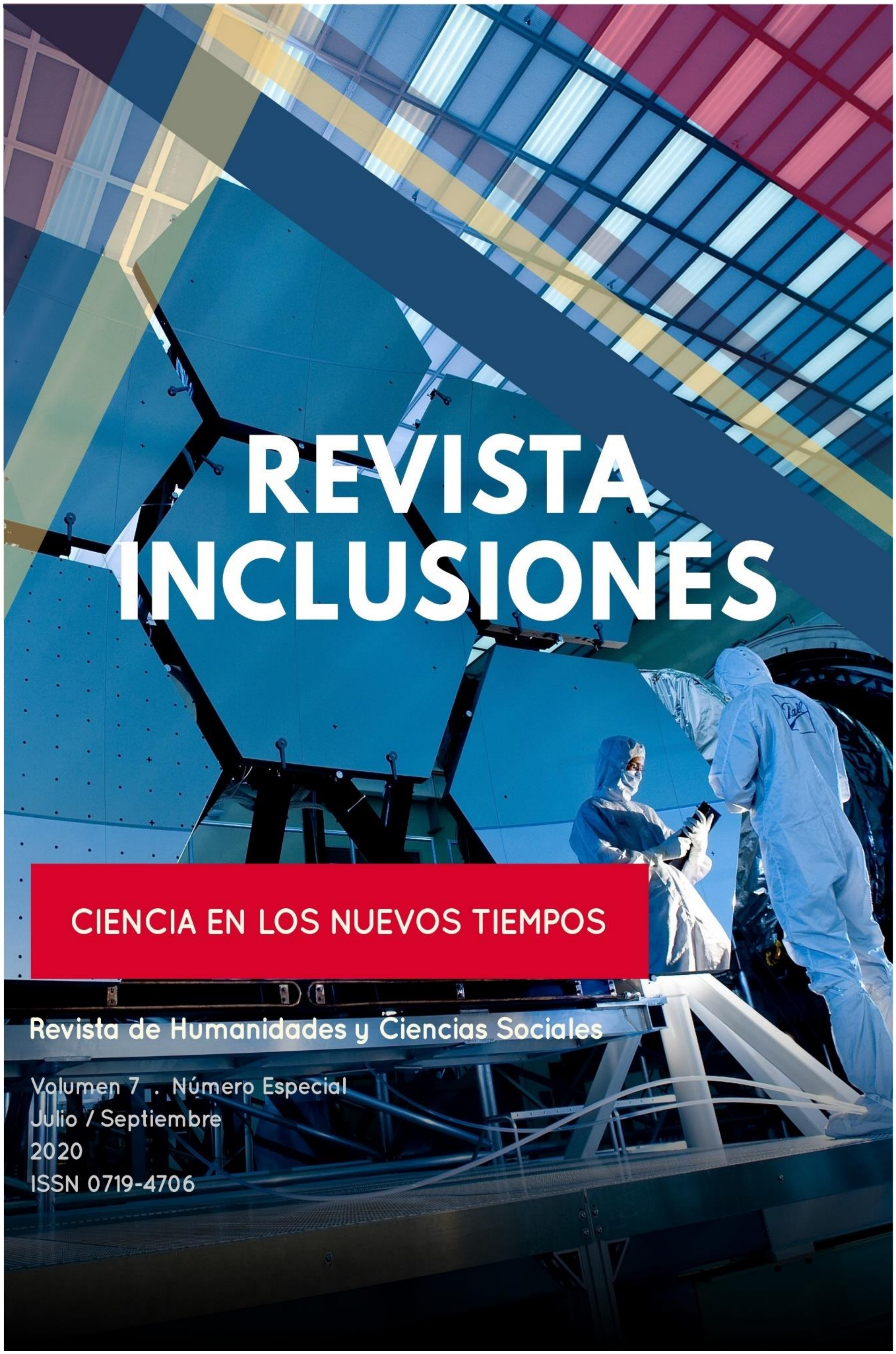
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VISUALIZATION TECHNOLOGIES IN THE STUDY OF COMPUTER SCIENCE BY UNIVERSITY STUDENTS: IMPROVEMENT OF EDUCATIONAL SUCCESS

Lic. Julia V. Stepanova
St. Petersburg State University, Russian Federation
ORCID ID: 0000-0002-9710-3246
stepanova7.93@mail.ru
Ph. D. (C) Igor Mikhailovich Tararin
State University of Management, Russia
ORCID ID: 0000-0002-0822-1073
Igor-tararin@rambler.ru
Ph. D. Nina Valentinovna Kudryashova
Russian State Social University, Russian Federation
ORCID: 0000-0002-0504-9570
ninakudryashova60@gmail.com
Ph. D. (C) Diana Igorevna Stepanova
Plekhanov Russian University of Economics, Russia
ORCID ID: 0000-0001-5981-6889
s_diana@mail.ru
Ph. D. (C) Vitaliy Viktorovich Belobragin
Russian Academy of Natural Sciences, Russia
Institute of Economics and Culture, Russia
ORCID ID: 0000-0003-1086-2440
vvbelobragin@mail.ru

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Abstract

The rapid penetration of ICT into human life and the overload of information flows require modern education to adopt new technologies, change educational methods, present educational information, and introduce new educational technologies that would be effective in today's conditions. This article shows the relevance of the educational process visualization, characterizes visualization technologies as a tool to increase the success of learning, determines the essence of visualization in education, and gives a description of virtualization as one of the technological trends in the visualization of education. Due to the experimental study of the use of virtualization technologies of operating systems in the discipline "Computer Science Fundamentals", it is concluded that their use leads to the increase in the success of student learning.

Keywords

Visualization – Augmented reality – Virtualization – Computer Science Fundamentals

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Introduction

Over the past half-century, the world has undergone revolutionary changes in all areas of science and technology. Such transformational changes directly affected the education sectors. Modern youth significantly differs from previous in terms of the way of thinking, the speed of development, and the ability to learn on the Internet[1]. Such a generation has "clip" thinking and perceives the world as a series of practically unrelated events and facts, thinks globally, asks questions rather than receives answers to them, and spends more time with electronic devices than with peers. It would seem that the current world of information excess should increase the intelligence of the younger generation but often has the exact opposite effect, and young people don't have time to absorb and use the incoming information[2].

Considering the features of the modern digital generation, which has formed fundamentally different ways of receiving, perceiving, and assimilating information, the ways of thinking and understanding have changed. Compared with previous generations, there is a rejection of verbal ways of presenting material and the presence of "clip" thinking aimed at a vivid visual image. According to researchers, it is appropriate to consider these features and provide an opportunity to submit and assimilate educational material in a convenient visual form[3].

The visualization of educational information is based on the use of the visual system and the innate ability of the human brain to work effectively with visual images. The human visual system is dominant not only because it acts as the most important source of information about the world but also because it plays the role of an internal communication channel between all analyzers and is a functional organ — a signal converter[4]. The visualization of information allows translating the educational information coming through different channels of perception into a visual form, which increases the speed of processing and assimilation of the material due to the most effective ways of working with it[5].

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[1] A. D. Matraeva; M. V. Rybakova; M. V. Vinichenko; A. A. Oseev y N. V. Ljapunova, "Development of Creativity of Students in Higher Educational Institutions: Assessment of Students and Experts", Universal Journal of Educational Research Vol: 8 num 1 (2020): 8-16 y M. V. Vinichenko; D. S. Klementyev; M. V. Rybakova; M. A. Malyshev; N. F. Bondaletova y I. V. Chizhankova, „Improving the efficiency of the negotiation process in the social partnership system", Entrepreneurship and sustainability issues Vol: 7 num 1 (2019): 92-104.

[2] M. N. Dudin; V. N. Alferov; D. Y. Taburov y G. N. Nikolaeva, "Labor market and transformation of labor relations in the light of the marxist, libertarian and neoinstitutional paradigm", Journal of interdisciplinary research Vol: 9 num 2 (2019): 31-38 y V. V. Ryabov; V. V. Kirillov; R. G. Rezakov y N. I. Muzafarova, "International practice of professional integration of People with Disabilities: Educational Programs", Revista Inclusiones Vol: 7 num Especial Enero-Marzo (2020): 42-53.

[3] M. S. Kukhta, Vospriyatie vizualnoi informatsii: filosofiya protsessa (Tomsk: Izd-vo TGPU, 2004); J.-W. Ahn y P. Brusilovsky, "Adaptive visualization of search results: Bringing user models to visual analytics", Information Visualization Vol: 8 num 3 (2009): 167-179; J. Gilbert, "Visualisation: a metacognitive skill in science and science education", Visualisation in Science Education (2005): 9-27 y N. A. Pervushina, "Uspeshnost vizualizatsii informatsii v protsesse obucheniya", Nauchno-pedagogicheskoe obozrenie Vol: 2 num 2 (2013): 30-35.

[4] D. Roem, Vizualnoe myshlenie. Kak «prodavat» svoi idei pri pomoshchi vizualnykh obrazov (Moscow: Eksmo, 2013), 300.

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Researchers consider the concept of visualization from different sides. Thus, T.T. Sidelnikova notes that visualization is a way of recording and transmitting information, not only complementing but also serving as an alternative to verbal and written communication[6]. Psychologists and philosophers turn their attention not only to the role of visualization in the convenience of perceiving information but also emphasize its developing character in the human mental processes. According to researchers[7], the conversion of information into visual images leads to a deeper understanding, generalization, and effective perception of information by a person.

Researchers[8] pay attention to the convenience, accessibility, and advantage of using visualization in the presentation of educational information and its developing role in maintaining the student's mental processes in the implementation of educational activities. As a result of the use of visual images, emotional and imaginative components of thinking are activated. This provides cognitive structuring of the content of knowledge, cognitive modelling of the elements of activity structure and processes of objects interaction, as well as the construction of new thought patterns and new visual forms necessary for the study and understanding of the surrounding reality and universal values.

N.N. Manko writes that "by making the meaning visible", visualization provides the mobilization of the resources of the learner's figurative, logical, and integrated thinking, as well as the aesthetic, cultural, and artistic potential and other important properties and qualities of their personality[9].

In the studies of E.A. Makarova[10], it is noted that visualization allows actualizing various forms of thinking: visual-effective, figurative, associative, etc. It supplements and develops auditory perception in verbal learning, activates various types of memory — verbal-logical, visual-figurative, emotional, etc. However, most importantly, visualization stimulates the comprehension, generalization, and refinement of perceived images and ensures the completeness and integrity of their perception.

K.U. Hall and R. Obregon[11] pay attention to the fact that while perceiving educational material via visualization, a person can cover all the components that make up the whole with a single glance, trace possible connections between them, and categorize them according to the degree of significance and generality. All these factors, according to

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[6] T. T. Sidelnikova, "Potentsial i ogranicheniya vizualizatsii kak metoda izucheniya sotsialno-gumanitarnykh distsiplin", Integratsiya obrazovaniya Vol: 20 num 2 (2016): 281-292.

[7] J. M. Dodero; Á. M. del Val y J. Torres, "An extensible approach to visually editing adaptive learning activities and designs based on services", Journal of Visual Languages & Computing Vol: 21 num 6 (2010): 332-346 y M. Horne y E. Thompson, "The role of virtual reality in built environment education", Journal for Education in the Built Environment Vol: 3 num 1 (2008): 5-24.

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[9] N. N. Manko, Kognitivnaya vizualizatsiya didakticheskikh obektov: monografiya (Ufa, 2007).

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[11] K. W. Hall y R. Obregon, "Applications and Tools for Design and Visualization", The Technology Teacher Vol: 61 num 7 (2002): 7-11.

researchers, are the basis for a deeper understanding of the essence of new information. They facilitate the establishment of new connections between the personal experience of students and the content of abstract knowledge very distant from it and serve as a means of concretizing them.

Thus, the use of visualization technologies contributes to the solution of the main problems of modern education, precisely to the stimulation of interest in learning and the development of cognitive interest.

One of the striking and effective solutions to these issues is augmented reality. Augmented reality (virtualization) is an interactive visualization technology that complements the image of the real world with virtual elements[12].

The term "virtualization" is used in many branches of knowledge, particularly in computer science, education, philosophy, culturology, economics, sociology, psychology, etc. From the point of view of philosophy, virtualization can be described as the process of transition from actual reality to virtual (possible) reality through a specific human activity[13].

In computer science, virtualization can be interpreted in a broad and narrow sense. In a broad sense, virtualization involves creating abstractions for computing resources that users have at their disposal instead of hiding physical matches of those resources (for example, files and directories instead of sectors and tracks on disk).

At the same time, virtualization in computer science can be seen in a narrower sense as a concept that combines technologies, tools, methods, and so on, which have three main features at the same time:

(1) splitting the resources of one physical computer into several mutually independent virtual environments or combining the resources of several physical computers into one virtual environment;
(2) faster transition from one virtual environment to another;
(3) concealing real physical resources and replacing them with abstractions[14].

Some examples of virtualization technologies are virtual machines, virtual containers, virtual apps (virtual software applications), and virtual desktops. In this case, we will refer to hardware and software as the virtualization tools (VT), which in one way or another implement the three main features of virtualization mentioned above. Depending on whether we are talking about hardware or software, we distinguish between hardware and software VT[15]. Software VT is often based on hardware.

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[12] F. Sauer; A. Khamene; B. Bascle; L. Schimmang; F. Wenzel y S. Vogt, Augmented reality visualization of ultrasound images: System description, calibration and features (IEEE and ACM International Symposium on Augmented Reality, 2001) y D. Dobrilovic, B. Odadžic, “Virtualization technology as a tool for teaching computer networks. World Academy of Science”, Engineering and Technology num 13 (2008): 712-716.
[13] T. Bower, “Experiences with Virtualization Technology in Education”, Journal of Computing Science in Colleges Vol: 25 num 5 (2010): 311-331.
[14] D. Dobrilovic y B. Odadžic, “Virtualization technology as a tool for teaching computer networks. World Academy of Science”, Engineering and Technology num 13 (2008): 712-716.
[15] W. Xu; K. Madison; M. Flinn y W. Kwok, “Applying Virtualization Technology in Security Education. Procedia — Social and Behavioral Sciences num 141 (2014): 10-14 y D. L. Lunsford, “Virtualization

Virtualization in education does not necessarily involve technologies that match the above-mentioned definition. There are several means to ensure the effect of virtual reality during learning — both virtual machines, virtual containers, virtual apps (corresponding to the definition), and, for example, virtual laboratories, virtual classrooms, and virtual network communities (beyond the definition)[16].

In the course "Computer Science Fundamentals", several software and hardware virtualization technologies can be applied both locally installed in computer classes and with remote network access, including cloud services. The rapid development of virtualization technologies and the growth of available virtualization means lead to the fact that a professor should be informed about the diversity of modern VT and able to select and use VT for computer science teaching[17].

The objective of the article is to develop a method of using virtualization technologies of operating systems (OS) in education on the discipline "Computer Science Fundamentals".

The hypothesis of the research: the use of virtualization technologies of OS in teaching computer science leads to the increased success of students' learning.

According to the research results, it can be concluded that the objective set in the study has been achieved.

Methods

During the research, a complex of theoretical and empirical methods was used. Such theoretical methods were used as the analysis of monographs, articles, as well as psychological and pedagogical, methodological, and special literature on the research problem and the problem of using modern ICT; the analysis and generalization of Russian and foreign experience in teaching OS and the use of OS virtualization technologies; modelling of the educational process and pedagogical experiment in conditions of application of OS virtualization technologies.

The following empirical methods were used: pedagogical survey, conversations with teachers and students, direct and indirect observation of the process of using OS virtualization technologies, methods of statistical processing of the results of the pedagogical experiment and their analysis (the Student and Fisher criteria).

The objective and tasks of the application of virtualization technologies of OS in the course "Computer Science Fundamentals" were based on the creation of conditions for the formation of scientific and practical skills of students related to the knowledge of the theoretical foundations of the structure and functioning of OS. According to the objective, we formulated tasks, scientific and academic, and professional practical competencies which are to be formed, as well as the results of education (Table 1):

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technologies in information systems education", Journal of Information Systems Education Vol: 20 num 3 (2009): 339–348.

[16] M. Klement, "Models of integration of virtualization in education: Virtualization technology and possibilities of its use in education", Computers and Education num 105 (2017): 31-43.

[17] D.L. Lunsford, "Virtualization technologies in information systems education", Journal of Information Systems Education Vol: 20 num 3 (2009): 339–348.

- to know and understand the main stages, directions, and trends of OS development;

- to orient oneself in OS classification, considering their architecture and scope of application;

- to know and understand the theoretical foundations of the structure and functioning;

- to be able to obtain reference information about the use of OS.

Task	Competences
1) Teaching the basics of OS theory	- to know and understand the main stages, directions, and trends of OS development; - to orient oneself in OS classification, considering their architecture and scope of application; - to know and understand the theoretical foundations of OS structure and functioning
2) Mastering the basics of OS administration	- to be able to use the OS user interface; - to be able to set up a network connection in OS; - to be able to install software in tOS, perform the following updates and uninstall it
3) Creation of prerequisites for further self-education with OS	- to be able to obtain background information on OS usage

Table 1
Tasks of implementing OS virtualization technologies and their respective competences

Criteria for evaluation of the formation of competencies for the next involvement at the diagnostics stage were also defined (Table 2).

Criteria	Indicators
1. Theoretical Knowledge of the basics of OS theory	1.1 Knowledge and understanding of main stages, directions, and trends of OS development 1.2 Orientation in OS classification, considering their architecture and scope of application 1.3 Knowledge and understanding of the theoretical foundations of the OS structure and functioning
2. Administrative Understanding the basics of OS administration	2.1. Ability to use the OS user interface 2.2 Ability to work network connection settings in the OS 2.3. Ability to install software in the OS, perform the following updates and uninstall it
3. Self-learning ability for self-study with OS	3.1. Ability to get background information on OS usage

Table 2
Criteria and indicators of scientific, academic, and professional practical competencies

Each of these indicators can be assessed at four levels: primary, secondary, sufficient, and high.

I. Primary level (2 points). The student has a fragmented understanding of the main stages and directions of OS development, OS classification, and the basics of OS structure and functioning. With the active help of the professor, the student uses the user interface, explains individual ready-made OS settings, and performs individual steps to change them. Knows the names of individual help commands and web resources.

II. Secondary level (3 points). The student has a basic understanding of the main stages and directions of OS development, the basics of OS structure and operation, the main classes and architecture of the OS. With moderate help of the professor: uses the user interface; reviews and explains the basic ready-made OS settings; changes simple settings. Knows the basic commands and web resources and applies them to solve simple problems.

III. Sufficient level (4 points). The student is well-oriented in the main stages and directions of OS development, OS classes and architectures, and the basics of OS structure and functioning. With the occasional help of a professor and using reference materials uses the user interface, explains most of the ready OS settings, and changes their significant part. Knows basic commands and web resources and applies them to moderate complexity problems.

IV. High level (5 points). The student is familiar with the basic stages and directions of OS development, OS classes and architectures, and the basics of OS structure and operation. Freely or with occasional involvement of reference materials: uses the user interface; explains and changes OS settings. Knows basic commands and web resources and applies them to solving complex and non-standard problems.

Results

The following activities were implemented as part of the ascertaining phase.

- The analysis of Russian and foreign experience of OS teaching and the role of VT in it was carried out. The analysis was conducted by processing scientific and methodical publications, textbooks, curricula, Russian industry standards and foreign recommendations for curriculum development, materials from open educational resources of several universities around the world. Special attention was paid to the experience of foreign universities, which are leaders in the ratings for training in the specialty "Computer Science". It was found out what topics are studied; what OS are considered; how the practical part of the course is organized; what place in OS training is occupied by virtualization technologies; what VT are used.

- Conversations were held with students studying the course "Computer Science Fundamentals", Russian professors of the corresponding course, and specialists in the industry.

- Analysis of the points received by the students in the course "Computer Science Fundamentals" was carried out.

The analysis of Russian and foreign experience of OS teaching revealed the use of virtualization technologies in laboratory work in most cases and in some cases — their consideration in the lecture part of the course. The essential variety of concrete applied VT is pointed out, and in several foreign higher education institutions, the use of several means is marked as well. Although the education in the analyzed cases differed in the volume of hours and training programs, the priority in the vast majority of these cases was the study of unix-like OS.

During conversations with students and teachers, the following problems were noted, connected with the application of virtualization technologies for OS training:hardware and software failures, low speed of virtualized OS operation, lack of adapted instructions, uneven conditions in which students work with virtualized OS on their own, and others.

A comparison of student scores obtained during the course "Computer Science Fundamentals" showed that the general level of academic achievements related to OS was generally lower than the level of academic achievements in the discipline.

The participants in the survey of Russian university professors were professors of the "Computer Science Fundamentals" discipline (9 respondents). Considering the small number of respondents, the main purpose of the analysis was not to estimate the percentage ratio of manifestations of the studied features but to identify differences. Among such differences, the following ones were mentioned above all:

- differences between the studied OS (Linux and Windows);

- the variety of VT used and the tools that were planned for future use (hypervisors of different types, virtual containers, not planned);

- the uneven experience of professors in using virtualization tools (from a wide range of tools to none);

- differences in technical conditions (availability of VT alternatives for professors, availability of processors with hardware virtualization support, etc.).

The results of the survey for professors led to the conclusion that individual selection of VT for OS studies is necessary. At the same time, based on conversations with professors and students, the problems of frequent hardware and software failures and the uneven conditions in which students work independently were noted as well. This fact pushed to attract alternative VT along with the main ones. In connection with the above mentioned, a variant-based approach was used, which includes the following tasks: (1) to familiarize professors and students with the diversity of VT (Table 4); (2) to give an example of a combination of several VTs while studying OS (Table 5).

Options with Windows	Options with Linux
1) Relatively free virtual machine with Windows 2) Virtual machines with Windows in the cloud (Amazon EC2) 3) Windows without virtualization	1) Hypervisor Type II (locally) (Oracle VirtualBox) 2) Complete virtual machines (virtual containers) in the cloud (Amazon EC2) 3) Linux without virtualization

Table 4
Proposed VT

The result of these tasks was the proposal, together with VT, which are used in most cases (the main VT), to provide for the use of one or more alternative VT, as well as teaching options for OS without virtualization (e.g., multi-booting). An example of such combination is the above-mentioned combination of VT (Table 5), in which the first means is the main one and the rest are alternative and can be transformed according to the needs of a particular course.

Linux	Windows
1. VirtualBox 2. Amazon EC2 3. without virtualization	1. Amazon EC2 2. without virtualization

Table 5
Combinations of VT

A characteristic feature of the proposed approach is the flexibility to change. Since the approach is focused on a combination of different VT, it allows for the further addition of other VT, including experimental. Due to the availability of alternative means, the associated risks are reduced.

The formative stage of the pedagogical experiment was conducted in two groups of students. The volume of the control group (CG) was 53 people (the 2nd year, the discipline "Computer Science Fundamentals"), the experimental group (EG) — 50 people (the 2nd year, the discipline "Computer Science Fundamentals"). One hundred and three students took part in the formative stage of the experiment in total.

The EG studied based on the proposed methodology, while in the CG, the mentioned methodology was not used.

The points of the tested students were obtained and analyzed:

- points obtained by passing the control test survey on the theory of OS;

- the final point received for the presentations of their laboratory works (the sum of points for all protected works, divided by the total number of works provided by the course).

The assessment was conducted on a 100-point scale (from 0 to 100 points) with conversion to a point on a scale (from 2 to 5 points) and according to the criteria considered earlier. Test surveys contained theoretical and practical questions about the OS. The purpose of the surveys was to highlight some of the training results related to the OS.

The results of the statistical analysis of points for the test survey "Operating Systems" are presented. During the experiment, the students from CG and EG got the points presented in Table 6.

Levels of study achievements	CG		EG	
	Number of students	%	Number of students	%
Primary level	10	18.87%	7	14.00%
Secondary level	24	45.28%	11	22.00%
Sufficient level	13	24.53%	23	46.00%
High level	6	11.32%	9	18.00%

Table 6
Distribution by levels of study achievements of the results
of the "Operating Systems" test survey

Discussion

During the analysis of experimental data on the Student criterion for independent samples, the value $t_{emp} = 2.93$, was obtained, which corresponded to the statistical significance level $p = 0.01$. We conclude the reliability of differences between the distributions for the level of significance < 0.01.

The verification of the reliability of the obtained result was carried out using the Fisher criterion. In the subgroup "effect is achieved" we included observation with sufficient and high level of learning achievements and in the subgroup "no effect" —observation with the primary and secondary level. To identify differences between the subgroups, a table is provided (Table 7).

Group	"Effect is achieved"		"No effect"		Total
	Number of students	%	Number of students	%	
EG	32	64.0%	18	36.0%	50
CG	19	35.8%	34	64.2%	53

Table 7
Table for calculating the Fisher criterion in the "Operating Systems" test survey results

The following statistical hypotheses were tested: H_0 — the distribution by levels of study achievements in CG and EG are the same; H_1 — the distribution by levels of study achievements in CG and EG are different.

The empirical value of the criterion $\varphi_{emp} = 2.90$, was obtained, which corresponded to the value level $p < 0.01$. Consequently, the hypothesis H_0 was rejected and the hypothesis H_1 was accepted: the distributions of study achievements in the CG and EG differed.

The same results were obtained while processing the final point for the presentations of their laboratory works. Thus, for all four analyzed features, we reject hypothesis H_0 (the distributions by levels of study achievements in the CG and EG are the same) and accept hypothesis H_1 (the distributions by levels of study achievements in the CG and EG are different). This suggests that the proposed method is effective for the organization of OS learning, and its implementation in the learning process is reasonable.

Conclusion

Analyzing the experience of visualization implementation in the educational process, it is possible to conclude that the processes of visualization technology distribution occur rapidly, which necessitates the need for studies aimed at analyzing the impact of visualization implementation on learning efficiency. It is also important to pay attention to the development of practice-oriented pedagogical technologies as they can be effectively used in the educational process and the creation of appropriate educational and methodical support. While studying OS and applying VT, it was revealed that there are different features of teaching a course on OS, including the variety of used virtualization technologies and the importance of VT selection factors. We also noted differences regarding technical conditions of independent work of students and necessity in the attraction of alternative VT for the availability of additional means in case of technical failure. The idea of combining several VT in the study of OS is confirmed by foreign experience and meets the ideas of open education and person-oriented learning.

Thus, the results of the study confirmed the hypothesis that the use of virtualization technologies of OS in computer science education leads to increased success of students' learning. Further studies should be directed to justify and develop educational and methodological support for the use of virtualization technologies in higher education institutions.

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