Technology of application of 3D models of electrical engineering in the performing laboratory work

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Abstract. The article presents the technology of application of 3D models of electrical engineering in the performing laboratory work. It was outlined the organizational and methodological conditions, forms and methods, learning tools of the proposed technology. The organizational and methodological conditions include the use of computer 3D models in laboratory work; creation and implementation into the educational process laboratory work that involves the development of computer 3D modeling; providing the necessary guidelines for the use and development of computer 3D modeling during laboratory work. Application of the 3D models in the performing laboratory work of electrical engineering disciplines can be realised on the initial, average and high levels. Upon completion of the development of the presented technology, an experimental study was conducted, which included the identification of the appropriate level of use of 3D models in the process of performing laboratory work in the study of electrical engineering disciplines. The obtained experimental results were verified using Student's statistical t-test for relative indicators. The result of the implementation of technology is the application of 3D models in educational and professional activities in the field of electrical engineering.

Keywords: 3D models, laboratory work, electrical engineering disciplines

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1. Introduction

The development of new technologies, computerization of all sectors of the economy, science and education requires, on the one hand, the creation and implementation of new information tools and technologies, and, on the other hand, due to problems with their use in professional activities, it is necessary to implement new approaches in the training of future professionals. Thus, there is a need to improve pedagogical approaches to laboratory work, in particular in the study of electrical engineering disciplines. Creation of 3D models is currently in a new stage of development in the study of electrical engineering. Therefore, higher education applicants must use 3D models of electrical engineering equipment for successful laboratory work, and therefore in the future for professional activities.

In the last researches there are summarized advances and trends in 3D models and digital control [5]. It allows the study of physical processes, complex technical systems, provides the assistance in understanding existing engineering materials [24]. Many developments techniques arose initially as solutions to problems of modeling the physical and electronic behaviors of materials [6]. The 3D simulations involve various methods of hydrodynamics and computational fluid dynamics as a complex tool [12]. Cloud computing faces challenges because it is not economical and impractical for research institutions and industries to set up a physical cloud for research and experiments on it, the researchers have chosen to test their contributions with 3D models and simulators [2, 15, 22]. It is explored the relation of simulations to numerical methods [11]. Computers are widely used in physics and other natural sciences to simulate physical phenomena. Thus, people routinely use computers to model many and different physical systems [23]. Diouf and Lo [7] presented a numerical investigation about the dielectric properties. For the understanding of some physical parameters (spectral width, specific pulsation and the number of particle), these parameters were varied to observe their influences on the real and imaginary susceptibility as well as the reflective index of the environment. Rozhdestvensky et al. [26] gets acquainted with the hierarchical principle of building models from simple to complex.

Traditionally the majority of E-learning courses provide learners with text-based material and allow them to contact the course tutor via email [18]. Virtual Reality (VR) on the basis of 3D models has a lot to offer the e-learning paradigm [13], it can give people a sense of belonging and, as they mimic the real world, they are a natural way to access information [20]. The machine learning models assist the designers in choosing different design strategies [1, 31]. The visualization of line geometry via the 3D graphic statics is presented by Kodrnja, Baniček and Fresl [16]. Until sufficient practical experience and documented examples are available, emerging technological methods to create educational content typically require in-depth knowledge from different fields in order to apply them in the most beneficial way [25]. The method of creating photorealistic 3D models (PR3DMs) of real-world objects with the methods of photogrammetry is an example of such emerging technologies [21]. Tosheva [29] presents cloud solutions for 3D modeling, which can be used in technology education to create and visualize technical objects, when working on the design and solution of various technical and creative tasks. Experimenting projects and models is a current practice in education were described by Mihaila et al. [19]. Barkatov et al. [3] presents the instrument and verification learning through 3D modeling as educational process of documenting students' projects as

architectural exercises. 3D printing has been shown to be beneficial in several educational settings; however, to our knowledge, its effectiveness in pharmacy, medicinal chemistry and pharmacology learning [10]. The introduction of CAD and VR techniques is helpful to students in order to prepare them to consider these technologies as important supports, later in their professional practice [27]. In the conditions of blended learning the dialogue clusters of students were stronger when the interactions were related to the subject of the course [28]. Representing 3D objects by multiple views has become a common solution to the problem of 3D object retrieval [17]. 3D images contain depth information, they have gradually gained importance for numerical systems in image analysis [14].

The authors investigated some aspects of engineering education, for example, it was presented the implementation of future agricultural engineers' training technology in the informational and educational environment [30] and the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines [8]. There is investigation about technological model of training of Masters in Electrical Engineering to electrical installation and commissioning [4], but the using of 3D models in the performing laboratory work on electrical engineering disciplines was not the specific subject of the study.

The aim of the article is to develop technology of application of 3D models of electrical engineering in the performing laboratory work.

2. Methods

In the first stage of the study, it was used the survey method and took into account the quantitative and qualitative indicators of the use of computer modelling in the process of performing laboratory work in the study of electrical engineering disciplines. The experiment involved 40 higher education applicants in electrical engineering. The division into control and experimental groups was statistically checked for homogeneity using Fisher's test. It is determined that the formed groups are homogeneous. In the control group, the number of higher education applicants in electrical engineering is 19, in the experimental – 21 persons. After the division into control and experimental groups, we began to implement the author's model of application of 3D models in the process of performing laboratory work in the study of electrical engineering disciplines. At the end of the experimental work, the input and output quantitative indicators of the quality of training were checked using Student's t-test [9].

3. The implementation of technology of application of 3D models of electrical engineering in the performing laboratory work

In recent years, due to the development of graphical interfaces and graphics packages, 3D models have become widespread. 3D models model can be understood as a conditional image of an object or a system of objects (or processes) described by interdependent computer drawings and animations that reflect the structure and relationships between the elements of an object

or system. Creating 3D models in the process of performing laboratory work in the study of electrical engineering disciplines is a method of solving the technical problem of analysis or synthesis of a complex electrical system based on the use of its computer model. The computer model in the process of performing laboratory in the study of electrical engineering disciplines should reflect as fully as possible all the main factors and relationships that characterize real situations and limitations. In addition, 3D models should be as versatile (to cover the widest range of electrical objects as intended) and simple (to help perform the necessary research at minimal cost). It is considered the technology of application 3D models in the process of performing laboratory work in the study of electrical engineering disciplines (figure 1).

There is a need to visualize modern models of electrical elements in 3D space. Digitalization and the needs of remote work of specialists in the electrical industry outline the purpose of the investigation – the development of technology of the application of 3D models of electrical engineering in the performing laboratory work. The outlined goal is achieved through organizational and methodological conditions such as:

1) use of computer 3D models in laboratory work;
2) creation and implementation into the educational process of specialists in electrical engineering laboratory work, involving the development of computer 3D modeling;
3) providing the necessary guidelines for the use and development of computer 3D modeling during laboratory work.

This goal is achieved on the basis of such forms of training as instruction and laboratory work, as well as visual and practical methods. Instruction is a kind of explanation and presentation of the task by the tutor. It includes elements of conversation, demonstration of methods of work, procedures, demonstration of objects of labour, technological process. When performing laboratory work during the study of electrical engineering disciplines, the instruction includes the following:

1. Follow the sequence when performing work.
2. Carefully consider computer 3D models and study their components.
3. If there are difficulties in work of the 3D equipment, it is necessary to inform the tutor about it.
4. Enter the results of measurements / calculations in the table, having thought over their form in advance, if it is not specified in the instructions.
5. At the end of the experiment, the final results should be calculated and the results obtained discussed.
6. In defense of laboratory work, the higher education applicant submits a short-written report with the results of measurements, calculated values and constructed graphs, 3D models and conclusions. Then he must answer the questions asked by the supervisor regarding the laboratory work or its individual parts and present his own computer-generated 3D models.

Admission to laboratory work is given by the tutor. In the interview with the student the degree of their readiness for employment is revealed. If a higher education applicant cannot formulate the basic principles of the theory on which the work is based, describe the sequence of
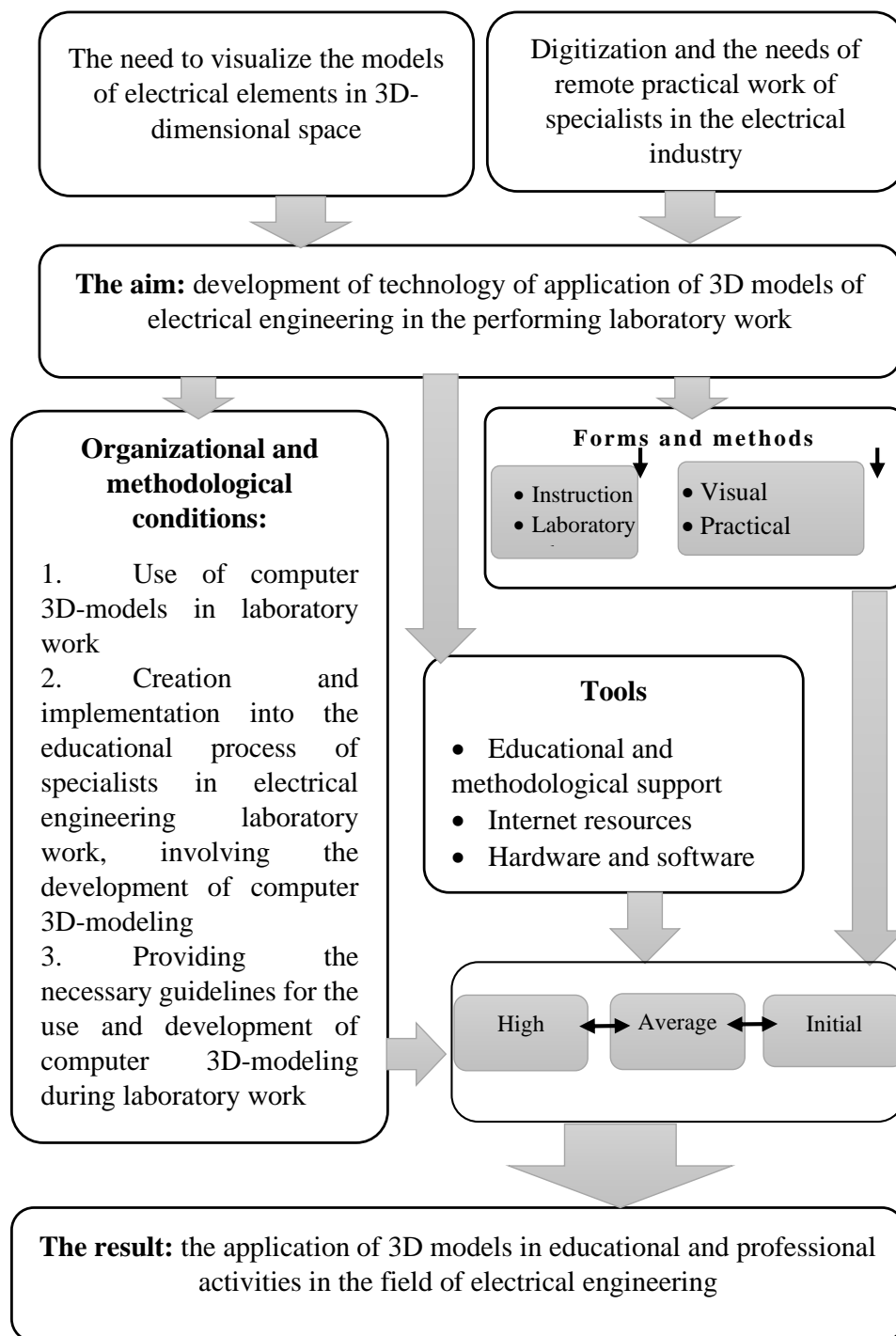
Figure 1: The technology of application 3D models of electrical engineering in the performing laboratory work.

research, does not know how to work with equipment and computer 3D models – then he is not allowed to do the work. After obtaining admission, students receive additional instruction on a specific job and specific tasks for it. Admission of students to work is assessed and recorded in the laboratory journal. Laboratory work is a form of study in which a higher education applicant, under the guidance of a tutor, personally conducts simulation experiments, based on the use of computer simulations or experiments to practically confirm certain theoretical positions in electrical engineering disciplines. By working with computer models acquires practical skills in working with laboratory equipment, hardware, computers, measuring equipment, methods of experimental research in a particular subject area.

In the process of performing laboratory work in electrical engineering disciplines, higher education applicants learn to apply the acquired theoretical knowledge. Studying the theory on the examples of computer 3D models taken from life on the basis of modern achievements of science and technology, clear organization of practical knowledge contribute to the formation of qualities that should be possessed by a future specialist in the field of electrical engineering. The technology of performing laboratory work in the study of electrical disciplines is presented in figure 2.
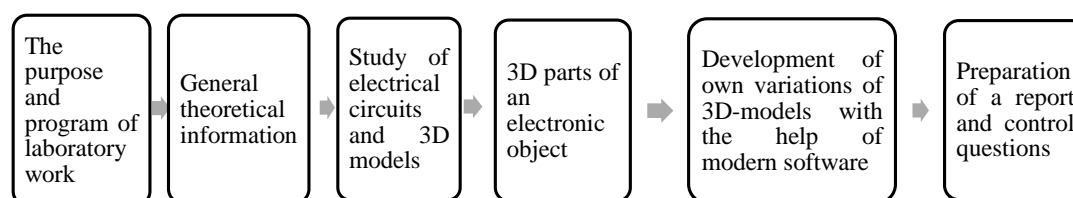
Figure 2: The technology of performing laboratory work in the study of electrical disciplines.

Before performing laboratory work, the higher education applicant must:

- process instructions for work;
- know the purpose of the work and its main tasks;
- understand the basic theoretical provisions and laws on which the work is based;
- if self-study of the material on the literature specified in the instructions was insufficient to understand the essence of phenomena or processes, higher education applicant should consult a tutor;
- get acquainted with the workplace and equipment used in the process of work;
- know the procedure and sequence of operations;
- prepare tables for recording the results of measurements and calculations, as well as paper for plotting.

To achieve the goal of this model, methods such as visual and practical are used.

Visual methods involve the representation of electrical objects in the form of 3D images for maximum convenience in their understanding; giving a tangible form to any electrical object, subject, process, etc. By visualization it is meant computer 3D objects – the visual information transmission system allows to control computer 3D models that are broadcast on the screen.

When visualizing educational material during laboratory work in electrical engineering disciplines, it should be considered that visual images shorten the chain of verbal considerations and expand the possibilities of distance learning during laboratory work in electrical engineering disciplines, in particular during a pandemic or lack of laboratory equipment.

Thus, visualization of educational information during laboratory work in electrical engineering disciplines allows to solve a number of pedagogical tasks:

- ensuring the intensification of laboratory classes;
- intensification of practical educational and cognitive activities;
- formation and development of critical and visual-spatial thinking and visual perception;
- presentation of electrical facilities and training activities in 3D space;
- increase of visual literacy and visual culture in the electric power industry.

Practical teaching methods involve different types of spatial activities and require independence of higher education applicants in learning. Performing exercises in 3D space provides repetition of certain actions in order to master them, which is based on understanding, accompanied by conscious control and adjustment. Exercises should not be a random set of similar actions, but should be based on a system, a clearly planned sequence of actions, including gradual complication, they should not be interrupted for a long time. The effectiveness of the exercise depends on the analysis of its results.

The value of the practical method is that they help to connect theory with practice, equip higher education applicants with one of the research methods in 3D space, develop skills in using devices, teach to process measurement results and make the right scientific conclusions and suggestions.

The learning tools included teaching and methodological support, Internet resources and hardware and software.

Educational and methodological support for laboratory work in electrical engineering disciplines that based on computer 3D models is a set of educational and methodological materials that provide the educational process. The specified support provides practical work in 3D space, the corresponding form of the reporting and forms of control of knowledge for the organization and performance of laboratory work in electrical engineering disciplines.

Internet resources are a set of links to relevant sources on the Internet. Such sources include:

- links to distance learning courses developed;
- references to mass open online courses, which provide for laboratory work in electrical engineering disciplines in the context of an educational program;
- links to interactive educational portals that provide work with 3D space;
- additional links to audiovisual electrical content.

Hardware and software are a set of programs for laboratory work in electrical engineering disciplines in 3D space. 3D simulation software can help turn tangible electrical objects into beautiful computer models and prototypes. Choosing the optimal simulation software is often difficult, as it is not easy to find a program that would have all the necessary functionality. In

our work, we have recommended for laboratory work in electrical engineering disciplines such as Wings 3D, 3DMonster, Daz Studio, AutoDesk 123D, PTC Creo, Autodesk 3ds Max.

Figure 3 shows an element of laboratory work in the discipline of "Lighting" on the topic "Research of natural and artificial light", which studies the structure of lamps of different types in 3D space.
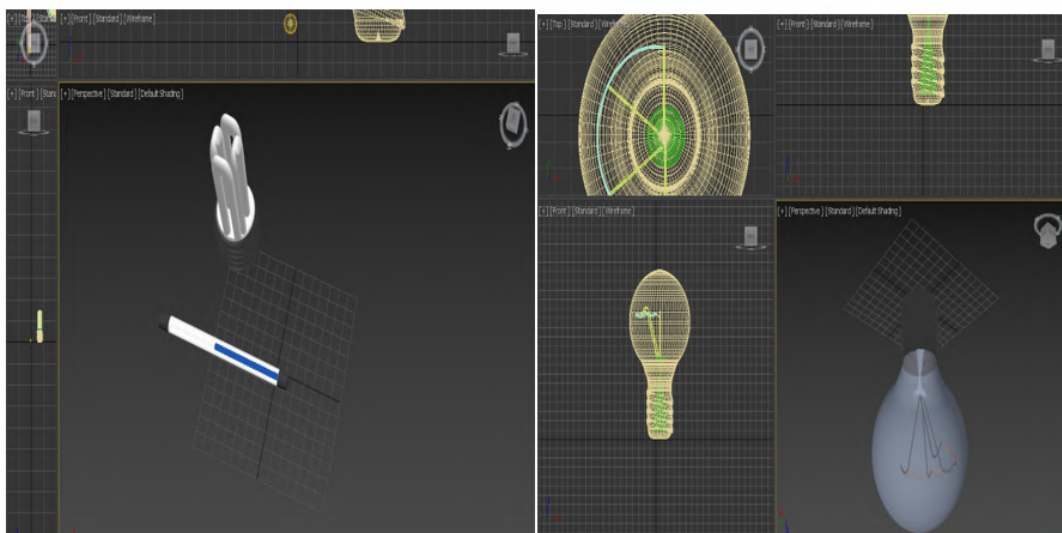
Figure 3: Laboratory work on the subject "Lighting" on "Research of natural and artificial light": a study of the structure of lamps of different types in 3D space.

With the help of computer 3D models, it is possible to study the structure of different types of lamps, consider the components that fill it.

Also, the hardware and software provide the ability to disassemble 3D models into structural elements or from the proposed components to assemble an electrical device in 3D space.
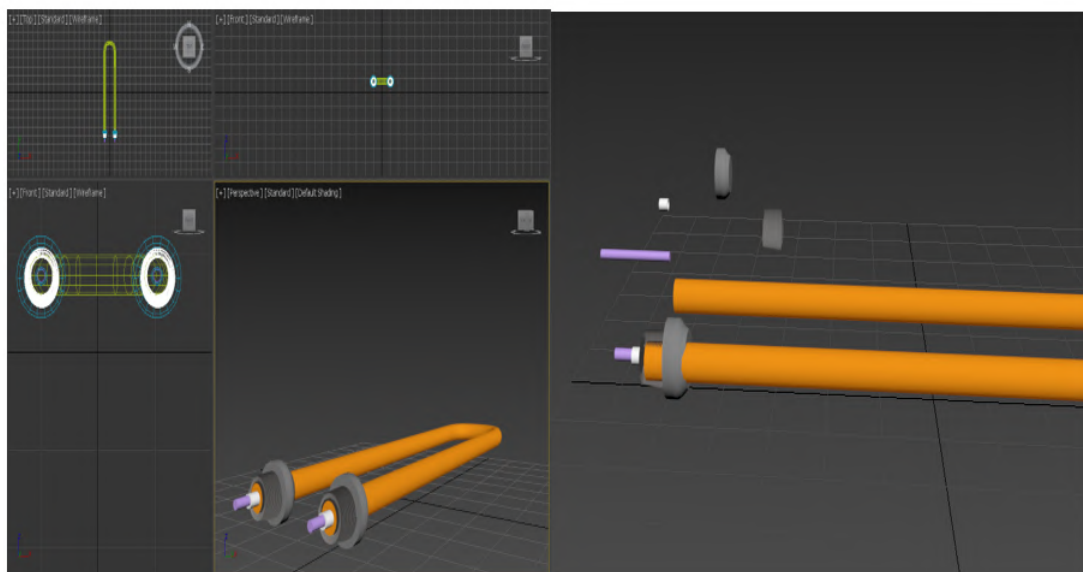
Figure 4 shows the element of laboratory work in the discipline of "Electrical technology" on the topic "The principle of operation of tubular electric heaters", which performs the analysis of the tubular electric heater into structural elements.

Also, the hardware and software provide an opportunity to assemble an electrical device from the proposed components in 3D space.

Organizational and methodological conditions, forms, methods and tools provide progress in the levels of use of computer simulation in the process of laboratory work in the study of electrical engineering disciplines. The *initial* level of use of computer simulation in the process of performing laboratory work in the study of electrical engineering disciplines is characterized by the presence of theoretical knowledge. The applicant has an idea of the basic terms and processes in the power industry, understands the phasing of laboratory work. Being theoretically knowledgeable, the applicant is able to work with computer 3D models.

The *average* level of use of computer simulation in the process of laboratory work in the study of electrical engineering disciplines takes into account the presence of theoretical knowledge that characterizes the initial level, as well as the understanding of work in 3D space. Computer

Figure 4: Laboratory work on the subject "Electrical technology" on the topic "The principle of operation of tubular electric heaters: disassembly of a tubular electric heater into structural elements".

components of electrical elements are able to consist of 3D components. Higher education applicant is able in the context of specific laboratory work to form 3D projects of computer models, to perform calculations independently.

The *high* level of use of computer simulation in the process of laboratory work in the study of electrical engineering disciplines takes into account the presence of key components that characterize the average level and also provides skills for self-formation of computer models in 3D space in the context of laboratory work. Higher education applicants are able to design step-by-step tasks for the formation of computer models in 3D space, understand the principles of formation of key 3D components of computer models.

The result of the model is the application of 3D models in educational and professional activities in the field of electrical engineering.

4. Results

The implementation of the technology of application of 3D models in the process of performing laboratory work in the study of electrical engineering disciplines was accompanied by a set of developed 3D models and tasks for their independent development. Upon completion of the development of the presented technology, an experimental study was conducted, which included the identification of the appropriate level of use of computer simulation in the process of performing laboratory work in the study of electrical engineering disciplines. The obtained experimental results were verified using Student's statistical t-test for relative indicators and are presented in table 1.

Note that for all three levels the differences are statistically significant ($p < 0.05$), and the

Table 1
The results of the study of the level of use of 3D models of electrical engineering in the process of performing laboratory work.

Level	CG	EG	CG	The share of units with this indicator in the 1st group	Average relative error, m_1	The share of units with this indicator in the 2nd group	Average relative error, m_2
High	3	10	15.79	± 8.59	47.62	± 11.17	2.26
Average	5	7	26.32	± 10.38	57.14	± 11.07	2.03
Initial	11	4	57.89	± 11.64	19.05	± 8.78	2.66
Total	19	21	-	-	-	-	-

number of degrees of freedom $f = 38$. The critical value of the Student's t-test is 2.024, with a significance level of $\alpha = 0.05$.

Thus, the obtained empirical values of Student's t-test are greater than critical, which means that they belong to the zone of significance. The levels of application of computer simulation in the process of performing laboratory work in the study of electrical engineering disciplines in control and experimental groups at the end of the experiment have significant differences.

It is obvious that the authors' technology of using computer simulation in the process of performing laboratory work in the study of electrical engineering disciplines is effective.

5. Conclusion

The technology of application computer simulation in the laboratory work on electrical engineering disciplines is based on the need to visualize modern models of electrical elements in 3D space, digitization and the need for remote work of electrical professionals. The development of technology involves organizational and methodological conditions (use of computer 3D models in laboratory work; creation and implementation in the educational process of specialists in electrical engineering laboratory work, providing for the development of computer 3D modeling; providing the necessary guidelines for use and development of computer 3D modeling during laboratory work), forms (instruction, laboratory work), methods (visual and practical) and tools (educational and methodological support, Internet resources and hardware and software). The result of the implementation of technology is the use of 3D models in educational and professional activities in the field of electrical engineering.

According to the obtained experimental results that were verified using Student's statistical t-test for relative indicators it can be claimed that the technology of application of computer simulation in the process of performing laboratory work in the study of electrical engineering disciplines is promising.

References

[1] Antoniuk, D.S., Vakaliuk, T.A., Didkivskyi, V.V. and Vizghalov, O.Y., 2022. Development of a simulator to determine personal financial strategies using machine learning. *Ceur workshop*

proceedings, 3077, pp.12–26. Available from: http://ceur-ws.org/Vol-3077/paper02.pdf.

[2] Antoniuk, D.S., Vakaliuk, T.A., Didkivskyi, V.V., Vizghalov, O.Y., Oliinyk, O.V. and Yanchuk, V.M., 2022. Using a business simulator with elements of machine learning to develop personal finance management skills. *Ceur workshop proceedings*.

[3] Barkatov, I.V., Farafonov, V.S., Tiurin, V.O., Honcharuk, S.S., Lozko, A.A., Marushchenko, V.V., Korytchenko, K.V., Barkatov, V.I. and Muravlyov, R.F., 2022. $360°$ photographic panoramas as an effective multifunctional aid for teaching technology subjects. In: S. Semerikov, V. Osadchyi and O. Kuzminska, eds. *Proceedings of the symposium on advances in educational technology, aet 2020*. University of Educational Management, Kyiv: SciTePress.

[4] Batsurovska, I., 2021. Technological model of training of Masters in Electrical Engineering to electrical installation and commissioning. *Journal of physics: Conference series*, 1946, p.012015. Available from: https://doi.org/10.1088/1742-6596/1946/1/012015.

[5] Bose, B.K., 2021. Chapter 9 - computer simulation and digital control. In: B.K. Bose, ed. *Power electronics and motor drives (second edition)*. Second edition ed. Academic Press, pp.687–764. Available from: https://doi.org/10.1016/B978-0-12-821360-5.00009-9.

[6] Bursten, J.R.S., 2020. Computer simulations. *Between making and knowing*. chap. Chapter 2.8, pp.195–206. Available from: https://doi.org/10.1142/9789811207631_0019.

[7] Diouf, A.A. and Lo, B., 2020. Dielectric properties: Computer simulation. *International journal of advanced research*, 8, pp.972–979. Available from: https://doi.org/10.21474/IJAR01/11178.

[8] Dotsenko, N., 2021. Technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines. *Journal of physics: Conference series*, 1946, p.012014. Available from: https://doi.org/10.1088/1742-6596/1946/1/012014.

[9] Goulden, C.H., 2007. *Methods of statistical analysis*. Koteliansky Press, pp.50–55.

[10] Hall, S., Grant, G., Arora, D., Karaksha, A., McFarland, A., Lohning, A. and Anoopkumar-Dukie, S., 2017. A pilot study assessing the value of 3D printed molecular modelling tools for pharmacy student education. *Currents in pharmacy teaching and learning*, 9(4), pp.723–728. Available from: https://doi.org/10.1016/j.cptl.2017.03.029.

[11] Humphreys, P., 2019. Computer simulations. *Philosophical papers*. pp.9–20. Available from: https://doi.org/10.1093/oso/9780199334872.003.0002.

[12] Janczarek, M. and Kowalska, E., 2021. Computer simulations of photocatalytic reactors. *Catalysts*, 11(2). Available from: https://doi.org/10.3390/catal11020198.

[13] Kadir, R.A., Ahmad, A. and Marstawi, A., 2018. Transformation of Text-to-3D Graphics. *Advanced science letters*, 24, pp.1085–1089. Available from: https://doi.org/10.1166/asl.2018.10692.

[14] Kaya, E. and Sert, E., 2020. A new 3D segmentation approach using extreme learning machine algorithm and morphological operations. *Computers & electrical engineering*, 84, p.106638. Available from: https://doi.org/10.1016/j.compeleceng.2020.106638.

[15] Kiv, A.E., Merzlykin, O.V., Modlo, Y.O., Nechypurenko, P.P. and Topolova, I.Y., 2019. The overview of software for computer simulations in profile physics learning. *Ceur workshop proceedings*, 2433, pp.352–362.

[16] Kodrnja, I., Baniček, M. and Fresl, K., 2019. Line geometry and 3D graphic statics. *Gradevinar*, 71(10), pp.863–875. Available from: https://doi.org/10.14256/JCE.2725.2019.

[17] Li, H., Zheng, Y., Cao, J. and Cai, Q., 2019. Multi-view-based siamese convolutional neural network for 3d object retrieval. *Computers & electrical engineering*, 78, pp.11–21. Available from: https://doi.org/10.1016/j.compeleceng.2019.06.022.

[18] Mgr, M.P., 2019. Use of 3D graphics in education. *2019 17th international conference on emerging elearning technologies and applications (iceta)*. pp.667–675. Available from: https://doi.org/10.1109/ICETA48886.2019.9040135.

[19] Mihaila, M., Mihailescu, S., Vlaiescu, S., Andreea, N. and Caragea, C., 2016. 3D modeling as educational process of documenting students projects: Architectural exercises. *Eurau 2016 european symposium on research in architecture and urban design: In between scales. eurau 2016 – proceedings*. pp.453–462. Available from: https://doi.org/10.13140/RG.2.2.30967.42401.

[20] Monahan, T., McArdle, G. and Bertolotto, M., 2005. Using 3D Graphics for Learning and Collaborating Online. In: J.J. Bourdin and H. McCabe, eds. *Eurographics 2005 - education papers*. The Eurographics Association. Available from: https://doi.org/10.2312/Conf/EG2005/Education/033-040.

[21] Nebel, S., Beege, M., Schneider, S. and Rey, G.D., 2020. A review of photogrammetry and photorealistic 3d models in education from a psychological perspective. *Frontiers in education*, 5. Available from: https://doi.org/10.3389/feduc.2020.00144.

[22] Oladimeji, O.O., Oyeyiola, D., Oladimeji, O. and Oyeyiola, P., 2021. A comprehensive survey on cloud computing simulators. *Scientific journal of informatics*, 8(1), pp.51–59. Available from: https://doi.org/10.15294/sji.v8i1.28878.

[23] Papadopoulos, G. and Syropoulos, A., 2021. Sense and boundaries of computer simulations. In: M. Khosrow-Pour, ed. *Encyclopedia of information science and technology*. 5th ed. IGI Global, pp.155–163. Available from: https://doi.org/10.4018/978-1-7998-3479-3.ch012.

[24] Pathria, R. and Beale, P.D., 2022. 16 - computer simulations. In: R. Pathria and P.D. Beale, eds. *Statistical mechanics (fourth edition)*. Fourth edition ed. Academic Press, pp.659–674. Available from: https://doi.org/10.1016/B978-0-08-102692-2.00025-9.

[25] Rashevska, N.V., Semerikov, S.O., Zinonos, N.O., Tkachuk, V.V. and Shyshkina, M.P., 2020. Using augmented reality tools in the teaching of two-dimensional plane geometry. *Ceur workshop proceedings*, 2731, pp.79–90. Available from: http://ceur-ws.org/Vol-2731/paper03.pdf.

[26] Rozhdestvensky, K., Ryzhov, V., Fedorova, T., Safronov, K., Tryaskin, N., Sulaiman, S.A., Ovinis, M. and Hassan, S., 2020. Computer simulation of dynamic systems. *Computer modeling and simulation of dynamic systems using wolfram systemmodeler*. Singapore: Springer Singapore, pp.89–130. Available from: https://doi.org/10.1007/978-981-15-2803-3_3.

[27] Sampaio, A.Z., Ferreira, M.M., Rosário, D.P. and Martins, O.P., 2010. 3D and VR models in Civil Engineering education: Construction, rehabilitation and maintenance. *Automation in construction*, 19(7), pp.819–828. Available from: https://doi.org/10.1016/j.autcon.2010.05.006.

[28] Shu, H. and Gu, X., 2018. Determining the differences between online and face-to-face student–group interactions in a blended learning course. *The internet and higher education*, 39, pp.13–21. Available from: https://doi.org/10.1016/j.iheduc.2018.05.003.

[29] Tosheva, E., 2020. 3D modeling solutions in the cloud. *Conference on information technology*

and development of education–itro 2019 zrenjanin. republic of serbia. pp.215–216. Available from: https://www.researchgate.net/publication/348806388_3D_Modeling_Solutions_in_the_Cloud.

[30] Uchitel, A.D., Batsurovska, I.V., Dotsenko, N.A., Gorbenko, O.A. and Kim, N.I., 2020. Implementation of future agricultural engineers' training technology in the informational and educational environment. *Ceur workshop proceedings*, 2879, pp.233–246.

[31] Zheng, H., Moosavi, V. and Akbarzadeh, M., 2019. Machine Learning Assisted Evaluations in 3D Graphic Statics. *Iass annual symposium 2019 - structural membranes 2019.* Available from: https://www.researchgate.net/publication/336313383_Machine_Learning_Assisted_Evaluations_in_3D_Graphic_Statics.