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A Method to Ensure the Effectiveness and Attractiveness of E-Learning. Human-Oriented Systemic Ergonomic Approach

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Abstract. The article deals with the problems of the low efficiency of e-learning systems. We reveal the main ergonomic problems of computer systems for training and propose the concept of a man-system approach to the creation of e-learning systems. We have developed a method and information technology for optimizing man-machine dialogue interaction, taking into account the characteristics of a particular person, working in the e-learning system.

Keywords: e-learning, human-operator, ergonomics, educational environment, optimization, information technology, agent-manager, cyberspace.

1 Introduction

The introduction of computers has completely changed the educational process in schools, universities, as well as the processes of training and retraining of employees of firms and corporations [1-5].Learning becomes continuous (both throughout life and throughout the day)[6-8]. People spend hours on a computer or mobile device daily[1,7,9].You can study, take tests and exams, being thousands of kilometers from the university campus[1,10].Even the defense of the thesis can be carried out remotely.

For these purposes[11-15]:

- Expensive equipment is purchased.
- Powerful databases and repositories are created.
- Organized are:
    - Technical support groups.
    - Scientific laboratories of distance learning, virtual and augmented reality.
    - Projects of remote access to unique technical equipment to study complex objects and conduct technical experiments and medical operations.

Thus, recent years can be associated with a revolutionary change in technical, software and information support, with a jump in technology, including artificial intelligence and an increase in capital investment in education[16-20].

2 Problem Statement

Despite the sound statements made by many universities about the victory of the concept of “paperless education”, the return on investments does not correspond to the expenditures of financial, technical and human resources[1,21-26].
The expected massive “world” leap in improving the quality of students' knowledge did not happen[27]. Moreover, there is a tendency towards a decrease in the quality of fundamental and natural science training (physics, mathematics, chemistry, biology, etc.)[28].
Students unlearn how to think and solve complex problems (if you have a smartphone with a calculator or a computer with a modeling program at hand).
The ability to explain the result, to analyze cause-effect relationships is reduced[15,22,28].
In the field of humanitarian training, the thoughtless unsystematic mass use of computer training leads, for example, to “coaching for tests” the journalist who is afraid and cannot work “live”, etc.[1,15].
Twenty years ago, the author of this article was the head of the project for the introduction of information technology for the management of the educational process at the Theological Academy (Sergiev Posad) and defended the concept of “maximum computerization of the educational process”. At the same time, the administration has proposed the concept of “intelligent automation”, figuratively explaining this by saying that a “robot priest” is unlikely to be useful in the field of serving God and People. (Of course, this is a unique but instructive story).
Often unsystematic informatization without focusing on a person gives only harm. We even discuss a problem like “when the computer kills us”[29]! At the same time, many researchers are concerned about the harmfulness of the Internet and social networks associated with the described problem. A number of scientists even set the task of ensuring cyber-security of e-learning and the health of students[24,29,32-34].Modern people cannot and do not want to work with complex software environments and training materials that are not adaptable to their needs and features[2,3,19,27].
Thus, the task of this work is defined as follows: to identify the reasons for the low efficiency of e-learning and to develop a method that provides flexible adaptation of electronic educational environments to the psychophysiological and motivational characteristics of people working with the system, based on advanced achievements in engineering psychology, ergonomics, and the theory of adaptive systems.

3 Research of the Problem and Development of Methodological Basis for its Solution

3.1 Reasons for the low efficiency of e-learning. Students survey results

Very often, students drop out of school because “they don’t get what they expect from the system.”We organized a special survey of students (Ukraine, Poland, Bela-

rus, Kazakhstan and Germany - 389 students in total) about their assessment of the reasons for the low efficiency of e-learning systems (Table 1).

Table 1. Reasons for undersatisfaction of students by electronic training technologies (average percentage of students reporting this reason as the main one)

The complexity and imperfection of the learning environment	***Undergraduate***	***Master's***
The difficulty of establishing a dialogue with the teacher to solve problematic issues	27.3	23.0
Inability to flexibly change the structure of the dialogue	25.1	20.0
Problems with modality, inconsistency of the presentation of information to the style convenient for the student	19.5	17.4
The inability to flexibly change the complexity of the material (depending on motivation and level of preparedness)	8.8	17.2
Lack of ability to evaluate quickly possible learning outcomes (to predict the time spent and assessment)	7.9	11.9
Lack of uniform standards for learning management	6.2	3.3
Errors, poor formatting, color gamut, etc.	3.1	3.0
Low flexibility to enable self-monitoring of the learning process and error explanations	1.1	3.3
Etc.	1.0	0.9

These results allowed us to find "painful" problematic issues that scientists and practitioners need to work on.

3.2 Development of a methodology for an ergonomic approach to the design of an information learning environment

Disappointing assessments of existing e-learning technologies are forcing scientists and developers to turn to the ergonomic methodology of complex systems "man-technology-environment"[35-40].

Today, there is an opinion that the operator is a person who controls the technological process or watches the target on the radar screen, etc. Moreover, engineering psychology and ergonomics are mainly engaged in ensuring their comfort. At the same time, it is subjected to no less influence of negative factors, including stress than the operator managing the blast furnace or the call center operator. Only the nature of these negative influences is completely different. In this regard, when developing e-learning systems, it is necessary not to mechanically accumulate training electronic materials, but to design individual interactive training procedures that can flexibly adapt to a particular operator and environmental conditions.

In science, there are the following concepts for taking into account the characteristics of man and technology:

- Technical approach (today prevails in electronic education).
- Equal-element approach.
- Humanitarian approach (a person is at the forefront, technical features are not taken into account).

- human-system approach (man is the main element, but working in a specific system and environment, the features of which should be taken into account.

Obviously, it is necessary to reorient in the models of creating e-learning, switching from a technical approach to a human-system approach.

Using the principles of ergonomics and a human-system approach can dramatically change the situation with the attractiveness and effectiveness of e-learning. However, this is due to a lot of scientific, technical and organizational work.

4 Organization of Works for the Creation of Adaptive Human-Machine Training Systems

4.1 Creation of prerequisites

Adaptive e-learning technology is possible only in the conditions of a developed electronic university management system [41] with:

- Developed database system and documentation of the learning process and outcomes.
- Unified electronic document management system

4.2 Technology for the development and certification of electronic training modules

Preparation of training modules should not be entrusted only to the teacher. A whole group is being created, including (except for leading teachers):

- Content specialists.
- Designers, videographers.
- Programmers.
- Testers.
- Ergonomists.

Module requirements:

- For the same educational material, alternative modules are developed that focus on different styles of information presentation, for example:
  - Predominantly text.
  - Predominantly graphics.
  - Using audio and video.
  - “From general to particular”.
- The module should be assembled from individual elements (or submodules) as a “designer” or “nesting doll”: this means the level of complexity of the material (which will be offered to the student in the future depending on motivation, preparedness and time reserve):
  - Low.
  - Medium.
  - High.

- Each submodule is associated with several options for self-diagnosis or self-monitoring (with varying degrees of accuracy), which are turned on or off, depending on the available time resource.
- Each submodule is assigned a dialogue procedure with an explanatory component, which is turned on or off, depending on the results of self-monitoring and the time resource.
- Each module is assigned its:
    - Formal model describing its properties.
    - Functional networks [35,36,38] to describe the structure of the dialogue.
    - Mathematical models for predicting the time spent and the amount of points gained as a result of the dialogue.

The developed modules for inclusion in the database of training materials must undergo examination and certification procedures.

Special groups are created for this purpose:

- A group of experts.
- A working group (analysts, cognitologists, managers, and technical personnel).

Thus, evaluation criteria are created, some of which are given in the article [42] and a bank of mathematical methods and interactive procedures for processing expert estimates.

The idea of a certification system based on the principles of multicriteria assessment "on the scale of a thermometer with a slider" and fuzzy logic [42] is shown in Fig. 1

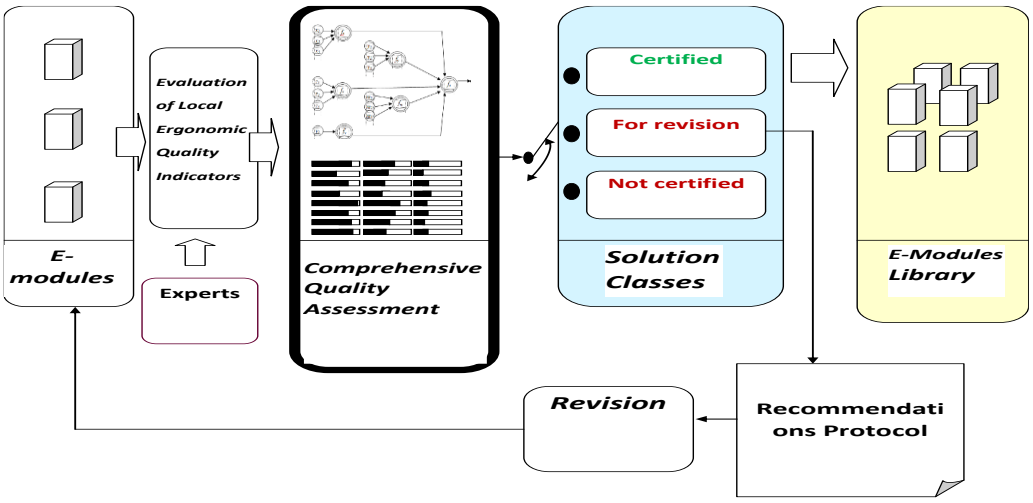

Fig.1. Certification of e-modules in the e-learning system. Functioning principle

Thus, only certified training modules that meet all the requirements relevant to the system are allowed to operate.

4.3 Study of characteristics and maintaining models of trainees (operators)

For each system operator are determined:

- H1- Psychophysiological characteristics.
- H2- Learning Styles (desired).
- H3- Level of motivation (for discipline).
- H4- Preparedness for the study of discipline.
- H5- Functional Status (current).
- H6- Results ("history", protocol) of all previous sessions of working with the system (which module was studied, how much time was spent, what were the results of self-monitoring and final control).
- To determine the characteristics of H1 and H2, computer diagnostic tools are stored in the database of the university management system. Such testing is carried out once, and the results are entered into the database of user models of the system and are used to adapt to each specific person..
  H3 and H4 are determined before starting the study of discipline.

  H5 is constantly monitored (after 10-30 minutes of operation in the system).

  H6 is ongoing. The results are required to predict the reliability and timing of the implementation of elementary learning operations both for a given student and for others.

4.4 Information support for adaptive interactive learning processes

The system "man-equipment-environment", which we analyze, for making optimal decisions should be described in all necessary "sections". These include:

- Modules.
- Students.
- Hardware and software.
- Communication channels.
- Resource constraints.

We describe the entire list of such necessary "sections" (there are more than 50) and, accordingly, the databases that we have developed in [37,43,44].Such information is required to generate the initial data necessary for assessing the likely learning outcomes and time spent in each specific situation in order to offer optimal interactive learning technology.

4.5 Method for evaluating the effectiveness of learning and cognitive activities and optimizing dialogue interaction

In order to conduct an assessment, the system builds a functional network [35,36,38] that describes the dialogue interaction and, using the mathematical models that we have developed for the probability of error-free execution of procedures and time costs [36,38,45], makes a forecast of the results and proposes an adjustment of the learning technology. Such adjustment is carried out according to the results of the study of each submodule.

4.6 Program-manager to manage the learning process

To manage the adaptive dialogue process, a special program has been developed that on-line solves a number of optimization problems for choosing the structure of dialogue interaction (Fig. 2).

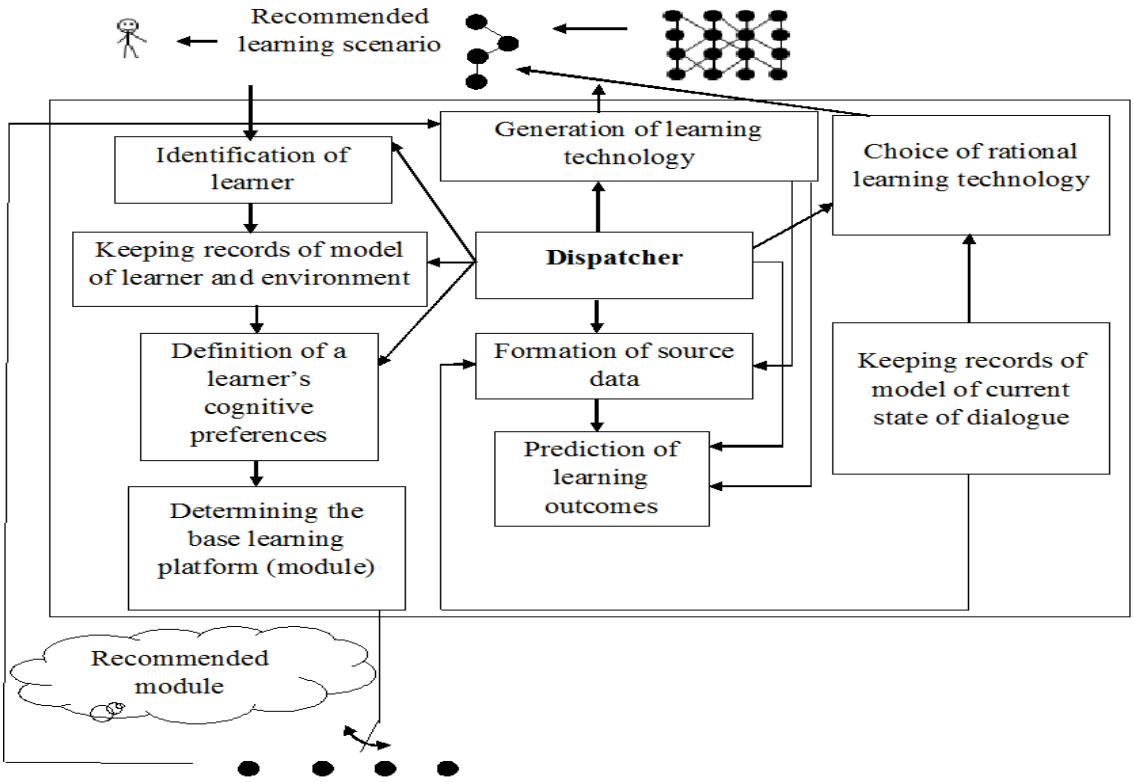

Fig.2. Manager for e-learning: functioning principle

The operator model is used for:

- Selection of a basic module (providing maximum cognitive comfort)
- Formation of initial data on the characteristics of performing elementary actions (the approximation problem is solved using all the data on training sessions of all users on which a special neural network was trained).

The initial data generated in this way are sent to the functional network, which makes it possible to predict the result and adjust the learning technology.

5 Approbation

We used this method in the framework of complex projects for the introduction of computer control systems at 20 universities of Ukraine (Kharkiv, Kremenchug, Vinni-

tsa, Sumy, Kryvyi Rih and other cities) and confirmed its effectiveness. Let us show just one indicator (for Sumy Agrarian University, Ukraine) for example [41]:

- In 2018, the average grade point at the Faculty of Agriculture was 72.1, and after the introduction of the system, it was 81.6 (on a 100-point scale).

The percentage of students refusing to use e-learning technology decreased from 25.8 percent to 7.0 percent.

6 Conclusion

The effectiveness of existing e-learning projects does not match the efforts and resources expended. Students do not want to work with uncomfortable and non-adaptive learning systems. The revealed list of claims to modern e-learning systems made it possible to justify the need for a transition to the human-system principle of designing such technologies. The transition to adaptive learning becomes possible if the system is described in the required sections and the corresponding databases are created, as well as if the functional network is used as a dialogue model. The adaptation process is reduced to the sequential solution of a number of optimization problems and can be implemented in the environment of a specially developed agent-manager.

Using the proposed technology can significantly improve the quality of the educational process and the attractiveness of e-learning.

References

1. Mehzbin, N., Rahman, A. and Sarma, P.: e-Learning for Children on Flora of North East India. In 2019 Second International Conference on Advanced Computational and Communication Paradigms (ICACCP), Gangtok, India, pp. 1-7. (2019) doi: 10.1109/ICACCP.2019.8882971
2. Verkhova, G. V., Akimov, S. V. : Electronic educational complex for training specialists in the field of technical systems management. In Proceedings of IEEE II International Conference on Control in Technical Systems (CTS), pp. 26–29 (2017).
3. Costa, L., Souza, M., Salvador, L. and Amorim, R.: Monitoring Students Performance in E-Learning Based on Learning Analytics and Learning Educational Objectives. In IEEE 19th International Conference on Advanced Learning Technologies (ICALT), Maceió, Brazil, pp. 192-193(2019) doi: 10.1109/ICALT.2019.00067
4. Zubov, I. K., Gorin, A. A. , Shahgeldyan K. I., and Berlova, N. V. :The Introduction of E-Learning Technologies Using Agile Software Development Methodology. In 2019 International Science and Technology Conference "EastConf", Vladivostok, Russia, pp. 1-4 (2019) doi: 10.1109/EastConf.2019.8725421
5. Blaschke, L. M.: Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. The International Review of Research in Open and Distributed Learning, **13(1)**, 56-71(2012) doi: 10.19173/irrodl.v13i1.1076 2.
6. Pereira, O. R. E., and Rodrigues, J. J. P. C.: “Survey and analysis of current mobile learning applications and technologies”. ACM Computing Surveys, **46(2)**, 28- 35(2013)

7. Cochrane, T., Narayan, V., Oldfield, J. : iPadagogy: Appropriating the iPad within pedagogical contexts". International Journal of Mobile Learning and Organisation, **7(1),** 2013, 48-65 (2013) doi: 10.1504/ijmlo.2013.051573
8. Semingson, P., Crosslin M. and Dellinger, J. : Microlearning as a tool to engage students in online and blended learning .In Proc of Society for Information Technology & Teacher Education International Conference,pp. 474–479(2015).
9. Pereira, O. R. E. and Rodrigues, J. J. P. C. :Survey and analysis of current mobile learning applications and technologies". ACM Computing Surveys, **46(2)**, 28-35 (2013)
10. AlQahtani, A. A. Y. and Higgins, S. E. : Effects of traditional, blended and e-learning on students' achievement in higher education". Journal of Computer Assisted Learning, **29(3)**, 220–234 (2012) doi: 10.1111/j.1365- 2729.2012.00490.x
11. Subha, S. and Priya, S. B. : A Model For Enhancing The Structure And Strategy In An E-Learning Environment. In 2019 3rd International Conference on Computing and Communications Technologies (ICCCT), Chennai, India, pp. 141-148 (2019)
12. Islam, A. N.: E-learning system use and its outcomes: Moderating role of perceived compatibility. Telematics and Informatics, 33(1), 48-55 (2016).
13. Joshua, D. : E-Learning platform system for the department of library and information science, Modibbo Adama University of Technology, Yola: A Developmental plan. Information Impact. Journal of Information and Knowledge Management, **7(1)**, 51–69 (2016)
14. Tawafak, R. M., Romli, A. B. and Arshah, R. B. A.: E-learning Model for Students' Satisfaction in Higher Education Universities: Review Paper. In International Conference on Fourth Industrial Revolution (ICFIR), Manama, Bahrain, pp. 1-6 (2019)
15. Khramova, L.N., Tsakhaeva, A.A., Posokhova, A.V., Lavrov, E.A. ,. Litvishkov, V.M. and Vilkova, A.V. : Modern managers training in the context of competence approach. The Journal of Social Sciences Research, **S5**, 194-199 (2018) doi.10.32861/jssr.spi5.194.199
16. Kotova, E. E.: Communication Technologies in the Training of IT Specialists in the Digital Economy. In Communication Strategies in Digital Society Workshop (ComSDS), Saint Petersburg, Russia, pp. 30-33 (2019) doi: 10.1109/COMSDS.2019.8709638
17. Atto, K. and Kotova, E. E. :Communication models in the E-learning environment based on intelligent agents. In IEEE Communication Strategies in Digital Society Workshop (ComSDS), St. Petersburg, pp. 3-6 (2018) doi: 10.1109/COMSDS.2018.8354952
18. Morozov, V., Shelest, T. and. Proskurin, M.: Create the Model for Development of Virtual Reality E-Learning. In IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON), Lviv, Ukraine, pp. 1265-1270 (2019)
19. Kotova, E. E. :Application of intelligent agents to control the process of blended learning in an educational environment. In IEEE V Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations), St. Petersburg, pp. 39-42 (2016) doi: 10.1109/IVForum.2016.7835848
20. Verkhova, G. V., Akimov, S. V. and Gusev, A. N.: Information environment for the training of highly qualified personnel in the system of continuous education. In IEEE VI Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (SPUE), St. Petersburg, pp. 77-80 (2017).doi: 10.1109/IVForum.2017.8246056
21. Mahajan, R. K. : E-learning and pedagogical challenges: A study in student's response. In 4th International Conference on Distance Learning and Education, San Juan, PR, pp. 159-162 (2010)
22. Cochrane, T.: Secrets of mlearning failures: confronting reality. Research in Learning Technology, 20, 123-134 (2012)

23. Rajab, K. D.: The Effectiveness and Potential of E-Learning in War Zones: An Empirical Comparison of Face-to-Face and Online Education in Saudi Arabia. IEEE Access, **6**, 6783-6794(2018) doi: 10.1109/ACCESS.2018.2800164
24. . Burov, O. Y, Pinchuk, O. P., Pertsev, M. A .and Vasylchenko, Y. V.:Using the students' state indices for design of adaptive learning systems". Information Technologies and Learning Tools, **68(6)**, 20-32 (2018)
25. Burov, O.Y.: ICT for performance assessment of emergent technologies operators. In Proceedings of the 13th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, Kyiv, Ukraine, May 15-18, CEUR-WS 2017, Vol. 1844, pp. 127-138 (2017)
26. Bisikalo, O., Kovalenko, O. and Palamarchuk Y.: Models of Behavior of Agents in the Learning Management System. In IEEE 14th International Conference on Computer Sciences and Information Technologies (CSIT), Lviv, Ukraine, pp. 222-227 (, 2019) doi: 10.1109/STC-CSIT.2019.8929751
27. Bagrova, E. V. , Kruchinin, S. V. and Nazarenko, M. A. : Quantity Measures of Quality in Higher Education in Russia. How Information Technologies Can Help?. In IEEE International Conference "Quality Management, Transport and Information Security, Information Technologies" (IT&QM&IS), St. Petersburg, pp. 557-560 (2018) doi: 10.1109/ITMQIS.2018.8525044
28. Iwane, N. and Saito, N.: Reuse of mathematical problems and answers with e-learning system. In IEEE Region 10 Humanitarian Technology Conference, Sendai, pp. 227-231 (2013)
29. Etelson,E.: Is modern technology killing us?" Truthout (2014) Available at: http://www.truth-out.org/opinion/item/26295-is-modern-technology-killing-us
30. Alqahtani, N. et al. : Internet risks for children: Parents' perceptions and attitudes: An investigative study of the Saudi Context. In Internet Technologies and Applications (ITA), Wrexham, pp. 98-103 (2017) doi: 10.1109/ITECHA.2017.8101918
31. Alqahtani, N. : A state of the art review of Internet risks on children. In 2nd International Conference on Anti-Cyber Crimes (ICACC), Abha, pp. 108-112 (2017)
32. Žufić, J., Žajgar, T. and Prkić, S.: Children online safety. In 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, pp. 961-966 (2017) doi: 10.23919/MIPRO.2017.7973563
33. Tsirtsis, A. , Tsapatsoulis, N., Stamatelatos, M. , Papadamou, K. and Sirivianos, M. : Cyber security risks for minors: A taxonomy and a software architecture. In 11th International Workshop on Semantic and Social Media Adaptation and Personalization (SMAP), Thessaloniki, pp. 93-99 (2016) doi: 10.1109/SMAP.2016.7753391
34. Pinchuk, O., Burov, O., Lytvynova, S.: Learning as a Systemic Activity. Advances in Intelligent Systems and Computing, Vol. 963, pp. 335-342, doi.org/10.1007/978-3-030-20135- 7_33). URL: link.springer.com/content/pdf/10.1007%2F978-3-030-20135-7_33.pdf. (2019).
35. Popovich, P. R., Gubinskiy, A. I. and Kolesnikov, G.M.: Ergonomic support of astronauts' activities. Moscow, Russia: Mechanical Engineering, 1985. (In Russian).
36. Lavrov, E. and Pasko, N. : Automation of Assessing the Reliability of Operator's Activities in Contact Centers that Provide Access to Information Resources. In Proceedings of the 14th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, vol. I: Main Conference. - Kyiv, Ukraine, May 14–17, pp.445–448 (2018)
37. Lavrov, E., Barchenko, N., Pasko, N. and Borozenec, I.: Development of models for the formalized description of modular e-learning systems for the problems on providing ergo-

nomic quality of human-computer interaction. Eastern-European Journal of Enterprise Technologies. Ser. “Information technology”, **2/2(86)**, 4–13 (2017) doi: 10.15587/1729-4061.2017.97718

38. Lavrov , E., Volosiuk, A., Pasko, N., Gonchar , V. and Kozhevnikov, G. : Computer Simulation of Discrete Human-Machine Interaction for Providing Reliability and Cybersecurity of Critical Systems. In Proceedings of the Third International Conference Ergo-2018: Human Factors in Complex Technical Systems and Environments (Ergo-2018) July 4 – 7, 2018, St. Petersburg Russia, pp.67–70 (2018) doi:10.1109/ERGO.2018.8443846
39. Cacciabue, P. C. : Human error risk management for engineering systems: a methodology for design, safety assessment, accident investigation and training. Reliability Engineering & System Safety, **83(2)**, 229–269 (2014) doi: 10.1016/j.ress.2003.09.013.
40. Havlikovaa, M., Jirglb, M.and Bradac, Z.: Human reliability in man-machine systems. Proc.Engineering, **100**,1207–1214 (2015)
41. Lavrov, E. and Lavrova, O.: Intelligent adaptation method for human-machine interaction in modular E-learning systems”, in. Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops, Kherson, Ukraine, June 12-15, pp.1000-1010 (2019)
42. Lavrov, E., Kupenko, O., Lavryk , T. and Barchenko, N.: Organizational Approach to the Ergonomic Examination of E-Learning Modules. Informatics in Education, **12(1)**, 107-124 (2013)
43. Lavrov, E., Barchenko, N., Pasko,N. and Tolbatov, A.: Development of Adaptation Technologies to Man-Operator in Distributed E-Learning Systems. In Proceedings of 2nd International Conference on Advanced Information and Communication Technologies-2017 (AICT-2017), Lviv, Ukraine, July 4-7, pp. 83-87 (2017)
44. Lavrov, E., Barchenok,N., Lavrova, O. and Savina, N. : Models of the Dialogue “Human - Computer” for Ergonomic Support of E-Learning. In 3rd International Conference on Advanced Information and Communications Technologies (AICT), Lviv, Ukraine, pp. 187-190 (2019) doi: 10.1109/AIACT.2019.8847763
45. Lavrov, E.A., Paderno, P. I., Volosiuk, A. A., Pasko,N.B. and Kyzenko, V.I.: Automation of Functional Reliability Evaluation for Critical Human-Machine Control Systems. In 2019 III International Conference on Control in Technical Systems (CTS), St. Petersburg, Russia, 2019, pp. 144-147(2019) doi: 10.1109/CTS48763.2019.8973294.