 7 shows the graphs of the characteristic functions of the responses to all distractors.

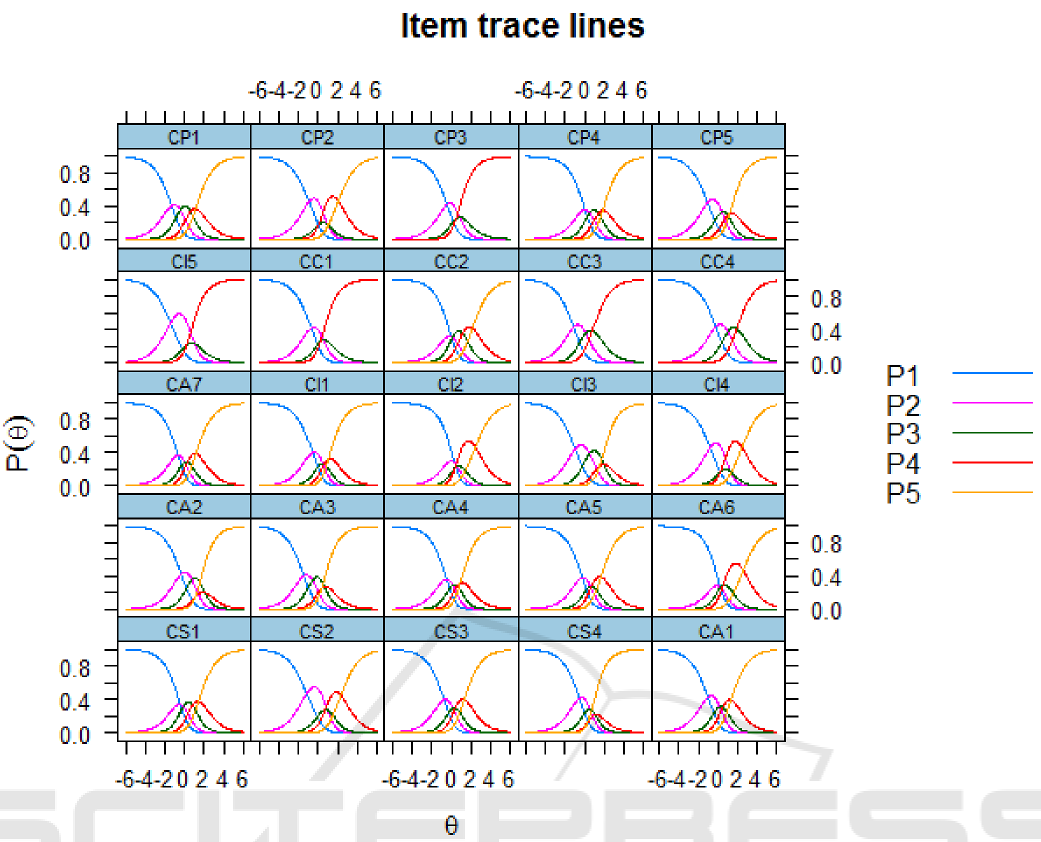

Figure 7: Characteristic curves of response levels.

As can be seen from these graphs, the probability of putting 1 point in students with a low level of preparation and the probability of putting 5 points in students with a high level of preparation was approximately 0.9. This is the case for all distractors. The probability of setting an average score by a student with an average level of preparation is low. But this is due to the higher frequency of averaging by most students.

4 CONCLUSIONS

The problem of integrating cloud-based tools and open online courses in the process of training future computer science teachers is relevant and needs further research. Cloud labs are one such form of integration. They ensure ubiquity and cooperation in learning. In particular, the authors deployed cloud labs to support training in Cisco CyberSecurity Operations and DevNet Associate Fundamentals Courses.

Learning the basics of cybersecurity is a topical issue of ICT students training. The course “CCNA Cyber Operations” of Cisco Network Academy provides an opportunity to organize such training. It contains a lot of theoretical materials, quiz tasks, discussion questions, labs, chapters exams and final exam. A virtual cloud laboratory was designed to carry out laboratory works at the course. For this purpose, the Apache CloudStack and EVE-NG Community Edition platforms were used. The virtual cloud laboratory provides the following possibilities: to create the required number of virtual machines; to change the computing power; to simulate the work of real computers and networks; to visualize different network topologies; to keep the state of virtual computers; to work remotely through a virtual private network; to combine separate virtual networks of students into a single network; to help students and control their learning outcomes.

DevNet Associate Fundamentals Courses is a very successful integrated course. It gives students the opportunity to put into practice theoretical lessons in networking and programming. It is also important to teach students to work with modern APIs. So future professionals will be able to create applications that process data obtained from the clouds. The course also demonstrates modern automation tools for the deployment of network and cloud infrastructures. The cloud lab also provides great learning opportunities in the DevNet course. In it, students can run VMs with basic development tools, run and test their application for a long time.

The conducted research and its statistical processing have limitations. They are associated with a small number of students have participated in the experiment. This sample size did not allow us to conduct a qualitative experiment to verify the statistical differences between the control and experimental groups. Nevertheless, statistical processing of the questionnaire "Course feedback" given by all students (even those who did not pass the final exam) indicates efficiency of the use of the deployed cloud laboratories. Along with high-quality training materials from the Cisco Network Academy, the students appreciated highly the functional and widespread access to the virtual objects of the cloud labs.

REFERENCES

Bond, T., Yan, Z., and Heene, M. (2021). *Applying the Rasch model: Fundamental measurement in the human sciences*. 4 edition.

Bondarenko, O., Pakhomova, O., and Zaselskiy, V. (2019). The use of cloud technologies when studying geography by higher school students. *CEUR Workshop Proceedings*, 2433:377–390.

Bykov, V., Mikulowski, D., Moravcik, O., Svetsky, S., and Shyshkina, M. (2020). The use of the cloud-based open learning and research platform for collaboration in virtual teams. *Information Technologies and Learning Tools*, 76(2):304–320. https://journal.iitta.gov.ua/index.php/itlt/article/view/3706.

Bykov, V. Y. and Shyshkina, M. P. (2018). The conceptual basis of the university cloud-based learning and research environment formation and development in view of the open science priorities. *Information Technologies and Learning Tools*, 68(6):1–19. https://journal.iitta.gov.ua/index.php/itlt/article/view/2609.

Cisco (2019). Cisco CCNA Cyber Ops. https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/associate/ccna-cyber-ops.html.

Cornetta, G., Mateos, J., Touhafi, A., and Muntean, G.-M. (2019). Design, simulation and testing of a cloud platform for sharing digital fabrication resources for education. *Journal of Cloud Computing*, 8(1):12.

Gillet, D. and Li, N. (2015). Case study 2: designing PLE for higher education. In Kroop, S., Mikroyannidis, A., and Wolpers, M., editors, *Responsive Open Learning Environments: Outcomes of Research from the ROLE Project*, pages 115–133. Springer International Publishing, Cham.

Glazunova, O. and Shyshkina, M. (2018). The concept, principles of design and implementation of the university cloud-based learning and research environment. *CEUR Workshop Proceedings*, 2104:332–347.

Kukharenko, V. and Oleinik, T. (2019). Open distance learning for teachers. *CEUR Workshop Proceedings*, 2393:156–169.

Kuzminska, O., Mazorchuk, M., Morze, N., and Kobylin, O. (2019). Attitude to the digital learning environment in Ukrainian universities. *CEUR Workshop Proceedings*, 2393:53–67.

Liu, C.-W. and Chalmers, R. P. (2018). Fitting item response unfolding models to Likert-scale data using mirt in R. *PLOS ONE*, 13(5):1–22.

Lovianova, I., Bobyliev, D., and Uchitel, A. (2019). Cloud calculations within the optional course Optimization Problems for 10th-11th graders. *CEUR Workshop Proceedings*, 2433:459–471.

Markova, O. M., Semerikov, S. O., Striuk, A. M., Shalatska, H. M., Nechypurenko, P. P., and Tron, V. V. (2018). Implementation of cloud service models in training of future information technology specialists. *CEUR Workshop Proceedings*, 2433:413–428.

Merzlykin, P., Popel, M., and Shokaliuk, S. (2017). Services of SageMathCloud environment and their didactic potential in learning of informatics and mathematical disciplines. *CEUR Workshop Proceedings*, 2168:13–19.

Moss, N. and Smith, A. (2010). Large scale delivery of cisco networking academy program by blended distance learning. In *2010 Sixth International Conference on Networking and Services*, pages 329–334.

Ponomareva, N. S. (2021). Role and place of informatics in the training of future teachers of mathematics. *Journal of Physics: Conference Series*, 1840(1):012035.

Savchenko, S., Shekhavtsova, S., and Zaselskiy, V. (2020). The development of students' critical thinking in the context of information security. *CEUR Workshop Proceedings*, 2731:383–399.

Spirin, O., Oleksiuk, V., Balyk, N., Lytvynova, S., and Sydorenko, S. (2019). The blended methodology of learning computer networks: Cloud-based approach. *CEUR Workshop Proceedings*, 2393:68–80.

Vlasenko, K., Chumak, O., Achkan, V., Lovianova, I., and Kondratyeva, O. (2020). Personal e-learning environment of a mathematics teacher. *Universal Journal of Educational Research*, 8(8):3527–3535.

WINSTEPS (2019). WINSTEPS & Facets Rasch Software . http://www.winsteps.com/index.

Zinovieva, I. S., Artemchuk, V. O., Iatsyshyn, A. V., Romanenko, Y. O., Popov, O. O., Kovach, V. O., Taraduda, D. V., and Iatsyshyn, A. V. (2021). The use of MOOCs as additional tools for teaching NoSQL in blended and distance learning mode. *Journal of Physics: Conference Series*, 1946(1):012011.