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Serhiy Semerikov

Viacheslav Osadchyi

Olena Kuzminska

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BRIEF CONTENTS

| | |
|-----------------------------|----|
| ORGANIZING COMMITTEES | IV |
| FOREWORD | IX |
| CONTENTS | XI |

CONTENTS

PAPERS

FULL PAPERS






- Online Training of Youth Club Members of Ukraine in Projecting Volunteer Activities in the Conditions of the Spread of COVID-19 5
Oleksandr Kucheryavii, Dmytro Gryshchuk and Olena Glazunova
- The Psychological Safety of the Educational Environment of Ukrainian Higher Education Institutions in a Pandemic: Empirical Data of a Comparative Analysis of Participants' Assessments Studying Online 14
Olena Bondarchuk, Valentyna Balakhtar, Yuriy Ushenko, Olena Gorova, Iryna Osovska, Nataliia Pinchuk, Nataliia Yakubovska, Kateryna Balakhtar and Maksym Moskalov
- Strategic Branches of Economic and Managerial Training of Principals in Ukraine using Business-simulations 32
Vitalii Pazdrii, Viktoriya Kuprievych and Svitlana Lytvynova
- Training on Gender Mainstreaming in Project Management: Case of International Donor Programs and Projects for Ukrainian Local Communities' Development 39
Galina Berezhna, Olena Aleinikova, Oksana Kovtun, Hanna Danylchuk, Vitalina Babenko and Pavlo Nechypurenko
- Development of Heads' Personal Readiness of Vocational Education Institutions for Managerial Activity in the Conditions of Distance Postgraduate Education 61
Nataliia Pinchuk, Svitlana Kazakova, Yuriy Ushenko, Ivan Pustovalov, Nataliia Hordienko, Oksana Anufrieva, Olena Prokopenko, Oleksandra Pinchuk and Olga Fliarkovska
- Creativity of Foreign Languages Teachers in Ukrainian Higher Education Institutions: Empirical Data 81
Kateryna Balakhtar, Olena Bondarchuk and Serhii Ostapov
- Build a Technology for Mass Organization of Distance Learning for Pupils in Quarantine 97
Oleg Spirin, Kateryna Kolos, Olena Kovalchuk, Olena Demianchuk and Feliks Zhuravlev
- CoCalc Tools as a Means of Open Science and Its Didactic Potential in the Educational Process 109
Pavlo Merzlykin, Maiia Marienko and Svitlana Shokaliuk
- The Method of Teaching Graphic 3D Reconstruction of Architectural Objects for Future IT Specialists 119
Ihor Hevko, Olha Potapchuk, Iryna Lutsyk, Viktorya Yavorska, Lesia Hiltay and Oksana Stoliar
- Selection Cloud-oriented Learning Technologies for the Formation of Professional Competencies of Bachelors Majoring in Statistics and General Methodology of Their Use 132
Tetiana Vakaliuk, Olga Gavryliuk, Valerii Kontsedailo, Vasyl Oleksiuk and Olga Kalinichenko
- Introspection as a Condition of Students' Self-management in Programming Training 142
Liudmyla Bilousova, Oleksandr Kolgatin, Larisa Kolgatina and Olena Kuzminska
- Digital Educational Environment of Teachers' Professional Training in Pedagogical University 154
Nadiia Balyk, Galyna Shmyger, Yaroslav Vasylenko and Vasyl Oleksiuk

| | |
|--|-----|
| Development of Professional Competence of Primary School Teachers of the New Ukrainian School in the Aspect of Foreign Language Teaching <i>Inna Kravtsova, Alina Kravtsova, Vita Hamaniuk, Olga Bilozir and Andrei Voznyak</i> | 167 |
| The Use of Software and Hardware Arduino for the Students' Formation of Research and Engineering Competencies <i>Vitalii Zadorozhnii and Nataliia Valko</i> | 188 |
| Social Media as a Strategic Tool in School Management: Experience of Ukraine and USA <i>Liubov Kartashova, Nataliia Prykhodkina, Tetiana Makhynia, Hanna Tymoshko, Olena Sholokh and Feliks Zhuravlev</i> | 196 |
| Methodology of M. Montessori as the Basis of Early Formation of STEM Skills of Pupils <i>Iryna Slipukhina, Arkadiy Polishchuk, Sergii Mienailov, Oleh Opolonets and Taras Soloviev</i> | 211 |
| The Role of Media Literacy in the Conditions of Information Risks: Specifics of Educational Communicative Experience 2020 Regarding the Freedom of Media Communication and Social Isolation <i>Iryna Pokulyta, Olha Sotska and Ivan Riznitskii</i> | 221 |
| Prospects of Quantum Informatics and the Study of Its Basics in the School Course <i>Liudmyla Lehka, Andrii Bielinskyi, Svitlana Shokaliuk, Vladimir Soloviev, Pavlo Merzlykin and Yelyzaveta Bohunencko</i> | 233 |
| The Use of Ensemble Classification and Clustering Methods of Machine Learning in the Study of Internet Addiction of Students <i>Oksana Klochko, Vasyl Fedorets, Vitalii Klochko and Maryna Kormer</i> | 241 |
| Theoretical Bases of Application of Free Software in Preparation of Pre-service Teachers of Mathematics, Physics and Computer Science <i>Vladyslav Velychko, Elena Fedorenko and Olga Serdiuk</i> | 261 |
| The Problem of the Limitations of the Educational Model Experiment on Population Genetics and Its Solution <i>Elena Komarova and Arnold Kiv</i> | 272 |
| The Evolution of the Information and Educational Environment in the Context of the Theory of Generational Development <i>Aleksander Spivakovsky, Lyubov Petukhova, Serhii Omelchuk, Yevheniia Spivakovska, Vira Kotkova and Yuriy Yurchuk</i> | 287 |
| Structural Equation Modeling in Educational Research: A Case-study for PhD Training <i>Liubov Panchenko and Vladyslav Velychko</i> | 300 |
| Cloud Labs as a Tool for Learning Cisco CyberSecurity Operations and DevNet Associate Fundamentals Courses <i>Nadiia Balyk, Yaroslav Vasylenko, Vasyl Oleksiuk, Olesia Oleksiuk and Galina Shmyger</i> | 308 |
| Using the Virtual Chemical Laboratories in Teaching the Solution of Experimental Problems in Chemistry of 9th Grade Students While Studying the Topic "Solutions" <i>Pavlo Nechypurenko, Tetiana Selivanova, Maryna Chernova, Olga Evangelist, Yevhenii Modlo and Vladimir Soloviev</i> | 319 |
| Using Dynamic Vector Diagrams to Study Mechanical Motion Models at Agrarian University with GeoGebra <i>Leonid Flehantov, Yuliia Ovsienko, Anatolii Antonets and Vladimir Soloviev</i> | 336 |

| | |
|---|-----|
| Professional Training of Bachelors in Information Technologies based on Education for Sustainable Development Principles <i>Serhii Koniukhov, Iryna Krasheninnik, Kateryna Osadcha, Evgeniy Lavrov and Olha Kotova</i> | 354 |
| The Values of Biological Education from the Point of View of 2020 Events (or Biotechnological Human Improvement through the Eyes of Students) <i>Elena Komarova and Arnold Kiv</i> | 365 |
| The Learning-style-based Approach and Optimal Use of e-Resources in Teaching Ecological Disciplines <i>Tetiana Derkach, Tetiana Starova and Alexander Krajnikov</i> | 381 |
| Experience of using ICT Tools for Monitoring the Psychological Component of the Quality of Teacher's Activity of the Higher Education Institutions <i>Olena Bondarchuk, Valentyna Balakhtar, Kateryna Balakhtar, Valeriy Kyrichuk, Nataliia Yakubovska, Serhii Ostapov and Tamara Grubi</i> | 400 |
| Analysis and Application of Semantic Networks in Education <i>Arnold Kiv, Vladimir Soloviev, Elena Tarasova, Tetyana Koycheva and Katrina Kolesnykova</i> | 416 |
| The Practical Experience of the Use of Digital Learning Resources by Ukrainian Teachers to Ensure the Sustainable Development and Democratization of Education Process <i>Oksana Ovcharuk, Iryna Ivaniuk, Oleksandr Burov, Maiia Marienko, Nataliia Soroko, Olena Gritsenchuk and Oksana Kravchyna</i> | 432 |
| Methodology for using Cloud-oriented Environment for Flipped Learning of the Future IT Specialists <i>Olena Glazunova, Valentyna Korolchuk, Oleksandra Parhomenko, Tetiana Voloshyna, Natalia Morze and Eugenia Smyrnova-Trybulska</i> | 445 |
| The Criteria of Usability Design for Educational Online Courses <i>Kateryna Vlasenko, Sergii Volkov, Iryna Lovianova, Irina Sitak, Olena Chumak, Serhiy Semerikov and Nataliia Bohdanova</i> | 461 |
| Methodical Recommendations for the Development of Online Course Structure and Content <i>Kateryna Vlasenko, Irina Sitak, Daria Kovalenko, Sergii Volkov, Iryna Lovianova, Serhiy Semerikov and Serhiy Zahrebelnyi</i> | 471 |
| Content Analysis of Course Books and Online Courses for Teaching English for Specific Purposes for IT Professionals <i>Svitlana Symonenko, Nataliia Zaitseva, Kateryna Osadcha and Olena Kuzminska</i> | 486 |
| Modelling in GeoGebra in the Context of Holistic Approach Realization in Mathematical Training of Pre-service Specialists <i>Liudmyla Bilousova, Liudmyla Gryzun, Svitlana Lytvynova and Valentyna Pikalova</i> | 499 |
| Use of YouTube Resources in the Process of Training German Language Teachers <i>Olha Chorna, Vita Hamaniuk, Oksana Markheva, Andrei Voznyak and Aleksandr Uchitel</i> | 511 |
| Ontological Approach to the Presentation of the Subject Area of the Discipline <i>Ivan Tsidylo, Serhii Kozibroda, Oleksii Sysoiev, Tetiana Gargula, Anatolii Hryhoruk, Lyubov Lytvyn and Andrei Voznyak</i> | 527 |
| Systematicity of Students' Independent Work in Cloud Learning Environment of the Course "Educational Electronic Resources for Primary School" for the Future Teachers of Primary Schools <i>Oleksandr Kolgatin, Larisa Kolgatina, Nadiia Ponomareva, Ekaterina Shmeltser and Aleksandr Uchitel</i> | 538 |

| | |
|--|-----|
| Data Science in Economics Education: Examples and Opportunities <i>Nina Rizun, Maryna Nehrey and Nataliia Volkova</i> | 550 |
| Integration of Modern Higher Education into the Global Information Space <i>Elena Fedorenko, Vladyslav Velychko, Olha Naboka, Olena Havrysh and Hennadiy Kravtsov</i> | 565 |
| Digital Technologies in Specialized Mathematics Education: Application of GeoGebra in Stereometry Teaching <i>Tetiana Kramarenko, Olha Pylypenko and Olga Serdiuk</i> | 576 |
| An Experiment on the Implementation the Methodology of Teaching Cloud Technologies to Future Computer Science Teachers <i>Vasyl Oleksiuk, Olesia Oleksiuk and Tetiana Vakaliuk</i> | 590 |
| Familiarity with Free Software through Online Services <i>Vladyslav Velychko, Svitlana Omelchenko, Elena Fedorenko and Hennadiy Kravtsov</i> | 605 |
| The Use of Moodle in the Teaching of Philosophy and Distance Learning <i>Andrii Abdula, Halyna Baluta, Nadiia Kozachenko, Darja Kassim and Feliks Zhuravlev</i> | 616 |
| Applied Technology of Fiction and Non-fiction Conceptual Presentation via ICT Tools: Pedagogical Function of Graphic Mimesis <i>Rusudan Makhachashvili, Svetlana Kovpik, Anna Bakhtina, Nataliia Morze and Ekaterina Shmeltser</i> | 631 |
| Experimental Verification of Efficiency of the Formation of Information and Digital Competence of Bachelors of Primary Education based on an Integrated Approach <i>Olga Yaroshenko, Olena Samborska and Arnold Kiv</i> | 644 |
| Development of Augmented Reality Mobile Application in Physics to Study the Electric Circuit <i>Oleksandr Kanivets, Irina Kanivets, Tetyana Gorda and Oleksandr Burov</i> | 653 |
| Possibilities of using the Game Simulator Software Inc in the Training of Future Software Engineers <i>Tetiana Vakaliuk, Valerii Kotsedailo, Dmytro Antoniuik, Olha Korotun, Serhiy Semerikov, Iryna Mintii and Olga Kalinichenko</i> | 665 |
| Digital Technology Implementation for Students' Involvement Base on 3D Quest Game for Career Guidance and Estimating Students' Digital Competences <i>Oleksandr Prokhorov, Vladyslav Lisovichenko, Mariia Mazorchuk and Olena Kuzminska</i> | 676 |
| 360° Photographic Panoramas as an Effective Multifunctional Aid for Teaching Technology Subjects <i>Igor Barkatov, Volodymyr Farafonov, Valeriy Tiurin, Serhiy Honcharuk, Andrei Lozko, Volodymyr Marushchenko, Kostyantyn Korytchenko, Vitaliy Barkatov and Roman Muravlyov</i> | 691 |
| Professional Preparation of Future Teachers of Vocational Training in the Transport Area of Expertise with Use of the Author's Educational Application <i>Mykhailo Pohorielov, Olena Lavrentieva, Volodymyr Bondarenko, Igor Britchenko, Andrii Dorohan and Aleksandr Uchitel</i> | 702 |
| Teaching Foreign Language Professional Communication using Augmented Reality Elements <i>Svitlana Amelina, Rostyslav Tarasenko, Serhiy Semerikov and Yuliya Kazhan</i> | 714 |
| Using the Augmented/Virtual Reality Technologies to Improve the Health-preserving Competence of a Physical Education Teacher <i>Oksana Klochko, Vasyl Fedorets, Mariya Shyshkina, Tetiana Branitska and Nina Kravets</i> | 726 |

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

Nadiia R. Balyk¹^a, Yaroslav Ph. Vasylenko¹^b, Vasyl P. Oleksiuk^{1,2}^c, Olesia R. Oleksiuk³^d and Galina P. Shmyger¹^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 Courses) (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>

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.

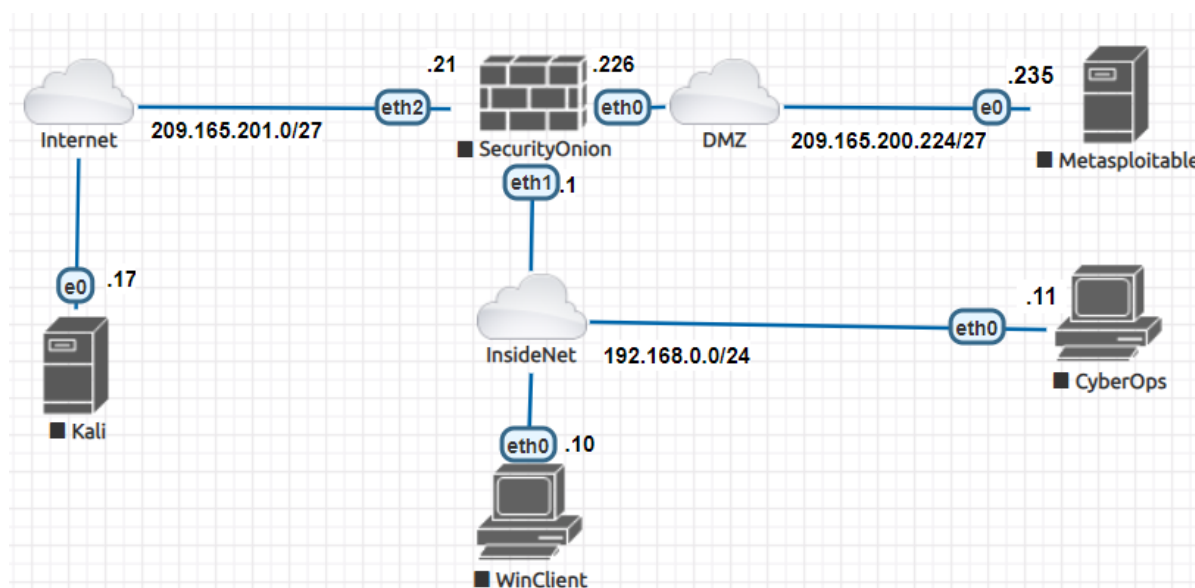


Figure 1: The network topology for labs.

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 Cloud-Stack 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 $\alpha=0.96$.

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

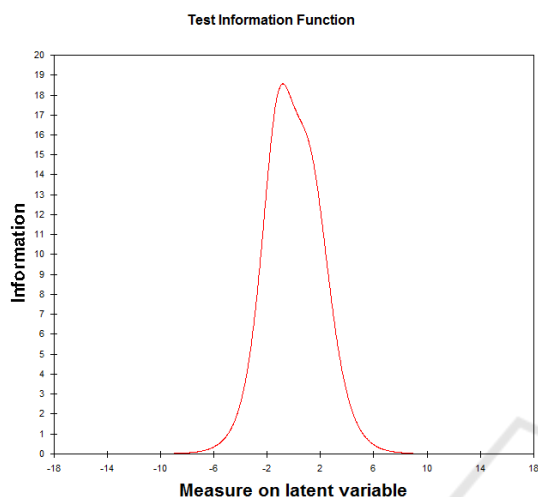


Figure 2: Information function.

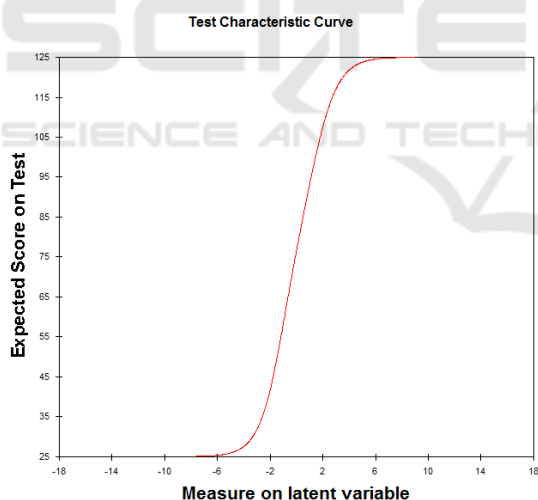


Figure 3: Characteristic function.

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 |

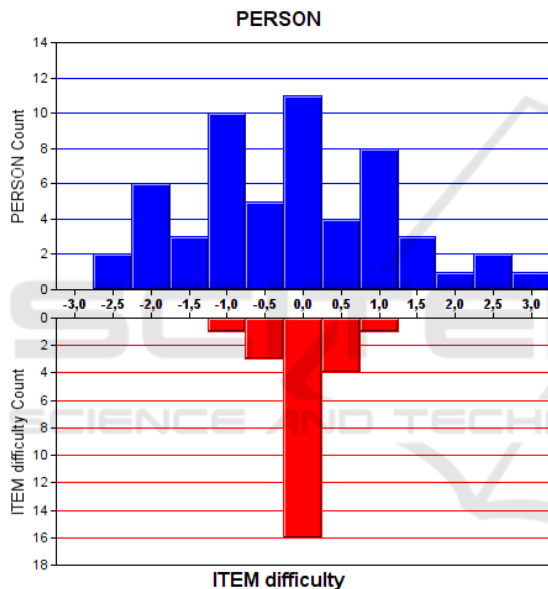


Figure 4: The relationship between the level of efficiency of the designed and deployed cloud-based virtual lab and the indicator variables.

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 | |

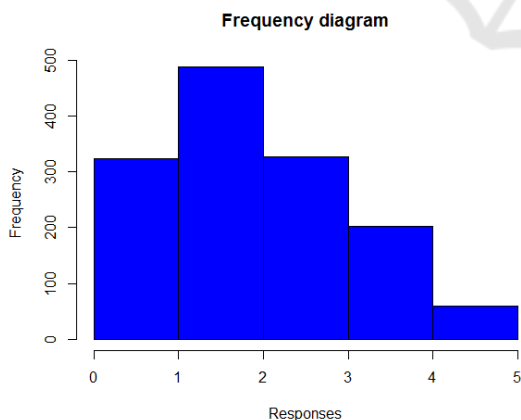


Figure 5: Histogram of response frequencies.

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 infor-

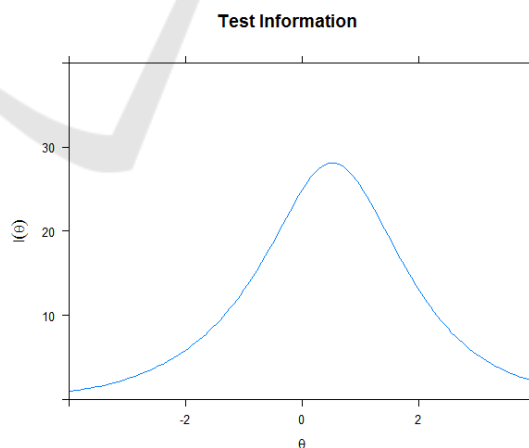


Figure 6: Graph of the information function of the questionnaire.

mativ. 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.

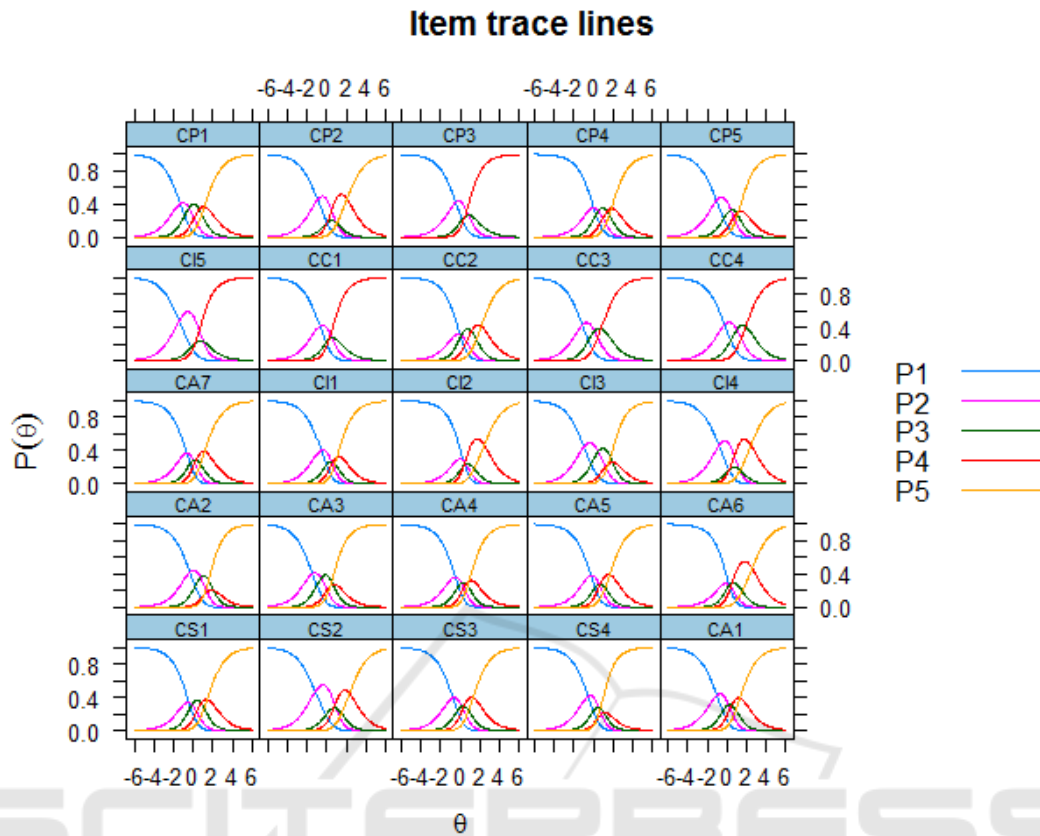


Figure 7: Characteristic curves of response levels.

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.

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