Using corporate cloud for teaching Cisco Network Academy courses: a case study

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Abstract. This paper explores using the university's corporate cloud to teach some Cisco Network Academy courses, a common feature of many universities. The paper presents two cloud labs based on the open-source platforms Apache CloudStack and EVE-NG Community Edition and operating on the IaaS model. The labs support the courses "CCNA CyberOperations" and "DevNet Associate Fundamentals Courses," allowing students to access various virtual machines, store their state, analyse traffic, and visualise network topologies. The paper also reports on the students' satisfaction with the courses based on a survey of students majoring in "Secondary Education. Computer Science". The survey results were statistically analysed using the Rasch model with MiniSteps software and R language. The students gave positive feedback on the online curriculum materials, the virtual machines, the clarity and simplicity of the lessons, and the multiple ways of presenting information.

Keywords: cloud computing, cloud labs, Cisco Network Academy, Apache CloudStack, EVE-NG Community Edition, Rasch model

1. Introduction

The preparation of future professionals in computer science is a vital and challenging task, especially for computer science teachers [14, 18]. They need to be equipped with the skills and knowledge to cope with the demands of the global digital world. One way to enhance their learning is to use e-learning systems [20, 27, 29], which can provide access to various educational resources and opportunities. However, more than e-learning systems are required, as they may need to foster more independent work and student engagement.

Open education is a concept that aims to overcome these limitations by offering massive open online courses (MOOCs) [8, 25]. MOOCs are online courses open to anyone who wants

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to learn and provide various benefits such as flexibility, diversity, interaction, feedback and reflection. Cisco Network Academy is a similar initiative that offers online courses in computer networking and related fields. Cisco Network Academy is a social responsibility program of Cisco, a leading company in the IT industry. The program allows any educational institution to host Cisco courses and provide students access to high-quality curriculum materials and certification exams.

Cisco Network Academy courses effectively teach computer science students [10]. However, one of the challenges of these courses is to provide students with access to the objects of study, such as network devices, security tools and development platforms. This is especially relevant for cybersecurity and network applications development courses, which require complex and dynamic environments for learning and practice. Cloud technologies can solve this challenge by enabling the virtualisation of the objects of study in the cloud labs.

This paper aims to present the model of cloud labs as learning tools in Cisco CyberSecurity Operations and DevNet Courses and to investigate the students' feedback on these labs.

2. Results

As the experience of a secondary school shows, an informatics teacher is the leading ICT specialist. In providing information security [17], he balances 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 providing 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 monitor changes and adjust learning objectives constantly.
- Deployment virtual machines. In this case, the training takes place in an artificially created environment, created specifically for this course and containing 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 analysed the available free courses, we chose CCNA Cyber Operations [4] as a basic course for forming teachers' cybersecurity competencies. By the end of this course, the students will be able to:

- Install virtual machines to analyse 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.
- Analyse 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.
- Analyse 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.

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 the mentioned courses.

Each chapter reviews terms and concepts, quizzes, labs, and exams. While teaching the course, we met with the problem of organising laboratory work. Cisco Network Academy offers to run them on virtual student machines. This approach is justified, but it limits students' universal and everywhere access to study. Using separate virtual machines does not ensure students' cooperation between themselves and the teacher.

An effective way to overcome these limitations is to use the cloud technologies. Bykov and Shyshkina [3] note that the development of cloud computing technologies, adaptive information and communication network services, and virtual and mobile learning facilities are essential steps 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 the demonstration of them on the concrete examples [11–13, 15, 16, 19, 21–24, 26, 28]. Glazunova and Shyshkina [7] distinguishes the following levels of the University Cloud-based Learning and Research Environment: physical, level of virtualisation and virtual resource management, and 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 corporate cloud platforms are widely using virtualisation technology, we see the deployment of cloud laboratories on their basis.

After analysing the interpretation of Bykov et al. [2], we note that the cloud laboratory is an information system in which network virtual ICT objects are formed thanks to a special user interface 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. [5] 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 using 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 [6] explore the concept of cloud laboratories as common spaces that integrate applications. Researchers are also studying the problem of integrating MOOCs into the learning environment. They note that cloud labs can enable the implementation of connectivist MOOCs, allowing teachers or students to collect and monitor 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 can carry out any experiments, not limited to a previously prepared set of results. Thanks to the virtualisation technology of operating systems, the last approach should be tried to implement in the designed laboratory. Cloud virtualisation technologies provide unique opportunities for the learning organisation 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, 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. These 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 can store their virtual computers and other devices in their personal or several guest networks.

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

Every student's copy of the EVE-NG platform is a separate virtual machine in the Apache CloudStack cloud. Each EVE-NG node is a virtual machine, so hosts integrated into Apache CloudStack infrastructure must support nested virtualisation.

The laboratory work involves using such virtual machines: CyberOps WorkStation (based on Arch Linux), Kali Linux, Security Onion (based on Ubuntu Linux), Metasploitable, and Windows Client.

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

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

 https://doi.org/10.55056/cte.665

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 shown in figure 1.

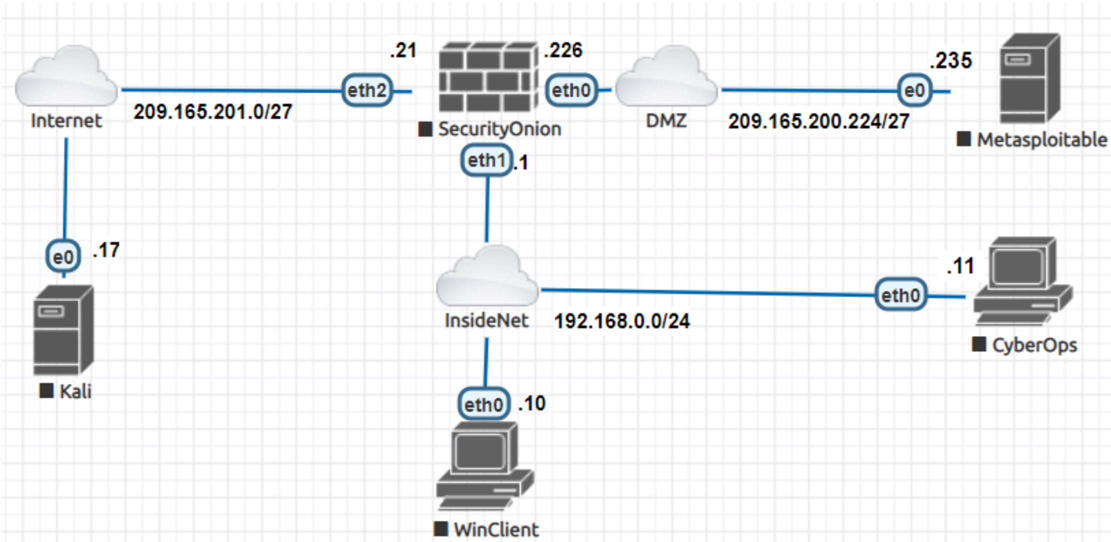

Figure 1: The network topology for labs.

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 in the classroom and online.

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

1. Introduction. The module is devoted to the organisation of the learning environment. Since students will be working in a cloud lab, we slightly modified this section. In

particular, they explained how to deploy a VM, what its parameters should be specified, and 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. The 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. Students use code to configure, deploy, and manage applications with the compute, storage, and network infrastructures and services in this topic.
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.

The course offers 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, and found messages with the city's name. In the next step, the script called the MapQuest service API to determine the city's geographical coordinates. Another step was determining the nearest time to observe the International Space Station in this city. In the last step, the chatbot sent a message to the Webex Teams room.

After taking these courses, students completed the final exam. He contained 60 questions from all the topics of the course, as well as fragments of laboratory work. Fifty-six 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 students' ratings 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 into five 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 latent variable scale was used. This is one of the

Table 1
List of distractors (items) in the 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	Analyse 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

models of Rasch's family, which is used in the case of polytomous indicators.

In the modern Item Response Theory (IRT), Rasch's model allows us to assess the meaning of latent variables, investigate the relationship between them, and identify factors that influence the behaviour of latent variables. IRT is based on the theory of latent-structural analysis: the final score results from the combined interaction of latent parameters – the actual level of preparation of students and the complexity of the questions (tasks). This approach to evaluating 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.

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

[1]:

1. The difficulty of tasks and the level of preparedness of persons being tested can be measured on one scale with a common standard unit of measurement.
2. In the presence of such a scale, the probability of the test person's correct answer 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, then the probability of his correct answer to the task of a fixed level of complexity should be higher.

The unit of measurement, called logit, measures the complexity of tasks and the level of knowledge. In our research, we used the WINSTEPS program. The program is commercial, but it is a free version called MINISTEP. It allows one 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) [30].

Standardised Residuals in Rasch's model are modelled 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 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 the 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 measure the same property (quality). The coefficient's high value indicates 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.

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 characterise the correspondence of the data to Rasch's model. In the MNSQ (mean-square statistic) field, the statistics of the correspondence of the output data to the measuring model are shown based on the average sums of the squares of the deviations of the theoretical values from the empirical ones. The MNSQ values characterise 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 are 0.5 to 1.5. Higher values (> 1.5) indicate uncertainty and "noise" in input data. Too low values (<0.5) are also not desirable because they indicate excessive, "information overload" of the instrument. In the ZSTD field, the standardised MNSQ values are shown (with an average of 0 and a standard deviation of 1). Valid value is $-2.0 \leq$ ZSTD $\leq +2.0$.

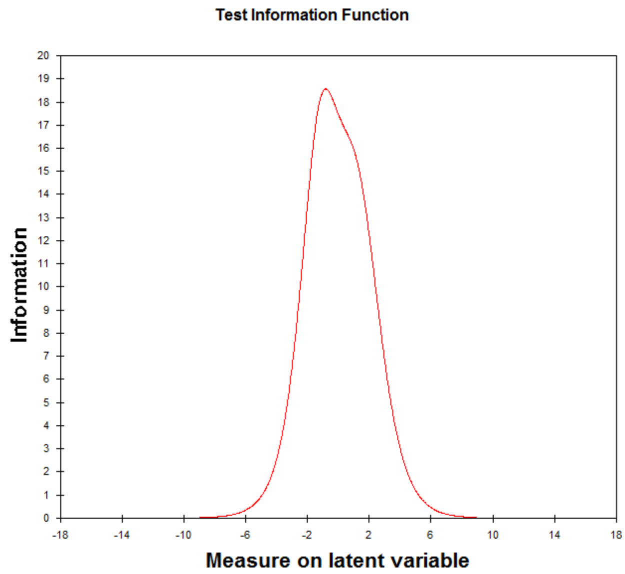

Figure 2: Information function.

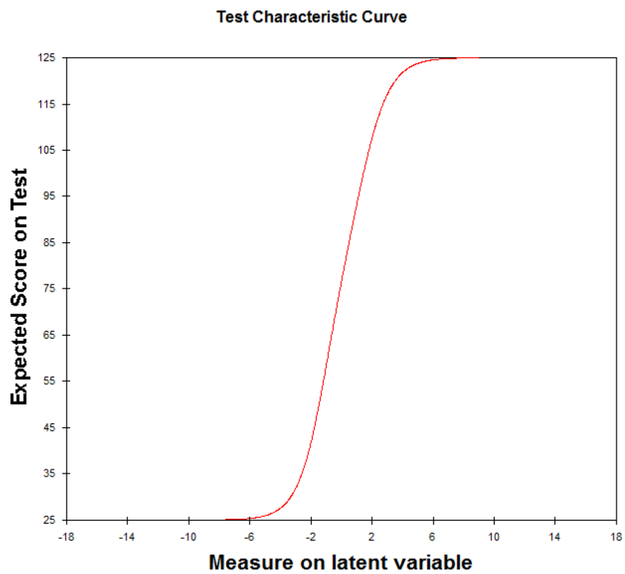

Figure 3: Characteristic function.

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 are satisfactory – this is evident from the second bar graph in figure 4. However, respondents' answers to the questions posed need to be balanced.

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

	Total Score	Count	Measure	Model S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	MNSQ
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 items).

	Total Score	Count	Measure	Model S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	MNSQ
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

This means that some respondents answered randomly or needed help to orient themselves with the choice of an adequate response.

The following conclusions can be drawn by analysing table 4 regarding the distractors included in the poll. 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 significant 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 distractors at the content level will allow for the adjustment of the structure of some components in the design of virtual cloud labs for learning Cisco CyberSecurity Operations.

We used the R language in the RStudio environment to analyse the study data further. 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 [9]. This open-source software is helpful 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 visualise the data. Here is the function call:

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

where

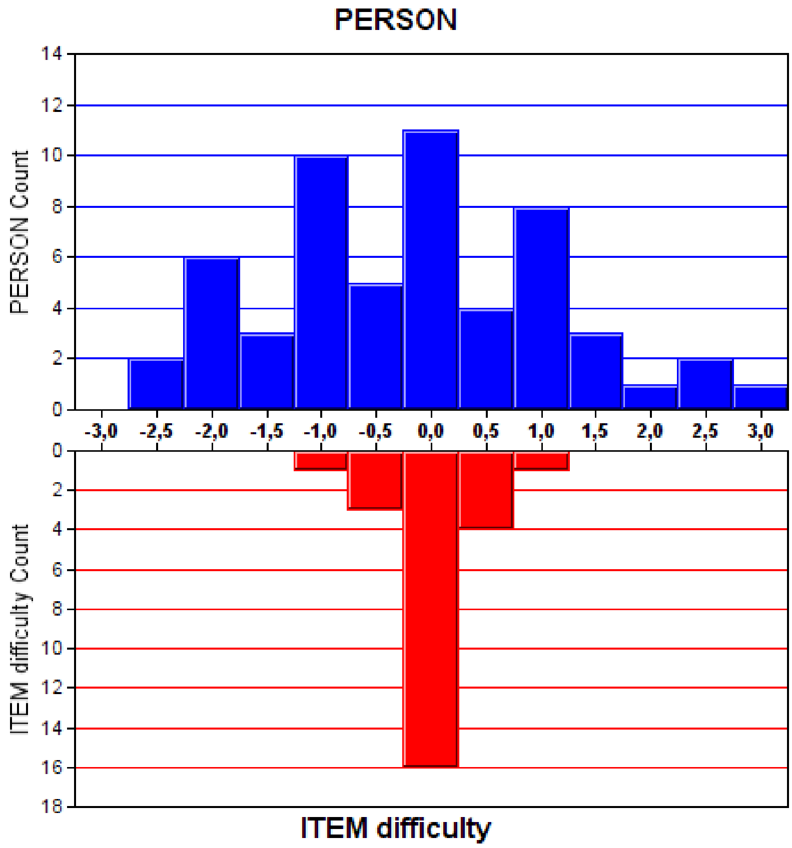

Figure 4: The relationship between the efficiency level of the designed and deployed cloud-based virtual lab and the indicator variables.

- expdata is a data frame with students' grades (link was provided above).
- itemtype is a type of item to be modelled. 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 header extracts the vector d from the entire data frame. 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 because the proposed approach to studying disciplines is innovative. Therefore, there is vigilance and caution for 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 following function.

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	

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

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 the formulated questions were the most informative for students with an average level of preparation or slightly higher. The shape of the information curve (bell-shaped) indicates that the distractors were selected correctly and their description was made correctly.

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

As can be seen from these graphs, the probability of putting 1 point in students with a low level of preparation and 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. Nevertheless, this is due to most students' higher frequency of averaging.

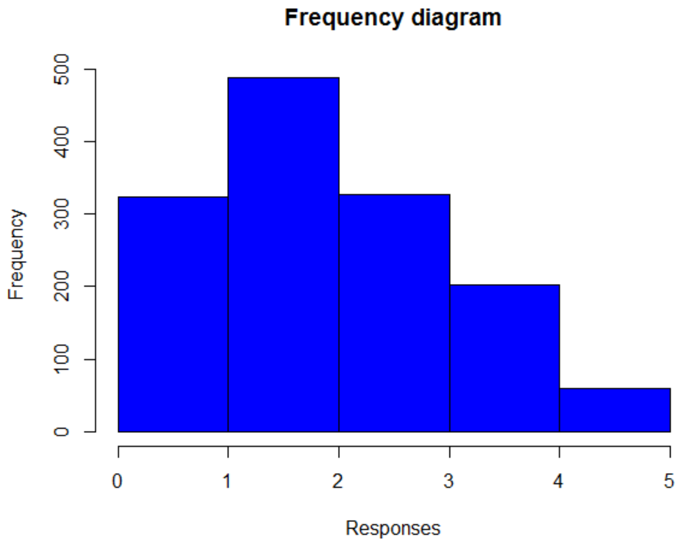

Figure 5: Histogram of response frequencies.

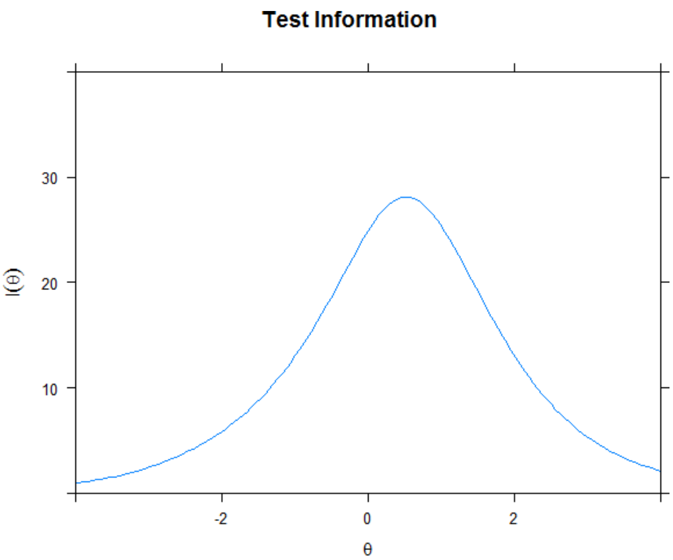

Figure 6: Graph of the information function of the questionnaire.

4. Conclusions

This paper addressed the issue of integrating cloud-based tools and open online courses in the training of future computer science teachers. Cloud labs are an effective way of providing students with access to virtual objects of study in the courses of Cisco Network Academy. The paper presented two cloud labs designed and implemented for the Cisco CyberSecurity Operations and DevNet Associate Fundamentals courses.

The Cisco CyberSecurity Operations course covers cybersecurity fundamentals and prepares

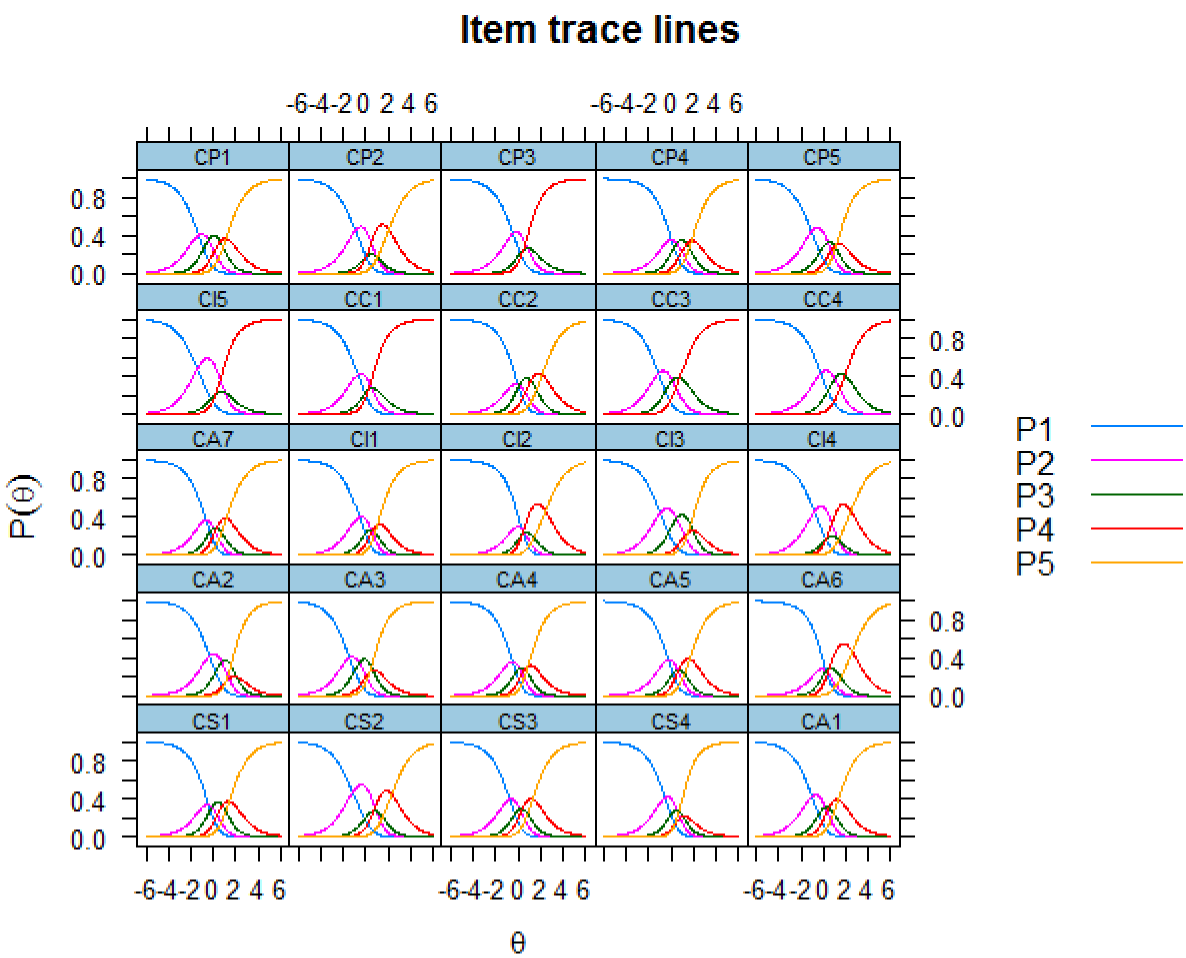

Figure 7: Characteristic curves of response levels.

students for the CCNA CyberOps certification exam. The course comprises theoretical materials, quizzes, discussions, labs, chapter exams and a final exam. The cloud lab for this course was built using Apache CloudStack and EVE-NG Community Edition platforms, which allow the creation and management of various virtual machines and network topologies. The cloud lab enables the students to simulate the work of real computers and networks, analyse traffic and security incidents, store their state, work remotely through a VPN, collaborate with other students and receive feedback and assistance from the instructor.

The DevNet Associate Fundamentals course teaches students how to develop network applications using modern APIs and automation tools. The course also integrates networking and programming concepts and provides practical exercises. The cloud lab for this course offers the students the opportunity to run VMs with basic development tools, create and test their applications, access data from the clouds, and automate the deployment of network and cloud infrastructures.

The paper also reported the students' feedback on the cloud labs based on a survey of students majoring in Secondary Education (Computer Science). The survey results were statistically analysed using the Rasch model with MiniSteps software and R language. The students expressed high satisfaction with the cloud labs and the online curriculum materials from Cisco Network Academy. The students appreciated the functionality and accessibility of the virtual objects of study, as well as the clarity and simplicity of the lessons.

The paper has some limitations, such as the small sample size of the students who participated in the experiment, which did not allow a qualitative comparison between the control and experimental groups. However, the paper demonstrates that cloud labs are a valuable tool for enhancing computer science students' learning outcomes and experience in Cisco Network Academy courses.

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