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9th Workshop on Cloud Technologies in Education: Report

Arnold E. Kiv[1], Serhiy O. Semerikov[2,3,4,5], Mariya P. Shyshkina[4], Andrii M. Striuk[3], Mykola I. Striuk[3], Yuliia V. Yechkalo[3], Iryna S. Mintii[2,4], Pavlo P. Nechypurenko[2], Olga O. Kalinichenko[2], Larisa S. Kolgatina[6], Kateryna V. Vlasenko[7,8], Svitlana M. Amelina[9] and Olena V. Semenikhina[10]

[1]*Ben-Gurion University of the Negev, P.O.B. 653, Beer Sheva, 8410501, Israel*

[2]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

[3]*Kryvyi Rih National University, 11 Vitalii Matusevych Str., Kryvyi Rih, 50027, Ukraine*

[4]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[5]*University of Educational Management, 52A Sichovykh Striltsiv Str., Kyiv, 04053, Ukraine*

[6]*H. S. Skovoroda Kharkiv National Pedagogical University, 29 Alchevskyh Str., Kharkiv, 61002, Ukraine*

[7]*National University of "Kyiv Mohyla Academy", 2 Hryhoriya Skovorody Str., Kyiv, 04070, Ukraine*

[8]*Technical University "Metinvest Polytechnic" LLC, 71A Sechenov Str., Mariupol, 87524, Ukraine*

[9]*National University of Life and Environmental Sciences of Ukraine, 15 Heroiv Oborony Str., Kyiv, 03041, Ukraine*

[10]*Sumy Makarenko State Pedagogical University, 87 Romenska Str., Sumy, 40002, Ukraine*

Abstract

This is an introductory text to a collection of selected papers from the 9th Workshop on Cloud Technologies in Education (CTE 2021) which held in Kryvyi Rih, Ukraine, on the December 17, 2021. It consists of short introduction, papers' review and some observations about the event and its future.

Keywords

Adaptive Cloud Learning Platforms, Blended Learning, Blockchain in Education, Cloud-based AI Education Applications, Cloud-based E-learning Platforms, Tools and Services, Cloud-based Learning Environments, Competency-Based Education Platforms, Digital Transformation of Education, Educational Data Mining, Emotion AI, Immersive Technology Applications in Education, Mobile Learning, Smart Campus Technologies, Social Analytics in Education

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1. Introduction

1.1. CTE 2021: At a glance

Cloud **T**echnologies in **E**ducation (CTE) is a peer-reviewed international Computer Science workshop focusing on research advances, applications of cloud technology in education.

The Workshop occupies contributions in all aspects of educational technologies and cloud-based learning tools, platforms, paradigms and models, functioning programmes or papers relevant to modern engineering and technological decisions in the IT age.

CTE topics of interest since 2017 [1, 2, 3, 4]:

- Adaptive Cloud Learning Platforms
- Blended Learning
- Blockchain in Education
- Cloud-based AI Education Applications
- Cloud-based E-learning Platforms, Tools and Services
- Cloud-based Learning Environments
- Competency-Based Education Platforms
- Digital Transformation of Education
- Educational Data Mining
- Emotion AI
- Immersive Technology Applications in Education
- Mobile Learning

Figure 1: CTE 2021 logo.

CTE 2021: 9th Workshop on Cloud Technologies in Education, December 17, 2021, Kryvyi Rih, Ukraine
kiv.arnold20@gmail.com (A. E. Kiv); semerikov@gmail.com (S. O. Semerikov); marimodi@gmail.com (M. P. Shyshkina); andrey.n.stryuk@gmail.com (A. M. Striuk); stryukm@gmail.com (M. I. Striuk); uliaechk@gmail.com (Y. V. Yechkalo); irina.mintiy@kdpu.edu.ua (I. S. Mintii); acinonyxleo@gmail.com (P. P. Nechypurenko); olgakalinichenko6@gmail.com (O. O. Kalinichenko); larakl@ukr.net (L. S. Kolgatina); vlasenkokv@ukr.net (K. V. Vlasenko); svetlanaamelina@ukr.net (S. M. Amelina); e.semenikhina@fizmatsspu.sumy.ua (O. V. Semenikhina)
https://ieeexplore.ieee.org/author/37087598865 (A. E. Kiv); https://kdpu.edu.ua/semerikov (S. O. Semerikov); https://iitlt.gov.ua/eng/structure/departments/cloud/detail.php?ID=269 (M. P. Shyshkina); http://mpz.knu.edu.ua/pro-kafedru/vikladachi/224-andrii-striuk (A. M. Striuk); https://scholar.google.com.ua/citations?user=hNEo4l8AAAAJ (M. I. Striuk); https://scholar.google.com.ua/citations?user=OuJGtoUAAAAJ (Y. V. Yechkalo); https://kdpu.edu.ua/personal/ismintii.html (I. S. Mintii); https://kdpu.edu.ua/personal/pnpavlo.html (P. P. Nechypurenko); https://kdpu.edu.ua/personal/ookalinichenko.html (O. O. Kalinichenko); http://hnpu.edu.ua/uk/kolgatina-larysa-sergiyivna (L. S. Kolgatina); http://irbis-nbuv.gov.ua/ASUA/0005870 (K. V. Vlasenko); https://nubip.edu.ua/node/6245 (S. M. Amelina); https://fmo-journal.org/index.php/fmo/Editor-in-chief (O. V. Semenikhina)
0000-0002-0991-2343 (A. E. Kiv); 0000-0003-0789-0272 (S. O. Semerikov); 0000-0001-5569-2700 (M. P. Shyshkina); 0000-0001-9240-1976 (A. M. Striuk); 0000-0002-7456-3725 (M. I. Striuk); 0000-0002-0164-8365 (Y. V. Yechkalo); 0000-0003-3586-4311 (I. S. Mintii); 0000-0001-5397-6523 (P. P. Nechypurenko); 0000-0002-7057-2675 (O. O. Kalinichenko); 0000-0003-2650-8921 (L. S. Kolgatina); 0000-0002-8920-5680 (K. V. Vlasenko); 0000-0002-6008-3122 (S. M. Amelina); 0000-0002-3896-8151 (O. V. Semenikhina)
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- Smart Campus Technologies
- Social Analytics in Education

This volume represents the proceedings of the 9th Workshop on Cloud Technologies in Education (CTE 2021), held in Ukraine, Ukraine, on December 17, 2021. It comprises 26 contributed paper that were carefully peer-reviewed and selected from 37 submissions (https://notso.easyscience.education/cte/2021/). Each submission was reviewed by at least 3 program committee members. The accepted paper present the state-of-the-art overview of successful cases and provides guidelines for future research.

The volume is structured in six parts, each presenting the contributions for a particular workshop session.

1.2. CTE 2021 Program Committee

Assoc. Prof. **Leon A. Abdillah**, Associate Professor of Computer Science and Information Systems, Department of Information Systems, Universitas Bina Darma, Palembang, Indonesia.

Leon A. Abdillah, was born in Limau Barat, Prabumulih/Muara Enim, South Sumatra. He has studied Information Systems, Information Systems Management, and Information Retrieval Systems during the study period. In 2001 he joined as a lecturer at one of the leading private universities in the city of Palembang. In 2010 he became Associate Professor (Assoc. Prof.) at the Faculty of Computer Science Program Information Systems Studies (Accredited A). Assoc. Prof. Leon A. Abdillah is active as speaker, author, editor, reviewer, committee on a number of journals (Scopus, Clarivate Analytics/WoS, SINTA, etc.), conferences/seminars [AIP, Atlantis Press, EAI, IEEE, IOP, SCITEPRESS], books/book chapters, etc. He includes 500 Indonesian scientists (Webometrics, 2015), examiner at Monash University (Group of Eight), Australia, and mentor at Publons, New Zealand. He also often gets awards for the best undergraduate and post graduate categories, the best computer science lecturer, the best reference article, excellent paper, top reviewer, selected article, Sinta Award, etc. His research lately has been related to Human-Computer Interaction, UI-UX, Financial Technology (Fintech), Social Media, E-Learning, Knowledge Management Systems, Management Administration, etc.

WWW: https://leonabdillah.wordpress.com/

E-mail: leon.abdillah@yahoo.com

Dr. **Fernando Almeida**, Professor of Computer Science and Innovation, Head of School of Science and Technology, ISPGAYA, V.N.Gaia, Portugal.

Fernando Luís Almeida has a Ph.D. in Computer Science Engineering from the Faculty of Engineering of University of Porto (FEUP). He also holds an MSc in Innovation and Entrepreneurship and in Informatics Engineering from FEUP. He has around 10 years of teaching experience at higher education levels in the field of computer science and management. He has also worked for 15 years in several positions as a software engineer and project manager for large organizations and research centers like Critical Software, CICA/SEF, INESC TEC, and ISR Porto. He is a founder member of the International Association of Innovation Professionals and he is involved in the development of the US TAG group for ISO 56000 (Innovation Management). His current research areas include innovation policies, entrepreneurship, software development, and decision support systems.

WWW: https://orcid.org/0000-0002-6758-4843
E-mail: almd@fe.up.pt

Prof. Dr. **Vitalina Babenko** is Professor (Full) of International E-commerce and Hotel&Restaurant Business Department, V. N. Karazin Kharkiv National University (Ukraine), Dr. Sci. (habil.) in Economics, PhD in Technical Sciences.

Her sphere of scientific interests includes the management of innovation processes, economic-mathematical modelling, information systems and technologies. She has published around 300 papers in peer-reviewed journals and in the proceedings of conferences. She has taken part in more than 100 conferences and workshops as a Chair, Keynote Speaker, member of the Scientific Program Committee, an Organizer and Session Chair. She is Editor-in-Chief of Journal of International Relations, Economics, Country Studies, Tourism; International Journal of Economics and Management Systems and member of editorial board of some scientific journals. She is the Member of Doctoral Academic Councils in Economics, Expert of the Ministry of Education of Ukraine and Expert of Ukrainian Institute Scientific Technical Information. Council many national and international informatics associations.

WWW: http://international-relations-tourism.karazin.ua/Babenko
E-mail: vitalinababenko@karazin.ua

Dr. **Liudmyla Bilousova**, Full Professor, Independent researcher, Kharkiv, Ukraine.

Liudmyla Bilousova got a M.A. in Radio-physics from Kharkiv State University, USSR (1959), and PhD in physical-mathematical science from Kharkiv State University, USSR (1970). Liudmyla Bilousova headed Computer Science Department at G.S. Skovoroda Kharkiv National Pedagogical University for 27 years (1991–2018).

She is a founder and a head of her scientific school on the problems of development of Informatics education and the implementation of innovative technologies in educational process. In the framework of the school a series of PhD and doctoral research has been completed. Dr. Liudmyla Bilousova is a scientific supervisor of 23 PhD theses. She is an author of about 400 scientific and methodical works including 5 collective monograph and 64 tutorials. Liudmyla Bilousova is a PC member of International Conference ICTERI-2019, International Workshop CTE, and ICon-MaSTEd 2020, 2021.

WWW: http://web.archive.org/web/20201027120942/http://hnpu.edu.ua/uk/bilousova-lyudmyla-ivanivna

E-mail: lib215@gmail.com

Dr. **Olga Bondarenko**, Candidate of Pedagogical Sciences, Associate Professor, Department of Economic and Social Geography and Methods of Teaching, Kryvyi Rih, Kryvyi Rih State Pedagogical University Kryvyi Rih, Ukraine.

Olga Bondarenko, born in 1979, in 2001 graduated with honors from the geographical faculty of Kryvyi Rih State Pedagogical University, majoring in "Pedagogy and Methodology of Secondary Education. Geography and Biology", acquired Bachelor Degree. In 2002 she received a Master Degree with honors in the major "Pedagogy and Methodology of Secondary Education. Geography", qualified as a teacher of geography. In 2009, she successfully defended her PhD thesis at the Republican Higher Educational Institution "Crimean Humanities University" (Yalta) and received a PhD in Pedagogical Sciences. Since 2005 he has been working at Kryvyi Rih State Pedagogical University. Author of a number of scientific publications on vocational education, training of future teachers for pedagogical activity. Her research interests include teacher training, the use of ICTs and GIS technologies in the educational process.

WWW: https://kdpu.edu.ua/personal/ovbondarenko.html

E-mail: bondarenko.olga@kdpu.edu.ua

Dr. **Chun-Yen Chang** is a science education scholar in Taiwan. Currently, he serves as National Taiwan Normal University (NTNU) Chair Professor, Director of Science Education, Professor of the Graduate Institute of Science

Education and the Department of Earth Sciences.

Over the past few years, he has been a Visiting Professor at the Taipei Medical University, The Education University of Hong Kong, and the Paris 8 University. Dr. Chang's major research interests include science education, e-Learning, interdisciplinary science learning and science communication. Dr. Chang now is the Editor-in-Chief of the *Eurasia Journal of Mathematics, Science and Technology Education* and *European Journal of Mathematics and Science Education*, as well as the Co-editor of *International Journal of Educational Methodology*. He is also on the Editorial Board of three SSCI-level journals: (1) *Studies in Science Education* (science education); (2) *Learning, Media & Technology* (learning technology); (3) *Journal of Science Education and Technology* (science education & technology). In February 2013, Dr. Chang's catechol-O-methyltransferase (COMT) study was privileged with a report by the New York Times Sunday Magazine, as well as in the news featured on Association of Psychological Science website.

WWW: http://changcy.com/index_eng.html

E-mail: changcy@ntnu.edu.tw

Dr. **Roman Danel**, researcher at Department of Mechanical Engineering, Faculty of Technology, Institute of Technology and Businesses (VŠTE) in České Budějovice, Czech Republic; assistant at Department of Applied Informatics, Faculty of Economics, VŠB-Technical university of Ostrava, Czech Republic; visiting professor at WSG Bydgoszcz, Poland.

Roman Danel, born in 1967, spent 18 years in commercial practice in the field of IT / ICT, where he worked as an analyst, senior programmer, database and system administrator, project manager in information systems development, branch manager and for 4 years ran his own company specializing in SW supplies for industrial systems. He has been working at the university since 2009, in 2012–2017 he was the head of the Automation department at the Faculty of Mining and Geology, VŠB-Technical university of Ostrava. Since 2012, he has also been lecturing databases, information systems, operating system, MES system in production and www technologies at University of Economy Bydgoszcz (WSG), Poland. His research interests include information systems and automatic control in industry, databases, software engineering and business information systems.

E-mail: danel@rdanel.cz

Ing. **Helena Fidlerová**, Ph.D., is a senior researcher at the Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Institute of Industrial Engineering and Management, Slovakia.

Ing. Helena Fidlerová, Ph.D. received her Ph.D. degree in the field of Industrial Management in 2006. Her research aims at education, STEM education, digital competencies, Industry 4.0, Education 4.0, industrial engineering, sustainable competencies, and the application of statistical methods ahivng more than 79 domestic and international responses, including 33

in WOS/Scopus. Since her study has extensive experience in domestic research projects under the Slovak Ministry of Education VEGA, KEGA), and international projects, e.g. ALTECS – Knowledge exchange in the framework of alternative economic systems for the promotion of sustainable regional development; International Visegrad Fund No. 21810100: Academic Research Consortium integrating databases, robotics, and language technologies. She is a project leader for Slovakia in Erasmus + KA2 project: Knowledge Alliance for Business Opportunity Recognition in SDGs. She is a member of the Slovak Statistical and Demographic Society (SDSS), a member of the International Association of Engineers (IAENG) and a member of the editorial board of scientific journals Acta logistica, ARCHIWUM WIEDZY INŻYNIERSKIEJ; Information Technologies and Learning Tools; EDUCATIONAL DIMENSION.

WWW: https://orcid.org/0000-0002-3426-5803
E-mail: helena.fidlerova@stuba.sk

Dr. **Irina Georgescu**, Lecturer of Computational Intelligence, Department of Informatics and Economic Cybernetics, Bucharest University of Economics, Bucharest, Romania.

Irina GEORGESCU holds a PhD in Economics from Turku Centre for Computer Science, Turku, Finland. Currently she is a lecturer at the Department of Economic Informatics and Cybernetics, Bucharest Academy of Economic Studies. Her research interests lie in the areas of fuzzy economics, computational intelligence and econometrics. She is the author of about 40 journal papers and 2 books published in Springer Verlag.

E-mail: irina.georgescu@csie.ase.ro

Dr. **Liudmyla Gryzun**, Full Professor of Information System Department at Simon Kuznets Kharkiv National University of Economics, Ukraine.

Liudmyla Gryzun earned a M.A. in Applied Mathematics from the Kharkiv State University, USSR (1986); PhD and Second Doctoral Degree in Pedagogical science from G.S. Skovoroda Kharkiv National Pedagogical University (Ukraine). The sphere of her research is focused on the curriculum and educational content design in higher education, the process of curriculum disciplines structuring, based on scientific knowledge integration; AI application to pedagogical problems solution; IT tools for inquiry-based and holistic learning etc. She is an author of more than 120 scientific and methodical works including 1 monograph, 2 collective monographs, and 6 tutorials. Liudmyla Gryzun has delivered a number of Keynote presentations at the International conferences: 2018 ICTEL (Rome, Italy), 2018 ICRTEL (Barcelona, Spain), 2019 ICSTR

(Rome, Italy), 2020 ICSTR (Berlin, Germany; Paris, France; London, UK) and others. She is also a reviewer of the foreign journals (Universal Journal of Educational Research (USA); Athens Journal of Education, IJIRES (International Journal of Innovation and Research in Educational Sciences)). Liudmyla Gryzun is a PC member of International Workshop CTE and ICon-MaSTEd 2020, 2021.

WWW: http://www.is.ksue.edu.ua/?q=node/295, https://www.linkedin.com/in/liudmyla-gryzun-68769280/, https://www.researchgate.net/profile/Liudmyla_Gryzun

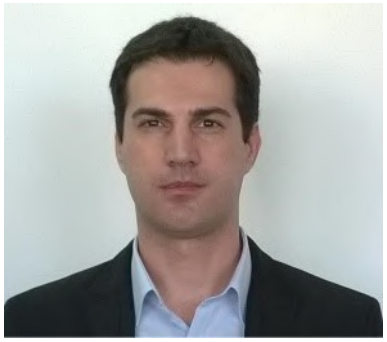
E-mail: Lgr2007@ukr.net

Dr. **Vita Hamaniuk**, Professor of German, Literature and Didactics, Department of German, Literature and Didactics, Kryvyi Rih State Pedadogical University, Kryvyi Rih, Ukraine.

Vita Hamaniuk, born in 1965, 1995 received a Candidate of Pedagogical Sciences degree (Dr. ped.) from the Kharkiv State Pedagogical H. Scovoroda University, in 2013 – a Doctor of Pedagogical Sciences degree (Dr. habil.) from the East-Ukrainian National Volodymyr Dahl University. In 2001 she received his habilitation as the Docent (Assoc. Prof.) at the Department of Foreign Languages of Kryvyi Rih State Pedagogical University. In 2015 she received his habilitation as the Professor (Full Prof.) at the Department of German, Literature and Didactics of Kryvyi Rih State Pedagogical University. From September 1995 until now Vita Hamaniuk worked as a head of Department of Foreign Languages, as an Associate Professor, Head of Department, Full Professor of Department of German, Literature and Didactics. From April 2017, she works as vice-rector for research at Kryvyi Rih State Pedagogical University. Her research interests include foreign languages teaching and learning, didactics of multilingualism, e-learning, blended learning, comparative researches in Education. She has published a number of papers in Ukrainian and international journals, actively participates in international conferences and projects.

WWW: https://kdpu.edu.ua/personal/vagamanuk.html

E-mail: vitana65@gmail.com



Dr. **Dragoș Daniel IORDACHE** is a scientific researcher 2nd degree in the "Systems and Applications for Society" department of ICI Bucharest and university lecturer at the Faculty of Psychology and Educational Sciences from University of Bucharest. He received the PhD degree in Science of Education from the University of Bucharest in 2012. His research interests include: virtual learning environments, augmented reality, professional and career counseling, usability and pedagogical evaluation of e-Learning systems, user testing and heuristic evaluation of interactive systems.

WWW: https://www.researchgate.net/profile/Dragos_Iordache
E-mail: dragos.iordache@ici.ro

M.-Carmen Juan has a Ph.D. in Computer Science (2000) from the Universitat Politècnica de València (UPV). She has been a professor at the UPV since 1996 and a Full Professor since 2014. Her areas of interest include: computer graphics, virtual and augmented reality, advanced user interfaces and their applications to psychology, medicine, and education-entertainment.

WWW: http://personales.upv.es/mjuanli/, http://www.upv.es/ficha-personal/mjuanli

E-mail: mcarmen@dsic.upv.es

Arnold Kiv received the D. Sc. (Dr. Hab.) degree in solid state physics from Tartu Institute of Physics, Tartu, Estonia, in 1978.

From 1964 to 1982, he was a Senior Researcher and a Head of the Laboratory of Radiation Effects, Institute of Nuclear Physics, Academy of Sciences, Tashkent, Uzbekistan. From 1983 to 1998, he was a Head of the Department of Theoretical Physics, South-Ukrainian National Pedagogical University, Odessa, Ukraine. In 1997, he was an Invited Professor, Western Ontario University, Canada. From 1999 to the present, he is a Professor-Researcher in the Department of Materials Engineering, Ben-Gurion University of the Negev, Israel. In 1996 and 2011 he was co-Director of NATO Advanced research Workshops and an Editor of two NATO Series books. He has about 200 publications, three monographs and three Invention Certificates in the field of radiation effects in solid state electronics. His research interests include mechanisms of formation of radiation defects in solids, interaction of fast particles with materials, radiation methods in microelectronics, including computer simulation, analytical calculations and experimental studies.

Dr. **Oleksandr Kolgatin**, Professor of Informatics, Department of Information Systems, Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine.

Oleksandr Kolgatin, born in 1966, received a Candidate of Technical Sciences degree (Dr. phil.) from the Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, in 1995, the field of scientific interests was computational modeling of the heat and mass transfer processes. Since 1990, he worked in the field of teaching informatics and using information

technologies in education and received a Doctor of Pedagogical Sciences degree (Dr. habil.) from the Institute of Information technologies and Learning Tools of the National Academy of Pedagogical Sciences of Ukraine, in 2011. His research interests include computational modeling, pedagogical diagnostics, information systems and technologies in education. He has published a number of papers in international journals and volumes in book series, is a member of editorial boards of Journal of Information Technologies in Education and associate editor of Information Technologies and Learning Tools.

WWW: http://www.is.hneu.edu.ua/?q=node/294
E-mail: kolgatin@ukr.net

Assoc. Prof. **Yaroslav Krainyk**, Head of Computer Engineering Department, Petro Mohyla Black Sea National University, Mykolaiv, Ukraine.

Yaroslav Krainyk, born in 1990, received a Ph.D. degree in Computer Systems and Components from Petro Mohyla Black Sea State University, Ukraine, in 2016. His research interests include computer systems and their applications, embedded systems, reconfigurable computing, FPGA. Since 2016, he has been a member of Computer Engineering Department as a senior lecturer, doctoral student, and associate professor. In 2019, he became a head of Computer Engineering Department. He has participated in the reviewing of papers published by Elsevier, IEEE, and Springer. He is a section editor in Computer Science & Engineering Journal (https://cse-journal.com/index.php/journal).

WWW: https://www.scopus.com/authid/detail.uri?authorId=56925498100, https://orcid.org/0000-0002-7924-3878, https://scholar.google.com/citations?user=-GCy09MAAAAJ
E-mail: yaroslav.krainyk@chmnu.edu.ua

Dr. **Hennadiy Kravtsov**, Kherson State University, Ukraine.

WWW: http://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Kravtsov.aspx
E-mail: kgmkherson@gmail.com

Dr. **Volodymyr Kukharenko**, Professor of Technical Cryophisics Department, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine.

Volodymyr Kukharenko, born in 1947, received a Candidate of Technical Sciences degree from Physical Technic Institute of Low Temperature National Academy of Sciences

of Ukraine. Since 1976, he has been working in the field of low temperature at the National Technical University "Kharkiv Polytechnic Institute", where he is professor of Technical Cryophisics Department and academician of International Academy of Refrigeration UD.

His research interests include distance learning. He has published a number of papers in international journals and six books from creating distance courses, about tutor, blended learning.

WWW: https://dl.khpi.edu.ua

E-mail: kukharenkovn@gmail.com

Dr. **Andrey Kupin**, Professor, Head of the Department of Computer Systems and Networks, Kryvyi Rih National University, Kryvyi Rih, Ukraine.

Andrey Kupin was born in Slovianoserbsk, Luhansk region, Ukraine, in 1972. He received the engineering degree in robotic systems and complexes from East-Ukrainian State University, in 1994 and the Ph.D. degree in automation from Kryvyi Rih Technical University, in 2001. From 2006 to 2007, he worked as an Associated Professor of the Department of Informatics, Automation and Control Systems. In 2010 he became a doctor of science in automation, professor (2013). Dean of the Faculty of Information Technology (2011-2015). From 2007 he is the Head of the Department of Computer Systems and Networks. He is the author more than 190 articles and 8 patents. Professor Kupin as a scientific adviser has prepared 4 PhD and 1 DrSc. His research interests include artificial intelligence, information and integrated automation of technological processes.

WWW: http://fit.knu.edu.ua/page/kafedra-komp-yuternykh-sistem-i-setey

E-mail: kupin@gmail.com

Oksana Lytvyn, Head of the Chair of Computer Science and Mathematics, Faculty of Information Technology and Management, Borys Grinchenko Kyiv University, Kyiv, Ukraine.

Oksana Lytvyn, born in 1970, received a Candidate of Sciences in Physics and Mathematics (PhD) from the V.Ye. Lashkaryov Institute of Semiconductor Physics, NAS of Ukraine, in 2001. Research interests: mathematical methods and information-analytical technologies, solid state physics.

WWW: http://eportfolio.kubg.edu.ua/teacher/301

E-mail: o.lytvyn@kubg.kiev.ua

Liliia Midak, Candidate of chemical sciences, Associate Professor at the Department of Environmental Chemistry and Chemical Education, Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk, Ukraine.

Liliia Midak graduated from the Vasyl Stefanyk Precarpathian University in 2002 (speciality Chemistry). In 2006 presented the candidate dissertation on subject "Physic-chemical and antifriction properties of composites on thermal stability polymers in interaction with titanium alloys". She is a corresponding member of the Technical sciences Academy of Ukraine, the chairman of the public organization "STUDY INNOVATION WORKSPACE LICO". Her research interests include technology and characteristics of antifriction composite polymeric materials; mathematical methods of planning and experiment analysis; safety of food (products); toxicology of synthetic washing chemicals; modern educational learning technologies; digital learning tools; augmented and virtual reality in education.

WWW: https://chemeducation.pnu.edu.ua/5319-2/

E-mail: lilia.midak@gmail.com

Ph. D. **Iryna Mintii**, associate professor of Computer Science, Department of Computer Science and Applied Mathematics, vice dean of Faculty of Physics and Mathematics, Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine.

Iryna Mintii received a Candidate of Pedagogical Sciences degree (Ph. D.) from the National Pedagogical Dragomanov University, Kyiv, Ukraine, in 2013. Her research interests include ICT in education. She has published a number of papers in international journals.

WWW: https://kdpu.edu.ua/personal/ismintii.html

E-mail: irina.mintiy@kdpu.edu.ua

Dr. **Natalia Moiseienko**, Associated professor of Computer Science and Applied Mathematics Department, Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine.

Natalia Moiseienko, born in 1973, received a Candidate of Philosophical Sciences degree (Dr. phil.) from the Odessa National Polytechnic University, Ukraine, in 2004. Since 1995, she has been working in the field of programming and computer modelling at the Kryvyi Rih State Pedagogical University, where she is currently associated professor. Her research interests include computer graphics, computer game programming and educational technologies. She has published a number of papers in international journals, is a Member of the Program Committee of many international conferences.

WWW: https://kdpu.edu.ua/personal/nvmoiseienko.html
E-mail: n.v.moiseenko@gmail.com

Dr. **Nataliia Morze**, Corresponding Member of National Academy of Pedagogical Sciences of Ukraine, Professor of Borys Grinchenko Kyiv University Department of Computer Science and Mathematics, Borys Grinchenko Kyiv University, Kyiv, Ukraine.

Nataliia Morze, received a Candidate of Pedagogical Sciences degree (Dr. phil.) from the Dragomanov National Pedagogical University (Kiev) in 1987, and a Doctor of Pedagogical Sciences degree (Dr. habil.) in 2004. Her professional and scientific interests are in the areas of distance learning technologies, education for adults, implementation of information and communication technologies into education process of secondary and higher educational institutions, creation of teaching and scientific e-learning environment and development of teachers information competence. She is the author of more than 400 scientific papers in the field of computer science, informatics in a primary and secondary schools, learning methodology, ICT in education, multimedia, teacher training in the area of ICT and e-learning. She is researcher and coordinator of Ukraine and international scientific and educational projects.

WWW: http://wiki.kubg.edu.ua/%D0%9C%D0%BE%D1%80%D0%B7%D0%B5_%D0%9D%D0%B0%D1%82%D0%B0%D0%BB%D1%96%D1%8F_%D0%92%D1%96%D0%BA%D1%82%D0%BE%D1%80%D1%96%D0%B2%D0%BD%D0%B0
E-mail: n.morze@kubg.edu.ua

Pavlo Nechypurenko, Associate Professor of Department of Chemistry and Methods of its Teaching, Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine.

Pavlo Nechypurenko, born in 1981, received a Magister of Teaching of Chemistry from Kryvyi Rih State Pedagogical University, Ukraine, in 2004, and a Candidate of Pedagogical Sciences degree (Dr. phil.) from the Luhansk Taras Shevchenko National University, Ukraine, in 2017. Since 2004, he has been working in the field of analytical chemistry and method of solving chemical problems at the Kryvyi Rih State Pedagogical University. His research interests include using of ICT on Chemistry education, Analytical Chemistry, Technique of chemical experiment. He has published a number of papers in Ukrainian and international journals and developed a series of virtual laboratory work to teaching chemistry.

WWW: https://kdpu.edu.ua/personal/pnpavlo.html
E-mail: acinonyxleo@gmail.com, acinonyxleo@kdpu.edu.ua

Yulia Nosenko, Leading Researcher, Department of Cloud-Oriented Systems of Education Informatization, Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, Kyiv, Ukraine.

Yuliia Nosenko, born in 1984, received a Candidate of Pedagogical Sciences degree (Ph.D.) in 2011. In 2010-2015 worked at Taras Shevchenko National University of Kiev (part time). Since 2010 has been working at the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, where she is currently leading researcher. Her research interests relates to implementation and use of cloud services in education, formation and development of educators' digital competence, use of ICT as a tool for supporting inclusive learning. She has published over 80 scientific papers, including articles in international journals, is a member of editorial board of peer-reviewed e-journal "Information Technologies and Learning Tools".

WWW: http://iitlt.gov.ua/structure/departments/cloud/detail.php?ID=48

E-mail: nosenko-y@ukr.net

Vasyl Oleksiuk, PhD (pedagogical sciences), associate professor of the Department of Computer Science and Teaching Techniques, Ternopil Volodymyr Hnatiuk National Pedagogical University, Ternopil, Ukraine.

Vasyl Oleksiuk, born in 1980, received a Candidate of Pedagogical Sciences degree (Dr. phil.) from the National Pedagogical University, Kyiv, Ukraine, in 2007. Since 2003, he has been working Department of Computer Science and Teaching Techniques at Ternopil Volodymyr Hnatiuk National Pedagogical University, where he is currently associate professor. His research interests include computer networks, cloud computing, e-learning, electronic libraries. He has published a number of papers in Ukrainian and international journals, is a member of editorial boards of the journals Information Technologies and Learning Tools (Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine) and The Scientific Issues of Ternopil Volodymyr Hnatiuk National Pedagogical University (Series: pedagogy).

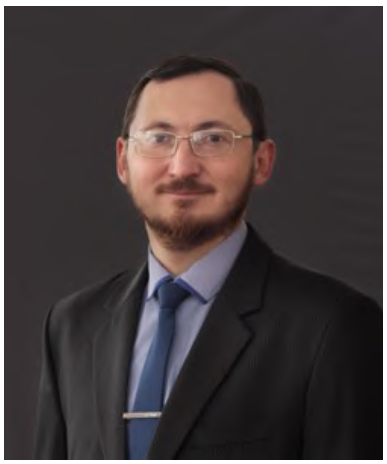
WWW: http://tnpu.edu.ua/faculty/fizmat/oleksyuk-vasil-petrovich.php

E-mail: oleksyuk@fizmat.tnpu.edu.ua

DSc **Kateryna Osadcha**, Professor, Department of Computer Science and Cybernetics, Bogdan Khmelnitsky Melitopol state pedagogical university, Melitopol, Ukraine.

Kateryna Osadcha, born in 1977, received a Candidate of Pedagogical Sciences (PhD in Education) from the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynsky, Ukraine, in 2010, and a Doctor of Pedagogical Sciences (Dr. Sc) from Classic Private University, in 2020. Since 2011, she has been working as an Associate professor of the Department of Computer Science and Cybernetics at the Bogdan Khmelnitsky Melitopol state pedagogical university. Her research interests include: computer science, network technology, programming, ICT, e-learning, engineering education, educational technology, tutoring. She is author of about a hundred scientific works, including textbooks, monographs, author's certificates. She is a member of editorial boards of "Ukrainian Journal of Educational Studies and Information Technology" (Ukraine), "International Conference on Higher Education Advances" (Spain), "Transactions of Kremenchuk Mykhailo Ostrohradskyi National University" (Ukraine), "Professional Education: Methodology, Theory and Technologies" (Ukraine).

WWW: http://osadcha.mdpu.org.ua
E-mail: okp@mdpu.org.ua



Dr. **Viacheslav Osadchyi**, Professor of Department of Computer Science and Cybernetics, Bogdan Khmelnitsky Melitopol state pedagogical university, Melitopol, Ukraine.

Viacheslav Osadchyi, born in 1975, received a Candidate of Pedagogical Sciences (PhD in Education) from the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynsky, Ukraine, in 2006, and a Doctor of Pedagogical Sciences from the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynsky, Ukraine, in 2013. Since 1999, he has been working in the field of information technology and vocational education at the Bogdan Khmelnitsky Melitopol state pedagogical university. Now – Head of the Department of Computer Science. His research interests include: computer science, information networks, ICT, programming, software development, information systems, data science. He has published a number of papers in international journals. He is a member of editorial boards of "Ukrainian Journal of Educational Studies and Information Technology" (Ukraine), "Computing Conference" (formerly called "Science and Information (SAI) Conference") (UK), Intelligent Systems Conference (IntelliSys) (The Netherlands), "International Conference on Higher Education Advances" (Spain), "Transactions of Kremenchuk Mykhailo Ostrohradskyi National University" (Ukraine), "Information Technologies and Learning Tools" (Ukraine), "Scientific papers of Berdyansk State Pedagogical University Series: Pedagogical sciences" (Ukraine).

WWW: http://osadchyi.mdpu.org.ua

E-mail: poliform55@gmail.com

Dr. **Liubov Panchenko**, Professor at the Department of Sociology, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine.

Liubov Panchenko was awarded a Candidate of Pedagogical Sciences degree (Dr. phil.) from H. S. Skovoroda Kharkiv National Pedagogical University, Kharkiv, Ukraine, in 1995, and a Doctor of Pedagogical Sciences degree (Dr. habil.) from the Luhansk Taras Shevchenko National University, in 2012. Since 1993, she has been working in the field of information and communication technology in education. Since 2016 she has been a Professor at the Department of Sociology, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Her research interests include information and communication technology in education, university's educational environment, MOOCs, data analysis and multivariate methods in scientific research, digital storytelling, adult education. She has published a number of papers and text books ("Computer data analysis", "Data analysis practicum", "Mathematical and statistical methods of sociological information's analysis") and is an editorial board member of the Ukrainian journals "Information Technologies and Learning Tools" (associated editor), "e-Environment of Modern University", and "Humanization of the educational process".

WWW: http://www.sociology.kpi.ua/en/faculty-2

E-mail: lubov.felixovna@gmail.com

Dr. **Stamatios Papadakis** has been a postdoctoral researcher in Educational Technology, with emphasis on mobile learning, at the Department of Preschool Education at the University of Crete, Greece, since 2016. He has graduated from the Department of Informatics, Athens University of Economics and Business, Athens, Greece. In 2016, he completed a Ph.D. at the University of Crete, Department of Education in Rethymnon, Greece. He has worked as an adjunct Lecturer in Education teaching Didactics in Programming (2017–2018) at the Department of Computer Sciences, School of Sciences and Engineering at the University of Crete, Greece. Since 2017 he has worked as an adjunct Lecturer in Education teaching Informatics (2017–2018) at the Department of Preschool Education, School of Education, University of Crete, Greece. His scientific and research interests include the study of mobile learning, especially on the use of smart mobile devices and their accompanying mobile applications (apps) in Preschool and Primary Education, focusing on the development of Computational Thinking and students' understanding of numbers. Furthermore, he currently investigates how a STEM learning approach influences learning achievement through a context-aware

mobile learning environment in the preschool classroom and explain the effects on preschoolers' learning outcomes.

WWW: https://www.researchgate.net/profile/Stamatios_Papadakis, https://independent.academia.edu/PapadakisStamatis, https://scholar.google.gr/citations?user=e3vLZegAAAAJ&hl=en, https://orcid.org/0000-0003-3184-1147, https://www.scopus.com/authid/detail.uri?authorId=57038471800, http://moeads.edc.uoc.gr/

E-mail: stpapadakis@uoc.gr

Olga Pinchuk, PhD (in Pedagogics), Senior Researcher in the field of information and communication technologies in education. Education: M.P. Drahomanov Kyiv State Pedagogical Institute in specialties of Mathematics, Computer Science and Computer Engineering teacher.

Olga Pinchuk, born in 1969, received the degree of Candidate of Pedagogical Sciences (PhD) at the National Pedagogical Dragomanov University, Ukraine, in 2011. Since 2005 she has been working in the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, Deputy Director for Scientific Experimental Work, Leading Researcher. Her research interests include scientific and methodological foundations use of computer oriented tools in teaching natural and mathematical subjects, organization of the educational environment of distance learning, formation of digital competencies of participants in the learning process, design and technological support of web platforms of online encyclopedias. She has published a number of papers in international journals and chapters in collective monographs. Holds the post of co-editors-in-chief of "Information Technologies and Learning Tools", a peer-reviewed e-journal in educational sphere.

WWW: http://iitlt.gov.ua/

E-mail: opinchuk@iitlt.gov.ua

Dr. **Oleg Pursky**, Professor of Computer Science and Information Systems, Chief of Department of Computer Science and Information Systems, Kyiv National University of Trade and Economics, Kyiv, Ukraine.

Oleg Pursky, born in 1967, received a Candidate of Sciences in Physics and Mathematics degree (Dr. phil.) from the Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, in 2001, and a Doctor of Sciences in Physics and Mathematics degree (Dr. habil.) from the Taras Shevchenko National University of Kyiv, Ukraine, in 2010. His research interests include informational systems development, computer simulation and modeling of socio-economic systems. He has published

a number of papers in international journals, monographs
and volumes in book series, is a member of editorial board of International Journal of Economic Theory and Application, reviewer of scientific journals International Journal of Modern Physics (B) and Heat Transfer and certified Data Science&Machine Learning specialist. He is a member of Scientific Council section of Ukrainian Ministry of Education and Science on the specialty "Informatics and Cybernetics". Currently, he is working as a Head of Department of Computer Science and Information Systems, Kyiv National University of Trade and Economics.

WWW: https://knute.edu.ua/blog/read/?pid=12695&uk, https://knute.edu.ua/file/MTcyNjQ=/98717622ed46f90a934d4e922d214fbc.pdf

E-mail: Pursky_O@ukr.net

Dr. **Serhiy Semerikov**, Professor of Computer Science and Educational technology, Kryvyi Rih State Pedagogical University, Ukraine.

Serhiy Semerikov is professor of Department of Computer Science and Applied Mathematics at Kryvyi Rih State Pedagogical University. He got both PhD and DSc in education (informatics) from the National Pedagogical Dragomanov University in 2001 and 2009, respectively. The main directions of Dr. Semerikov' research is methods of learning and educational technology.

WWW: https://kdpu.edu.ua/semerikov/

E-mail: semerikov@gmail.com

Dr. **Yevhenii Shapovalov**, Senior researcher in Junior Academy of Sciences of Ukraine, Kyiv.

Yevehenii Shapovalov, born in 1992, received a Candidate of Technical Sciences degree (Dr. techn.) from the National University of Life and Environmental Sciences of Ukraine, in 2019. Since 2012, he has been working in the field of STEM education, using of IT in education, development of informational technologies, environmental engineering (anaerobic waste treatment), Sustainable development and European integration. He has published a number of papers in international journals and volumes in book series, is a member of editorial boards of Journal "Scientific letters of Junior Academy of Sciences" and reviewer in conferences of Academy of Cognitive and Natural Sciences.

WWW: http://www.nas.gov.ua/UA/PersonalSite/Pages/default.aspx?PersonID=0000026333

E-mail: sjb@man.gov.ua

Dr. **Andrii Striuk**, Ph.D., Head of Simulation and Software Engineering department of Kryvyi Rih National University, Kryvyi Rih, Ukraine.

Andrii Striuk, born in 1979. In 2000 he graduated from the Kryvyi Rih Technical University with a degree in Automated Systems Software. In 2001, he received a master's degree in computer science. Has been working at the Department of Modeling and Software of Kryvyi Rih National University since 2000. Combines educational activities with practical, developing and implementing educational software products. In 2011 he defended his Ph.D. thesis. From 2014 to 2017 he is studying at the doctoral program in Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine (Kyiv, Ukraine). In 2017, he was awarded the Prize of the President of Ukraine for young scientists. Heads the Simulation and Software Engineering department of Kryvyi Rih National University since 2018. Field of scientific interest: professional training of software engineers, mobile learning technologies, the use of augmented reality technologies in education.

WWW: http://mpz.knu.edu.ua/pro-kafedru/vikladachi/224-andrii-striuk

E-mail: andrii.striuk@knu.edu.ua

Dr. **Yurii Tryus**, Professor of Applied Mathematics, Department of Computer Science and System Analysis, Cherkasy State Technological University, Cherkasy, Ukraine.

Yurii Tryus, born in 1957, received a Candidate of Candidate Physics and Mathematics Sciences degree (PhD) from the Shevchenko Kyiv State University, in 1987, and a Doctor of Pedagogical Sciences degree (Dr. habil.) from the National Pedagogical Dragomanov University, in 2005. Since 2012, he is head of the Department of Computer Science and System Analysis, Cherkasy State Technological University. His research interests include Theory and Methods of Optimization and Operations Research, Decision Theory, Information and Communication Technologies in Higher Education, Theory and methods of teaching mathematics and computer science. He has published near 230 of papers in Ukrainian and international journals, 10 monographs and manuals, is a member of editorial boards of E-journal "Information Technologies and Learning Tools", Journal "Information Technologies in Education", Scientific journal of the National Pedagogical Dragomanov University. Series 2. Computer-based learning systems.

WWW: https://knsa.chdtu.edu.ua/tryus-yurii-vasylovych

E-mail: tryus@chdtu.edu.ua

Dr. **Tetiana Vakaliuk**, professor, professor of the department of Software Engineering, Zhytomyr Polytechnic State University, Zhytomyr, Ukraine.

Tetiana Vakaliuk, born in 1983, received a Candidate of Pedagogical Sciences degree from the National Pedagogical Dragomanov University, Ukraine, in 2013, and a Doctor of

Pedagogical Sciences degree from the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, in 2019. Since 2019, she has been working in the field of information technologies at the Zhytomyr Polytechnic State University. Her research interests include information technologies, ICT in Education, Cloud technologies. She has published a number of papers in international journals, is a member of editorial boards of Information Technologies and Learning Tools, Zhytomyr Ivan Franko State University Journal: Pedagogical Sciences, Collection of Scientific Papers of Uman State Pedagogical University.

WWW: https://sites.google.com/view/neota
E-mail: tetianavakaliuk@gmail.com

Dr. **Nataliia Valko**, DSc in Pedagogical, PhD of Physics and Mathematic Sciences, Department of Informatics, Software Engineering and Economic Cybernetics, Kherson State University, Kherson, Ukraine.

Nataliia Valko, in 2006 earned a PhD degree of Physics and Mathematic Sciences in specialty "Mathematical modeling and numerical methods", and a Doctor of Pedagogical Sciences degree (Dr. habil.) in 2020. She has extensive experience in teachers education via modern teaching technologies, blended learning, STEM-education. Her teaching experience in University is over 20 years. She is one of the organizers of the STEM school of KSU. She has management skills in the field of teacher training, planning educational activities, creating distance learning courses on the Moodle platform. She manages students design work to create models of robotic systems. Effectively applies innovative teaching methods for future teachers of natural-mathematical disciplines using robotics and their preparation for using STEM-technologies in teaching. She actively studies innovative teaching methods, methods of project activity. She has published a number of papers of different kinds (including books, articles in scientific international journals, conference proceedings etc.), is a member of editorial boards of Journal of Information Technologies in Education (ITE).

WWW: http://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/NValko.aspx
E-mail: valko@ksu.ks.ua

Dr. **Vladyslav Velychko**, Associate Professor of Methods of Teaching Mathematics and Methods of Teaching Computer Science, Faculty of Physics and Mathematics, Donbas State Pedagogical University, Sloviansk, Ukraine

Vladyslav Velychko, born in 1973, received a Candidate of Physical and Mathematical Sciences degree (Dr. phil.) from the Kyiv Taras Shevchenko National University, Ukraine,

in 2006, and a Doctor of Pedagogical Sciences degree (Dr. habil.) from the Donbas State Pedagogical University, in 2019. Since 1994, he works in the field of algebra, methods of teaching computer science, the use of information and communication technologies in education at Donbas State Pedagogical University, where he is now head of the department. Research interests – quasi-ideals of semigroups, algorithms on algebraic structures, free software, open electronic educational resources. He has published a number of articles in international journals and made presentations at international conferences and seminars.

WWW: https://ddpu.edu.ua/cc/velychko

E-mail: vladislavvelichko@gmail.com

Nataliia Veretennikova, PhD, candidate of social communication, assistant of the Department of Information Systems and Networks, Lviv Polytechnic National University, Lviv, Ukraine.

Nataliia Veretennikova, born in 1990, received PhD degree from Vernadsky National Library of Ukraine in 2017. She is a winner of the President's Award for Young Scientists in 2019 and a winner of the Regional Prize for Young Scientists and Researchers for Scientific Achievements that Contribute to Social and Economic Transformation in the Region and Affirm the High Authority of Lviv Region Scholars in Ukraine and in the World. Her scientific research relates to the field of electronic science, linguistic support, and social communications. She is an author of a lot of papers in domestic and international journals as well as volumes. She is a member of editorial boards and joins in Programme and Organizing committees of international conferences or workshops.

WWW: http://wiki.lp.edu.ua/wiki/%D0%92%D0%B5%D1%80%D0%B5%D1%82%D0%B5%D0%BD%D0%BD%D1%96%D0%BA%D0%BE%D0%B2%D0%B0_%D0%9D%D0%B0%D1%82%D0%B0%D0%BB%D1%96%D1%8F_%D0%92%D1%8F%D1%87%D0%B5%D1%81%D0%BB%D0%B0%D0%B2%D1%96%D0%B2%D0%BD%D0%B0

E-mail: nataver19@gmail.com

Dr. **Kateryna Vlasenko**, Professor of Maths, Department of Mathematics, National University of "Kyiv Mohyla Academy", Ukraine.

Kateryna Vlasenko, born in 1966, received a Candidate of Pedagogical Sciences degree (PhD) from the National Pedagogical Dragomanov University, Ukraine, in 2004, and a Doctor of Pedagogical Sciences degree (D.Sc. in Educational Science) from the Bohdan Khmelnytsky National University of Cherkasy, in 2011. Since 2008, she has been working in the field of mathematical and pedagogical modeling at National University of "Kyiv Mohyla Academy". Her research interests include the issues of mathematics education. She has published a number of papers in international journals

and volumes in book series, is a member of editorial boards of Innovative Solutions in Modern Science, Topical Issues of Natural and Mathematical Education Sumy State Pedagogical University named after A. Makarenko.

WWW: http://formathematics.com/tutors/kateryna-vlasenko/

E-mail: vlasenkokv@ukr.net

Dr. **Yuliia Yechkalo**, Associate professor, Department of Physics, Kryvyi Rih National University, Kryvyi Rih, Ukraine.

Yuliia Yechkalo, born in 1981, received a Candidate of Pedagogical Sciences degree from the Kirovograd State Vladimira Vinnichenka Pedagogical University, Ukraine, in 2013. Since 2005, she has been working at the National Metallurgical Academy of Ukraine. She has been working at the Kryvyi Rih National University since 2012. Her research interests include theory and methods of education (physics) and information and communication technologies in education.

E-mail: uliaechk@gmail.com

2. Articles overview

2.1. Session 1: Digital Transformation of Education

Digital technology permeates all aspects of life. During the pandemic, all countries in the world began to use distance learning methods through the use of digital platforms, classes, labs. Digitalization avoided the collapse of the educational system. The aim of the article "Problematic issues of digitalization of education in Eastern Europe" [5] by Anastasiia O. Simakhova (figure 2), Artem E. Artyukhov, Halina A. Shmarlouskaya is to analyze the processes of digitization of education in Eastern Europe. To achieve the goal of the article, the following tasks were set: to study the theoretical basis of the digitization of education, to analyze the trends in the digitization of education in Eastern Europe, to develop recommendations for improving the digitization of education. The article analyzed the ranks of the Network Readiness Index and the Global Digital Readiness Index in terms of the technological readiness of higher education institutions and students for distance education. The article offers a case study of the Ukrainian university for the implementation of an e-learning environment. The authors grouped countries from Eastern Europe according to their potential for digitizing education. For these groups of countries, the authors identified specific criteria. SWOT an analysis of the digitization of education was conducted for the countries of Eastern Europe.

In the article "The use of digital tools by secondary school teachers for the implementation of distance learning in the context of digital transformation in Ukraine" [6], Oksana V. Ovcharuk, Andrii M. Gurzhii, Iryna V. Ivaniuk, Liubov A. Kartashova, Olena O. Hrytsenchuk, Tetiana A. Vakaliuk, Mariya P. Shyshkina (figure 3) raise the discussion on the use of digital learning tools

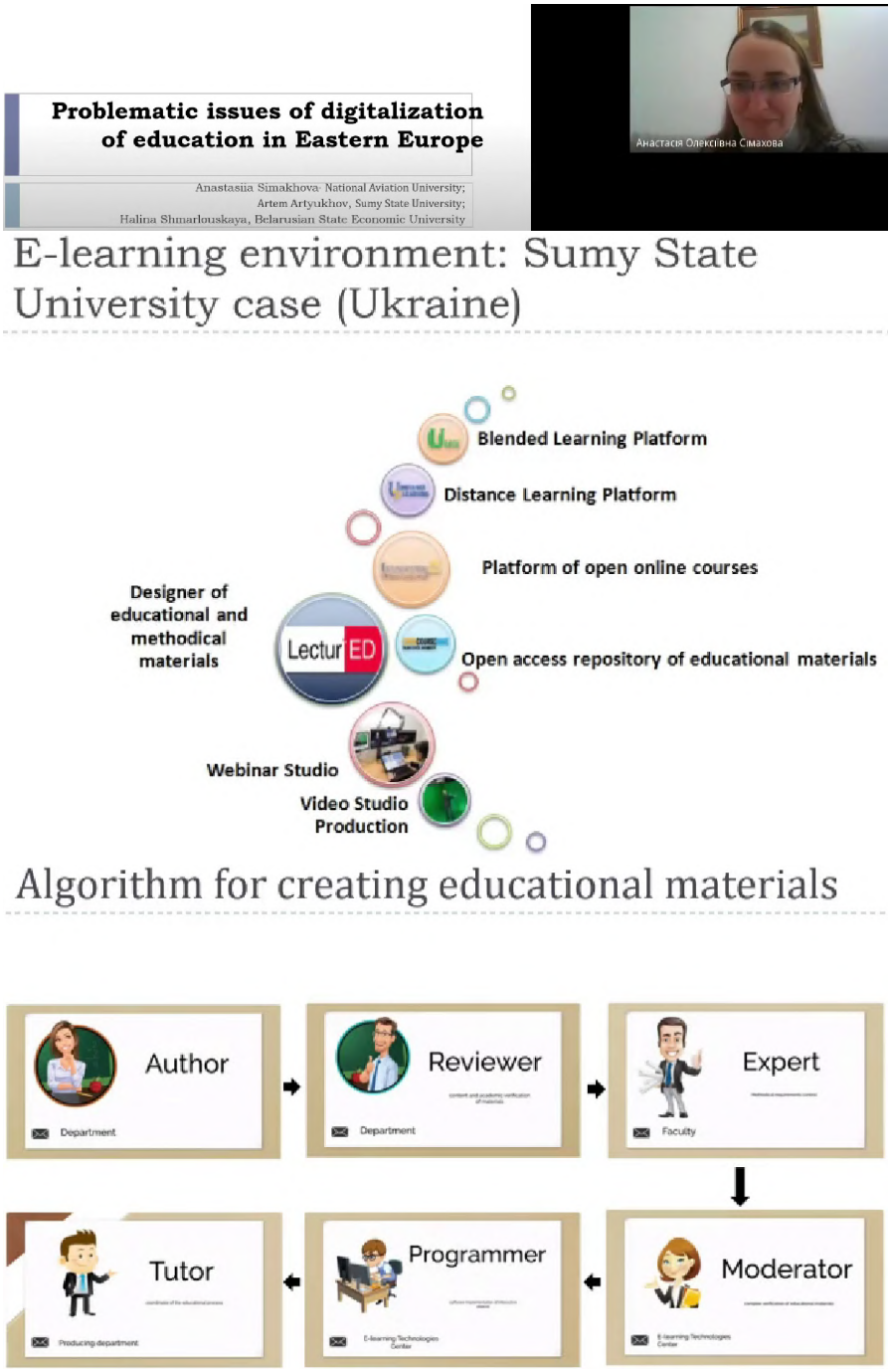


Figure 2: Presentation of paper [5].

by teachers of Ukrainian secondary schools for the organization of distance learning. In order to collect data authors have used the survey instruments (Google questionnaire) and involved

1463 respondents who revealed the state of the use of digital learning tools for the organization of distance learning in the quarantine period caused by COVID-19 pandemic. The study was conducted in all regions of Ukraine. The results show that teachers have a need to master their knowledge and practical skills on digital instruments for the organization of distance learning with students. On the other hand the paper presents the experience on how the problem of the mastering of teachers' digital competencies can be organized and what are the steps to the organization of special distance learning courses for teachers in Ukraine. The experience of the creation of Web portal of Ukrainian Open University of Postgraduate Education is presented. Authors propose on how the needs and requirements of teachers regarding the implementation of the distance learning in schools and the development of their digital competencies should be resolved.

This article highlights further research by the authors, begun in [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22].

The problems of contemporary IT specialists' training in terms of the high requirements to their computational thinking skills as well as the urgency of raising their motivation to mastering algorithmization and programming are discussed in the article "Computer modeling of the tournament of game algorithms in the process of learning of basics of algorithmization and programming by pre-service IT-specialists" [23]. It is emphasized by Liudmyla E. Gryzun (figure 4), Oleksandr V. Shcherbakov and Svitlana H. Lytvynova that initial university courses should focus pre-service IT-specialists on the deep understanding of an algorithmic nature of any coding task, to realize basic characteristics of the algorithms, to understand their role in modern software development. Due to the contemporary demands, programming should rest on algorithms building and has to be a part of lager scale experiences in order to realize its full potential. One of such experiences offered by the authors in the paper is involving the students into specially arranged activity focused on efficient game algorithms creation and simulation of the tournament between the algorithms. The offered activity is elaborated based on the applying the gamification elements into the learning process. Basing on the core gamifiaction principles, there were thought over and arranged an activity involving the students into the creation of gamified products. In this case, the gamified product which the students had to develop in the process of learning of algorithmization and programming was the software platform which enables a computer simulation of the tournament between the different game algorithms which realize winning strategies. The peculiarities and the stages of the said activity are covered in details along with the description of the final software product. Analyzing the described functionality of the computer simulator of the algorithms tournaments based on the gamification ideas, authors can emphasize its significant didactic facilities in the context of its using for IT-specialists training. In particular, the developed gamified product was probed in the process of other students' mastering algorithmization and programming as well as of the schoolchildren training during summer IT schools. The prospects of the research are outlined in the lines of using the obtained results for holding the empirical research for the verification of offered activity impact on the results of IT-specialists training.

This article highlights further research by the authors, begun in [24, 25, 26, 27, 28, 29, 30, 31, 32, 33].

The aim of the article "ICT and current trends as a path to STEM education: implementation and prospects" [34] by Natalia S. Lukychova (figure 5), Nataliia V. Osypova, Galina S. Yuzbasheva

The use of digital tools by secondary school teachers for the implementation of distance learning in the context of digital transformation in Ukraine

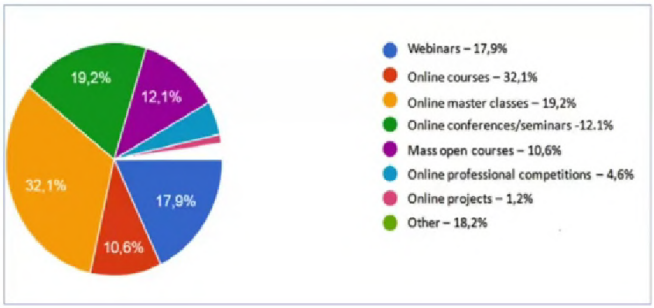
Oksana Ovcharuk, Iryna Ivaniuk, Olena Hrytsenchuk, Andrii Gurzhii, Lubov Kartashova, Tetiana Vakaliuk, Mariia Shyskina

Institute of Information Technologies and Learning Tools of the NAES of Ukraine. Kyiv, Ukraine

9th Workshop on Cloud Technologies in Education (CTE 2021)

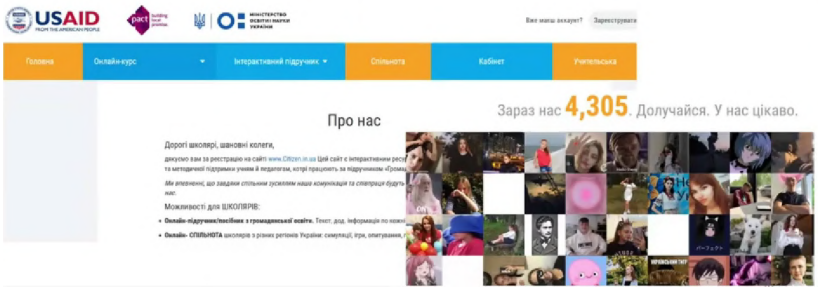
The most effective online forms of professional development

- online courses - 32.1%
- online master classes - 19.2%
- webinars - 17.9%
- online conferences / seminars - 12.1%
- mass open courses - 10.6%
- online professional competitions - 4.6%



Good practices

3D Democracy: think, care, act' (https://citizen.in.ua/about.php), created by NGO 'Nova Doba' with the support of USAID, MoES and others



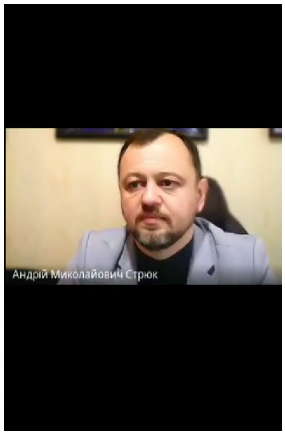


Figure 3: Presentation of paper [6].

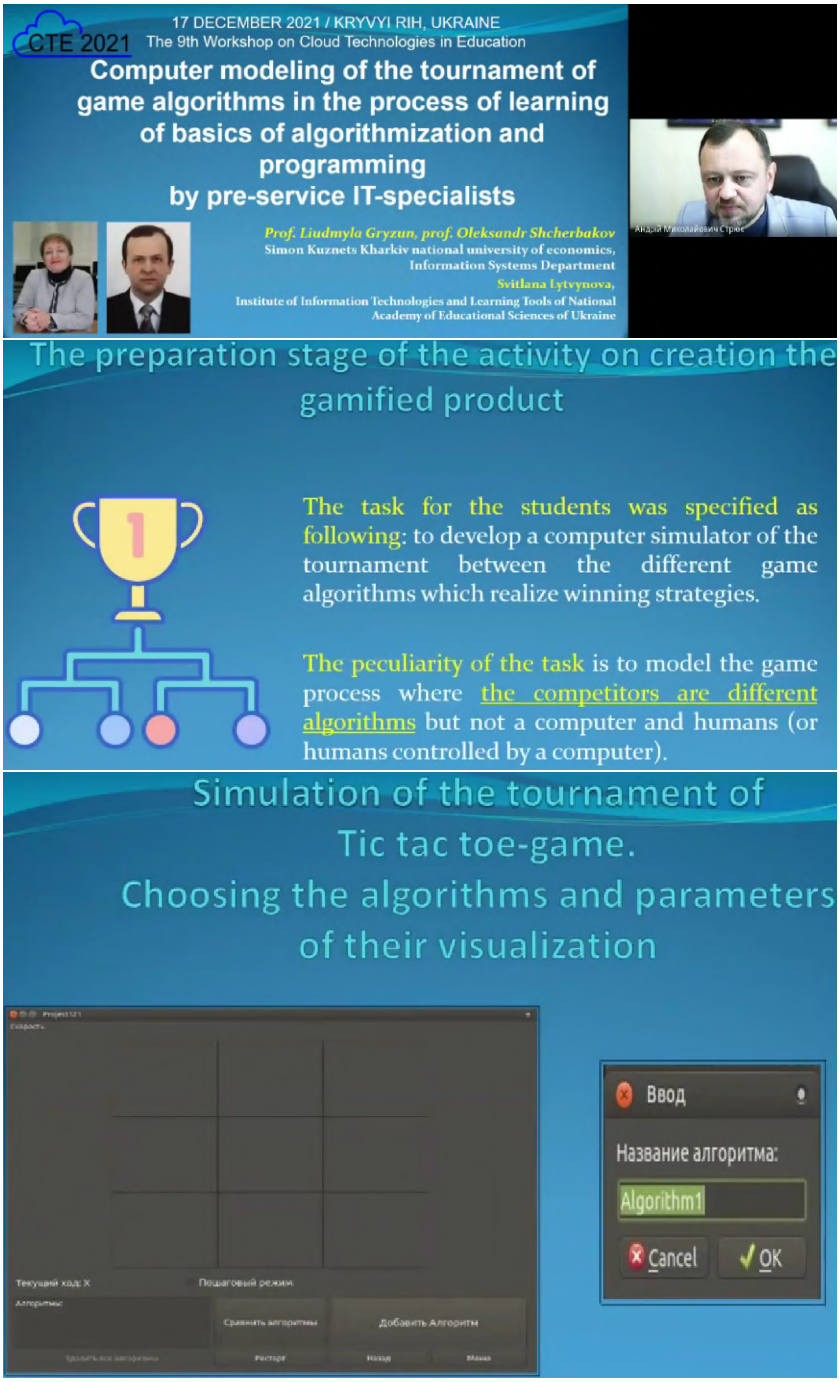


Figure 4: Presentation of paper [23].

is to build a model for the introduction of STEM education in institutions of general secondary education, to demonstrate the experience of using ICT in STEM education. Analysis of scientific

publications makes it possible to determine the role and place of ICT in the model of introduction of STEM education in general secondary education institutions. The presented experience of the systemic implementation of STEM education in general secondary education institutions allows the formation of professional competencies of teachers in the field of STEM education and can be useful in their professional activities. The study shows that the systemic implementation of STEM technologies in the educational process increases the effectiveness of training, the level of motivation of participants in the educational process and the quality of knowledge in the subjects of the natural science cycle, and also contributes to the formation of key competencies of students.

This article highlights further research by the authors, begun in [35, 36, 37].

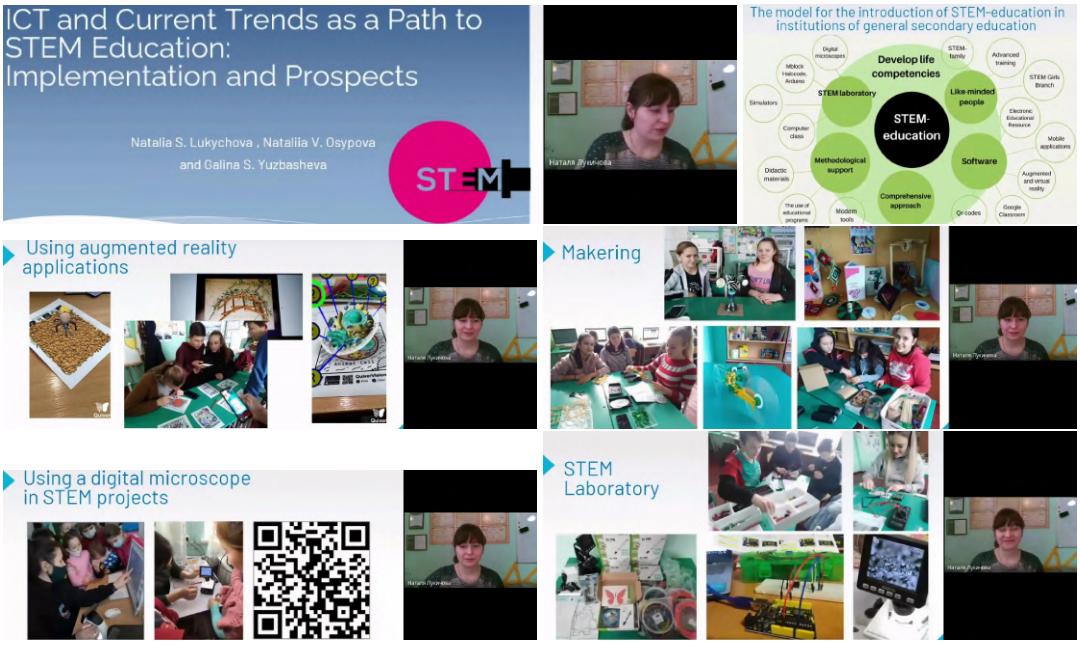


Figure 5: Presentation of paper [34].

Synergetics as a scientific area of research is in demand by society. The context of synergetics makes it possible for scientists of different specializations to interact fruitfully in the language of systematic understanding and search for new solutions. The article “Complex systems and physics education” [38] by Andrii O. Bielinskyi (figure 6), Arnold E. Kiv, Yuliya O. Prikhozha, Mykola A. Slusarenko, Vladimir N. Soloviev raises the question of how the theory of self-organization can help in the reformation of the higher education system, why this is relevant, and what can lead to the training of both teachers and students within the framework of an interdisciplinary approach. In the future, authors will highlight the most important characteristics of complex systems and the simplest and at the same time conceptually simplest methods for analyzing complexity. As part of the complex systems modeling course, which will first be presented to students of physics and mathematics, and then, possibly, to students of other specialties, authors present signals of seismic activity, gravitational waves and magnetic

activity, and demonstrate how authors can identify critical or crash phenomena in such systems. This kind of analysis can serve as a good basis for the formation of professional skills and universal competencies.

This article highlights further research by the authors, begun in [39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53].

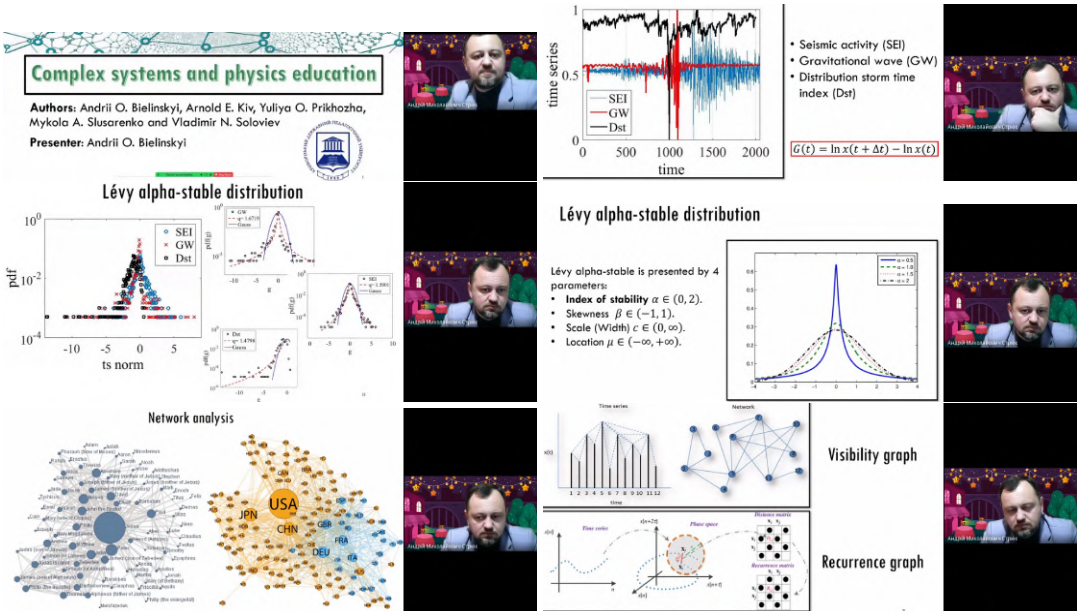


Figure 6: Presentation of paper [38].

The article "Agile methodology in higher education quality assurance system for SDGs 4, 8 and 9 achievement: national experience" [54] is focused on considering agile methodology as an instrument to use in education quality assurance. Artem E. Artyukhov, Iurii Iu. Volk (figure 7) and Tetiana A. Vasylieva propose the Scrum method applicable for education quality assurance based on adapted Manifesto for Agile Education Quality Assurance and twelve principles behind it. The Scrum procedure is described and roles are distributed for two real-life cases of external and internal educational program quality evaluation. Authors illustrate that proposed Scrum procedure perfectly fits existing practices and can be used to enhance both external and internal quality assurance processes in higher education. Authors consider achievement of SDG 4 targets through proposed methodology as the necessary step to take in achieving SDGs 8 and 9. It is concluded that stakeholders feedback about their satisfaction by economic and innovative factors should be included in each sprint review procedure in proposed Scrum methodology. Authors discuss SDG 4 achieving within multilayered DIKW+DM hierarchy as a framework for education quality assurance that allow to join information processing, knowledge acquisition and corresponding decision-making algorithm.

Today in most countries there is a lack of qualifications in areas, which require specialists with mathematical competencies, despite the high unemployment rate in many countries. At the same time, it is generally recognized that most likely those sciences are developing, the

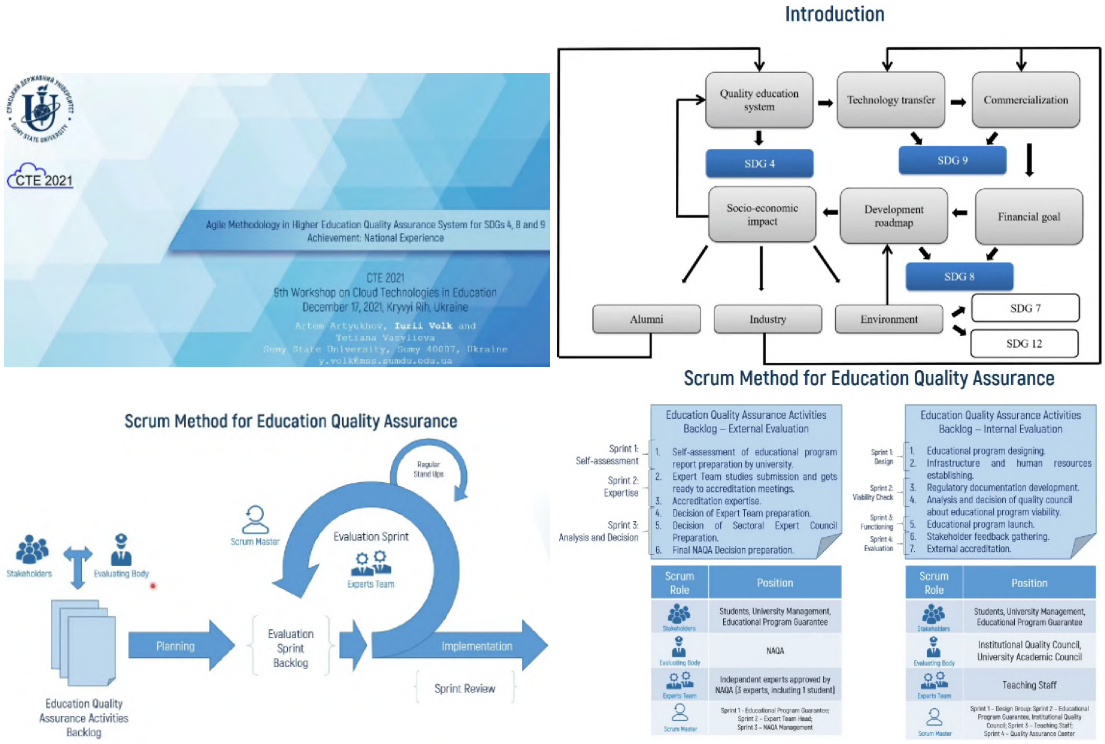


Figure 7: Presentation of paper [54].

fundamental results of which can be formulated mathematically. Using mathematical methods, Nataliia V. Morze, Iryna V. Mashkina (figure 8) and Mariia A. Boiko draw important conclusions that could hardly be obtained otherwise. Digital transformation of all industries requires specialists with a sufficient level of mathematical competence and skills in ICT tools, including computer modeling using the approach called Inquiry-Based Mathematics Education (IBME).

This article highlights further research by the authors, begun in [55, 56, 57, 58, 59].

Modern society is characterized by a significant impact of information technologies on all spheres of human life. In a special way, the processes of digital transformation affect educational institutions, including vocational (vocational and technical) ones. Now vocational (vocational and technical) education occupies an important place in the sector of the country's economy, prioritizing effective training of highly qualified labourers in the state policy of Ukraine. Nowadays, the professional activity of labourers incorporates an intellectual component related to working with electronic devices, artificial intelligence systems, etc. Monitoring of the labor market shows that a skilled worker of the XXI century should be able to think critically, process information analytically, and work with mechatronics systems. The analysis of the European experience in training qualified workers reflects a certain lag of domestic institutions in terms of digital supply. At the same time, the level of teachers' digital competence at vocational (vocational and technical) education institutions needs improving. As a result, the issues of digital transformation for educational institutions are urgent and topical [61]. Provision of modern digital equipment, formation and development of digital competence of all participants

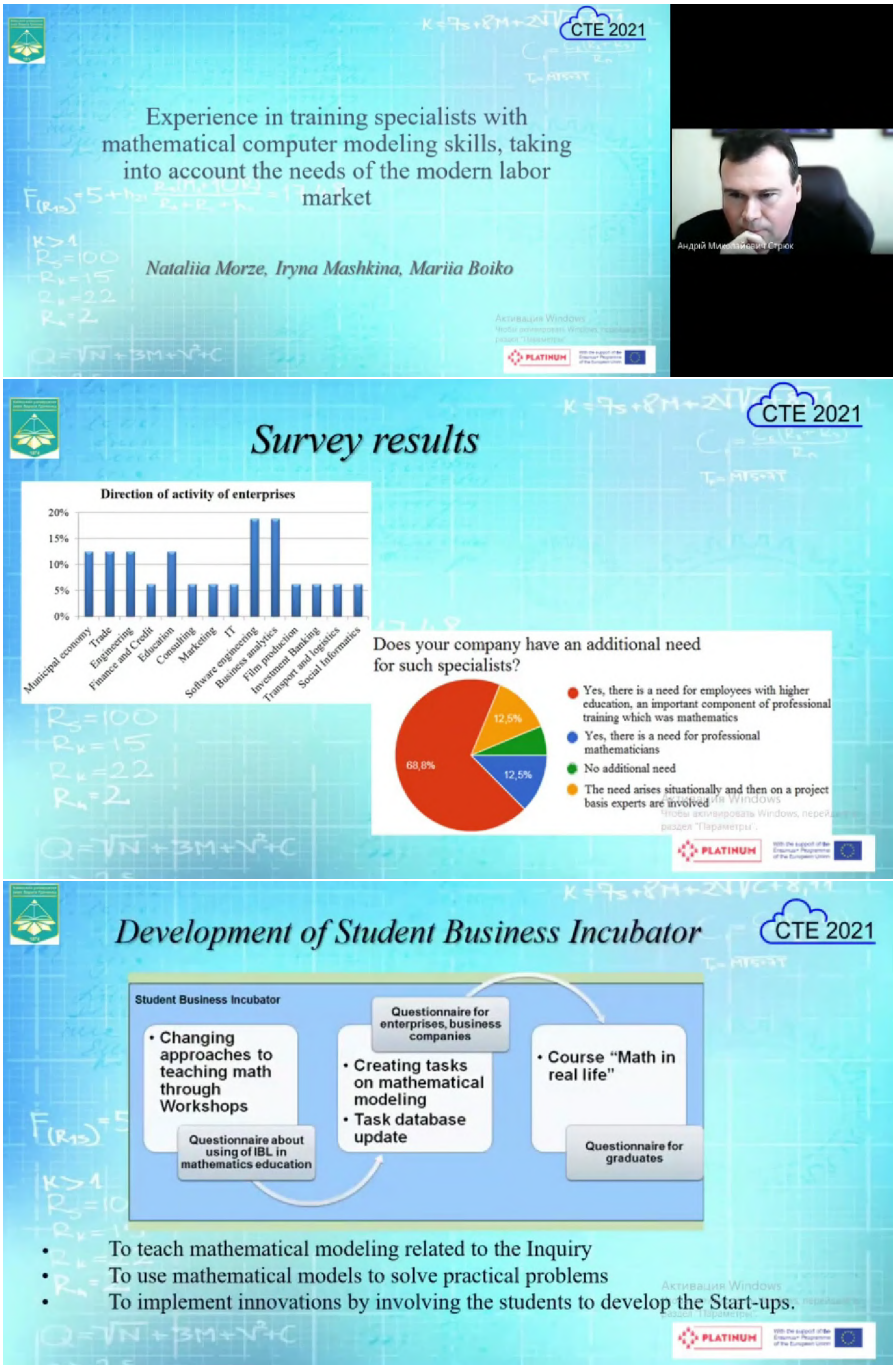


Figure 8: Presentation of paper [60].

in the educational space are becoming the main tasks of teaching stuff in the current conditions. In a special way, the tasks set become relevant during the period of quarantine restrictions,

when educational institutions mainly work on distance and mixed forms of teaching.

This article highlights further research by the authors, begun in [62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73].

Figure 9: Presentation of paper [61].

2.2. Session 2: Competency-Based Education Platforms and Social Analytics in Education

The article "Social dimension of higher education: definition, indicators, models" [74] by Liubov F. Panchenko (figure 10), Hennadii O. Korzhov, Andrii O. Khomiak, Vladyslav Ye. Velychko and Vladimir N. Soloviev deals with the problem of strengthening the social dimension of higher education. It discusses the definition of social dimension, its indicators, models of student retention and student engagement. The article argues that students should act as active researchers of the topic of social dimension and present the ways to update the content of university courses for Sociology majors, such as "Mathematical and statistical methods of social information analysis", "Social statistics and demography", "Multivariate data analysis", "Structural equation modeling" and other courses for bachelors, master students, and PhDs in Sociology.

This article highlights further research by the authors, begun in [75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 53, 87, 88, 89, 90].

One of the indicators of the influence and competitiveness of university is participation in international and local rankings. In the methodologies of the most authoritative rankings, the quality and transparency of Universities is assessed by indicators of the university teachers' publishing activity. The article "Designing a rating system based on competencies for the analysis of the University teachers' research activities" [91] by Nataliia V. Morze, Oksana P. Buinytska, Valeriia A. Smirnova (figure 11) analyzes the experience of designing systems that analyses university teachers research activities, tools and components of evaluating the effectiveness of research, designed a structural and functional model of rating system for the analysis the university teachers' research activities taking into account research and digital competencies. The developed model provides performance of the basic functions and allows

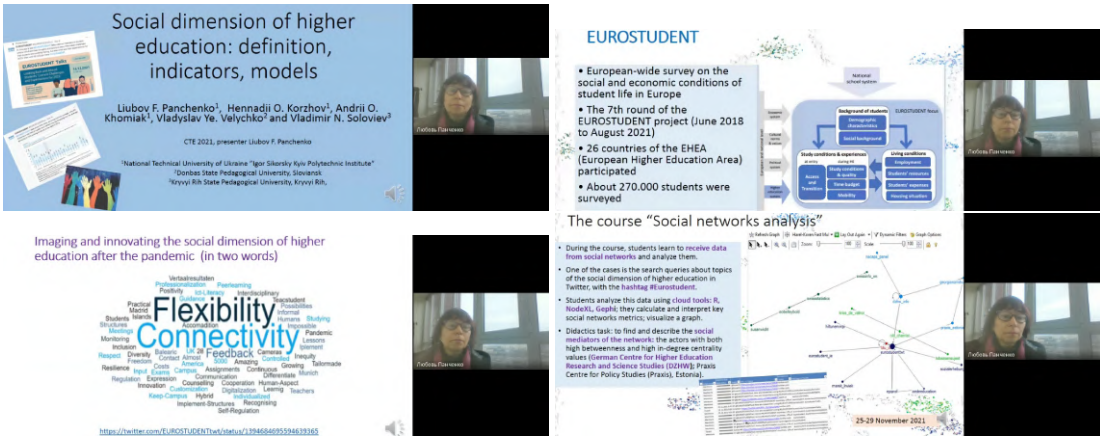


Figure 10: Presentation of paper [74].

for systematic monitoring of openness, transparency, efficiency of the research component of university teachers' professional activity. The model was based on key indicators for evaluating the effectiveness of research – citation indicators of the three most important scientometric databases – Scopus, Web of Science, Google Scholar. The connection between the indicators presented in the model forms a portrait of the university teachers' scientific activity, gives an overall assessment of productivity, influence and contribution to the research direction of the university as a whole. The article describes 1 stage of implementation of the presented model by developing a "Rating of Transparency of Structural Units", the effectiveness of experimental ranking. The study has established the positive impact of the implementation of the rating system, identified the main activities to increase the visibility, presence, dissemination of research results, the systematic implementation of which contributes to the optimal representation of the scientist in the rating evaluation of the research component of the university teachers professional activities, improving the digital competence of teachers and positively affects the quality indicators of the university scientific work in local and international rankings, as the existence of the system and the formation of ratings is an incentive for university teachers to present and disseminate their own publishing activities in the international online scientific community.

This article highlights further research by the authors, begun in [92, 93, 94, 95].

2.3. Session 3: Cloud-based AI Education Applications

In the process of self-assessment and accreditation examination, assessment is carried out according to a scale that covers four levels of compliance with the quality criteria of the educational program and educational activities. Assessing the quality of education is complicated by the fact that the value of quality criteria is due to a large number of factors, possibly with an unknown nature of influence, as well as the fact that when conducting pedagogical measurements it is necessary to work with non-numerical information. To solve these problems, the Andriy V. Ryabko (figure 12), Oksana V. Zaika, Roman P. Kukharchuk, Tetiana A. Vakaliuk

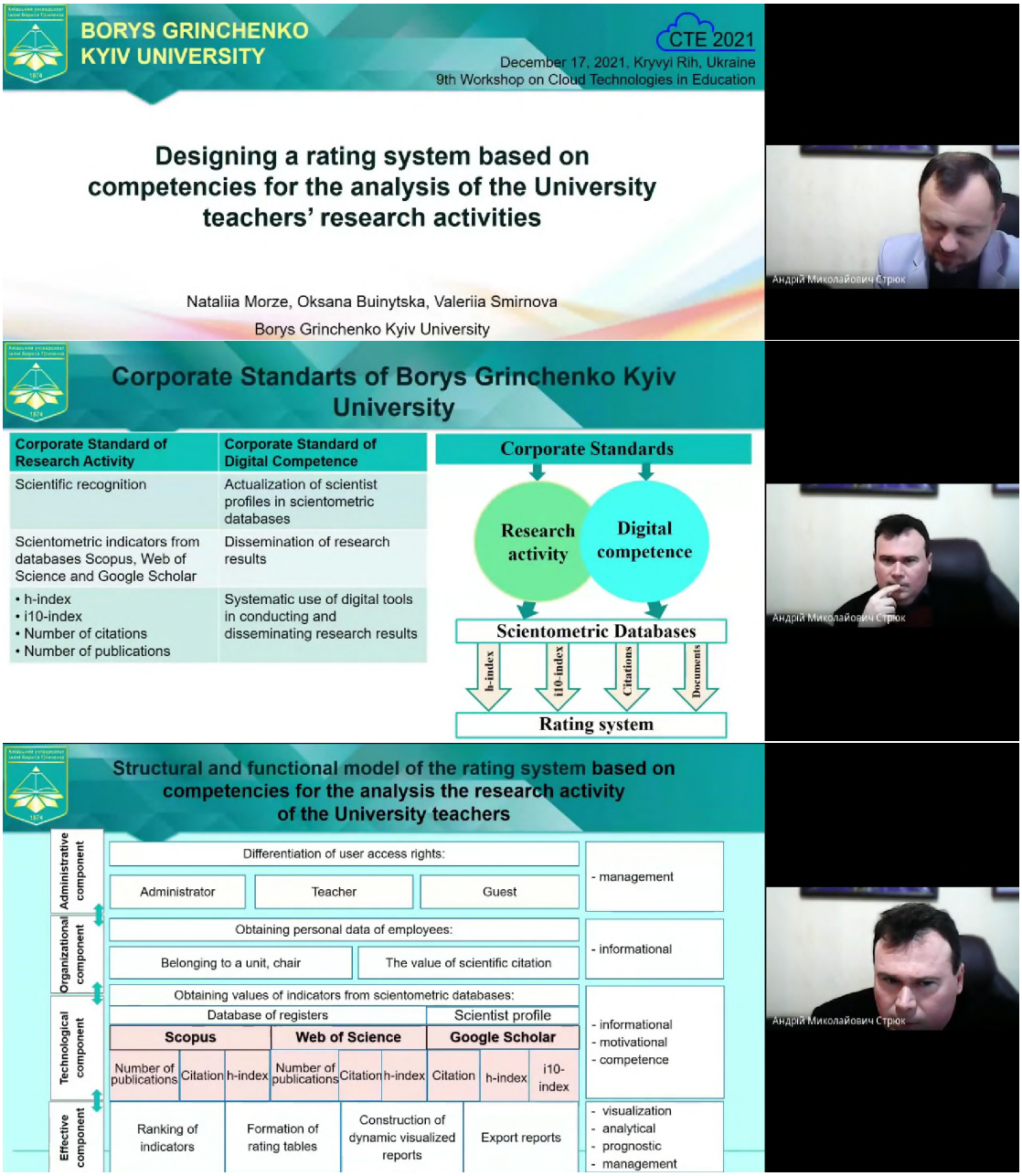


Figure 11: Presentation of paper [91].

and Viacheslav V. Osadchyi proposed a method for assessing the quality of educational programs and educational activities based on the adaptive neuro-fuzzy input system (ANFIS), implemented in the package Fuzzy Logic Toolbox system MATLAB and artificial neural network direct propagation with one output and multiple inputs. As input variables of the system ANFIS used criteria for evaluating the educational program. The initial variable of the system formed a

total indicator of the quality of the curriculum and educational activities according to a certain criterion or group of criteria. The article considers a neural network that can provide a forecast for assessing the quality of educational programs and educational activities by experts. The training of the artificial neural network was carried out based on survey data of students and graduates of higher education institutions. Before the accreditation examination, students were offered questionnaires with a proposal to assess the quality of the educational program and educational activities of the specialty on an assessment scale covering four levels. Student assessments were used to form the vector of artificial neural network inputs. It was assumed that if the assessments of students and graduates are sorted by increasing the rating based on determining the average grade point average, the artificial neural network, which was taught based on this organized data set, can provide effective forecasts of accreditation examinations. As a result of comparing the initial data of the neural network with the estimates of experts, it was found that the neural network does make predictions quite close to reality.

This article highlights further research by the authors, begun in [96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106].

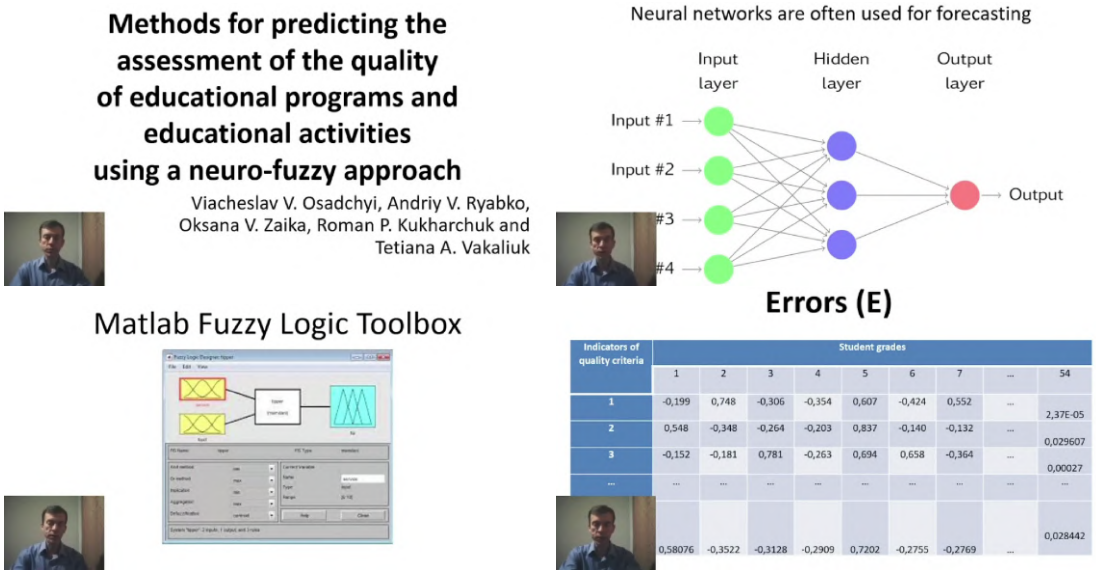


Figure 12: Presentation of paper [107].

Changes in society related to the development of science, technology, computing power, cloud services, artificial intelligence, increasing general access to huge amounts of open data, lead to increased global investment in technology and services. Appropriate training is required by specialists to create a workforce to work with artificial intelligence. On the one hand, it puts forward new requirements for the training of young people, and educational content, on the other hand, provides opportunities for the use of cloud technologies during the educational process. Widespread use of AI in various fields and everyday life poses the task of understanding the basic terms related to Artificial intelligence (AI), such as Machine learning (ML), Neural network (NN), Artificial neural networks (ANN), Deep Learning, Data Science, Big Data, mastering the

basic skills of using and understanding the AI principles, which is possible during the study in the school course of computer science. Cloud technologies allow to use the power of a remote server (open information systems, digital resources, software, etc.) regardless of the location of the consumer and provide ample opportunities for the study of artificial intelligence. In article "Cloud technologies for basics of artificial intelligence study in school" [108] Nataliia V. Valko, Tatiana L. Goncharenko, Nataliya O. Kushnir (figure 13) and Viacheslav V. Osadchyi reveal the possibilities of cloud technologies as a means of studying artificial intelligence at school, consider the need for three stages of training and provide development of tasks and own experience of using cloud technologies to study artificial intelligence on the example of DALL-E, Google QuickDraw, cloud technologies Makeblock, PictoBlox, Teachable Machine at different stages of AI study.

This article highlights further research by the authors, begun in [109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122].

2.4. Session 4: Cloud-based Learning Environments

The article "UI/UX design of educational on-line courses" [123] by Kateryna V. Vlasenko, Iryna V. Lovianova, Sergii V. Volkov (figure 14), Iryna V. Sitak, Olena O. Chumak, Andrii V. Krasnoshchok, Nataliia G. Bohdanova and Serhiy O. Semerikov considers the problem of an interface for educational platform, which is fully effective for achieving the outcomes of educational activity. The current research is a theoretical analysis of existing recommendations on UI/UX design, applied when creating educational systems, as well as of research papers that study user interface (UI) usability and evaluate user experience (UX) in designing on-line platforms. This article describes a mechanism for evaluating usability with the help of baseline and final evaluation tool. It also studies UX components, that ensure its high quality. A list of standard components of web-design is being discussed in the present paper; modern trends in web-design of educational platforms are identified. The paper provides the description of an on-line course model, which is built on the basis of analysis of the prerequisites for existing and functioning of educational on-line systems and which is aimed at achieving outcomes of educational activity. There is ground to believe that the design of educational on-line courses will contribute to achieving the outcomes of educational activity, if user interface components comply with a list of criteria, such as easy-to-perceive content, no extra information, easy and simple navigation on the pages of the course, following the principles of usability.

This article highlights further research by the authors, begun in [124, 125, 19, 126, 127, 128, 129, 130, 131, 132, 133, 134].

The world wide pandemic situation revealed the problems in all spheres of human life which haven't been faced before. Recently the world has changed greatly as well as the relationship between people and their professional activity. The great bunch of the workload, if basically acceptable, is done with the use of modern innovative technologies. Such problems have not trampled down the sphere of higher education as well. Distance learning, which was previously addressed to only as accompanying possibility of lessons conduct, nowadays is considered to be the only practicable form of conducting lectures, practical lessons, tests, i.e. it has become a usual daily practice for both teachers and students. Among the basic functional requirements to the electronic educational resources in the system of distance learning there are the visualization

Figure 13: Presentation of paper [108].

and interaction principles both when getting familiar with the theoretical material and when completing virtual laboratory and practical tasks. The Microsoft Office documents have become the most widespread elements among the electronic educational resources. That is why there is a pressing need in presenting the electronic MS Excel spreadsheets on the resource web-pages.

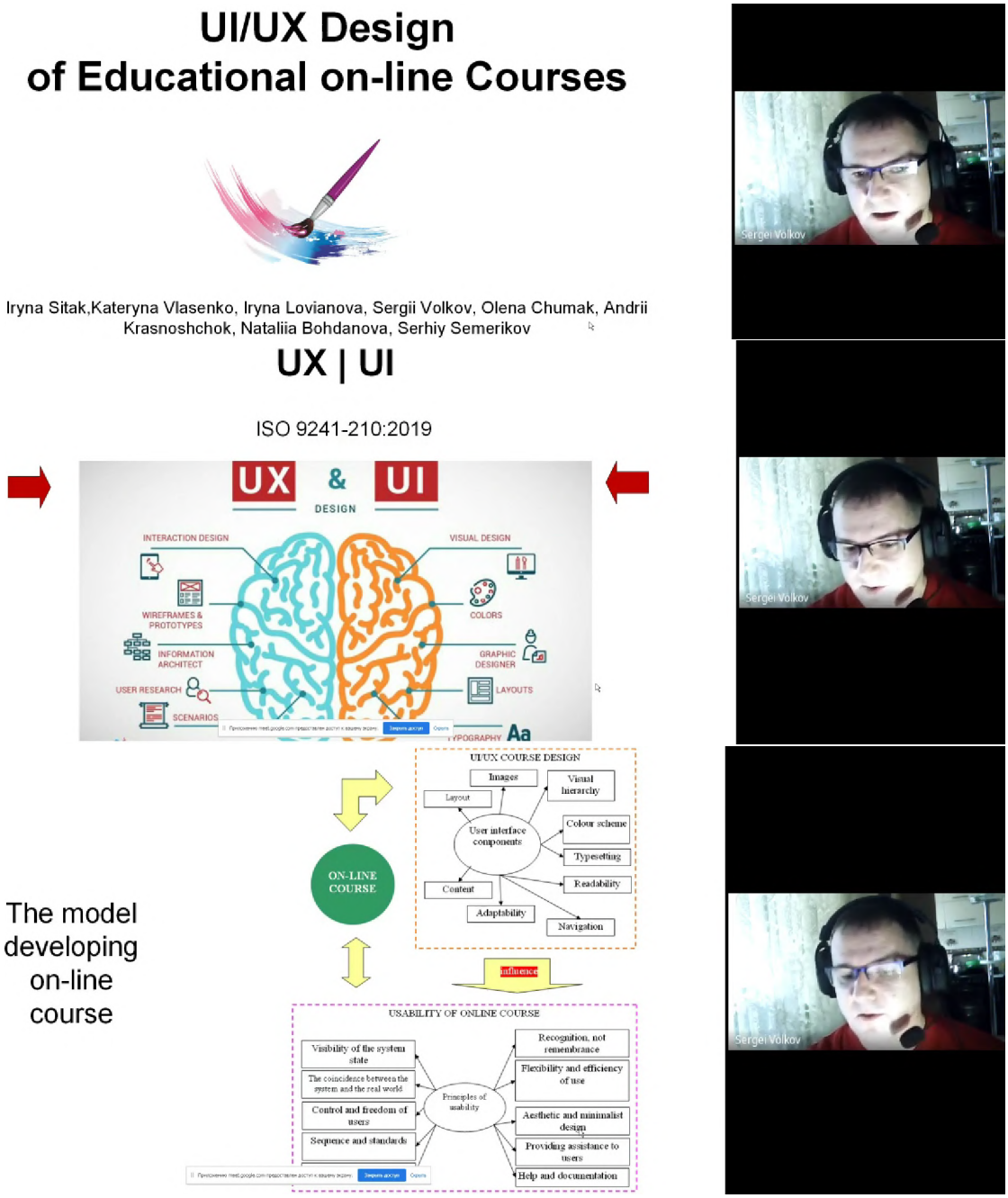


Figure 14: Presentation of paper [123].

The simple and convenient way to solve the problem of Excel documents introduction into the electronic resources of the distance learning systems is the use of cloud services. The services help to acquire the access to the information resources of any level and of any capacity with

the possibility to allocate the rights of the users belonging to different groups in relation to the resources. For that purpose the availability of the Internet network access and web-browser would be enough. The cloud calculation technologies introduction allows for the use of the programs that do not require special licensing, update versions monitoring and eliminates the need of software technical support as the provider himself exercises control over the functioning, data saving, antivirus protection and possible cyberassaults. The peculiarities of professional training of navigators require the students to acquire the knowledge of professionally-oriented tasks algorithms as well as the knowledge of technologies that can help to implements them. One of the main routines the officer needs to deal with on the navigational bridge is the use of the information systems of shipboard hardware. But before usage he needs to assure of the systems reliability. That is why it is extremely important to gain during the course of professional training the necessary skills of navigation equipment exploitation reliability assessment by means of Microsoft Office documents and cloud services. So the subject matter of the article "The optimum assessment of the information systems of shipboard hardware reliability in cloud services" [135] by Lyudmyla V. Kravtsova, Tatyana V. Zaytseva, Oleh M. Bezbakh (figure 15), Hennadiy M. Kravtsov and Nataliia H. Kaminska is the procedure development for the navigation equipment exploitation reliability assessment by means of modern services use in the course of professional training of future seafarers. The aim of the paper is the solution of the problems of optimum assessment of the information systems of shipboard hardware reliability by means of cloud technologies usage. The following tasks are completed in the course of the research: the peculiarities and characteristics of navigational information processed by the shipboard navigation and information system have been analyzed; the results of the information systems of shipboard hardware usage have been studied; the technological diagram of the basic components structuring of the "Information systems of shipboard hardware" complex for the Master's degree training course has been created; the effective technology of the program Excel documents processing has been chosen; the system of access and usage of web-services for calculation tables processing in the system of distance learning has been designed;the process of competency formation which will enable students to use cloud services has been suggested.

This article highlights further research by the authors, begun in [136, 137, 138, 139, 140, 141, 142, 143, 144].

2.5. Session 5: Cloud-based E-learning Platforms, Tools and Services

The article "Selecting cloud computing software for a virtual online laboratory supporting the Operating Systems course" [145] by Olena S. Holovnia and Vasyl P. Oleksiuk (figure 16) provides a survey on cloud platforms suitable for a virtual online laboratory, which contains Linux online environments and is intended to support the Operating Systems course. The study justifies the choice of utilizing private cloud as a deployment model and IaaS as a service model and substantiates the decision to create specially tailored cloud environments adapted for educational needs in contrast to applying ready-made IaaS (Infrastructure as a Service) cloud services given by providers. The related works on cloud platforms for teaching operating systems are analyzed. The study also makes a review of the authors' previous research on virtualization tools and environments for the Operating Systems course and Cisco CyberSecurity Operations course. The basic and additional requirements for cloud computing software for

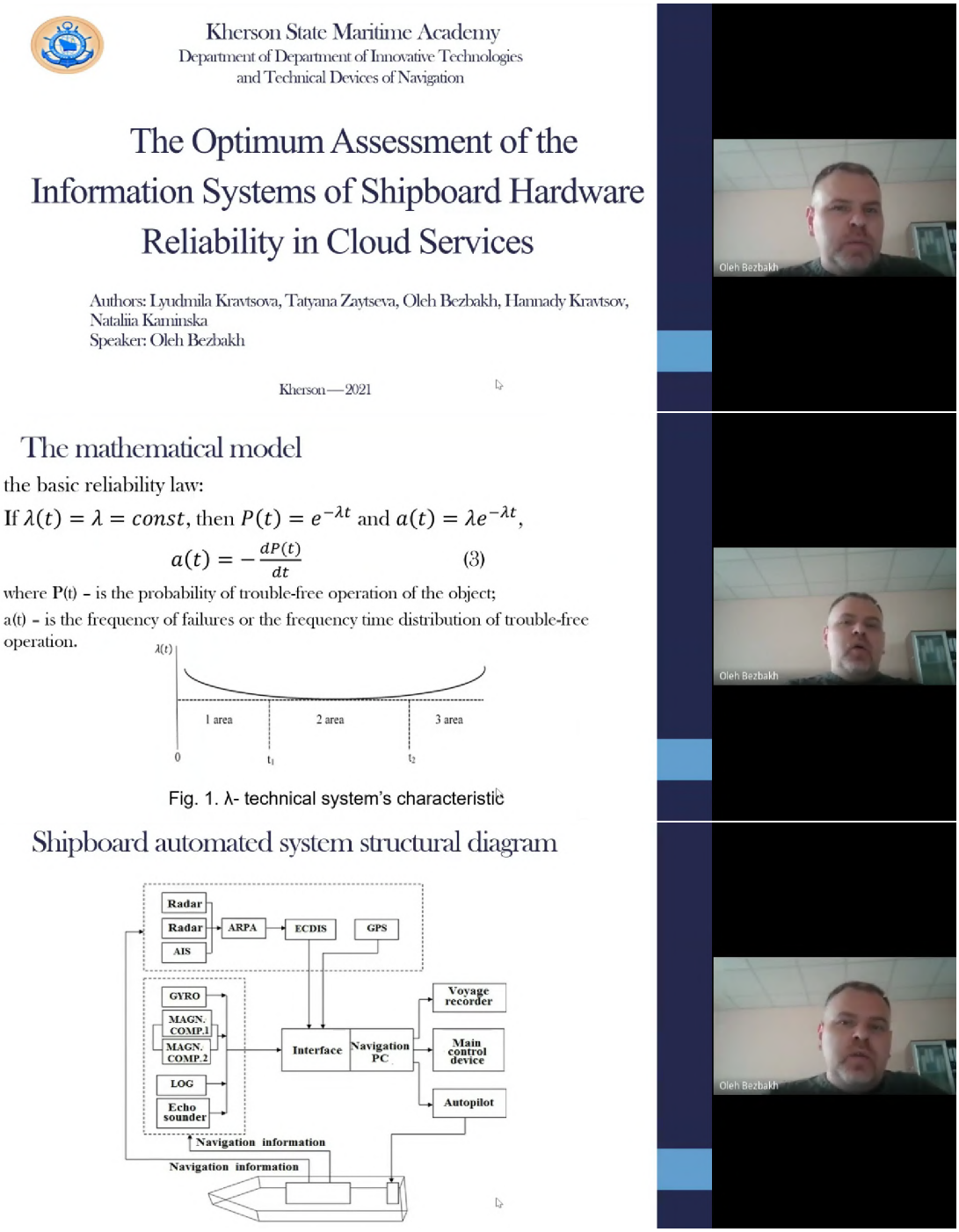


Figure 15: Presentation of paper [135].

virtual online laboratory supporting Operating Systems course have been elaborated. Finally,

the work makes the comparison of Eucalyptus, OpenStack, CloudStack and OpenNebula cloud platforms and substantiates the selection among these cloud computing software the platforms of the first and the second choice.

This article highlights further research by the authors, begun in [146, 147, 148, 149, 150, 151].

Figure 16: Presentation of paper [145].

The article “Hardware and software tools for teaching the basics of quantum informatics to students of specialized (high) schools” [152] by Liudmyla V. Lehka (figure 17), Svitlana V. Shokaliuk, Viacheslav V. Osadchyi defines the criteria for choosing a cloud-based platform for mastering the basics of quantum informatics by students of a specialized (high) schools: cross-browser; intuitive interface; the possibility of free access; access without registration and simplified registration; the presence of a systematized reference system with examples; support for the development of the environment by the developer; support for working in a personal educational environment; support for working with quantum algorithms in graphical mode; automatic conversion of quantum algorithms from graphic format to program code text; support for the Ukrainian-language localization; availability of a mobile application; responsive design. The possibilities of platforms for implementing quantum algorithms from the following companies are analyzed: Microsoft, QuTech, Amazon Braket, IBM. The choice

of the IBM Quantum cloud-based platform is justified. Work at IBM Quantum Composer and IBM Quantum Lab is described. Information about quantum operations and gates is presented: their designation in IBM Quantum Composer and IBM Quantum Lab, the gate matrix, and the purpose of the gate. An example of implementing quantum teleportation in the form of a circuit and program is given.

This article highlights further research by the authors, begun in [153, 154, 155, 156, 157, 158, 159, 160, 161, 162].

The article "Using the Yammer cloud service to organize project-based learning methods" [163] by Dmytro M. Bodnenko (figure 18), Halyna A. Kuchakovska, Oleksandra V. Lokaziuk, Volodymyr V. Proshkin, Svitlana H. Lytvynova and Olha H. Naboka reveals and interprets the key features of project-based learning based on cloud-based services: social activity; convenient communication in a team during the project implementation and at the resulting stage; open educational space; self-learning and self-improvement; use of interdisciplinary links to combine students of different years of study (1–4 degrees of the first (bachelor's) level and students of the second master's level) to joint research teams to study through research; purposeful motivation of cognitive and research activity of students within the discipline with the use of interdisciplinary connections; formation of digital literacy of students. The advantages and disadvantages of the Yammer cloud service are presented and a comparative analysis of this service with similar cloud services is performed. Examples of using Yammer in professional project activity are given. The stages of using project methods using the small group method are analyzed and detailed: initiation; planning; conducting/implementation; presentation; assessment/defense.

This article highlights further research by the authors, begun in [164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175].

The article "The didactic potential of cloud technologies in professional training of future teachers of Ukrainian language and literature" [176] by Olha B. Petrovych (figure 19), Alla P. Vinnichuk, Oksana A. Poida, Viktoriia I. Tkachenko, Tetiana A. Vakaliuk and Olena H. Kuzminska deals with the peculiarities of the usage cloud technologies for the organization of students-philologists' individual and group work in studying the discipline "Scientific Research Basics". The relevance of the introduction of cloud technologies for formation the readiness of the future teachers of Ukrainian language and literature to the professional activity is substantiated. Analysis of the scientific sources suggested that the quality of professional training process of future teachers-philologists has reached a new level by the means of cloud technologies. The domestic and foreign experience of cloud technologies implementation into current educational practices is generalized. The features of blended learning organization for professional training students-philologists at the Mykhailo Stelmakh Faculty of Philology and Journalism of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University during the studying the discipline "Scientific Research Basics" by using cloud technologies are described. The practical aspects and experience of preparation the future teachers of Ukrainian language and literature to a fluent usage of innovative cloud-based means are detailed. It is specified that the educational process is based on the communication by Gmail, Viber and Telegram messengers, store on Google Drive resource, work with educational video on YouTube, conducting online classes in Google Meet, creation publication in any of the social networks (Facebook, Instagram, TikTok), formation the different styles of references design on The Cite This for Me resource, conducting

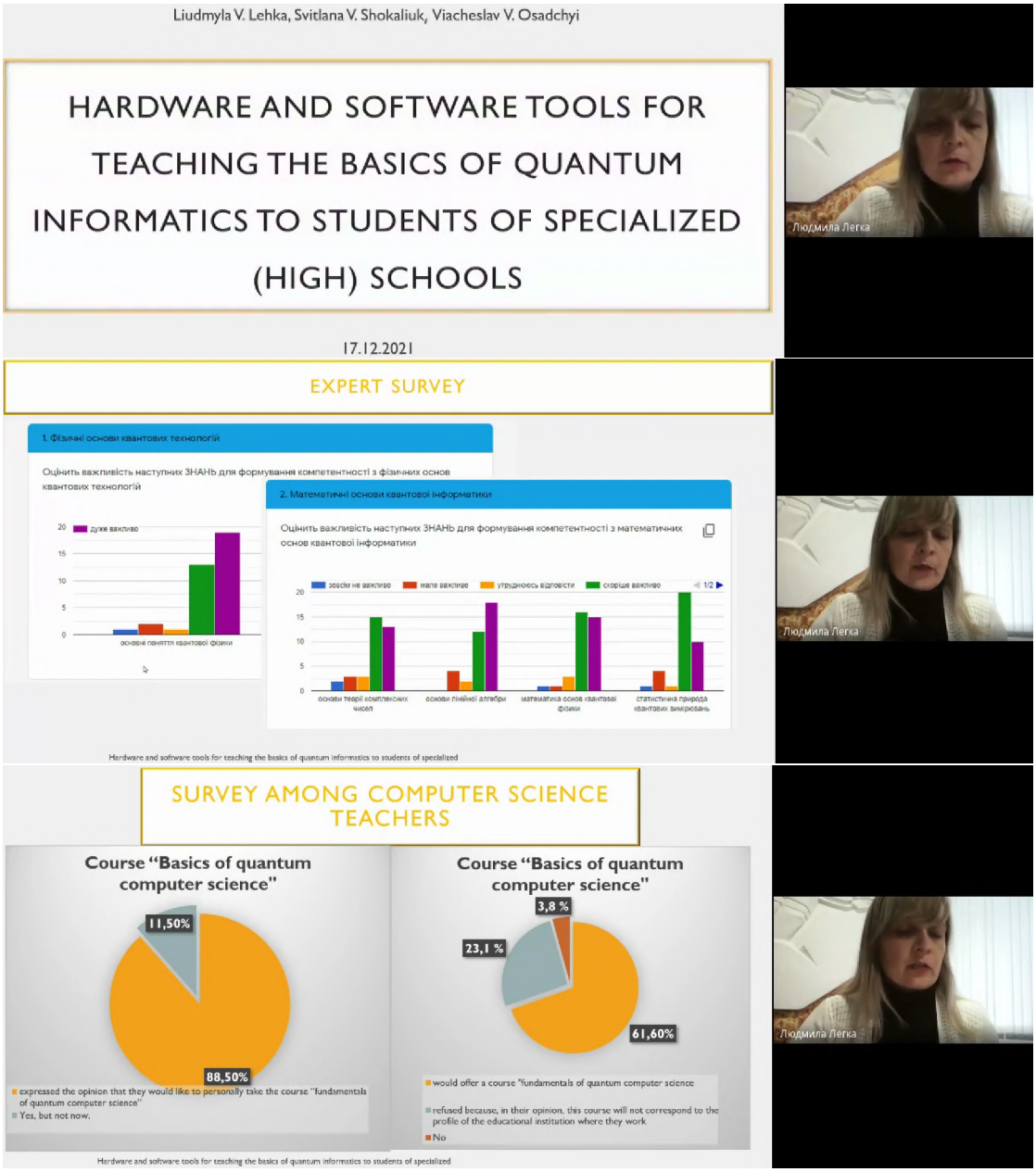
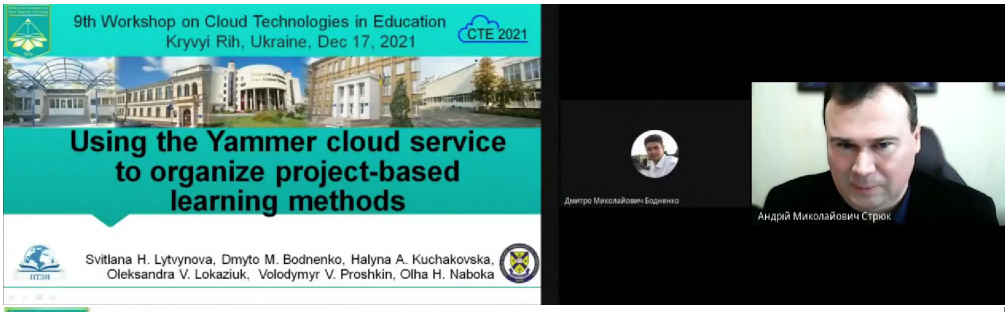
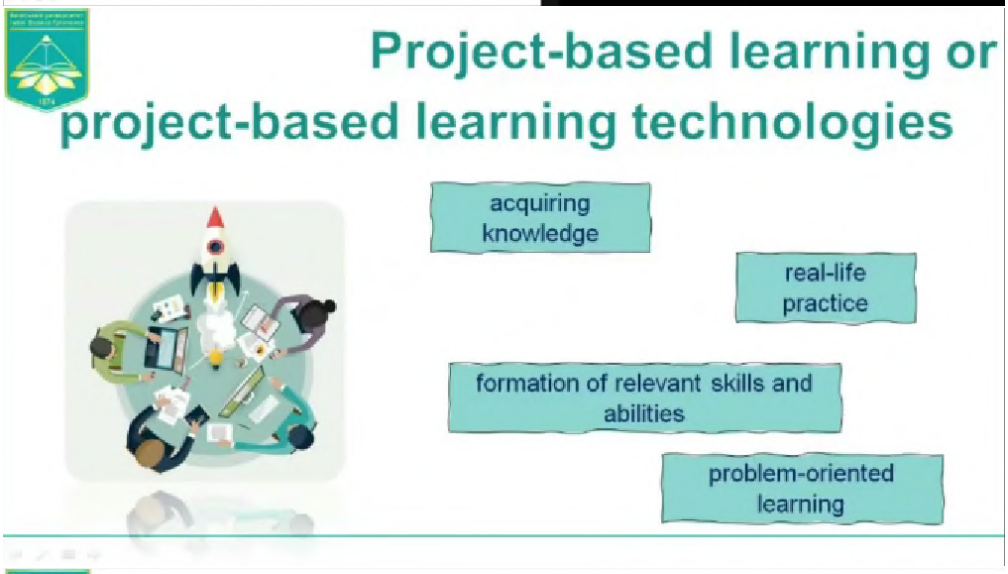


Figure 17: Presentation of paper [152].

literature search on various search engines, namely Google Scholar, ScienceDirect, Web of Science, creating multimedia presentation at Prezi or Canva, making MindMaps on Mindomo, infographics on interactive board Google Jamboard or Padlet, on services for graphic design Canva and Visme, etc. Prospects for experimental studying the effectiveness of using cloud technologies in learning discipline "Scientific Research Basics" are determined.





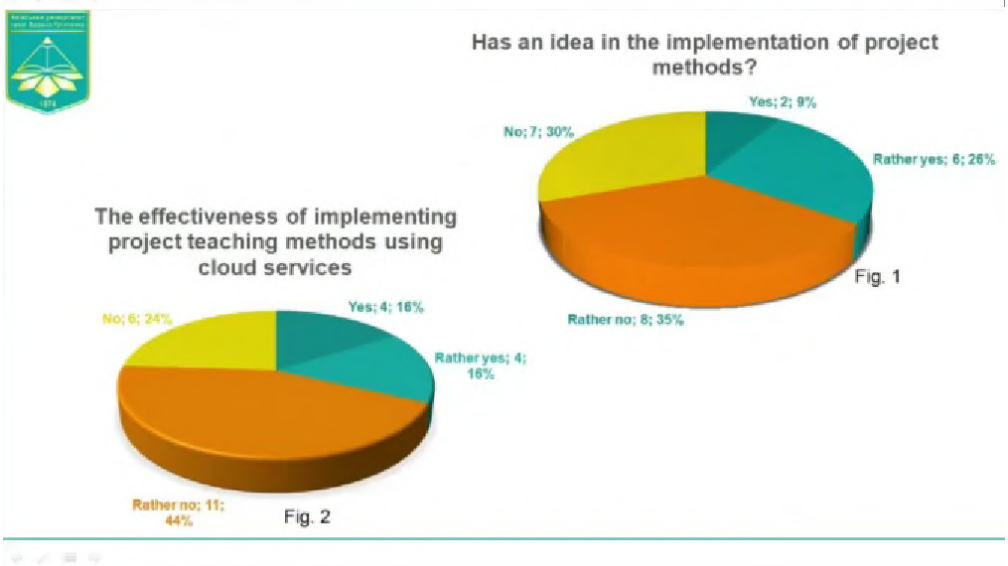


Figure 18: Presentation of paper [163].

This article highlights further research by the authors, begun in [177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187].

Figure 19: Presentation of paper [176].

Practical training is an integral part of the professional training of future teachers. During the practical training, trainees not only implement their own theoretical training in practice, but also increase the level of information competence. The rapid use of e-learning resources for distance learning during epidemiological constraints caused by biological threats poses new challenges to education in the availability of e-learning resources. The development of electronic educational resources is a difficult task, one of the ways to solve it is to involve future teachers in this process during the initial practice. In the article "Creation of open educational resources during educational practice by means of cloud technologies" [188] by Vladyslav Ye. Velychko (figure 20), Elena G. Fedorenko, Vladimir N. Soloviev and Ludmila V. Dolins'ka, the experiment of creating open educational resources by means of cloud technologies during the training practice showed the probability of solving this problem. Restrictions in direct contact between participants in the experiment, both due to epidemiological restrictions and through practical training in various educational institutions, are solved through the use of cloud technologies. The latter provides an opportunity to easily disseminate developed open educational resources and disseminate best practices in creating educational content.

This article highlights further research by the authors, begun in [189, 190, 191, 192, 193, 194, 195, 196].

The system for remote assessment of knowledge automates formation of task (tickets) with questions and tasks for conducting intermediate and final monitoring of knowledge of students is offered by Mykhailo I. Sherman, Yaroslava B. Samchynska (figure 21) and Vitaliy M. Kobets in the article "Development of an electronic system for remote assessment of students' knowledge

Figure 20: Presentation of paper [188].

in cloud-based learning environment" [197]. In the process of developing an electronic system for knowledge assessment, the basic requirements for a web application and the modules that the system consists of were determined, the main roles of users in the system and their

functionality were identified, access rights were established. The technical, functional, and non-functional features of the software product are described, web technologies for creating an application for knowledge assessment are considered. The diagram of system sequences, the use-case diagram, which schematically describing roles and functions of agents in an information system, the diagram of classes of a database structure are presented with UML description. Based on the defined requirements for the resource in cloud-based learning environment, the following technologies for its development were chosen: the server programming language PHP, JavaScript programming language and its libraries were used, as well as the MySQL database with PhpMyAdmin tool for administration of chosen database management system. OpenServer software complex system was used to develop and test the application functionality. The usage of the proposed electronic assessment system of knowledge contributes to the formation of an open information and cloud-based learning environment of a modern educational institution, enhances the efficiency and more rational distribution of teacher time in preparing tests or exams, activates repetition of educational material and knowledge assimilation, indirectly motivates students to more honest learning.

This article highlights further research by the authors, begun in [198, 199, 200, 201, 202].

2.6. Session 6: Immersive Technology Applications in Education

The article "The use of specialized software for liquid radioactive material spills simulation to teach students and postgraduate students" [203] by Oleksandr O. Popov, Yurii O. Kyrylenko, Iryna P. Kameneva, Anna V. Iatsyshyn, Andrii V. Iatsyshyn, Valeriia O. Kovach (figure 22), Volodymyr O. Artemchuk, Valery N. Bliznyuk and Arnold E. Kiv proves relevance of specialized software use to solve problems of emergencies prevention of radioactive liquids spills to teach students and graduate students. Main assessment criteria of accidents at radiation-hazardous objects associated with radioactive liquids spillage is identified. A model of radioactive substances transport in emergency rooms is developed. It takes into account physical features of radioactive liquid spill from the source, air pollution during transition of radioactive liquid from the spill surface into the air and subsequent scattering in the emergency room under influence of local air flows. It is determined that the existing software tools for radiation exposure assessment do not comprehensively cover features of such events and possess number of shortcomings regarding accidents modeling with spillage of radioactive liquids indoors. Computer modeling and forecasting examples for hypothetical event related to liquid radioactive spill in the JRODOS system are presented. The training process of future specialists, specialties 183 "Environmental Protection Technologies", 143 "Nuclear Energy", 103 "Earth Sciences", and 122 "Computer Science" should be based on application of powerful scientific and methodological training base using modern achievements in the field of digital technologies. It is advisable to supplement curricula for students‘ and postgraduate students' preparation in the mentioned above specialties by studying issues related to: development of mathematical models and software for solving problems of emergencies prevention in case of radioactive liquids spills; usage of features of specialized decision software of emergencies prevention during spills of radioactive liquids.

This article highlights further research by the authors, begun in [204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220].

The article [221] by Ilona V. Batsurovska, Nataliia A. Dotsenko (figure 23), Vladimir N. Soloviev,

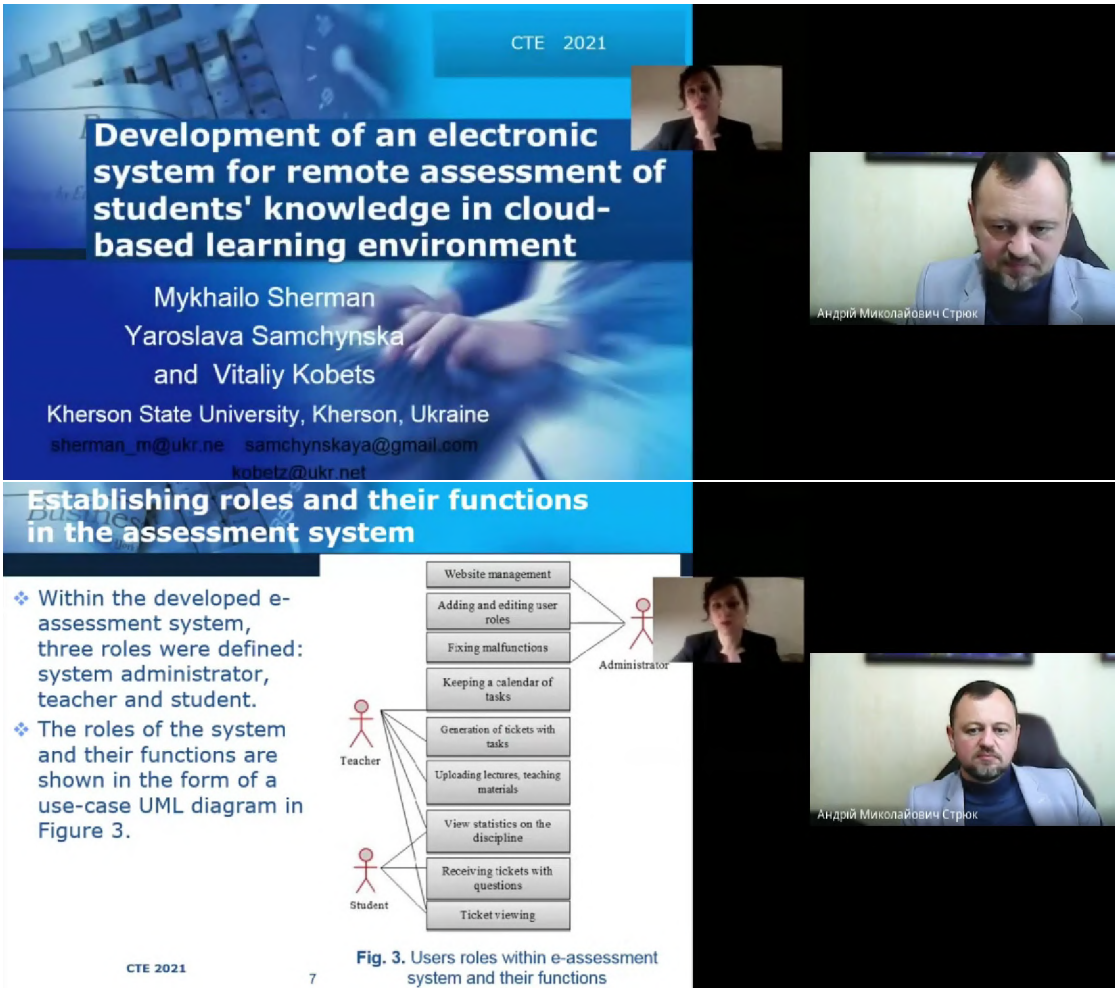


Figure 21: Presentation of paper [197].

Svitlana H. Lytvynova, Olena A. Gorbenko, Nataliia I. Kim and Antonina P. Haleeva 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

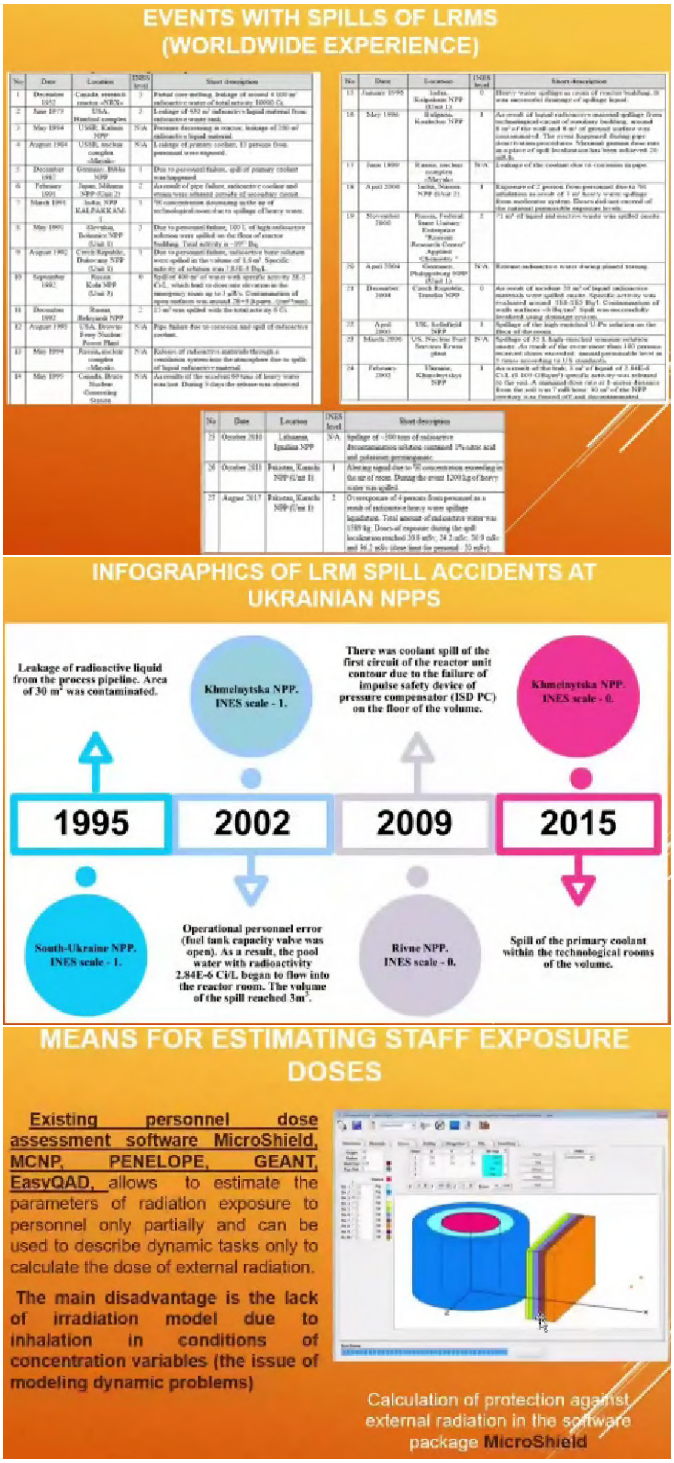


Figure 22: Presentation of paper [203].

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.

This article highlights further research by the authors, begun in [222, 223, 224, 225, 226, 227, 228, 229, 230].

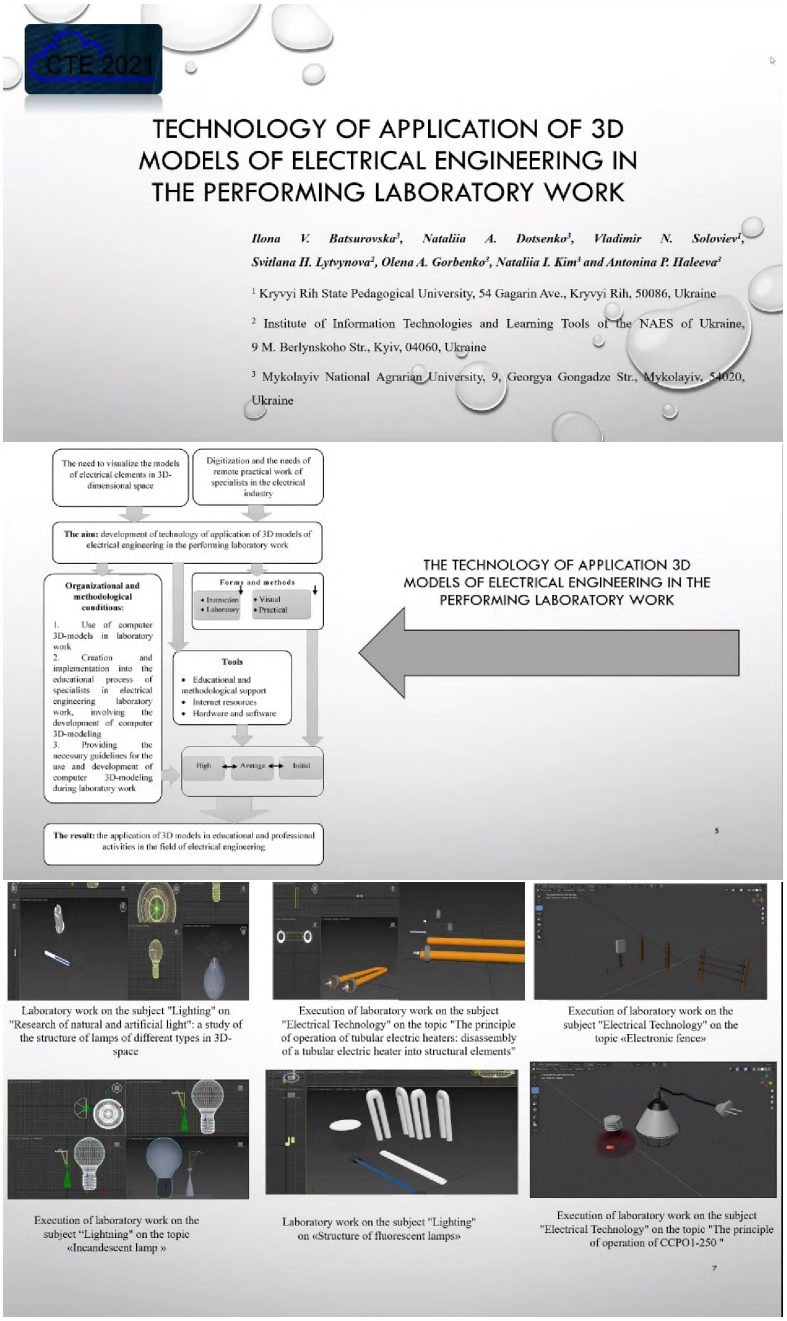


Figure 23: Presentation of paper [221].

The article “Immersive learning technology for ensuring quality education: Ukrainian university case” [231] by Volodymyr O. Liubchak, Yurii O. Zuban and Artem E. Artyukhov (figure 24) considers the problem of using immersive learning in the educational and scientific activities of the university. Literature survey revealed that there is a need for an integrated approach for introduction of immersive learning at the university. It involves the creation of a specialized laboratory of virtual and augmented reality with appropriate technical equipment, introduction of immersive learning methodology in university educational programs, development of software and hardware solutions for immersive learning, and research on the immersive learning effectiveness. Authors present the description of a specialized university department acting as a developer of software products for immersive learning. Authors show original developments in the field of immersive education for exact sciences and arts and humanities students. The article describes products that are designed to fulfill the third university mission: to ensure the citizens well-being. Authors propose "immersive institute" model which can be implemented both at the level of the university in general and at the level of its educational and scientific departments.

Being popular world-wide, virtual laboratories enter into different fields of education and research and practitioners have to be responsible for choosing the most suitable and then adapt them to particular field. The aim of the article “Enhancing digital and professional competences via implementation of virtual laboratories for future physical therapists and rehabilitologist” [232] by Halina I. Falfushynska (figure 25), Bogdan B. Buyak, Grygoriy M. Torbin, Grygorii V. Tereshchuk, Mykhailo M. Kasianchuk and Mikołaj Karpiński was to assess the effectivity of the implementation of Praxilab, Labster, and LabXchange virtual laboratories as the powerful digital tool into teaching protocols of “Clinical and laboratory diagnostics” discipline for physical therapists and rehabilitologist. Authors have carried out the online survey for 45 students enrolled in physical rehabilitation degree program. About 70% surveyed students reported that implementation of virtual laboratories in “Clinical and laboratory diagnostics” discipline met individual learning needs of students, helped acquired digital skills (25%), and supported them to stay ahead of the curve. The virtual lab applications, not only assisted harness students fair against lack of practical skills, but also brought about a new dimension to the classes and helped overcome digital alienation and gain their digital skills and abilities. Indeed, a virtual lab can’t completely replace the experimental work and teacher’s explanation, but it might support teaching activities of a modern mentor and learning activities of a modern student. Almost all of surveyed students (82%) expected that in near future the virtual laboratories would take the dominant place in the education market due to possibility of students’ pre-train the key points of practical activities before real experiments in lab and better understand their theoretical backgrounds. Thus, this study is intended to contribute to utilization of virtual labs by students enrolled in study physical therapy/physical rehabilitation with expected efficiency.

This article highlights further research by the authors, begun in [233, 234, 235, 236, 237, 238, 239, 240, 241, 242].

Nowadays simulation training technology is a priority method of maritime specialists’ practical training in the world. The main purpose of using VR simulators within an educational process is to simulate work on real equipment in order to form professional competencies of seafarers. The article “Formation of professional competency in life saving appliances operation of future seafarers by means of online and simulation VR technologies” [243] by Serhii A. Voloshynov,

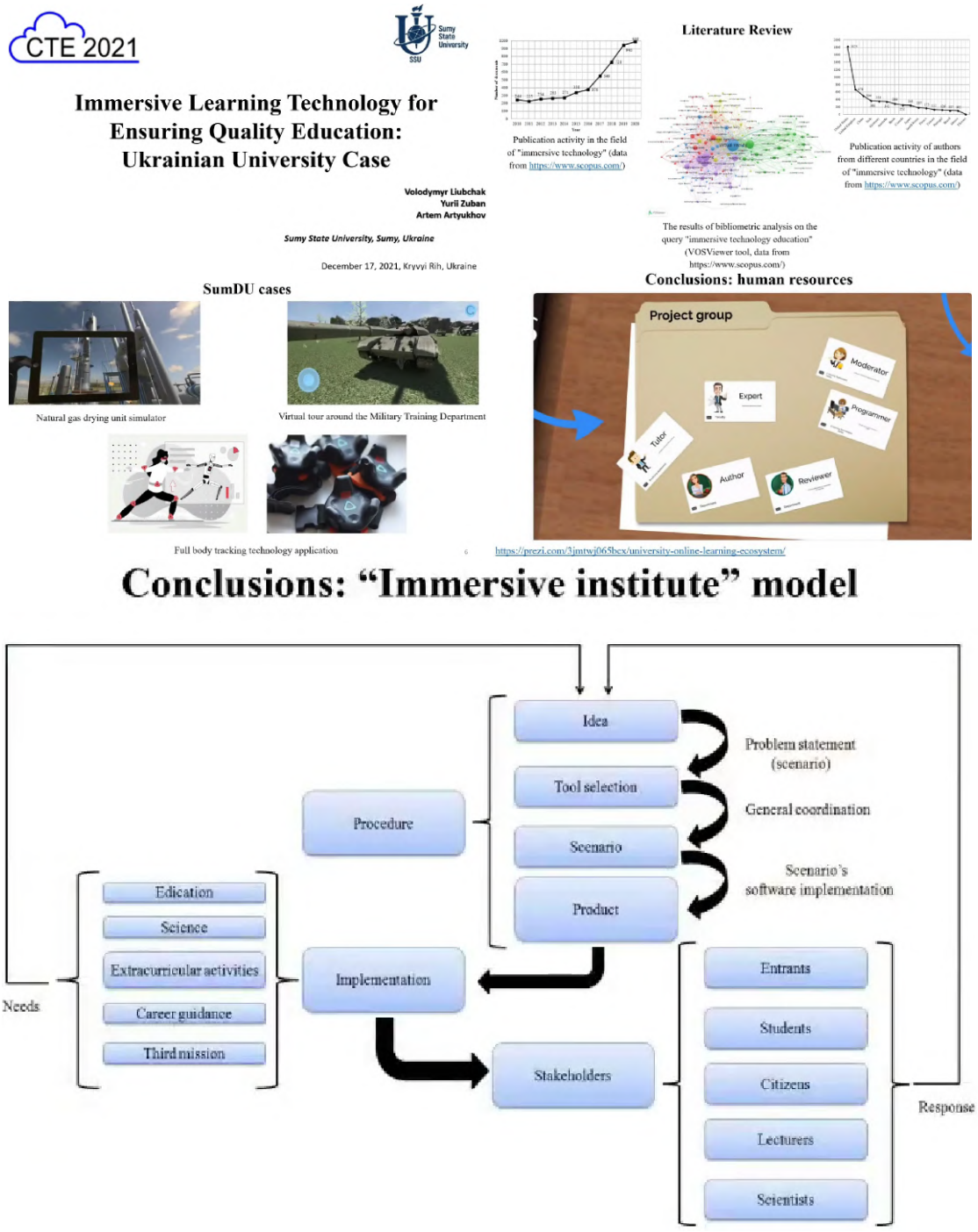


Figure 24: Presentation of paper [231].

Halyna V. Popova, Olena S. Dyagileva, Nataliya N. Bobrysheva and Olha V. Fedorova (figure 26)

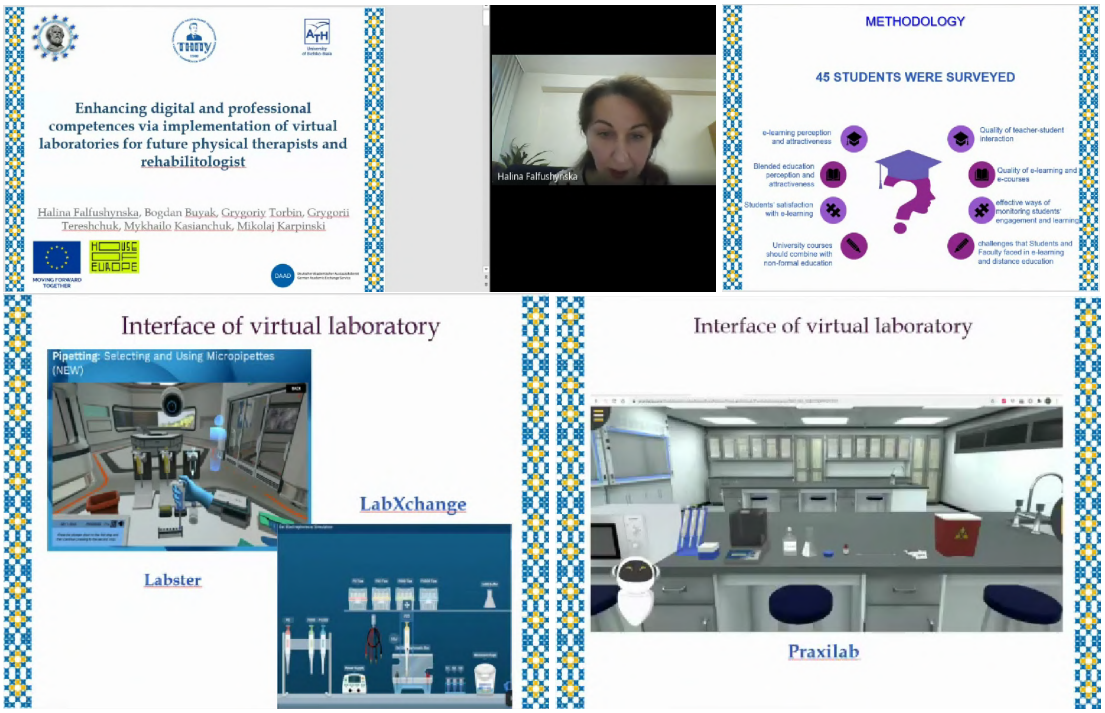


Figure 25: Presentation of paper [232].

describes system of blended learning on the basis of Kherson State Maritime Academy, that includes alternation of traditional and online learning, virtual training by means of the VR technology, training on simulators. In accordance with the principles of blended learning in Academy, there was developed an author's course "Rescue boats and life rafts specialist", which aims at providing theoretical and practical training of seafarers on launching and handling the lifeboats and liferafts and, as a result, ensures seafarers' formation of professional competency "life-saving appliances operation". The article also reveals the results of an experiment with implementation of VR technologies in forming the professional competency "life-saving appliances operation". The deviation of the results in control and experimental groups was 9,8%. The effectiveness of the research was manifested in the fact that students have gained experience of practical skills before coming to the vessel and showed higher level of educational achievements in professional competency "life-saving appliances operation".

This article highlights further research by the authors, begun in [244, 245, 246, 247].

The article "Clouds of words as a didactic tool in literary education of primary school children" [248] by Liudmyla L. Nezhyva (figure 27), Svitlana P. Palamar, Maiia V. Marienko reveals the possibilities of using the words' cloud in the literary education of primary school children. The authors consider the possibility of using a cloud of words to visualize the keywords of the text for the translation of the work of art, the interpretation of the main idea and the characteristics of the artistic image. The words' cloud can also be used as a reference summary to answer questions about the content of the work or to present the results of a school project by students. Moreover, in reading lessons, this tool can be used as a tool to identify the topic

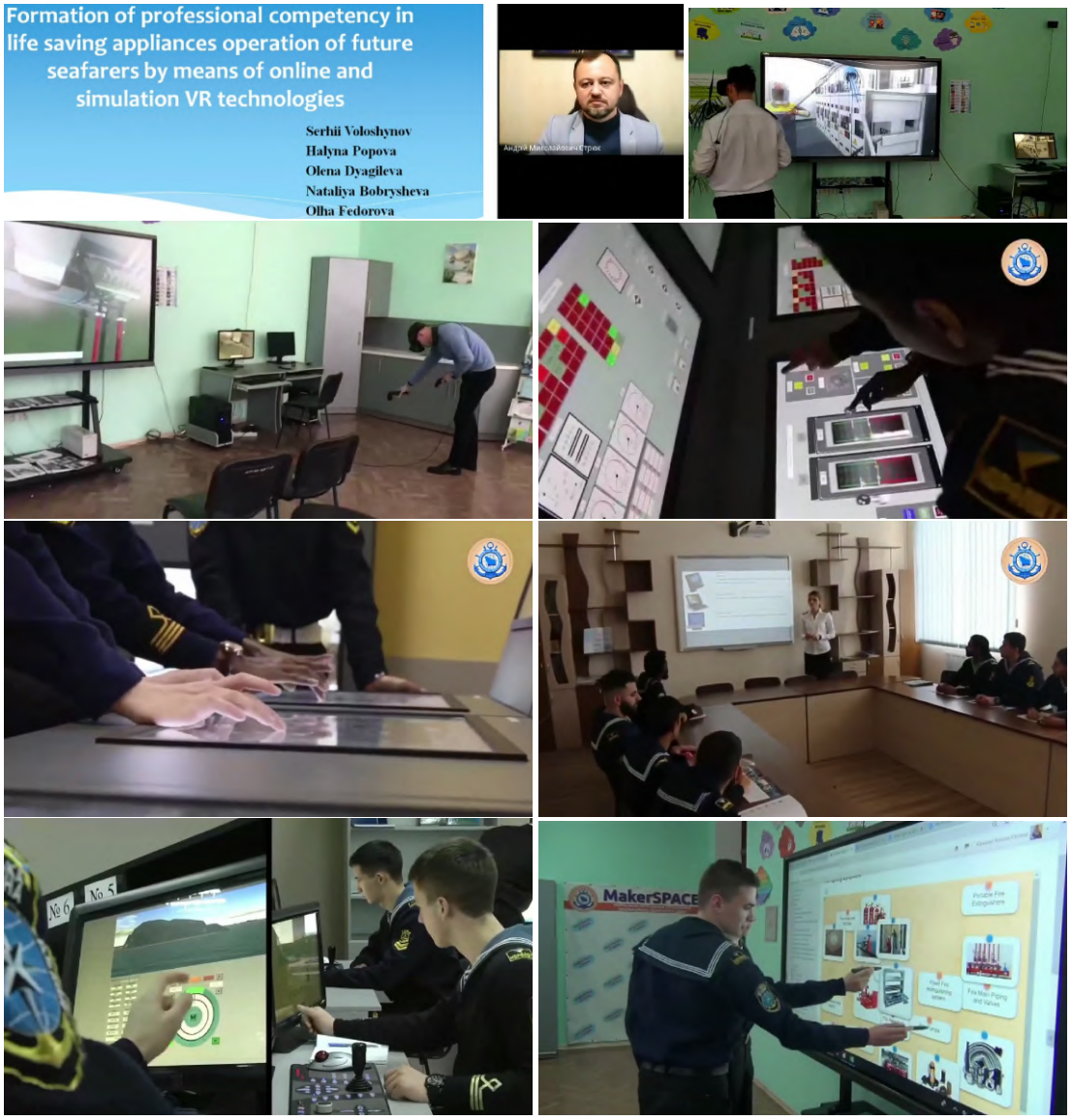


Figure 26: Presentation of paper [243].

of the lesson. The study reveals the possibilities of the didactic tool of the words' cloud for the development of speech of primary school children, in particular, in composing their own texts and editing them, the ability to explore words that the student uses too often and avoid tautology. Using the method of a problem situation and visually demonstrating information through a cloud of words, the teacher pro-motes the activation of students' mental activity, the development of creative abilities and critical thinking. The study tested the use of the electronic resource WordArt in primary school – a website for creating a "word's cloud" and proved its effectiveness in reflection, as well as creating an image of the main idea of the lesson, general

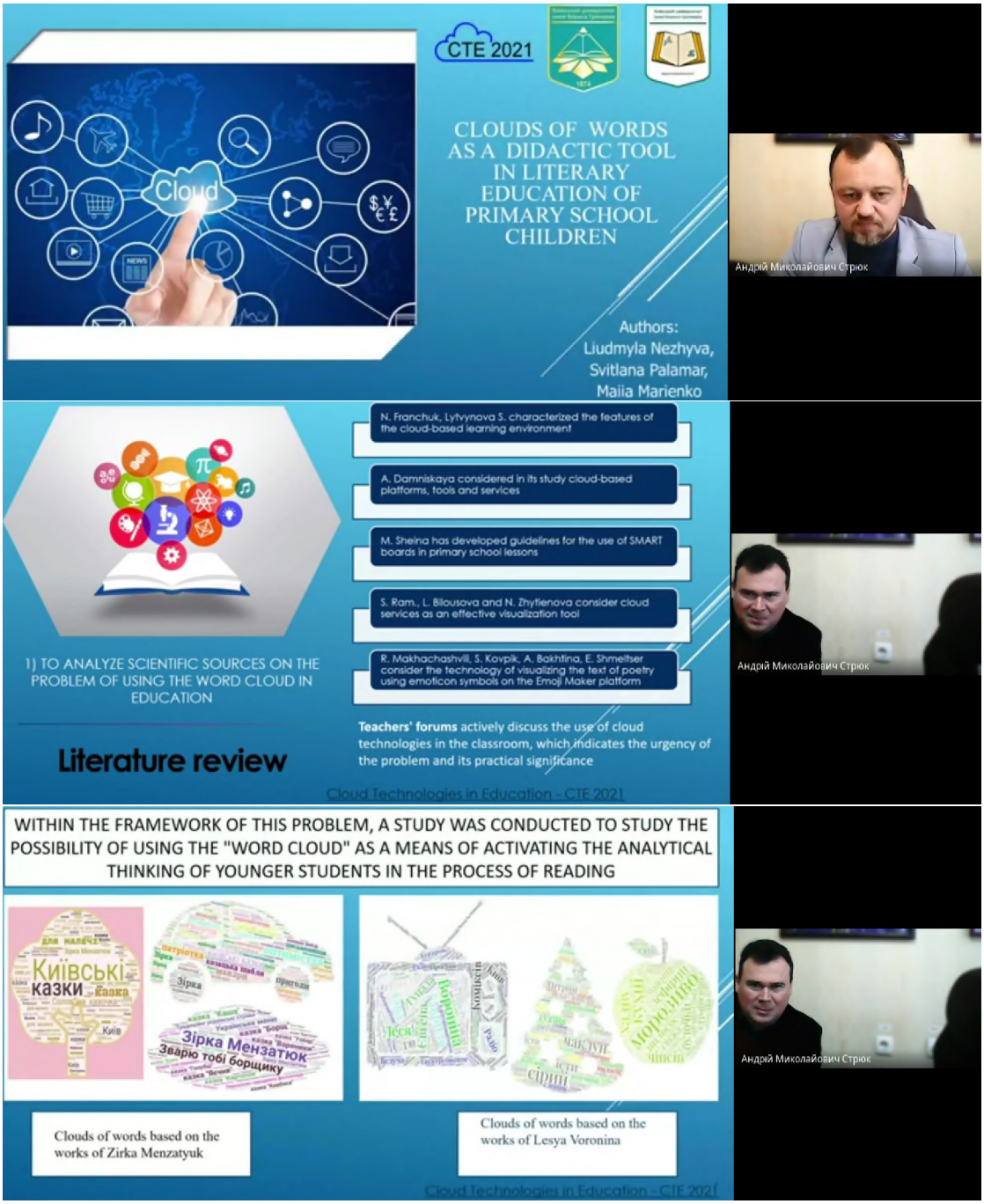


Figure 27: Presentation of paper [248].

conversation, its use as didactic material. The authors used the technology of learning using a cloud office package Google Drive to write a draft of their own statement of primary school

children. The authors investigated the use of the service in the lesson of literary reading during the organization of reading activities in the following areas: in the "cloud of words" to encrypt the topic of the lesson; using the cloud as visual material or as basic information to explain new material; encrypt certain words from the text in the cloud, students' task to guess the work; create a cloud of words of positive and negative characters of the work; write a story on the topic; create an "encrypted postcard" to the writer or hero of the work. In the course of experimental work, the effectiveness of the use of this didactic tool in the lessons of literary reading in primary school during the analysis of texts in order to identify the most important associations of students was confirmed.

This article highlights further research by the authors, begun in [249, 250, 251, 252, 253, 254, 255, 256].

3. Conclusion

9th Workshop on Cloud Technologies in Education (CTE 2021) was organized by Kryvyi Rih National University (with support of the rector Mykola I. Stupnik) in collaboration with Kryvyi Rih State Pedagogical University (with support of the rector Yaroslav V. Shramko), Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine (with support of the director Valeriy Yu. Bykov) and University of Educational Management (with support of the vice-rector for research and digitalization Oleg M. Spirin).

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References

[1] S. O. Semerikov, M. P. Shyshkina, Preface, CEUR Workshop Proceedings 2168 (2017). URL: http://ceur-ws.org/Vol-2168/preface.pdf.

[2] A. E. Kiv, V. N. Soloviev, S. O. Semerikov, CTE 2018 – How cloud technologies continues to transform education, CEUR Workshop Proceedings 2433 (2019) 1–19. URL: http://ceur-ws.org/Vol-2433/paper00.pdf.

[3] A. E. Kiv, M. P. Shyshkina, S. O. Semerikov, A. M. Striuk, Y. V. Yechkalo, AREdu 2019 – How augmented reality transforms to augmented learning, CEUR Workshop Proceedings 2547 (2020) 1–12. URL: http://ceur-ws.org/Vol-2547/paper00.pdf.

[4] A. E. Kiv, S. O. Semerikov, M. P. Shyshkina, A. M. Striuk, M. I. Striuk, Y. V. Yechkalo, I. S. Mintii, P. P. Nechypurenko, O. O. Kalinichenko, L. S. Kolgatina, K. V. Vlasenko, S. M. Amelina, O. V. Semenikhina, 9th Workshop on Cloud Technologies in Education: Report, CEUR Workshop Proceedings (2022) i–lxxvii.

[5] A. O. Simakhova, A. E. Artyukhov, H. A. Shmarlouskaya, Problematic issues of digitalization of education in Eastern Europe, CEUR Workshop Proceedings (2022) 1–15.

[6] O. V. Ovcharuk, A. M. Gurzhii, I. V. Ivaniuk, L. A. Kartashova, O. O. Hrytsenchuk, T. A. Vakaliuk, M. P. Shyshkina, The use of digital tools by secondary school teachers for the implementation of distance learning in the context of digital transformation in Ukraine, CEUR Workshop Proceedings (2022) 16–27.

[7] O. V. Ovcharuk, I. V. Ivaniuk, O. Y. Burov, M. V. Marienko, N. V. Soroko, O. O. Gritsenchuk, O. Y. Kravchyna, The practical experience of the use of digital learning resources by Ukrainian teachers to ensure the sustainable development and democratization of education process, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[8] O. Ovcharuk, Attitude of Ukrainian educators toward the use of digital tools for teaching and professional development: Survey results, CEUR Workshop Proceedings 2732 (2020) 746–755. URL: http://ceur-ws.org/Vol-2732/20200746.pdf.

[9] O. Ovcharuk, I. Ivaniuk, N. Soroko, O. Gritsenchuk, O. Kravchyna, The use of digital learning tools in the teachers' professional activities to ensure sustainable development and democratization of education in European countries, E3S Web of Conferences 166 (2020) 10019. doi:10.1051/e3sconf/202016610019.

[10] L. A. Kartashova, A. M. Gurzhii, V. O. Zaichuk, T. M. Sorochan, F. M. Zhuravlev, Digital twin of an educational institution: an innovative concept of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[11] O. Glazunova, T. Voloshyna, A. Gurzhii, V. Korolchuk, O. Parhomenko, T. Sayapina, T. Semyhinivska, Cloud resources and services for development of self-educational competence of future IT specialists: Business process modelling and examples of using, CEUR Workshop Proceedings 2732 (2020) 591–606. URL: http://ceur-ws.org/Vol-2732/20200591.pdf.

[12] L. A. Kartashova, N. O. Prykhodkina, T. A. Makhynia, H. M. Tymoshko, O. A. Sholokh, F. M. Zhuravlev, Social media as a strategic tool in school management: experience of Ukraine and USA, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[13] D. S. Antoniuk, T. A. Vakaliuk, V. V. Didkivskyi, O. Y. Vizghalov, Development of a simulator to determine personal financial strategies using machine learning, CEUR Workshop Proceedings 3077 (2022) 12–26. URL: http://ceur-ws.org/Vol-3077/paper02.pdf.

[14] N. I. Cheboksarova, T. A. Vakaliuk, I. M. Iefremov, Development of CRM system with a mobile application for a school, CEUR Workshop Proceedings 3077 (2022) 44–65. URL: http://ceur-ws.org/Vol-3077/paper09.pdf.

[15] T. Vakaliuk, I. Novitska, I. Verbovsky, T. Rozhnova, V. Kontsedailo, Management of educational institutions with inclusive education based on innovative technologies, SHS Web of Conferences 104 (2021) 03008. doi:10.1051/shsconf/202110403008.

[16] T. A. Vakaliuk, O. D. Gavryliuk, V. V. Kontsedailo, V. P. Oleksiuk, O. O. Kalinichenko, Selection cloud-oriented learning technologies for the formation of professional competencies of bachelors majoring in statistics and general methodology of their use, in:

S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[17] V. P. Oleksiuk, O. R. Oleksiuk, T. A. Vakaliuk, An experiment on the implementation the methodology of teaching cloud technologies to future Computer Science teachers, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[18] O. V. Klochko, V. M. Fedorets, M. P. Shyshkina, T. R. Branitska, N. P. Kravets, Using the augmented/virtual reality technologies to improve the health-preserving competence of a physical education teacher, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[19] K. V. Vlasenko, O. H. Rovenska, I. V. Lovianova, O. M. Kondratyeva, V. V. Achkan, Y. M. Tkachenko, M. P. Shyshkina, The implementation of inquiry-based learning in the organization of students' research activities on Mathematics, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[20] O. P. Voitovych, R. M. Horbatiuk, I. S. Voitovych, M. P. Shyshkina, N. M. Shostakivska, Formation of information culture of vocational education specialists, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[21] I. A. Bezverbnyi, M. P. Shyshkina, The use of serverless technologies to support data processing within the open learning and research systems, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[22] M. B. Yevtuch, V. M. Fedorets, O. V. Klochko, M. P. Shyshkina, A. V. Dobryden, Development of the health-preserving competence of a physical education teacher on the basis of N. Bernstein's theory of movements construction using virtual reality technologies, CEUR Workshop Proceedings 2898 (2021) 294–314. URL: http://ceur-ws.org/Vol-2898/paper16.pdf.

[23] L. E. Gryzun, O. V. Shcherbakov, S. H. Lytvynova, Computer modeling of the tournament of game algorithms in the process of learning of basics of algorithmization and programming by pre-service IT-specialists, CEUR Workshop Proceedings (2022) 28–38.

[24] L. Bilousova, I, L. E. Gryzun, N. V. Zhytienova, Fundamentals of UI/UX design as a component of the pre-service specialist's curriculum, SHS Web of Conferences 104 (2021) 02015. doi:10.1051/shsconf/202110402015.

[25] L. I. Bilousova, L. E. Gryzun, S. H. Lytvynova, V. V. Pikalova, Modelling in GeoGebra in the context of holistic approach realization in mathematical training of pre-service specialists, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[26] L. I. Bilousova, L. E. Gryzun, N. P. Volkova, Features of design of digital aids for training

students with autistic disorders, CEUR Workshop Proceedings 2879 (2020) 221–232. URL: http://ceur-ws.org/Vol-2879/paper10.pdf.

[27] L. I. Bilousova, L. E. Gryzun, D. H. Sherstiuk, E. O. Shmeltser, Cloud-based complex of computer transdisciplinary models in the context of holistic educational approach, CEUR Workshop Proceedings 2433 (2019) 336–351. URL: http://ceur-ws.org/Vol-2433/paper22.pdf.

[28] L. I. Bilousova, L. E. Gryzun, J. O. Rakusa, E. O. Shmeltser, Informatics teacher's training for design of innovative learning aids, CEUR Workshop Proceedings 2643 (2020) 563–577. URL: http://ceur-ws.org/Vol-2643/paper33.pdf.

[29] V. Y. Pazdrii, V. O. Kuprievych, S. H. Lytvynova, Strategic branches of economic and managerial training of principals in Ukraine using business-simulations, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[30] K. M. Binytska, O. O. Bilyakovska, O. I. Yankovych, G. V. Buchkivska, O. P. Binytska, V. V. Greskova, I. P. Ocheretna, O. Y. Burov, S. H. Lytvynova, Implicit potential of immersive technologies implementation in the educational process at the universities: world experience, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[31] I. M. Barna, L. R. Hrytsak, H. R. Henseruk, S. H. Lytvynova, Features of utilization information and communication technology in the process of teaching the "Environmental Impact Assessment" course, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[32] S. H. Lytvynova, S. O. Semerikov, A. M. Striuk, M. I. Striuk, L. S. Kolgatina, V. Y. Velychko, I. S. Mintii, O. O. Kalinichenko, AREdu 2021 – Immersive technology today, CEUR Workshop Proceedings 2898 (2021) 1–40. URL: http://ceur-ws.org/Vol-2898/paper00.pdf.

[33] H. B. Varina, V. V. Osadchyi, K. P. Osadcha, S. V. Shevchenko, S. H. Lytvynova, Peculiarities of cloud computing use in the process of the first-year students' adaptive potential development, CEUR Workshop Proceedings 2879 (2020) 521–538. URL: http://ceur-ws.org/Vol-2879/paper31.pdf.

[34] N. S. Lukychova, N. V. Osypova, G. S. Yuzbasheva, ICT and current trends as a path to STEM education: implementation and prospects, CEUR Workshop Proceedings (2022) 39–55.

[35] N. V. Osypova, V. I. Tatochenko, Improving the learning environment for future mathematics teachers with the use application of the dynamic mathematics system GeoGebra AR, CEUR Workshop Proceedings 2898 (2021) 178–196. URL: http://ceur-ws.org/Vol-2898/paper10.pdf.

[36] N. Osypova, O. Kokhanovska, G. Yuzbasheva, H. Kravtsov, Augmented and virtual reality technologies in teacher retraining, CEUR Workshop Proceedings 2732 (2020) 1203–1216. URL: http://ceur-ws.org/Vol-2732/20201203.pdf.

[37] N. Kushnir, N. Osypova, N. Valko, L. Kuzmich, Distance learning technologies in institution of higher education by means of LCMS Moodle, CEUR Workshop Proceedings 2732

(2020) 1152–1163. URL: http://ceur-ws.org/Vol-2732/20201152.pdf.

[38] A. O. Bielinskyi, A. E. Kiv, Y. O. Prikhozha, M. A. Slusarenko, V. N. Soloviev, Complex systems and physics education, CEUR Workshop Proceedings (2022) 56–80.

[39] A. O. Bielinskyi, O. A. Serdyuk, S. O. Semerikov, V. N. Soloviev, Econophysics of cryptocurrency crashes: a systematic review, CEUR Workshop Proceedings 3048 (2021) 31–133. URL: http://ceur-ws.org/Vol-3048/paper03.pdf.

[40] A. O. Bielinskyi, S. V. Hushko, A. V. Matviychuk, O. A. Serdyuk, S. O. Semerikov, V. N. Soloviev, Irreversibility of financial time series: a case of crisis, CEUR Workshop Proceedings 3048 (2021) 134–150. URL: http://ceur-ws.org/Vol-3048/paper04.pdf.

[41] A. Bielinskyi, V. Soloviev, S. Semerikov, V. Solovieva, Detecting stock crashes using Levy distribution, CEUR Workshop Proceedings 2422 (2019) 420–433. URL: http://ceur-ws.org/Vol-2422/paper34.pdf.

[42] V. Soloviev, A. Bielinskyi, O. Serdyuk, V. Solovieva, S. Semerikov, Lyapunov exponents as indicators of the stock market crashes, CEUR Workshop Proceedings 2732 (2020) 455–470. URL: http://ceur-ws.org/Vol-2732/20200455.pdf.

[43] A. Bielinskyi, S. Semerikov, O. Serdyuk, V. Solovieva, V. Soloviev, L. Pichl, Econophysics of sustainability indices, CEUR Workshop Proceedings 2713 (2020) 372–392. URL: http://ceur-ws.org/Vol-2713/paper41.pdf.

[44] A. E. Kiv, S. O. Semerikov, V. N. Soloviev, A. M. Striuk, 4th Workshop for Young Scientists in Computer Science & Software Engineering, CEUR Workshop Proceedings 3077 (2022) i–xxxv. URL: http://ceur-ws.org/Vol-3077/intro.pdf.

[45] A. E. Kiv, V. N. Soloviev, S. O. Semerikov, H. B. Danylchuk, L. O. Kibalnyk, A. V. Matviychuk, A. M. Striuk, Machine learning for prediction of emergent economy dynamics, CEUR Workshop Proceedings 3048 (2021) i–xxxi. URL: http://ceur-ws.org/Vol-3048/paper00.pdf.

[46] E. V. Komarova, A. E. Kiv, The problem of the limitations of the educational model experiment on population genetics and its solution, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[47] E. V. Komarova, A. E. Kiv, The values of biological education from the point of view of 2020 events (or biotechnological human improvement through the eyes of students), in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[48] A. E. Kiv, V. N. Soloviev, E. Y. Tarasova, T. I. Koycheva, K. V. Kolesnykova, Analysis and application of semantic networks in education, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[49] P. P. Nechypurenko, T. V. Selivanova, M. P. Chernova, O. O. Evangelist, Y. O. Modlo, V. N. Soloviev, Using the virtual chemical laboratories in teaching the solution of experimental problems in chemistry of 9th grade students while studying the topic “Solutions”, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[50] L. O. Flehantov, Y. I. Ovsiienko, A. V. Antonets, V. N. Soloviev, Using dynamic vector diagrams to study mechanical motion models at agrarian university with GeoGebra, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[51] D. O. Bukreiev, A. V. Chorna, I. M. Serdiuk, V. N. Soloviev, Features of the use of software and hardware of the educational process in the conditions of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[52] E. G. Fedorenko, N. V. Kaidan, V. Y. Velychko, V. N. Soloviev, Gamification when studying logical operators on the Minecraft EDU platform, CEUR Workshop Proceedings 2898 (2021) 107–118. URL: http://ceur-ws.org/Vol-2898/paper05.pdf.

[53] V. Y. Velychko, E. H. Fedorenko, N. V. Kaidan, V. N. Soloviev, O. V. Bondarenko, The support of the process of training pre-service mathematics teachers by means of cloud services, CEUR Workshop Proceedings 2879 (2020) 318–332. URL: http://ceur-ws.org/Vol-2879/paper17.pdf.

[54] A. E. Artyukhov, I. I. Volk, T. A. Vasylieva, Agile methodology in higher education quality assurance system for SDGs 4, 8 and 9 achievement: national experience, CEUR Workshop Proceedings (2022) 81–94.

[55] O. G. Glazunova, V. I. Korolchuk, O. V. Parhomenko, T. V. Voloshyna, N. V. Morze, E. M. Smyrnova-Trybulska, Methodology for using cloud-oriented environment for flipped learning of the future IT specialists, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[56] R. K. Makhachashvili, S. I. Kovpik, A. O. Bakhtina, N. V. Morze, E. O. Shmeltser, Applied technology of fiction and non-fiction conceptual presentation via ICT tools: pedagogical function of graphic mimesis, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[57] R. K. Makhachashvili, S. I. Kovpik, A. O. Bakhtina, N. V. Morze, E. O. Shmeltser, Perception and interpretation of emoji in the pedagogical process: aposterior features of artificial digital language, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[58] O. G. Glazunova, M. V. Mokriiev, O. H. Kuzminska, V. I. Korolchuk, N. V. Morze, L. O. Varchenko-Trotsenko, R. A. Zolotukha, Moodle tools for educational analytics of the use of electronic resources of the university's portal, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[59] N. V. Morze, O. V. Strutynska, Model of the competences in educational robotics, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[60] N. V. Morze, I. V. Mashkina, M. A. Boiko, Experience in training specialists with mathematical computer modeling skills, taking into account the needs of the modern labor market, CEUR Workshop Proceedings (2022) 95–106.
[61] V. I. Kovalchuk, S. V. Maslich, L. G. Movchan, V. V. Soroka, S. H. Lytvynova, O. H. Kuzminska, Digital transformation of vocational schools: problem analysis, CEUR Workshop Proceedings (2022) 107–123.
[62] T. B. Bykova, M. V. Ivashchenko, D. A. Kassim, V. I. Kovalchuk, Blended learning in the context of digitalization, CEUR Workshop Proceedings 2879 (2020) 247–260. URL: http://ceur-ws.org/Vol-2879/paper12.pdf.
[63] L. A. Martseva, L. H. Movchan, T. A. Vakaliuk, D. S. Antoniuk, Applying CDIO-approach at technical universities, Journal of Physics: Conference Series 1946 (2021) 012013. doi:10.1088/1742-6596/1946/1/012013.
[64] S. Lytvynova, Electronic textbook as a component of Smart Kids technology of education of elementary school pupils, CEUR Workshop Proceedings 2393 (2019) 105–120. URL: http://ceur-ws.org/Vol-2393/paper_204.pdf.
[65] S. Lytvynova, O. Burov, O. Slobodyanyk, The technique to evaluate pupils' intellectual and personal important qualities for ICT competences, CEUR Workshop Proceedings 2393 (2019) 107–177. URL: http://ceur-ws.org/Vol-2393/paper_382.pdf.
[66] O. Spirin, V. Oleksiuk, N. Balyk, S. Lytvynova, S. Sydorenko, The blended methodology of learning computer networks: Cloud-based approach, CEUR Workshop Proceedings 2393 (2019) 68–80. URL: http://ceur-ws.org/Vol-2393/paper_231.pdf.
[67] A. V. Iatsyshyn, V. O. Kovach, Y. O. Romanenko, I. I. Deinega, A. V. Iatsyshyn, O. O. Popov, Y. G. Kutsan, V. O. Artemchuk, O. Y. Burov, S. H. Lytvynova, Application of augmented reality technologies for preparation of specialists of new technological era, CEUR Workshop Proceedings 2547 (2020) 181–200. URL: http://ceur-ws.org/Vol-2547/paper14.pdf.
[68] S. L. Proskura, S. H. Lytvynova, The approaches to web-based education of computer science bachelors in higher education institutions, CEUR Workshop Proceedings 2643 (2020) 609–625. URL: http://ceur-ws.org/Vol-2643/paper36.pdf.
[69] O. Kuzminska, M. Mazorchuk, N. Morze, O. Kobylin, Attitude to the digital learning environment in Ukrainian universities, CEUR Workshop Proceedings 2393 (2019) 53–67. URL: http://ceur-ws.org/Vol-2393/paper_245.pdf.
[70] O. V. Prokhorov, V. O. Lisovichenko, M. S. Mazorchuk, O. H. Kuzminska, Developing a 3D quest game for career guidance to estimate students' digital competences, CEUR Workshop Proceedings 2731 (2020) 312–327. URL: http://ceur-ws.org/Vol-2731/paper18.pdf.
[71] M. S. Mazorchuk, T. S. Vakulenko, A. O. Bychko, O. H. Kuzminska, O. V. Prokhorov, Cloud technologies and learning analytics: web application for PISA results analysis and visualization, CEUR Workshop Proceedings 2879 (2020) 484–494.
[72] N. Morze, O. Kuzminska, G. Protsenko, Public information environment of a modern university, CEUR Workshop Proceedings 1000 (2013) 264–272. URL: http://ceur-ws.org/Vol-1000/ICTERI-2013-p-264-272.pdf.
[73] O. Kuzminska, M. Mazorchuk, N. Morze, V. Pavlenko, A. Prokhorov, Study of Digital Competence of the Students and Teachers in Ukraine, Communications in Computer and

Information Science 1007 (2019) 148–169. doi:10.1007/978-3-030-13929-2_8.
[74] L. F. Panchenko, H. O. Korzhov, A. O. Khomiak, V. Y. Velychko, V. N. Soloviev, Social dimension of higher education: definition, indicators, models, CEUR Workshop Proceedings (2022) 124–138.
[75] L. F. Panchenko, H. O. Korzhov, T. V. Kolomiiets, M. N. Yenin, PhD student training: principles and implementation, Journal of Physics: Conference Series 1840 (2021) 012056. doi:10.1088/1742-6596/1840/1/012056.
[76] L. F. Panchenko, A. O. Khomiak, A. V. Pikilnyak, Using Twitter in Ukrainian sociology majors training, CEUR Workshop Proceedings 2643 (2020) 253–263. URL: http://ceur-ws.org/Vol-2643/paper14.pdf.
[77] L. Panchenko, A. Khomiak, Education statistics: Looking for a case-study for modelling, CEUR Workshop Proceedings 2732 (2020) 948–963. URL: http://ceur-ws.org/Vol-2732/20200948.pdf.
[78] L. F. Panchenko, V. Y. Velychko, Structural equation modeling in educational research: a case-study for PhD training, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[79] L. Panchenko, Methodology of using structural equation modeling in educational research, CEUR Workshop Proceedings 2393 (2019) 895–904. URL: http://ceur-ws.org/Vol-2393/paper_411.pdf.
[80] L. F. Panchenko, I. O. Muzyka, Analytical review of augmented reality MOOCs, CEUR Workshop Proceedings 2547 (2020) 168–180. URL: http://ceur-ws.org/Vol-2547/paper13.pdf.
[81] L. F. Panchenko, T. A. Vakaliuk, K. V. Vlasenko, Augmented reality books: Concepts, typology, tools, CEUR Workshop Proceedings 2731 (2020) 283–296. URL: http://ceur-ws.org/Vol-2731/paper16.pdf.
[82] V. Steshenko, V. Velychko, S. Yashanov, N. Vovk, O. Kitova, Modelling of pedagogical technologies on the basis of activity approach, SHS Web of Conferences 104 (2021) 03015. doi:10.1051/shsconf/202110403015.
[83] V. Y. Velychko, E. H. Fedorenko, O. Y. Serdiuk, Theoretical bases of application of Free Software in preparation of pre-service teachers of Mathematics, Physics and Computer Science, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[84] E. G. Fedorenko, V. Y. Velychko, O. G. Naboka, O. H. Havrysh, H. M. Kravtsov, Integration of modern higher education into the global information space, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[85] V. Y. Velychko, S. O. Omelchenko, E. G. Fedorenko, H. M. Kravtsov, Familiarity with free software through online services, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[86] V. Y. Velychko, S. O. Omelchenko, I. A. Khyzhniak, E. G. Fedorenko, Developing and using open electronic educational resources in educational activities, Journal of Physics:

Conference Series 1840 (2021) 012063. doi:10.1088/1742-6596/1840/1/012063.
[87] A. E. Kiv, V. N. Soloviev, S. O. Semerikov, A. M. Striuk, V. V. Osadchyi, T. A. Vakaliuk, P. P. Nechypurenko, O. V. Bondarenko, I. S. Mintii, S. L. Malchenko, XIII International Conference on Mathematics, Science and Technology Education, Journal of Physics: Conference Series 1946 (2021) 011001. doi:10.1088/1742-6596/1946/1/011001.
[88] A. E. Kiv, S. O. Semerikov, V. N. Soloviev, A. M. Striuk, First student workshop on computer science & software engineering, CEUR Workshop Proceedings 2292 (2018) 1–10. URL: http://ceur-ws.org/Vol-2292/paper00.pdf.
[89] A. E. Kiv, S. O. Semerikov, V. N. Soloviev, A. M. Striuk, Second student workshop on computer science & software engineering, CEUR Workshop Proceedings 2546 (2019) 1–20. URL: http://ceur-ws.org/Vol-2546/paper00.pdf.
[90] A. Kiv, V. Soloviev, S. Semerikov, H. Danylchuk, L. Kibalnyk, A. Matviychuk, Experimental economics and machine learning for prediction of emergent economy dynamics, CEUR Workshop Proceedings 2422 (2019) 1–4. URL: http://ceur-ws.org/Vol-2422/paper00.pdf.
[91] N. V. Morze, O. P. Buinytska, V. A. Smirnova, Designing a rating system based on competencies for the analysis of the University teachers' research activities, CEUR Workshop Proceedings (2022) 139–153.
[92] N. V. Morze, V. O. Kucherovska, Ways to design a digital educational environment for K-12 education, CEUR Workshop Proceedings 2879 (2020) 200–211. URL: http://ceur-ws.org/Vol-2879/paper08.pdf.
[93] N. V. Morze, O. V. Strutynska, Digital transformation in society: key aspects for model development, Journal of Physics: Conference Series 1946 (2021) 012021. doi:10.1088/1742-6596/1946/1/012021.
[94] O. Glazunova, N. Morze, B. Golub, O. Burov, T. Voloshyna, O. Parhomenko, Learning style identification system: Design and data analysis, CEUR Workshop Proceedings 2732 (2020) 793–807. URL: http://ceur-ws.org/Vol-2732/20200793.pdf.
[95] N. Morze, L. Varchenko-Trotsenko, T. Terletska, E. Smyrnova-Trybulska, Implementation of adaptive learning at higher education institutions by means of Moodle LMS, Journal of Physics: Conference Series 1840 (2021) 012062. doi:10.1088/1742-6596/1840/1/012062.
[96] A. V. Ryabko, O. V. Zaika, R. P. Kukharchuk, T. A. Vakaliuk, Graph model of Fog Computing system, CEUR Workshop Proceedings 2850 (2021) 28–44. URL: http://ceur-ws.org/Vol-2850/paper2.pdf.
[97] T. A. Vakaliuk, V. V. Kontsedailo, D. S. Antoniuk, O. V. Korotun, S. O. Semerikov, I. S. Mintii, O. O. Kalinichenko, Possibilities of using the game simulator Software Inc in the training of future software engineers, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[98] T. A. Vakaliuk, D. S. Antoniuk, O. O. Kalinichenko, The state of ICT implementation in Ukrainian general secondary education institutions in 2019 and 2020, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[99] T. A. Vakaliuk, O. A. Chernysh, V. O. Babenko, The algorithm of electronic multilingual

terminological dictionary compilation, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[100] T. A. Vakaliuk, S. I. Pochtoviuk, Analysis of tools for the development of augmented reality technologies, CEUR Workshop Proceedings 2898 (2021) 119–130. URL: http://ceur-ws.org/Vol-2898/paper06.pdf.

[101] I. S. Mintii, T. A. Vakaliuk, S. M. Ivanova, O. A. Chernysh, S. M. Hryshchenko, S. O. Semerikov, Current state and prospects of distance learning development in Ukraine, CEUR Workshop Proceedings 2898 (2021) 41–55. URL: http://ceur-ws.org/Vol-2898/paper01.pdf.

[102] N. Valko, V. Osadchyi, Principles of effective functioning of training system of future teachers of natural science and mathematics for STEM technologies usage, SHS Web of Conferences 104 (2021) 02016. doi:10.1051/shsconf/202110402016.

[103] S. Symonenko, N. Zaitseva, V. Osadchyi, Implementation of MOOC platforms into teaching English to IT specialists, SHS Web of Conferences 104 (2021) 03007. doi:10.1051/shsconf/202110403007.

[104] T. M. Nikitchuk, T. A. Vakaliuk, O. A. Chernysh, O. L. Korenivska, L. A. Martseva, V. V. Osadchyi, Architecture for edge devices for diagnostics of students' physical condition, CEUR Workshop Proceedings 2850 (2021) 45–56. URL: http://ceur-ws.org/Vol-2850/paper3.pdf.

[105] D. S. Shepiliev, Y. O. Modlo, Y. V. Yechkalo, V. V. Tkachuk, M. M. Mintii, I. S. Mintii, O. M. Markova, T. V. Selivanova, O. M. Drashko, O. O. Kalinichenko, T. A. Vakaliuk, V. V. Osadchyi, S. O. Semerikov, WebAR development tools: An overview, CEUR Workshop Proceedings 2832 (2020) 84–93. URL: http://ceur-ws.org/Vol-2832/paper12.pdf.

[106] V. Osadchyi, H. Varina, N. Falko, K. Osadcha, T. Katkova, The peculiarities of the usage of AR technologies in the process of hardiness of future professionals, Journal of Physics: Conference Series 1840 (2021) 012059. doi:10.1088/1742-6596/1840/1/012059.

[107] A. V. Ryabko, O. V. Zaika, R. P. Kukharchuk, T. A. Vakaliuk, V. V. Osadchyi, Methods for predicting the assessment of the quality of educational programs and educational activities using a neuro-fuzzy approach, CEUR Workshop Proceedings (2022) 154–169.

[108] N. V. Valko, T. L. Goncharenko, N. O. Kushnir, V. V. Osadchyi, Cloud technologies for basics of artificial intelligence study in school, CEUR Workshop Proceedings (2022) 170–183.

[109] V. M. Zadorozhnii, N. V. Valko, The use of software and hardware Arduino for the students' formation of research and engineering competencies, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[110] N. V. Valko, V. V. Osadchyi, L. V. Kuzmich, Construction of an education model of natural disciplines' students in the distance learning conditions, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[111] I. M. Naumuk, N. V. Valko, Development of media education in Ukraine: current state and modern requirements, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[112] N. V. Valko, V. V. Osadchyi, Analysis and prospects of the future teachers training of the integrated course "Natural sciences", in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[113] N. V. Valko, V. V. Osadchyi, V. S. Kruhlyk, Cloud resources use for students' project activities, CEUR Workshop Proceedings 2879 (2020) 304–317. URL: http://ceur-ws.org/Vol-2879/paper16.pdf.

[114] T. Goncharenko, N. Kushnir, N. Valko, N. Osipova, Activity plan template for supporting study science with robotics and programming, CEUR Workshop Proceedings 2393 (2019) 132–143. URL: http://ceur-ws.org/Vol-2393/paper_257.pdf.

[115] T. Goncharenko, N. Yermakova-Cherchenko, Y. Anedchenko, Experience in the use of mobile technologies as a physics learning method, CEUR Workshop Proceedings 2732 (2020) 1298–1313. URL: http://ceur-ws.org/Vol-2732/20201298.pdf.

[116] V. Osadchyi, N. Valko, N. Kushnir, Determining the level of readiness of teachers to implementation of STEM-education in Ukraine, CEUR Workshop Proceedings 2393 (2019) 144–155. URL: http://ceur-ws.org/Vol-2393/paper_369.pdf.

[117] N. V. Valko, N. O. Kushnir, V. V. Osadchyi, Cloud technologies for STEM education, CEUR Workshop Proceedings 2643 (2020) 435–447. URL: http://ceur-ws.org/Vol-2643/paper25.pdf.

[118] K. P. Osadcha, V. V. Osadchyi, V. S. Kruglyk, O. M. Spirin, Analysis and summarization of the experience of developing adaptive learning systems in higher education, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[119] H. B. Varina, V. V. Osadchyi, S. V. Shevchenko, K. S. Averina, E. A. Lavrov, Peculiarities of using LearningApps service in the process of developing a motivational component of professional training of future professionals in terms of adaptive learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[120] E. A. Lavrov, V. G. Logvinenko, V. V. Osadchyi, O. Y. Siryk, Y. I. Chybiriak, Ensuring the effectiveness of e-learning based on online technology analysis of factors influencing the cognitive independence of students, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[121] V. V. Osadchyi, H. B. Varina, K. P. Osadcha, O. V. Kovalova, V. V. Voloshyna, O. V. Sysoiev, M. P. Shyshkina, The use of augmented reality technologies in the development of emotional intelligence of future specialists of socionomic professions under the conditions of adaptive learning, CEUR Workshop Proceedings 2898 (2021) 269–293. URL: http://ceur-ws.org/Vol-2898/paper15.pdf.

[122] K. P. Osadcha, V. V. Osadchyi, The use of cloud computing technology in professional training of future programmers, CEUR Workshop Proceedings 2879 (2020) 155–164. URL: http://ceur-ws.org/Vol-2879/paper05.pdf.

[123] K. V. Vlasenko, I. V. Lovianova, S. V. Volkov, I. V. Sitak, O. O. Chumak, A. V. Krasnoshchok,

N. G. Bohdanova, S. O. Semerikov, UI/UX design of educational on-line courses, CEUR Workshop Proceedings (2022) 184–199.

[124] K. V. Vlasenko, S. V. Volkov, I. V. Lovianova, I. V. Sitak, O. O. Chumak, S. O. Semerikov, N. H. Bohdanova, The criteria of usability design for educational online courses, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[125] K. V. Vlasenko, I. V. Sitak, D. A. Kovalenko, S. V. Volkov, I. V. Lovianova, S. O. Semerikov, S. L. Zahrebelnyi, Methodical recommendations for the development of online course structure and content, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[126] V. V. Achkan, K. V. Vlasenko, I. V. Lovianova, O. H. Rovenska, I. V. Sitak, O. O. Chumak, S. O. Semerikov, Web-based support of a higher school teacher, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[127] K. V. Vlasenko, S. V. Volkov, I. V. Lovianova, O. O. Chumak, I. V. Sitak, D. Y. Bobyliev, Management of online platform development and support process, CEUR Workshop Proceedings 2879 (2020) 333–345. URL: http://ceur-ws.org/Vol-2879/paper18.pdf.

[128] S. V. Shokaliuk, Y. Y. Bohunenko, I. V. Lovianova, M. P. Shyshkina, Technologies of distance learning for programming basics on the principles of integrated development of key competences, CEUR Workshop Proceedings 2643 (2020) 548–562. URL: http://ceur-ws.org/Vol-2643/paper32.pdf.

[129] I. V. Lovianova, D. Y. Bobyliev, A. D. Uchitel, Cloud calculations within the optional course Optimization Problems for 10th-11th graders, CEUR Workshop Proceedings 2433 (2019) 459–471. URL: http://ceur-ws.org/Vol-2433/paper31.pdf.

[130] A. P. Polishchuk, S. A. Semerikov, Concept of the course "Numerical methods in object methodology", ACNS Conference Series: Social Sciences and Humanities 1 (2022) 01003. URL: https://doi.org/10.55056/cs-ssh/1/01003. doi:10.55056/cs-ssh/1/01003.

[131] A. M. Striuk, S. O. Semerikov, H. M. Shalatska, V. P. Holiver, Software requirements engineering training: problematic questions, CEUR Workshop Proceedings 3077 (2022) 3–11. URL: http://ceur-ws.org/Vol-3077/paper01.pdf.

[132] V. Hamaniuk, S. Semerikov, Y. Shramko, ICHTML 2021 - A journal of the pandemic year, SHS Web of Conferences 104 (2021) 00001. doi:10.1051/shsconf/202110400001.

[133] R. Tarasenko, S. Amelina, S. Semerikov, Conceptual aspects of interpreter training using modern simultaneous interpretation technologies, CEUR Workshop Proceedings 3013 (2021) 239–252. URL: http://ceur-ws.org/Vol-3013/20210239.pdf.

[134] V. Tkachuk, Y. Yechkalo, S. Semerikov, M. Kislova, Y. Hladyr, Using Mobile ICT for Online Learning During COVID-19 Lockdown, in: A. Bollin, V. Ermolayev, H. C. Mayr, M. Nikitchenko, A. Spivakovsky, M. Tkachuk, V. Yakovyna, G. Zholtkevych (Eds.), Information and Communication Technologies in Education, Research, and Industrial Applications, Springer International Publishing, Cham, 2021, pp. 46–67. doi:10.1007/978-3-030-77592-6_3.

[135] L. V. Kravtsova, T. V. Zaytseva, O. M. Bezbakh, H. M. Kravtsov, N. H. Kaminska, The

optimum assessment of the information systems of shipboard hardware reliability in cloud services, CEUR Workshop Proceedings (2022) 200–215.
[136] T. Zaytseva, L. Kravtsova, A. Puliaieva, Computer modelling of educational process as the way to modern learning technologies, CEUR Workshop Proceedings 2393 (2019) 849–863. URL: http://ceur-ws.org/Vol-2393/paper_403.pdf.
[137] L. Kravtsova, T. Zaytseva, A. Puliaieva, Choice of ship management strategy based on wind wave forecasting, CEUR Workshop Proceedings 2732 (2020) 839–853. URL: http://ceur-ws.org/Vol-2732/20200839.pdf.
[138] A. Puliaieva, L. Kravtsova, T. Zaytseva, Formation of personalized learning path for foreign students based on the MOODLE e-learning platform using SCORM-package, CEUR Workshop Proceedings 2732 (2020) 1129–1140. URL: http://ceur-ws.org/Vol-2732/20201129.pdf.
[139] L. Kravtsova, N. Kaminska, H. Kravtsov, Cloud services in the distance learning system for future sailors, CEUR Workshop Proceedings 2732 (2020) 1187–1202. URL: http://ceur-ws.org/Vol-2732/20201187.pdf.
[140] V. S. Kruglyk, D. O. Bukreiev, P. V. Chornyi, E. O. Kupchak, A. A. Sender, H. M. Kravtsov, I. G. Riznitskii, Using the Discord platform in the educational process, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[141] H. M. Shalatska, O. Y. Zotova-Sadylo, O. V. Balanaieva, H. M. Kravtsov, Organisation of Business English for specific purposes course on Moodle, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[142] O. M. Mikhailutsa, T. O. Melikhova, A. V. Pozhuyev, H. M. Kravtsov, Innovative methods of information visualization in transport logistics and training organization, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[143] V. Ermolayev, F. Mallet, V. Yakovyna, V. Kharchenko, V. Kobets, A. Kornilowicz, H. Kravtsov, M. Nikitchenko, S. Semerikov, A. Spivakovsky, Preface, CEUR Workshop Proceedings 2393 (2019). URL: http://ceur-ws.org/Vol-2393/preface.pdf.
[144] O. Sokolov, G. Zholtkevych, V. Yakovyna, Y. Tarasich, V. Kharchenko, V. Kobets, O. Burov, S. Semerikov, H. Kravtsov, Preface, CEUR Workshop Proceedings 2732 (2020). URL: http://ceur-ws.org/Vol-2732/preface.pdf.
[145] O. S. Holovnia, V. P. Oleksiuk, Selecting cloud computing software for a virtual online laboratory supporting the Operating Systems course, CEUR Workshop Proceedings (2022) 216–227.
[146] O. Holovnia, Linux online virtual environments in teaching operating systems, CEUR Workshop Proceedings 2732 (2020) 964–973. URL: http://ceur-ws.org/Vol-2732/20200964.pdf.
[147] N. R. Balyk, G. P. Shmyger, Y. P. Vasylenko, V. P. Oleksiuk, Digital educational environment of teachers' professional training in pedagogical university, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educa-

tional Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[148] N. R. Balyk, Y. P. Vasylenko, V. P. Oleksiuk, O. R. Oleksiuk, G. P. Shmyger, Cloud labs as a tool for learning Cisco CyberSecurity Operations and DevNet Associate Fundamentals courses, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[149] V. P. Oleksiuk, O. R. Oleksiuk, Assessing augmented reality possibilities in the study of school Computer Science, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[150] V. P. Oleksiuk, O. R. Oleksiuk, O. M. Spirin, N. R. Balyk, Y. P. Vasylenko, Some experience in maintenance of an academic cloud, CEUR Workshop Proceedings 2879 (2020) 165–178. URL: http://ceur-ws.org/Vol-2879/paper06.pdf.

[151] B. Oliinyk, V. Oleksiuk, Automation in software testing, can we automate anything we want?, CEUR Workshop Proceedings 2546 (2019) 224–234. URL: http://ceur-ws.org/Vol-2546/paper16.pdf.

[152] L. V. Lehka, S. V. Shokaliuk, V. V. Osadchyi, Hardware and software tools for teaching the basics of quantum informatics to students of specialized (high) schools, CEUR Workshop Proceedings (2022) 228–244.

[153] L. V. Lehka, A. O. Bielinskyi, S. V. Shokaliuk, V. N. Soloviev, P. V. Merzlykin, Y. Y. Bohunenko, Prospects of quantum informatics and the study of its basics in the school course, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[154] L. V. Lehka, S. V. Shokaliuk, Quantum programming is a promising direction of IT development, CEUR Workshop Proceedings 2292 (2018) 76–82. URL: http://ceur-ws.org/Vol-2292/paper07.pdf.

[155] P. V. Merzlykin, M. V. Marienko, S. V. Shokaliuk, CoCalc tools as a means of open science and its didactic potential in the educational process, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[156] V. O. Ustinova, S. V. Shokaliuk, I. S. Mintii, A. V. Pikilnyak, Modern techniques of organizing computer support for future teachers' independent work in German language, CEUR Workshop Proceedings 2433 (2019) 308–321. URL: http://ceur-ws.org/Vol-2433/paper20.pdf.

[157] I. S. Mintii, S. V. Shokaliuk, T. A. Vakaliuk, M. M. Mintii, V. N. Soloviev, Import test questions into Moodle LMS, CEUR Workshop Proceedings 2433 (2019) 529–540. URL: http://ceur-ws.org/Vol-2433/paper36.pdf.

[158] V. D. Siokhin, V. V. Osadchyi, P. I. Gorlov, V. S. Yeremieiev, Identification of "Primorsk-1" wind power plant impact on the ecological situation connected with the behavior of ornithofauna on the azov sea coast, Journal of Physics: Conference Series 1946 (2021) 012007. doi:10.1088/1742-6596/1946/1/012007.

[159] S. V. Symonenko, N. V. Zaitseva, V. V. Osadchyi, Communicative patterns for IT pro-

fessionals as means of mastering communication skills, Journal of Physics: Conference Series 1946 (2021) 012020. doi:10.1088/1742-6596/1946/1/012020.

[160] V. V. Osadchyi, K. P. Osadcha, H. B. Varina, S. V. Shevchenko, I. S. Bulakh, Specific features of the use of augmented reality technologies in the process of the development of cognitive component of future professionals' mental capacity, Journal of Physics: Conference Series 1946 (2021) 012022. doi:10.1088/1742-6596/1946/1/012022.

[161] N. V. Valko, V. V. Osadchyi, Teaching robotics to future teachers as part of education activities, Journal of Physics: Conference Series 1946 (2021) 012016. doi:10.1088/1742-6596/1946/1/012016.

[162] S. V. Symonenko, N. V. Zaitseva, M. S. Vynogradova, V. V. Osadchyi, A. V. Sushchenko, Application of ICT tools in teaching american english for computer science students in the context of global challenges, Journal of Physics: Conference Series 1840 (2021) 012048. doi:10.1088/1742-6596/1840/1/012048.

[163] D. M. Bodnenko, H. A. Kuchakovska, O. V. Lokaziuk, V. V. Proshkin, S. H. Lytvynova, O. H. Naboka, Using the Yammer cloud service to organize project-based learning methods, CEUR Workshop Proceedings (2022) 245–258.

[164] A. E. Kiv, V. V. Bilous, D. M. Bodnenko, D. V. Horbatovskyi, O. S. Lytvyn, V. V. Proshkin, The development and use of mobile app AR Physics in physics teaching at the university, CEUR Workshop Proceedings 2898 (2021) 197–212. URL: http://ceur-ws.org/Vol-2898/paper11.pdf.

[165] D. M. Bodnenko, H. A. Kuchakovska, V. V. Proshkin, O. S. Lytvyn, Using a virtual digital board to organize student's cooperative learning, CEUR Workshop Proceedings 2731 (2020) 357–368. URL: http://ceur-ws.org/Vol-2731/paper21.pdf.

[166] M. G. Drushlyak, O. V. Semenikhina, V. V. Proshkin, S. Y. Kharchenko, T. D. Lukashova, Methodology of formation of modeling skills based on a constructive approach (on the example of GeoGebra), CEUR Workshop Proceedings 2879 (2020) 458–472. URL: http://ceur-ws.org/Vol-2879/paper26.pdf.

[167] O. M. Hlushak, V. V. Proshkin, O. S. Lytvyn, Using the e-learning course "Analytic Geometry" in the process of training students majoring in Computer Science and Information Technology, CEUR Workshop Proceedings 2433 (2019) 472–485. URL: http://ceur-ws.org/Vol-2433/paper32.pdf.

[168] V. H. Shamonia, O. V. Semenikhina, V. V. Proshkin, O. V. Lebid, S. Y. Kharchenko, O. S. Lytvyn, Using the Proteus virtual environment to train future IT professionals, CEUR Workshop Proceedings 2547 (2020) 24–36. URL: http://ceur-ws.org/Vol-2547/paper02.pdf.

[169] M. M. Astafieva, O. B. Zhyltsov, V. V. Proshkin, O. S. Lytvyn, E-learning as a mean of forming students' mathematical competence in a research-oriented educational process, CEUR Workshop Proceedings 2643 (2020) 674–689. URL: http://ceur-ws.org/Vol-2643/paper40.pdf.

[170] O. M. Hlushak, S. O. Semenyaka, V. V. Proshkin, S. V. Sapozhnykov, O. S. Lytvyn, The usage of digital technologies in the university training of future bachelors (having been based on the data of mathematical subjects), CEUR Workshop Proceedings 2643 (2020) 210–224. URL: http://ceur-ws.org/Vol-2643/paper11.pdf.

[171] I. Trubavina, S. Dotsenko, O. Naboka, M. Chaikovskyi, H. Meshko, Developing digital competence of teachers of humanitarian disciplines in the conditions of COVID-19

quarantine measures, Journal of Physics: Conference Series 1840 (2021) 012052. doi:10.1088/1742-6596/1840/1/012052.

[172] S. Lytvynova, M. Medvedieva, Educational computer modelling in natural sciences education: Chemistry and biology aspects, CEUR Workshop Proceedings 2732 (2020) 532–546. URL: http://ceur-ws.org/Vol-2732/20200532.pdf.

[173] O. Burov, V. Bykov, S. Lytvynova, ICT evolution: From single computational tasks to modeling of life, CEUR Workshop Proceedings 2732 (2020) 583–590. URL: http://ceur-ws.org/Vol-2732/20200583.pdf.

[174] S. L. Proskura, S. G. Lytvynova, O. P. Kronda, N. Demeshkant, Mobile learning approach as a supplementary approach in the organization of the studying process in educational institutions, CEUR Workshop Proceedings 2732 (2020) 650–664. URL: http://ceur-ws.org/Vol-2732/20200650.pdf.

[175] S. L. Proskura, S. G. Lytvynova, O. P. Kronda, Students academic achievement assessment in higher education institutions, CEUR Workshop Proceedings 2732 (2020) 734–745. URL: http://ceur-ws.org/Vol-2732/20200734.pdf.

[176] O. B. Petrovych, A. P. Vinnichuk, O. A. Poida, V. I. Tkachenko, T. A. Vakaliuk, O. H. Kuzminska, The didactic potential of cloud technologies in professional training of future teachers of Ukrainian language and literature, CEUR Workshop Proceedings (2022) 259–277.

[177] O. B. Petrovych, A. P. Vinnichuk, V. P. Krupka, I. A. Zelenenka, A. V. Voznyak, The usage of augmented reality technologies in professional training of future teachers of Ukrainian language and literature, CEUR Workshop Proceedings 2898 (2021) 315–333. URL: http://ceur-ws.org/Vol-2898/paper17.pdf.

[178] T. A. Vakaliuk, O. V. Korotun, S. O. Semerikov, The selection of cloud services for ER-diagrams construction in IT specialists databases teaching, CEUR Workshop Proceedings 2879 (2020) 384–397. URL: http://ceur-ws.org/Vol-2879/paper21.pdf.

[179] D. S. Antoniuk, T. A. Vakaliuk, V. V. Ievdokymov, A. V. Morozov, V. V. Kontsedailo, Integrating business simulations software into learning environment of technical university, Journal of Physics: Conference Series 1946 (2021) 012018. doi:10.1088/1742-6596/1946/1/012018.

[180] I. P. Varava, A. P. Bohinska, T. A. Vakaliuk, I. S. Mintii, Soft skills in software engineering technicians education, Journal of Physics: Conference Series 1946 (2021) 012012. doi:10.1088/1742-6596/1946/1/012012.

[181] T. Vakaliuk, V. Kontsedailo, D. Antoniuk, O. Korotun, S. Semerikov, I. Mintii, Using Game Dev Tycoon to develop professional soft competencies for future engineers-programmers, CEUR Workshop Proceedings 2732 (2020) 808–822. URL: http://ceur-ws.org/Vol-2732/20200808.pdf.

[182] S. Semerikov, S. Chukharev, S. Sakhno, A. Striuk, V. Osadchyi, V. Solovieva, T. Vakaliuk, P. Nechypurenko, O. Bondarenko, H. Danylchuk, Our sustainable coronavirus future, E3S Web of Conferences 166 (2020) 00001. doi:10.1051/e3sconf/202016600001.

[183] L. I. Bilousova, O. H. Kolgatin, L. S. Kolgatina, O. H. Kuzminska, Introspection as a condition of students' self-management in programming training, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[184] S. V. Symonenko, N. V. Zaitseva, K. P. Osadcha, O. H. Kuzminska, Content analysis of course books and online courses for teaching English for specific purposes for IT professionals, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[185] O. V. Prokhorov, V. O. Lisovichenko, M. S. Mazorchuk, O. H. Kuzminska, Digital technology implementation for students' involvement base on 3D quest game for career guidance and estimating students' digital competences, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[186] M. A. Galaburda, O. H. Kuzminska, M. K. Halaburda, Information and communication technologies in application, dissemination and evaluation of Erasmus+ Jean Monnet activities, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[187] M. S. Mazorchuk, T. S. Vakulenko, A. O. Bychko, O. H. Kuzminska, O. V. Prokhorov, Cloud technologies and learning analytics: Web application for PISA results analysis and visualization, CEUR Workshop Proceedings 2879 (2020) 484–494. URL: http://ceur-ws.org/Vol-2879/paper28.pdf.

[188] V. Y. Velychko, E. G. Fedorenko, V. N. Soloviev, L. V. Dolins'ka, Creation of open educational resources during educational practice by means of cloud technologies, CEUR Workshop Proceedings (2022) 278–289.

[189] V. Y. Velychko, E. H. Fedorenko, D. A. Kassim, Conceptual bases of use of free software in the professional training of pre-service teacher of mathematics, physics and computer science, CEUR Workshop Proceedings 2257 (2018) 93–102. URL: http://ceur-ws.org/Vol-2257/paper11.pdf.

[190] E. H. Fedorenko, V. Y. Velychko, A. V. Stopkin, A. V. Chorna, V. N. Soloviev, Informatization of education as a pledge of the existence and development of a modern higher education, CEUR Workshop Proceedings 2433 (2019) 20–32. URL: http://ceur-ws.org/Vol-2433/paper01.pdf.

[191] E. H. Fedorenko, V. Y. Velychko, S. O. Omelchenko, V. I. Zaselskiy, Learning free software using cloud services, CEUR Workshop Proceedings 2643 (2020) 487–499. URL: http://ceur-ws.org/Vol-2643/paper29.pdf.

[192] S. Semerikov, I. Teplytskyi, Y. Yechkalo, O. Markova, V. Soloviev, A. Kiv, Computer simulation of neural networks using spreadsheets: Dr. Anderson, welcome back, CEUR Workshop Proceedings 2393 (2019) 833–848. URL: http://ceur-ws.org/Vol-2393/paper_348.pdf.

[193] V. Soloviev, O. Serdiuk, S. Semerikov, A. Kiv, Recurrence plot-based analysis of financial-economic crashes, CEUR Workshop Proceedings 2713 (2020) 21–40. URL: http://ceur-ws.org/Vol-2713/paper01.pdf.

[194] V. Tkachuk, S. Semerikov, Y. Yechkalo, S. Khotskina, V. Soloviev, Selection of mobile ICT for learning informatics of future professionals in engineering pedagogy, CEUR Workshop Proceedings 2732 (2020) 1058–1068. URL: http://ceur-ws.org/Vol-2732/20201058.pdf.

[195] A. Kiv, P. Hryhoruk, I. Khvostina, V. Solovieva, V. Soloviev, S. Semerikov, Machine

learning of emerging markets in pandemic times, CEUR Workshop Proceedings 2713 (2020) 1–20. URL: http://ceur-ws.org/Vol-2713/paper00.pdf.

[196] V. Derbentsev, S. Semerikov, O. Serdyuk, V. Solovieva, V. Soloviev, Recurrence based entropies for sustainability indices, E3S Web of Conferences 166 (2020) 13031. doi:10.1051/e3sconf/202016613031.

[197] M. I. Sherman, Y. B. Samchynska, V. M. Kobets, Development of an electronic system for remote assessment of students' knowledge in cloud-based learning environment, CEUR Workshop Proceedings (2022) 290–305.

[198] V. Kobets, V. Yatsenko, M. Voynarenko, Cluster analysis of countries inequality due to IT development, CEUR Workshop Proceedings 2393 (2019) 406–421. URL: http://ceur-ws.org/Vol-2393/paper_341.pdf.

[199] D. Kilinich, V. Kobets, Support of investors' decision making in economic experiments using software tools, CEUR Workshop Proceedings 2393 (2019) 277–288. URL: http://ceur-ws.org/Vol-2393/paper_273.pdf.

[200] V. Kobets, V. Yatsenko, L. Buiak, Identifying the gaps in the preparing of a business analyst between the requirements of the labor market and the standards of study programs: Case of Ukraine, CEUR Workshop Proceedings 2732 (2020) 499–514. URL: http://ceur-ws.org/Vol-2732/20200499.pdf.

[201] V. Kobets, N. Tsiuriuta, V. Lytvynenko, V. Mykhaylova, Web-service management system for job search using competence-based approach, CEUR Workshop Proceedings 2732 (2020) 290–302.

[202] V. Kobets, I. Shakhman, A. Bystriantseva, Impact of the environmental externalities and technological progress on the stability of economic system development on the example of the Ingulets river basin, CEUR Workshop Proceedings 2732 (2020) 242–255. URL: http://ceur-ws.org/Vol-2732/20200242.pdf.

[203] O. O. Popov, Y. O. Kyrylenko, I. P. Kameneva, A. V. Iatsyshyn, A. V. Iatsyshyn, V. O. Kovach, V. O. Artemchuk, V. N. Bliznyuk, A. E. Kiv, The use of specialized software for liquid radioactive material spills simulation to teach students and postgraduate students, CEUR Workshop Proceedings (2022) 306–322.

[204] O. O. Popov, A. V. Iatsyshyn, A. V. Iatsyshyn, V. O. Kovach, V. O. Artemchuk, V. O. Gurieiev, Y. G. Kutsan, I. S. Zinovieva, O. V. Alieksieieva, V. V. Kovalenko, A. E. Kiv, Immersive technology for training and professional development of nuclear power plants personnel, CEUR Workshop Proceedings 2898 (2021) 230–254. URL: http://ceur-ws.org/Vol-2898/paper13.pdf.

[205] A. V. Iatsyshyn, I. H. Hubeladze, V. O. Kovach, V. V. Kovalenko, V. O. Artemchuk, M. S. Dvornyk, O. O. Popov, A. V. Iatsyshyn, A. E. Kiv, Applying digital technologies for work management of young scientists' councils, CEUR Workshop Proceedings 2879 (2020) 124–154. URL: http://ceur-ws.org/Vol-2879/paper04.pdf.

[206] I. S. Zinovieva, V. O. Artemchuk, A. V. Iatsyshyn, Y. O. Romanenko, O. O. Popov, V. O. Kovach, D. V. Taraduda, A. V. Iatsyshyn, The use of MOOCs as additional tools for teaching NoSQL in blended and distance learning mode, Journal of Physics: Conference Series 1946 (2021) 012011. doi:10.1088/1742-6596/1946/1/012011.

[207] A. V. Iatsyshyn, V. O. Kovach, V. O. Lyubchak, Y. O. Zuban, A. G. Piven, O. M. Sokolyuk, A. V. Iatsyshyn, O. O. Popov, V. O. Artemchuk, M. P. Shyshkina, Application of augmented

reality technologies for education projects preparation, CEUR Workshop Proceedings 2643 (2020) 134–160. URL: http://ceur-ws.org/Vol-2547/paper14.pdf.

[208] A. Iatsyshyn, A. Iatsyshyn, V. Kovach, I. Zinovieva, V. Artemchuk, O. Popov, O. Cholyshkina, O. Radchenko, O. Radchenko, A. Turevych, Application of open and specialized geoinformation systems for computer modelling studying by students and PhD students, CEUR Workshop Proceedings 2732 (2020) 893–908. URL: http://ceur-ws.org/Vol-2732/20200893.pdf.

[209] A. Iatsyshyn, A. Iatsyshyn, V. Artemchuk, I. Kameneva, V. Kovach, O. Popov, Software tools for tasks of sustainable development of environmental problems: Peculiarities of programming and implementation in the specialists' preparation, E3S Web of Conferences 166 (2020) 01001. doi:10.1051/e3sconf/202016601001.

[210] A. V. Iatsyshyn, V. O. Kovach, Y. O. Romanenko, A. V. Iatsyshyn, Cloud services application ways for preparation of future PhD, CEUR Workshop Proceedings 2433 (2019) 197–216. URL: http://ceur-ws.org/Vol-2433/paper12.pdf.

[211] V. Gurieiev, Y. Kutsan, A. Iatsyshyn, A. Iatsyshyn, V. Kovach, E. Lysenko, V. Artemchuk, O. Popov, Simulating systems for advanced training and professional development of energy specialists in power sector, CEUR Workshop Proceedings 2732 (2020) 693–708. URL: http://ceur-ws.org/Vol-2732/20200693.pdf.

[212] I. S. Zinovieva, V. O. Artemchuk, A. V. Iatsyshyn, O. O. Popov, V. O. Kovach, A. V. Iatsyshyn, Y. O. Romanenko, O. V. Radchenko, The use of online coding platforms as additional distance tools in programming education, Journal of Physics: Conference Series 1840 (2021) 012029. doi:10.1088/1742-6596/1840/1/012029.

[213] A. V. Iatsyshyn, O. O. Popov, V. O. Kovach, A. V. Iatsyshyn, V. O. Artemchuk, O. O. Radchenko, I. I. Deinega, V. V. Kovalenko, Formation of the scientist image in modern conditions of digital society transformation, Journal of Physics: Conference Series 1840 (2021) 012039. doi:10.1088/1742-6596/1840/1/012039.

[214] M. P. Leshchenko, A. M. Kolomiiets, A. V. Iatsyshyn, V. V. Kovalenko, A. V. Dakal, O. O. Radchenko, Development of informational and research competence of postgraduate and doctoral students in conditions of digital transformation of science and education, Journal of Physics: Conference Series 1840 (2021) 012057. doi:10.1088/1742-6596/1840/1/012057.

[215] A. D. Sverdlova, A. O. Zaporozhets, I. V. Bohachev, O. O. Popov, A. V. Iatsyshyn, A. V. Iatsyshyn, V. O. Kovach, V. O. Artemchuk, N. M. Hrushchynska, Self-organizing network topology for autonomous IoT systems, CEUR Workshop Proceedings 2850 (2021) 57–70. URL: http://ceur-ws.org/Vol-2850/paper4.pdf.

[216] O. G. Yaroshenko, O. D. Samborska, A. E. Kiv, Experimental verification of efficiency of the formation of information and digital competence of bachelors of primary education based on an integrated approach, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[217] V. S. Kuznetsov, M. V. Moiseienko, N. V. Moiseienko, B. A. Rostalny, A. E. Kiv, Using Unity to teach game development, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[218] A. E. Kiv, K. V. Kolesnykova, T. I. Koycheva, A. O. Vinkovska, I. I. Donchev, The development of creative thinking as an important task of educational process, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[219] Y. V. Kharchenko, O. M. Babenko, A. E. Kiv, Using Blippar to create augmented reality in chemistry education, CEUR Workshop Proceedings 2898 (2021) 213–229. URL: http://ceur-ws.org/Vol-2898/paper12.pdf.

[220] L. Y. Midak, I. V. Kravets, O. V. Kuzyshyn, T. V. Kostiuk, K. V. Buzhdyhan, V. M. Lutsyshyn, I. O. Hladkoskok, A. E. Kiv, M. P. Shyshkina, Augmented reality while studying radiochemistry for the upcoming chemistry teachers, CEUR Workshop Proceedings 2898 (2021) 147–158. URL: http://ceur-ws.org/Vol-2898/paper08.pdf.

[221] I. V. Batsurovska, N. A. Dotsenko, V. N. Soloviev, S. H. Lytvynova, O. A. Gorbenko, N. I. Kim, A. P. Haleeva, Technology of application of 3D models of electrical engineering in the performing laboratory work, CEUR Workshop Proceedings (2022) 323–335.

[222] A. D. Uchitel, I. V. Batsurovska, N. A. Dotsenko, O. A. Gorbenko, N. I. Kim, Implementation of future agricultural engineers' training technology in the informational and educational environment, CEUR Workshop Proceedings 2879 (2020) 233–246. URL: http://ceur-ws.org/Vol-2879/paper11.pdf.

[223] I. V. Batsurovska, Technological model of training of Masters in Electrical Engineering to electrical installation and commissioning, Journal of Physics: Conference Series 1946 (2021) 012015. doi:10.1088/1742-6596/1946/1/012015.

[224] I. Batsurovska, N. Dotsenko, O. Gorbenko, N. Kim, Organizational and pedagogical conditions for training higher education applicants by learning tools of a competence-oriented environment, SHS Web of Conferences 104 (2021) 02014. doi:10.1051/shsconf/202110402014.

[225] N. A. Dotsenko, 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 (2021) 012014. doi:10.1088/1742-6596/1946/1/012014.

[226] A. O. Bielinskyi, I. Khvostina, A. Mamanazarov, A. Matviychuk, S. Semerikov, O. Serdyuk, V. Solovieva, V. N. Soloviev, Predictors of oil shocks. Econophysical approach in environmental science, IOP Conference Series: Earth and Environmental Science 628 (2021) 012019. doi:10.1088/1755-1315/628/1/012019.

[227] A. E. Kiv, V. N. Soloviev, S. O. Semerikov, XII international conference on mathematics, science and technology education, Journal of Physics: Conference Series 1840 (2021) 011001. doi:10.1088/1742-6596/1840/1/011001.

[228] S. O. Semerikov, I. O. Teplytskyi, V. N. Soloviev, V. A. Hamaniuk, N. S. Ponomareva, O. H. Kolgatin, L. S. Kolgatina, T. V. Byelyavtseva, S. M. Amelina, R. O. Tarasenko, Methodic quest: Reinventing the system, Journal of Physics: Conference Series 1840 (2021) 012036. doi:10.1088/1742-6596/1840/1/012036.

[229] P. V. Zahorodko, S. O. Semerikov, V. N. Soloviev, A. M. Striuk, M. I. Striuk, H. M. Shalatska, Comparisons of performance between quantum-enhanced and classical machine learning algorithms on the IBM Quantum Experience, Journal of Physics: Conference Series 1840

(2021) 012021. doi:10.1088/1742-6596/1840/1/012021.
[230] A. O. Bielinskyi, V. N. Soloviev, Complex network precursors of crashes and critical events in the cryptocurrency market, CEUR Workshop Proceedings 2292 (2018) 37–45. URL: http://ceur-ws.org/Vol-2292/paper02.pdf.
[231] V. O. Liubchak, Y. O. Zuban, A. E. Artyukhov, Immersive learning technology for ensuring quality education: Ukrainian university case, CEUR Workshop Proceedings (2022) 336–354.
[232] H. I. Falfushynska, B. B. Buyak, G. M. Torbin, G. V. Tereshchuk, M. M. Kasianchuk, M. Karpiński, Enhancing digital and professional competences via implementation of virtual laboratories for future physical therapists and rehabilitologist, CEUR Workshop Proceedings (2022) 355–364.
[233] H. V. Tereshchuk, I. I. Kuzma, O. I. Yankovych, H. I. Falfushynska, I. A. Lyakhova, The formation of a successful personality of primary school children during media education implementation (using praxeological tales), in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[234] V. M. Chaika, I. I. Kuzma, O. I. Yankovych, K. M. Binytska, O. T. Pysarchuk, T. V. Ivanova, H. I. Falfushynska, I. A. Lyakhova, Media education technology at preschool educational institutions, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[235] H. I. Falfushynska, B. B. Buyak, H. V. Tereshchuk, G. M. Torbin, M. M. Kasianchuk, Strengthening of e-learning at the leading Ukrainian pedagogical universities in the time of COVID-19 pandemic, CEUR Workshop Proceedings 2879 (2020) 261–273. URL: http://ceur-ws.org/Vol-2879/paper13.pdf.
[236] O. I. Yankovych, V. M. Chaika, T. V. Ivanova, K. M. Binytska, I. I. Kuzma, O. T. Pysarchuk, H. I. Falfushynska, Technology of forming media literacy of children of the senior preschool age of Ukraine, CEUR Workshop Proceedings 2433 (2019) 126–144. URL: http://ceur-ws.org/Vol-2433/paper07.pdf.
[237] H. V. Tereshchuk, I. I. Kuzma, O. I. Yankovych, H. I. Falfushynska, The formation of a successful personality of a pupil in Ukrainian primary school during media education implementation, CEUR Workshop Proceedings 2433 (2019) 145–158. URL: http://ceur-ws.org/Vol-2433/paper08.pdf.
[238] B. B. Buyak, I. M. Tsidylo, V. I. Repskyi, V. P. Lyalyuk, Stages of conceptualization and formalization in the design of the model of the neuro-fuzzy expert system of professional selection of pupils, CEUR Workshop Proceedings 2257 (2018) 112–121.
[239] B. Buyak, I. Tsidylo, S. Kozibroda, V. Repskyi, Ontological model of representation of university resources, CEUR Workshop Proceedings 2393 (2019) 29–40. URL: http://ceur-ws.org/Vol-2393/paper_228.pdf.
[240] O. V. Strutynska, G. M. Torbin, M. A. Umryk, R. M. Vernydub, Digitalization of the educational process for the training of the pre-service teachers, CEUR Workshop Proceedings 2879 (2020) 179–199. URL: http://ceur-ws.org/Vol-2879/paper07.pdf.
[241] G. Tereshchuk, H. Meshko, M. Prochazka, O. Meshko, H. Radchuk, The problem of preserving and strengthening the occupational health of the teacher: a historical aspect,

SHS Web of Conferences 104 (2021) 01003. doi:10.1051/shsconf/202110401003.
[242] I. M. Tsidylo, H. V. Tereshchuk, S. V. Kozibroda, S. V. Kravets, T. O. Savchyn, I. M. Naumuk, D. A. Kassim, Methodology of designing computer ontology of subject discipline by future teachers-engineers, CEUR Workshop Proceedings 2433 (2019) 217–231. URL: http://ceur-ws.org/Vol-2433/paper13.pdf.
[243] S. A. Voloshynov, H. V. Popova, O. S. Dyagileva, N. N. Bobrysheva, O. V. Fedorova, Formation of professional competency in life saving appliances operation of future seafarers by means of online and simulation VR technologies, CEUR Workshop Proceedings (2022) 365–380.
[244] S. A. Voloshynov, F. M. Zhuravlev, I. M. Riabukha, V. V. Smolets, H. V. Popova, Application of VR technologies in building future maritime specialists' professional competences, CEUR Workshop Proceedings 2898 (2021) 68–81. URL: http://ceur-ws.org/Vol-2898/paper03.pdf.
[245] S. A. Voloshynov, H. V. Popova, A. Y. Yurzhenko, E. O. Shmeltser, The use of digital escape room in educational electronic environment of maritime higher education institutions, CEUR Workshop Proceedings 2643 (2020) 347–359. URL: http://ceur-ws.org/Vol-2643/paper20.pdf.
[246] O. Dyagileva, N. Goridko, H. Popova, S. Voloshynov, A. Yurzhenko, Ensuring sustainable development of education of future maritime transport professionals by means of network interaction, E3S Web of Conferences 166 (2020) 10003. doi:10.1051/e3sconf/202016610003.
[247] M. S. Lvov, H. V. Popova, Simulation technologies of virtual reality usage in the training of future ship navigators, CEUR Workshop Proceedings 2547 (2020) 50–65. URL: http://ceur-ws.org/Vol-2547/paper04.pdf.
[248] L. L. Nezhyva, S. P. Palamar, M. V. Marienko, Clouds of words as a didactic tool in literary education of primary school children, CEUR Workshop Proceedings (2022) 381–393.
[249] L. L. Nezhyva, S. P. Palamar, H. O. Vaskivska, O. V. Kotenko, L. A. Nazarenko, M. S. Naumenko, A. V. Voznyak, Augmented reality in the literary education of primary school children: specifics, creation, application, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[250] S. P. Palamar, G. V. Bielienka, T. O. Ponomarenko, L. V. Kozak, L. L. Nezhyva, A. V. Voznyak, Formation of readiness of future teachers to use augmented reality in the educational process of preschool and primary education, CEUR Workshop Proceedings 2898 (2021) 334–350. URL: http://ceur-ws.org/Vol-2898/paper18.pdf.
[251] L. L. Nezhyva, S. P. Palamar, O. S. Lytvyn, Perspectives on the use of augmented reality within the linguistic and literary field of primary education, CEUR Workshop Proceedings 2731 (2020) 297–311. URL: http://ceur-ws.org/Vol-2731/paper17.pdf.
[252] M. V. Marienko, The current state of using the cloud-based systems of open science by teachers of general secondary education, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[253] M. P. Shyshkina, M. V. Marienko, Augmented reality as a tool for open science platform by research collaboration in virtual teams, CEUR Workshop Proceedings 2547 (2020)

107–116. URL: http://ceur-ws.org/Vol-2547/paper08.pdf.

[254] M. P. Shyshkina, M. V. Marienko, The use of the cloud services to support the math teachers training, CEUR Workshop Proceedings 2643 (2020) 690–704. URL: http://ceur-ws.org/Vol-2643/paper41.pdf.

[255] M. V. Marienko, Y. H. Nosenko, M. P. Shyshkina, Personalization of learning using adaptive technologies and augmented reality, CEUR Workshop Proceedings 2731 (2020) 341–356. URL: http://ceur-ws.org/Vol-2731/paper20.pdf.

[256] M. Marienko, K. Bezverbna, The key features of the CoCalc cloud service use in the process of mathematics and science teachers training, CEUR Workshop Proceedings 2732 (2020) 1141–1151. URL: http://ceur-ws.org/Vol-2732/20201141.pdf.

Problematic issues of digitalization of education in Eastern Europe

Anastasiia O. Simakhova[1], Artem E. Artyukhov[2] and Halina A. Shmarlouskaya[3]

[1]National Aviation University, 1 Liubomyra Huzara Ave., Kyiv, 03058, Ukraine
[2]Sumy State University, 2 Rymskogo-Korsakova Str., Sumy, 40007, Ukraine
[3]Belarusian State Economic University, 26 Partizanskiy Ave., Minsk, 220070, Belarus

Abstract

Digital technology permeates all aspects of life. During the pandemic, all countries in the world began to use distance learning methods through the use of digital platforms, classes, labs. Digitalization avoided the collapse of the educational system. The aim of the article is to analyze the processes of digitization of education in Eastern Europe. To achieve the goal of the article, the following tasks were set: to study the theoretical basis of the digitization of education, to analyze the trends in the digitization of education in Eastern Europe, to develop recommendations for improving the digitization of education. The article analyzed the ranks of the Network Readiness Index and the Global Digital Readiness Index in terms of the technological readiness of higher education institutions and students for distance education. The article offers a case study of the Ukrainian university for the implementation of an e-learning environment. The authors grouped countries from Eastern Europe according to their potential for digitizing education. For these groups of countries, the authors identified specific criteria. SWOT an analysis of the digitization of education was conducted for the countries of Eastern Europe.

Keywords

digitization, distance education, technical provision, innovative economy, pandemic

1. Introduction

Digital transformation involves the transformation of all areas of public life under the influence of advanced innovative information and communication technologies (ICT), including in the education system, which is the foundation of an innovative economy and shapes its human potential. This determines the relevance of accelerating the digital transformation of education in the countries of Eastern Europe. The digital transformation of education is necessary to ensure that the educational process meets the needs of the labor market, increases the level of participation in these processes of educational institutions of all levels and other organizations of the educational system, as well as scientists, managers and specialists of government agencies,

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anastasiia.simakhova@npp.nau.edu.ua (A. O. Simakhova); a.artyukhov@pohnp.sumdu.edu.ua (A. E. Artyukhov); belarusgalina.shmarlovskaya@gmail.com (H. A. Shmarlouskaya)
http://feba.nau.edu.ua/en/kafedri/kafedra-ekonomichnoji-kibernetiki/simakhova-anastasiia-oleksiivna (A. O. Simakhova); https://personal.sumdu.edu.ua/artyukhov/en/ (A. E. Artyukhov); http://bseu.by/personalpages/shmarlovskajaG/biography.htm (H. A. Shmarlouskaya)
0000-0001-7553-4531 (A. O. Simakhova); 0000-0003-1112-6891 (A. E. Artyukhov); 0000-0001-9534-1251 (H. A. Shmarlouskaya)
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representatives of the private sector of business. Nevertheless, there are some problematic issues of digitalization of education, mainly: unequal access to the Internet of different kinds of families, the Internet cover of different regions and countries has different quality and level, lack of computers and laptops in some families etc.

The aim of the article is to analyze the processes of digitization of education in Eastern Europe. The object of the research is the digitization of education. The subject of the research is the process and potential of digitization of education in Eastern Europe.

The scientific novelty of the research is the grouping of the countries of Eastern Europe according to the potential of digitization of education.

The practical significance of the study is that the results of the article can be used by state authorities and universities in Eastern Europe to exploit the potential of digitization of education.

The research methods used in the article include literature analysis (a review of research to date in the field of digitalization of education) and taxonomic methods used to determine the development and potential of digitalization of education in the countries of Eastern Europe, according to the ranks of the Network Readiness Index and the Global Digital Readiness Index in terms of technological readiness of universities and students for distance education, as well as the method of SWOT analysis (according to the digitalization of education in Eastern Europe).

2. Literature review

The VOSViewer and SciVal tools were used to conduct a brief bibliometric analysis on the re quest "digitalization of education". The array of publications for analysis was obtained from the Scopus database (https://www.scopus.com/).

Bibliometric analysis using the VOSViewer tool (base for analysis – 1408 articles for the period 2010–2020) (figure 1) made it possible to identify the main keywords that are most often found in scientific papers in connection with the direction of digitalization in education. The cluster "education" is of great interest for analysis, which links the terms "e-learning", "virtual reality", "augmented reality", "decision making", "sustainable development", "economics" and, in fact, demonstrates the model of university development. in this direction. The relevance of considering this cluster is confirmed by a number of domestic works that are devoted to. In particular, digitalization of education in general [1], state regulation and management of the quality of education [2, 3], ensuring the quality of education in subject areas [4, 5], quality of education and sustainable development goals [6].

It should be noted that in the world the topic of digitalization of education is gaining momentum, as can be seen from the data in figure 2 (SciVal bibliometric analysis tool). However, the number of publications in comparison with other industries is insignificant, which confirms the relevance of studying various aspects of this direction.

Continuing the analysis, it is also necessary to address the topics that are most often associated with the request for digitalization of education (figure 3, SciVal bibliometric analysis tool). The combination of keywords shown in the figure that add up to topics (the figure shows top-1 % of topics by prominence, 2510 articles for the period 2011–2020 were used for analysis) leads the reader to the main promising ("breakthrough") directions of the development of the digitalization model of education. These areas can be taken as general ones when creating a

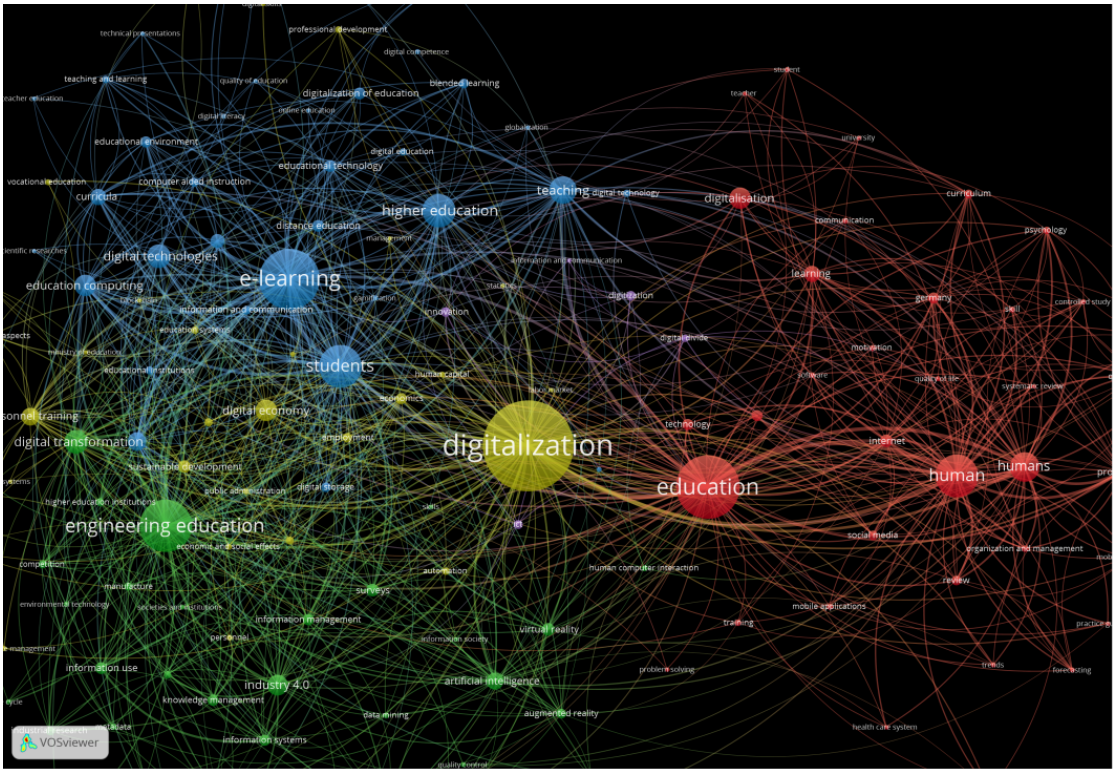

Figure 1: Results of bibliometric analysis using VOSViewer tool.

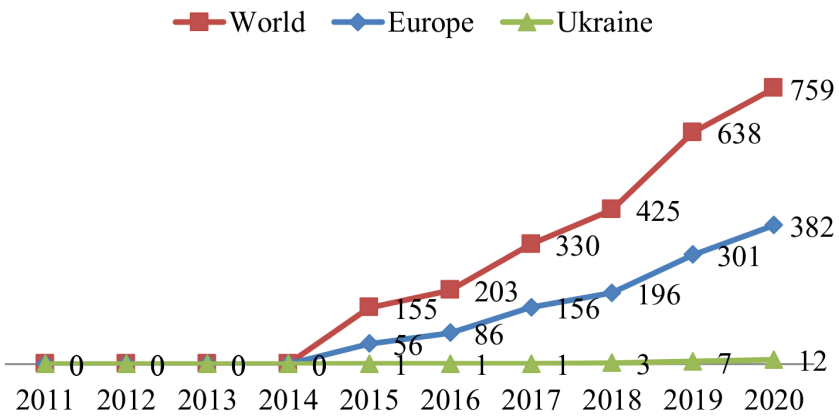

Figure 2: Number of publications in the field of digitalization of education.

digitalization strategy for the educational process at the university.

Thus, the data of bibliometric analysis provide a basis for finding optimal solutions for the digitalization of education in the region, which is studied in this work.

Turning to the authors of works related to the digitalization of education, the following should be noted. The problem of using digital technologies in education was studied by Henderson et al.

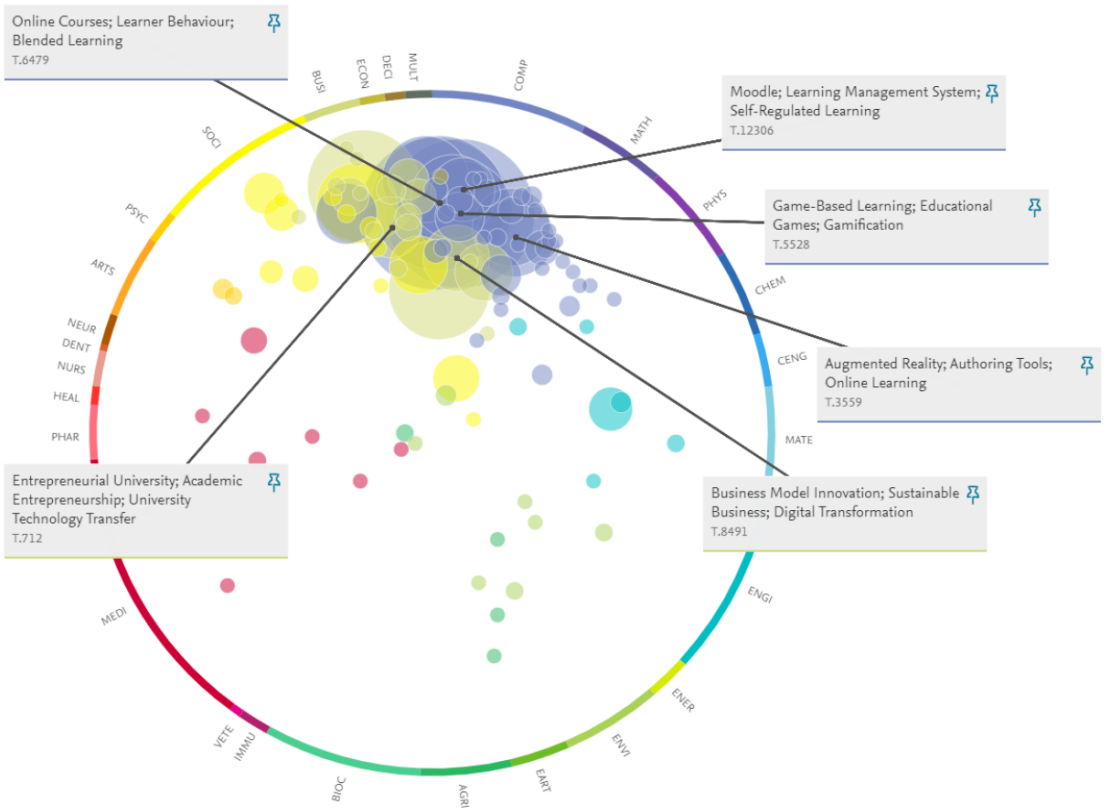

Figure 3: Top-1% of topics by prominence on digitalization of education.

[7], Khalid et al. [8], Pettersson [9], Kafyulilo et al. [10]. The authors examined the prospects for the digitalization of education, as well as the attitude of students towards distance and online learning.

The digitalization of education in Eastern Europe was dealt with by Chitez et al. [11], Rogobete and Chitez [12], Orr et al. [13], Burwell and Fleck [14]. These scientists have studied the strategies, models and phases of digitalization of education in Eastern Europe.

Despite the mentioned studies, the issue of comparing, grouping and highlighting the problems of digitalization of education in Eastern Europe has not been resolved. This led to the relevance of this research.

3. Cases of digitalization of education in Eastern Europe

The total quarantine and the abrupt conversion of educational institutions to distance learning in March 2020 revealed some of the problems with the digitization of education in the countries of Eastern Europe.

Since the beginning of the quarantine, higher education institutions in Ukraine were not fully prepared for online education, they used only certain elements of online education. And

online teaching methods needed development and clear regulation. During the interviews in May–June 2020, most HEIs noted that their institutions used certain elements of online education before the quarantine and relied heavily on the Moodle system. In addition, the development of online education had a specific date and was a response to the demands of time or circumstance. Thus, some online courses were introduced for students of the displaced HEI's (HEI's who were resettled from Donetsk and Luhansk region [15].

Nevertheless, online training courses on digital platforms, online courses, were established in the first month. In addition, the session, certification and even passing the state exams in the summer of 2020 were held online.

It is worth noting that Ukrainian universities have positive experience with online accreditation.

Distance education, new requirements for the educational process have become a challenge for the educational system. The pandemic has affected the habitual lifestyles of students, their families and teachers, caused economic and social consequences, exacerbated a number of socio-economic problems, including:

- Equitable access to education (disparity in families' provision of distance education resources and unequal access to quality Internet);
- Provision of educational services for children with special educational needs (children with certain pathologies are not able to receive educational services at a distance);
- other socio-economic problems caused by the pandemic.

Technical assistance component – access to high-speed Internet almost mirrored the situation shown in figure 4. The survey was conducted in such a way that 41% of the respondents believed that all or almost all teachers have access to the Internet, while only 7.4% of the respondents confirmed a similar level of provision for students. The percentage of "majority (75%)" responses was also high and was 45.9% for participants in the educational process and 36.2% for teachers.

Thus, the survey showed problems in the technical equipment of participants in the educational process.

The Ministry of Education and Science of Ukraine in May 2021 prepared a draft Concept of Digital Transformation of Education and Science for the period until 2026 [16], which is a strategic document with a state vision for the development of these industries and solving the problems of their development.

Unlike Ukraine, in the Republic of Belarus the digital transformation of processes in the education system, which includes updating the content of training specialists for various areas of the real sector of the economy and the educational process of training teachers, is carried out in two main areas:

1. The digital transformation of the educational process to form a corresponding infrastructure in educational institutions and transform the management in the educational system. It must provide the following:

- the access of all participants in the educational process to digital technologies that improve the educational process;
- the use of distance learning technologies and popularization of the principle of lifelong learning;

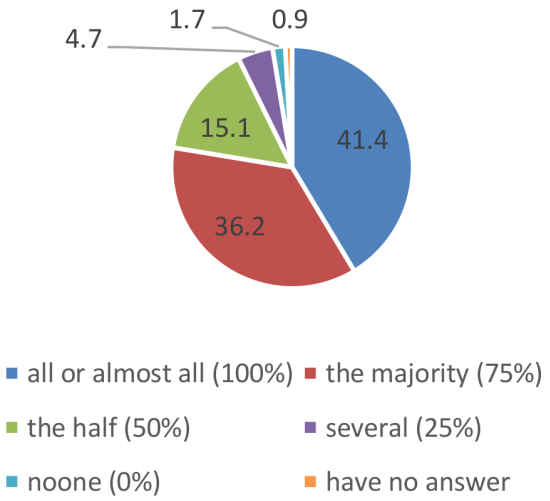

Figure 4: Survey of Ukrainian respondents "How many teachers at your institution have access to high-speed Internet".

- the improvement of the educational process through the harmonious implementation of achievements in the field of ICT;
- reference and information support for all participants in the educational process;
- unification and systematization of disparate information resources required in educational activities;
- the adaptation of the content of educational programs in view of the development of students' competences in the field of information technology;
- the use of electronic educational resources and the possibilities of modern didactic methods based on ICT in the educational process;
- improvement of the system of provided electronic educational services;
- digital documentation and analytics of the results of the educational process.

The Republic of Belarus is ready for the digital transformation of the educational process, as informatization is practically completed in it. The educational system currently includes more than 9 thousand students.

Educational institutions of various levels, educating more than 2 million students, including 51 higher education institutions. The educational process is provided by about 250 thousand teachers. The following data testify to the introduction of ICT in the education system. ICT is used in educational institutions of all types and kinds at all levels of primary, special and supplementary education. Almost all primary and secondary schools, lyceums, high schools, higher, secondary technical and vocational education institutions have computer classes or separate computers to support the educational process.

In 2018, 97.8% of educational institutions had access to the Internet, including 91% of institutions with broadband access. More than 90% of teachers (excluding computer science teachers) use or are willing to use ICT in their professional activities [17]. Higher education is also one of the "digital leaders" – the sectors of the economy the at use information and communication

technologies most intensively. Thus, in 2016, among the organizations of the Republic that run higher education programs, 96.6% used e-mail and had local networks, and 98.3% had access to the Internet and their own website [18, p. 21].

All educational institutions use or have the ability to use Internet services and Internet services: e-mail, remote access to Internet resources, interaction with information systems and resources, etc. The renewal and (or) increase in the number of computer equipment in educational institutions continues. Most educational institutions operate automated management systems that collect and process information about students, teachers, parents, material and technical base, and the organization of the educational process. There are a number of nationwide systems that allow automated collection and processing of statistical information in the field of education.

A department-wide document management system and a Business Automation and Electronic Document Management System DELO have been implemented to ensure electronic document management. Electronic copies of textbooks are posted on the website National Educational Portal. Modern competitive services developed by both public and private companies have been introduced and used: Progress monitoring services, knowledge gap filling services, access control services, payment services and services with additional educational content in electronic form. Since 2012, most of these services have been used in educational institutions and educational authorities.

2. Digital transformation of processes accompanying education (introduction of distance education, new educational methods and practices, the number of specialties in IT, new educational standards "University 3+") [17].

The development of distance education, which is an integral part of the digital transformation of higher education, as it provides an opportunity for lifelong learning for all citizens of the country with access to the Internet, as well as for foreign citizens interested in distance learning in the higher education institutions of the Republic [19].

Currently, there are distance learning programs in five higher education institutions. Belarusian State University of Informatics and Radioelectronics is considered a leader in the country in the development of distance education, but even there, in the 2017/18 academic year, distance education was available for only 22.2% of specializations (12 out of 54) [20].

Digitization of higher education in Poland is more developed than in other Eastern European countries. Kozminski University, Lodz University of Technology, Warsaw School of Economics and the Jagiellonian University are universities with different educational profiles combining exemplary use of digital tools in scientific, administrative and research activities. All four universities were the first in Poland to be awarded in the Most Innovative Universities Program and to receive the title of "Microsoft Cloud University" [21].

Despite the fact that Poland has more experience in distance education than Ukraine and Belarus, some important problems appeared in 2020 and 2021:

- insufficient supply of computers to participants of the educational process (97% of households have at least one computer, but many of them have difficulties because computers have to be shared by siblings, etc.) [22]
- reduced bandwidth of connection and limited amount of monthly data transfer;

- lack of digital skills among teachers (85% of teachers reported that they had very little experience in using the tools needed for distance education, and only 5% of them described their skills in this area as "very good". Only 8% of students believe that teachers are very well prepared for online learning, and 62% of them consider distance learning ineffective) [22].

Thus, the problems of digitization of education in Poland are similar to Ukrainian and Belarusian problems.

4. Problems of digitalization of education in Eastern Europe

The main problems of digitization of education in Eastern Europe:

- inadequate preparation of teachers for distance education (use of methods of cyber-pedagogy, work on online platforms, underdeveloped digital skills);
- management problems (insufficiently developed digital competences among representatives of the management of educational institutions);
- lack of technical equipment in educational institutions (virtual classrooms, electronic laboratories, etc.);
- lack of quality Internet connection among individual participants in the educational process in connection with their place of residence;
- insufficient provision of individual computers for all participants in the educational process;
- lack of methodological support for distance learning courses (workshops, lectures, etc.).

As the above analysis has shown, the countries of Eastern Europe have similar problems in providing digitalization of education. Let us analyze the ranks of the Network Readiness Index (NRI) and the Global Digital Readiness Index in terms of technological readiness of universities and students for distance education (table 1, table 2).

According to the NRI rating of the studied countries, Czech Republic and Poland have the highest position –28 and 33. Also, in terms of technology development, Czech Republic takes 26th place. Ukraine and Belarus occupy similar positions on the NRI – 64 and 65. Belarus has advantages in terms of access to technology and content. Ukraine has an advantage in future technologies.

According to table 2, all Eastern European countries have the Accelerate stage of digital readiness. The highest Global Digital Readiness Index in Czech Republic – 15.78. The country is adapted to the digitalization of education. Next in terms of indicators are Poland and Slovakia. Belarus and Ukraine have a low-tech adoption rate, which characterizes demand for digital products / services. Thus, the index confirms the presence of the problem of the availability of devices and Internet use among the participants of the educational process.

Table 1
Network Readiness Index ranks in 2020 [23, p. 32, 33, 19].

Countries	NRI rank	NRI score	Technology (Pillar) Rank	Technology Sub-pillars			Income group
				Access	Content	Future Technology	
Belarus	65	49.16	68	58	41	134	Upper-middle-income
Ukraine	64	49.93	62	79	46	53	Lower-middle-income
Poland	33	61.80	36	32	34	60	High-income
Bulgaria	46	55.03	43	50	33	78	Upper-middle-income
Czech Republic	28	66.33	26	33	20	32	High-income
Hungary	39	60.05	31	21	32	44	High-income
Moldova	71	47.09	74	56	66	126	Lower-middle-income
Romania	49	51.14	46	18	48	82	High-income
Slovakia	35	60.78	34	38	37	37	High-income

5. Potential of digitalization of education in Eastern Europe

The above analysis allowed the authors to group the countries of Eastern Europe according to their potential for the digitalization of education. Authors have highlighted specific criteria (table 3).

Thus, authors proposed 3 groups of Eastern European countries according to their potential for digitalization of education with their indicator. Also, it is necessary to mention that this potential correlates with countries‘ income group.

In our opinion, in order to activate the digitalization of education, it is necessary to expand public-private partnerships with the participation of manufacturers and suppliers of advanced information and communication technologies that have prospects of application in the educational process in higher education institutions of countries.

In the future, the digitalization of education will ensure the development of digital competences for all participants in the educational process, the formation of ecological and digital awareness among students [25], the adaptation of educational programs to changing socio-

Table 2
Global Digital Readiness Index scores in 2019 [24].

Countries	Score	Stage	Tech adoption (3)	Tech infrastructure (4)
Belarus	12.95	Accelerate	1.21	1.68
Ukraine	11.47	Accelerate	1.09	1.02
Poland	14.94	Accelerate	1.31	2.03
Bulgaria	13.72	Accelerate	1.12	1.84
Czech Republic	15.78	Accelerate	1.30	2.12
Hungary	14.13	Accelerate	1.23	1.89
Moldova	11.65	Accelerate	1.10	1.37
Romania	13.34	Accelerate	1.10	1.71
Slovakia	14.44	Accelerate	1.36	1.78

Table 3
Grouping Eastern European countries according to their potential of digitalization of education.

Group	Countries	Indicators	Income group
High potential for digitalization of education	Czech Republic, Poland, Slovakia, Hungary	NRI rank ≤ 40, Global Digital Readiness Index scores ≥ 14	High-income
Middle potential for digitalization of education	Romania, Bulgaria	$41 \leq$ NRI rank ≤ 60, $13 \leq$ Global Digital Readiness Index scores < 14	High-income, Upper-middle-income
Lower-middle potential for digitalization of education	Ukraine, Belarus, Moldova	NRI rank > 60, $11 \leq$ Global Digital Readiness Index scores < 13	Lower-middle-income, Upper-middle-income

economic conditions and the scientific and technological revolution, and the development of an innovative economy.

To summarize the results of the study, a SWOT analysis of the digitalization of education for the countries of Eastern Europe was carried out (table 4). SWOT analysis is a model for forming an information base and developing on its basis the most effective option for managing socio-economic processes (including the digitalization of education). It is assumed that SWOT analysis is used to assess the situation under conditions of uncertainty and to regulate individual parameters. In this case, the regulation of parameters is understood as the correction of the values of control parameters for the implementation of the optimal development scenario at a certain segment of the planning period.

5.1. E-learning environment: Ukrainian University's case

As an example, let us present the case of Sumy State University (Ukraine) on the creation of an e-learning platform based on its own unique developments. The e-learning environment is shown in figure 5.

Table 4
SWOT analysis of the digitalization of education for the countries of Eastern Europe

Strengths	Weakness
– highly qualified teachers; – state support; – relevant regulatory framework	– low digital competencies among participants in the educational process (85% of teachers reported that they had very little experience in using the tools needed for distance education); – lack of methodological support for distance courses
Opportunities	**Threats**
– development of the digital economy; – development of distance education; – the future of technology; – creation of the Eastern European University with Artificial Intelligence	– different level of provision of families with means for distance learning and unequal access to high-quality Internet; – lack of technical equipment of educational institutions (NRI score: 47-69)

The e-learning ecosystem includes various tools for the implementation of distance, e-learning and blended learning, platforms for creating educational materials, a platform for massive open online courses, a repository of educational materials. The developer of educational materials works autonomously, without involving technical services in the software implementation of the project in the process of creating a package of tasks. In the process of creation, only the developer communicates with consultants of various levels. After agreeing on the content, the materials are reviewed and posted in open or closed (directly for course students within the university) access; programmers implement only non-trivial tasks within the framework of educational courses (interactive elements, virtual and augmented reality, etc.) (figure 6).

As part of the implementation of various models of electronic learning, they are constantly being improved on the basis of feedback from developers of educational materials, reviewers, programmers, and listeners.As an example, the questionnaire of a survey of developers of educational materials of the Mix platform (blended learning) in 2021 is given.

The advantages of the Mix platform:

- all teachers and students are in a single learning space;
- the ability to control the educational process in real time;
- the platform is synchronized with the unified information system of the university;
- systematic support from the university;
- the opportunity for teachers to work collectively both in the creation of materials and in virtual classrooms;

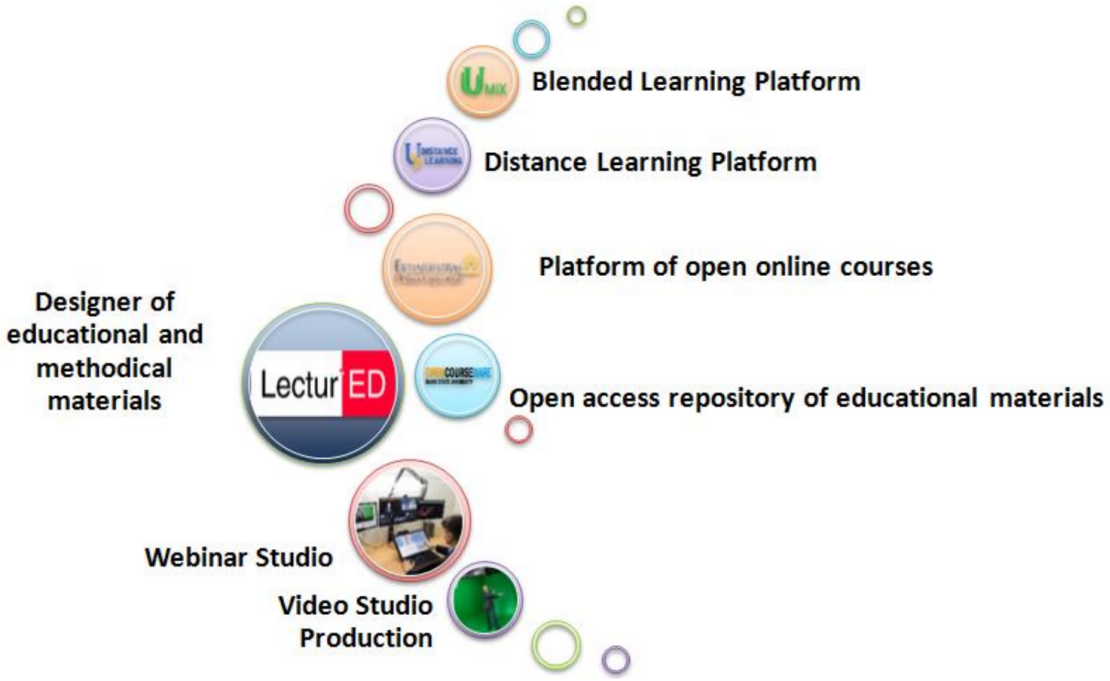

Figure 5: E-learning environment: Sumy State University case (Ukraine) [26].

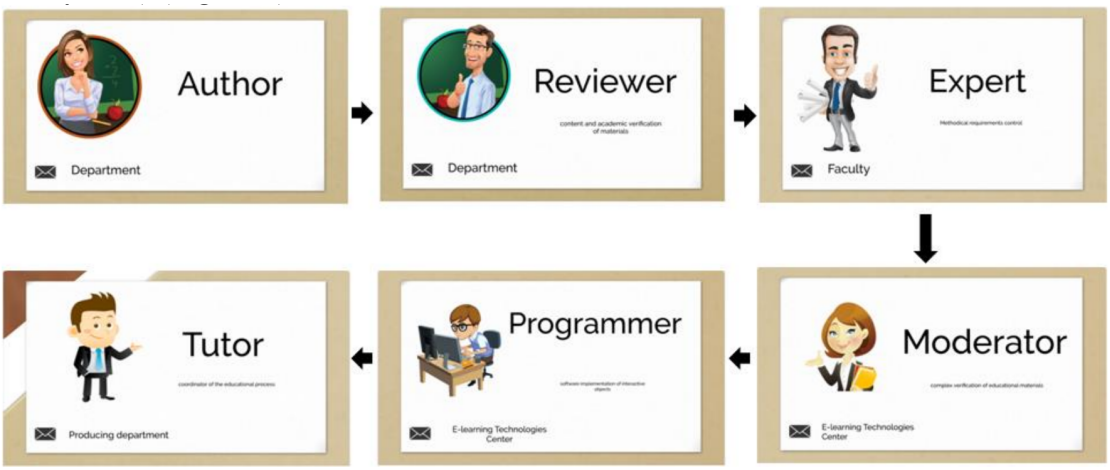

Figure 6: Algorithm for creating educational materials [26].

- unified tools simplifies the use of the platform for all users;
- automatic connection, control, archiving;
- the ability to manage user registration, define roles, manage content;
- creation of virtual classes, adjustment of the necessary parameters.

Disadvantages of the Mix platform:

- instability of work;
- inconvenient interface for working with mobile devices;
- insufficient functionality to provide the necessary activities;
- difficulty in settings;
- inconvenient interface for working with a personal computer;
- insufficient level of technical support for users;
- excessive openness and transparency for control by the university.

Measures to improve the Mix platform:

- integration with services for webinars (Meet, Zoom, Microsoft Teams, etc.);
- integration with plagiarism testing services;
- mobile version with chat;
- integration with additional services of ACS "University".

6. Conclusions

Thus, Eastern Europe countries can be divided into three groups according to their potential for digitizing education.

The pandemic COVID-19 has led to the active digitization of countries around the world, including the countries of Eastern Europe. Despite certain problems and unpreparedness for sharp digital transformation of education in these countries, in the first year of the pandemic it was possible to establish distance education with lectures, seminars, workshops, tests, exams and diplomas.

The implementation of the goals of the digital transformation of education, overcoming the existing problems will make it possible to carry out the digital transformation of teacher education on the basis of new e-learning models and move from a closed university system to an open, distributed and maximally flexible system, depending on the willingness to adapt to the changing needs of society.

In order to accelerate the digital transformation of processes in the educational system, it is advisable to create experimental educational institutions with the most complete set of ICT services possible, in order to evaluate their effectiveness in detail and subsequently implement them in all educational institutions.

The prospect of further digitalization of the educational system of these countries is the creation of an Eastern European University with artificial intelligence based on a partnership between the state and business.

References

[1] H. Yarovenko, Y. Bilan, S. Lyeonov, G. Mentel, Methodology for assessing the risk associated with information and knowledge loss management, Journal of Business Economics and Management 22 (2021) 369–387. doi:10.3846/jbem.2021.13925.

[2] A. Vorontsova, H. Shvindina, T. Mayboroda, H. Mishenina, I. Heiets, The impact of state regulation in a sphere of education on sustainable development of national economy, Problems and Perspectives in Management 18 (2020) 275–288. doi:10.21511/ppm.18(4).2020.23.
[3] P. Olena, M. Viktoriya, D. Olga, S. Denys, Analysis of influence of the quality of specialist training on social and economic development, Quality - Access to Success 21 (2020) 81–86.
[4] K. Onopriienko, V. Onopriienko, Y. Petrushenko, I. Onopriienko, Environmental education for youth and adults: a bibliometric analysis of research, E3S Web of Conferences 234 (2021) 00002. doi:10.1051/e3sconf/202123400002.
[5] S. Lyeonov, O. Liuta, Actual problems of finance teaching in Ukraine in the post-crisis period, in: T. Azarmi, W. Amann (Eds.), The Financial Crisis, Springer International Publishing, Cham, 2016, pp. 145–152. doi:10.1007/978-3-319-20588-5_8.
[6] A. Artyukhov, I. Volk, T. Vasylieva, S. Lyeonov, The role of the university in achieving SDGs 4 and 7: a Ukrainian case, E3S Web of Conferences 250 (2021) 04006. doi:10.1051/e3sconf/202125004006.
[7] M. Henderson, N. Selwyn, R. Aston, What works and why? Student perceptions of 'useful' digital technology in university teaching and learning, Studies in Higher Education 42 (2017) 1567–1579. doi:10.1080/03075079.2015.1007946.
[8] J. Khalid, B. R. Ram, M. Soliman, A. J. Ali, M. Khaleel, M. S. Islam, Promising digital university: a pivotal need for higher education transformation, International Journal of Management in Education 12 (2018) 264–275. doi:10.1504/IJMIE.2018.092868.
[9] F. Pettersson, Understanding digitalization and educational change in school by means of activity theory and the levels of learning concept, Education and Information Technologies 26 (2021) 187–204. doi:10.1007/s10639-020-10239-8.
[10] A. Kafyulilo, P. Fisser, J. Voogt, Factors affecting teachers' continuation of technology use in teaching, Education and Information Technologies 21 (2016) 1535–1554. doi:10.1007/s10639-015-9398-0.
[11] M. Chitez, R. Rogobete, A. Foitoş, Digital humanities as an incentive for digitalisation strategies in Eastern European HEIs: A case study of Romania, in: A. Curaj, L. Deca, R. Pricopie (Eds.), European Higher Education Area: Challenges for a New Decade, Springer International Publishing, Cham, 2020, pp. 545–564.
[12] R. Rogobete, M. Chitez, Disparities in humanities research initiatives within the European higher education area, Analele Universității de Vest din Timișoara, Seria Științe Filologice LVII/2019 (2019) 145–153.
[13] D. Orr, M. Weller, R. Farrow, How is digitalisation affecting the flexibility and openness of higher education provision? Results of a global survey using a new conceptual model, Analele Universității de Vest din Timișoara, Seria Științe Filologice 1 (2019) 9. doi:10.5334/jime.523.
[14] F. G. Burwell, J. Fleck, The Next Phase of Digitalization in Central and Eastern Europe: 2020 and Beyond, Technical Report, Atlantic Council, 2020. URL: http://www.jstor.org/stable/resrep26698.
[15] N. Stukalo, A. Simakhova, COVID-19 impact on ukrainian higher education, Universal Journal of Educational Research 8 (2020) 3673–3678. doi:10.13189/ujer.2020.080846.
[16] Draft Concept of Digital Transformation of Education and Science: MES

invites to public discussion, 2021. URL: https://mon.gov.ua/ua/news/koncepciya-cifrovoyi-transformaciyi-osviti-i-nauki-mon-zaproshuye-do-gromadskogo-obgovorennya.
[17] The concept of digital transformation of processes in the education system of the Republic of Belarus for 2019-2025, approved by the Minister of Education of the Republic of Belarus on March 15, 2019, 2019. URL: https://drive.google.com/file/d/1T0v7iQqQ9ZoxO2IIwR_OlhqZ3rjKVqY-/view.
[18] L. I. Karpenko, A. B. Belsky, Statistical Estimation Of The Readiness To The Digital Transformation Of The Economy Of The Republic Of Belarus, Digital Transformation (2018). URL: https://ideas.repec.org/a/abx/journl/y2018id60.html.
[19] V. Bogush, Digital transformation of higher education, in: Digital transformation of education: abstracts of 1st scientific-practical. conf., Minsk, May 30, 2018, 2018. URL: http://dtconf.unibel.by/doc/DTE_conference.pdf.
[20] P. A. Lis, It cluster on the example of a remote network university, in: Economic growth of the Republic of Belarus: globalization, innovation, sustainability: materials of the XI Intern. scientific practice. conf. (Minsk, May 17, 2018), 2018.
[21] Polskie uczelnie wzorem transformacji cyfrowej w sektorze edukacji, 2020. URL: https://brief.pl/polskie-uczelnie-wzorem-transformacji-cyfrowej-w-sektorze-edukacji/.
[22] D. Delmanowicz, Report reveals digital learning issues in Polish education, 2021. URL: https://www.thefirstnews.com/article/report-reveals-digital-learning-issues-in-polish-education-20042.
[23] S. Dutta, B. Lavin, Network Readiness Index 2020. Accelerating Digital Transformation in a post-COVID Global Economy, Technical Report, Portulans Institute, 2020.
[24] Cisco global digital readiness index 2019, 2019. URL: https://www.cisco.com/c/m/en_us/about/corporate-social-responsibility/research-resources/digital-readiness-index.html.
[25] N. Stukalo, A. Simakhova, Social dimensions of green economy, Filosofija. Sociologija 30 (2019) 91–99. doi:10.6001/fil-soc.v30i2.4015.
[26] University online learning ecosystem, 2020. URL: https://prezi.com/3jmtwj065bcx/university-online-learning-ecosystem/.

The use of digital tools by secondary school teachers for the implementation of distance learning in the context of digital transformation in Ukraine

Oksana V. Ovcharuk[1], Andrii M. Gurzhii[1], Iryna V. Ivaniuk[1], Liubov A. Kartashova[2], Olena O. Hrytsenchuk[1], Tetiana A. Vakaliuk[3,4,1] and Mariya P. Shyshkina[1]

[1]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[2]*University of Educational Management, 52A Sichovykh Striltsiv Str., Kyiv, 04053, Ukraine*

[3]*Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine*

[4]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

Abstract

In this paper, we raise the discussion on the use of digital learning tools by teachers of Ukrainian secondary schools for the organization of distance learning. In order to collect data we have used the survey instruments (Google questionnaire) and involved 1463 respondents who revealed the state of the use of digital learning tools for the organization of distance learning in the quarantine period caused by COVID-19 pandemic. The study was conducted in all regions of Ukraine. The results show that teachers have a need to master their knowledge and practical skills on digital instruments for the organization of distance learning with students. On the other hand the paper presents the experience on how the problem of the mastering of teachers' digital competencies can be organized and what are the steps to the organization of special distance learning courses for teachers in Ukraine. The experience of the creation of Web portal of Ukrainian Open University of Postgraduate Education is presented. We propose on how the needs and requirements of teachers regarding the implementation of the distance learning in schools and the development of their digital competencies should be resolved.

Keywords

secondary education, digital learning tools, distance learning, teacher

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oks.ovch@hotmail.com (O. V. Ovcharuk); gam@naps.gov.ua (A. M. Gurzhii); irinaivanyuk72@gmail.com (I. V. Ivaniuk); lkartashova@ua.fm (L. A. Kartashova); helenakyiv2017@ukr.net (O. O. Hrytsenchuk); tetianavakaliuk@gmail.com (T. A. Vakaliuk); marimodi@gmail.com (M. P. Shyshkina)

https://iitlt.gov.ua/eng/structure/departments/komparaktiv/detail.php?ID=300 (O. V. Ovcharuk); http://irbis-nbuv.gov.ua/ASUA/0145119 (A. M. Gurzhii); https://iitlt.gov.ua/eng/structure/departments/komparaktiv/detail.php?ID=304 (I. V. Ivaniuk); http://irbis-nbuv.gov.ua/ASUA/0006208 (L. A. Kartashova); https://iitlt.gov.ua/eng/structure/departments/komparaktiv/detail.php?ID=303 (O. O. Hrytsenchuk); https://sites.google.com/view/neota (T. A. Vakaliuk); https://iitlt.gov.ua/eng/structure/departments/cloud/detail.php?ID=269 (M. P. Shyshkina)

0000-0001-7634-7922 (O. V. Ovcharuk); 0000-0001-6729-6254 (A. M. Gurzhii); 0000-0003-2381-785X (I. V. Ivaniuk); 0000-0002-1270-4158 (L. A. Kartashova); 0000-0003-3173-7649 (O. O. Hrytsenchuk); 0000-0001-6825-4697 (T. A. Vakaliuk); 0000-0001-5569-2700 (M. P. Shyshkina)

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1. Introduction

The main goal of building an information society and its next phase – the knowledge society, is the formation of a developed information environment focused on the interests of citizens in Ukraine. This gives everyone the opportunity to fully realize their potential, as well as contribute to the sustainable development of the country and improve the quality of life. That is why the Government of Ukraine presented the Concept of Development of the Digital Economy and Society of Ukraine 2020, which identified opportunities for society to adapt to the realities of the digital world. One of the important factors of such adaptation is the development of the ability of the general population to use digital technologies in everyday life and at work [1]. We consider digital transformation as a strategic vision for how educational organizations evolve from a traditional model, for example, during traditional classroom learning, to student and teacher engagement to the new digitally enabled and data paradigm [2, 3, 4, 5].

The main role in the process of acquiring digital skills is played by teachers, who must not only be able to use IT to implement the learning process, but also be able to create a digital learning environment for students. The focus of our study is on teachers who answered the questionnaire about their readiness to use digital learning tools and who outlined the problems in the implementation of distance learning in schools that face them today during the quarantine period.

One of the main challenges facing education today is the lack of awareness of teachers about digital tools for distance learning in modern conditions. In addition, in today's digital society in Ukraine, the education system faces a limited number of available teaching materials and guidelines on how to use IT to teach their subjects; there is a problem of insufficient training of teachers to use digital tools in professional activities. This is evidenced by the results of recent research, which determined the readiness and needs of Ukrainian teachers for the use of digital tools and IT in quarantine [6, 7, 8, 9].

The study also outlines Ukraine's experience in creating a web portal of Ukrainian Open University of Postgraduate Education to improve the skills of teachers to acquire digital skills and reveals opportunities and prospects for improving the digital competencies of teachers [10, 11]. Additionally we give examples of good practices in creating a digital environment and the use of digital tools on the example of civic education in Ukrainian schools.

2. Literature review

The problems of using IT for distance learning by teachers in educational institutions are covered by Bobyliev and Vihrova [12], Franchuk and Prydacha [13], Havrilova et al. [14], Kukharenko and Oleinik [15], Mintii et al. [16], Syvyi et al. [17], Vakaliuk et al. [18]. These researchers raise questions about the implementation of IT in education, the methodology of using digital tools, creating a digital environment for teachers and students.

The issues of the development of digital competence of pedagogical university students are revealed by Hodovaniuk et al. [19], Kuzminska et al. [20], Moiseienko et al. [21], Soroko [22], The Council of the European Union [23], Yaroshenko et al. [24] who describe the definition, structure and didactic conditions in the context of lifelong learning.

The main issue, researchers consider the creation of the necessary educational and methodological support of the process distance learning, creating a digital environment in schools and postgraduate educational institutions. Issues of formation of digital competence of teachers and future teachers are revealed by Moiseienko et al. [21], The Council of the European Union [23], Ovcharuk et al. [25], Ovcharuk and Hrytsenchuk [26], Hrytsenchuk [27] from the point of view on how to create the digital support and appropriate environment in the classroom for teacher for successful application of the digital tools for key competencies development including digital competence. The scientists focus on the components of the teacher's digital competence and digital environment in schools. The scientists stress on the need to harmonize the framework for the development of digital competence of students and teachers with European approaches and the necessity to create mechanisms for assessing the level of digital literacy of educators in Ukraine. Gurzhii et al. [28], Kartashova et al. [29, 30], Petrenko et al. [31], Shokaliuk et al. [32], Spirin et al. [33] point out the aspects of the development of teacher's digital competency and the organization of distance learning in schools.

3. Research method

The goal of the article is to reveal the results of the survey about the Ukrainian teachers' readiness to conduct distance learning in schools in the quarantine period during 2020/2021 school year, to reveal problems and challenges, as well as to present the experience on how these problems can be resolved in the system of postgraduate teachers' education. The following methods were used by the authors to reveal this goal: analysis, synthesis, generalization and systematization of scientific sources – to determine the theoretical, methodological and applied aspects of the problem of using digital technologies in the implementation of distance education; empirical methods, in particular, questionnaires, surveys to find out the readiness of teachers to the use of digital learning tools in the process of distance education. In addition, computational methods of information processing were applied during the data processing online survey.

4. Research results

Scientists of the Department of the Comparative Studies for Educational Innovations of the Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine conducted research among teachers (the number of respondents is 1463) through an online survey in January 2021 [6]. The precondition for conducting this research was a preliminary online survey conducted in the spring 2020, which highlighted the problems and needs of teachers in the implementation of distance and blended learning in schools during the first wave of quarantine caused by the pandemic COVID-19 [7, 8, 9].

It was important to determine exactly how the survey participants organized distance learning and what tools they used to conduct lessons during distance and blended learning in a COVID-19 pandemic. It was also interesting to find out which online resources serve respondents to prepare for lessons, which of these resources are the most popular and useful for students and teachers. It was found that most respondents use the following digital tools to organize distance learning: Viber – 83%; Zoom – 58.7%; the site of the educational institution – 58.7%;

My Class – 20.7%; Padlet – 18%; Google Apps for Education – 15.1%; Skype – 14%; Telegram – 13.8%; Electronic diary - 11.7%; Educational platform of the educational institution – 10%; Jitsi Meet – 9.5%.

In addition, respondents pointed out to such tools as: Tik-Tok; Microsoft Teams; Cisco Webex; Class Dojo; Edmodo; Moodle; Twitter; WhatsApp. However, all these tools did not score more than 4% each. If we compare the results of two surveys (2020 and 2021) on the use of digital tools for distance learning, we can see that the most popular tools for teachers are: Viber (83%) and the school website (58.7%); The number of users increased from the 2020 period in comparison with 2021 school year, namely: Zoom (+30.2%), Padlet (+18.2%), Jitsi Meet (+8.8%); Cisco Webex (+3.3%); Edmodo (+3.2%). The responses showed less use of Google Apps for Education (-30.4%), Skype (-23.7%), Telegram (-7.1%); MyClass continues to be used at approximately the same level (+2.2%); Microsoft Teams (-0.7%); Electronic diary (+1.4%); ClassDojo (+1.6%). New tools such as flipped classroom (+4%), Tik-Tok (+4%), Twitter (+4%) were increased.

This indicates that Ukrainian teachers require additional training on the use of digital tools. The most effective online forms of professional development teachers consider the following:

- online courses – 32.1%;
- online master classes – 19.2%;
- webinars – 17.9%;
- online conferences / seminars – 12.1%;
- massive open online courses – 10.6%;
- online professional competitions – 4.6%.

Among other things, teachers indicated the following: online projects, webinars, online face-to-face courses, etc. (figure 1).

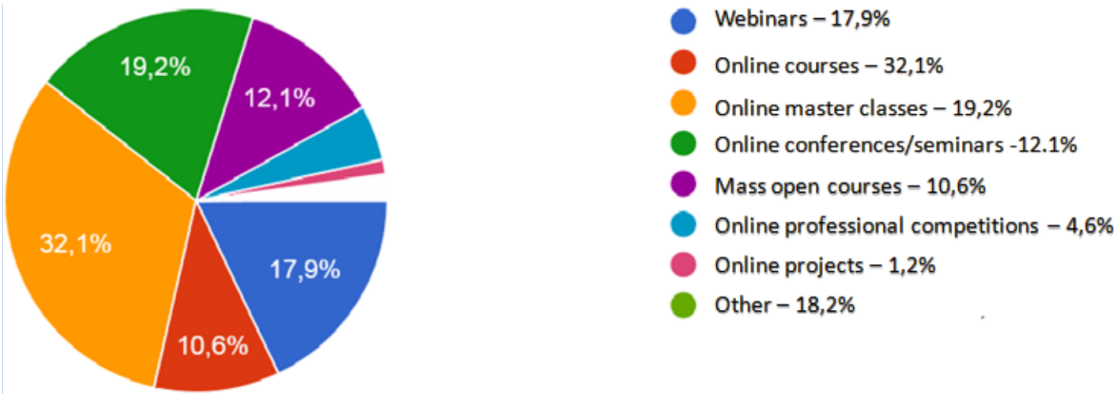

Figure 1: Distribution of respondents' answers to the question 'What online forms of professional development do you consider the most effective?'.

It was also interesting to identify the attitude of teachers to the use of digital learning tools in the teaching of civic education. For example, a study conducted in 2019 found that teachers of various subjects who teach civic education are interested in using digital tools in their professional activities [25].

A survey was conducted with 129 Ukrainian teachers. The results showed that 80% of the positive answers of respondents related to the importance of the use of ICT, namely: promoting the creation of free, accessible and secure information environment – 93.8%; understanding the risks and threats in digital environments; knowledge of security and privacy and data protection measures – 79.8%; knowledge of rules of conduct and know-how on the use of digital technologies and interaction in digital environments – 83.7%.

The answers concerning the awareness of teachers about modern digital tools and the possibilities of their use, demonstrated the lack of awareness and training of teachers and the need for methodological support. The question 'Am I able to protect myself and others from possible dangers in digital environments (for example, from cyber-bullying)' was answered only 18.6%; 'I can create and edit digital content in various formats, express myself digitally on the culture of democracy' – 20.2% of respondents said 'yes'. Cloud services are used remotely for training. Teachers identified Google services as the most popular among them (80.5%). Teachers also use Microsoft Office 365, Dropbox, Padlet, Google Apps, Google Drive and others (figure 2) [25, 29].

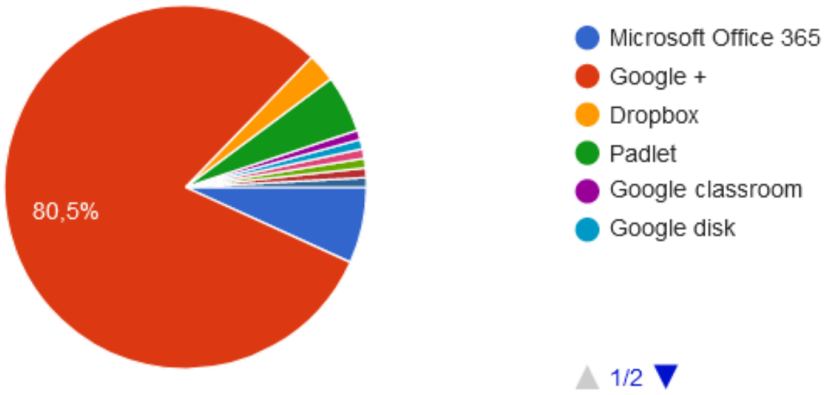

Figure 2: Distribution of respondents' answers to the question 'What cloud services do you use in teaching civic education with students?'.

The practice of using digital tools for teaching civic education in Ukraine is not wide-spread. However, among some good practices should be singled out, for example, the resource of '3D Democracy: think, care, act' https://citizen.in.ua/about.php, which was created with the support of the NGO 'Nova Doba'. The tools and materials of this digital resource are freely available, not only to students and teachers, but also anyone can join the use of resources and content in civic education remotely [34].

An online course and an interactive civic education textbook for 10th grade are available on a specially created website. Among the opportunities for teachers are the following: 'Online Teachers' is a community of civic education teachers; 'the Block of the School', which contains information about the institution that joined the net-work, provides information about the school on the map of Ukraine; 'Journal of Students' Achievements' is a place where activity of each registered student is fixed in the general 'electronic class journal' (by subjects and sections), it is accessible for viewing by teachers; 'Relevant Information' (methodical materials, information about webinars, training seminars, conferences for teachers, etc.).

‘3D Democracy’ proposes for students such online learning facilities as: online textbook and manual on civic education; additional information on each topic (texts, videos, life cases); online students’ community from different regions of Ukraine that contains online games, polls, petitions, elections, flash mobs (on civic education topics); personal students’ offices/portfolios of civic activities (specific practical cases in the course of civic activity, joint blogs, forums, discussions); assessment of student achievements (online testing, situation analysis, practical tasks (essay), and tools for students’ motivation (automatic scoring).

Since the start of the project, the number of registered students studying civic education has been constantly increasing. In the 2018/2019 school year, the community consisted of 3,036 students, in the 2019/2020 school year it grew up to 4,996 students. Today, the community has grown up to 7,648 participants. A total of 15,680 students and 2,646 teachers from all over Ukraine have joined the project. Participants worked on the ZOOM platform to create volunteer projects and implement them [34].

The relevance of distance learning by secondary school teachers has increased due to the long period of quarantine restrictions. The new conditions of uncertainty of the further course of events, the remoteness of the participants in the educational process prompted the solution of the problem of providing continuous assistance to teachers. Teachers in the use of digital tools for the implementation of distance learning were not sufficiently prepared.

OECD research states: ‘when teachers do not have the skills to effectively integrate digital devices into teaching, they can learn to use them if the resources are available’. However, not all teachers have access to effective professional resources to improve their understanding of technology and their knowledge of how to apply it. On average, in OECD countries, only 65% of 15-years-old attended schools whose principals felt that their teachers had the resources to expand their understanding of digital technologies in the classroom and beyond [35]. UNESCO has a response to these issues and proposes the distance learning solutions [36, 37, 38, 39]. The development of an innovative environment for the professional development of teachers, including distance learning, has become a challenge for Ukrainian teachers.

Currently, among the main functions of postgraduate education is to assist teachers in developing their skills to act well in the digital educational environment, the ability to independently organize distance learning, to independently search and select digital resources and their adaptation to the conditions of the educational process. Based on these problems, the authors have developed an innovative model that provides professional development of specialists – web portal ‘Ukrainian Open University of Postgraduate Education’ http://uvu.org.ua/ [10]. Web portal ‘Ukrainian Open University of Postgraduate Education’ is a multi-purpose, dynamic electronic educational resource designed to organize and support postgraduate education. This is a set of digital solutions aimed at the successful operation of virtual departments, the implementation of the educational process, professional development of students, coverage of innovative educational practices. The specialists of the University of Educational Management (Kyiv, Ukraine) taking into account the peculiarities of adult learning developed and put into use the Web platform ‘Learning Management System Adult Learning’ (LMS AdL) for the introduction of modern technologies of formal and non-formal postgraduate education. The platform is placed on the web-portal in order to provide a remote stage of professional development of students. Educational activities are carried out on the basis of virtual departments. Each virtual department of consists of technological and intellectual potential and resources of individual

scientists, departments, institutes, institutions of higher education, public organizations [30].

Departments provide open access to research carried out within the specified community, which includes: the use of remote communication; consistent formation of an educational virtual community of specialists; marketing of knowledge and distance educational services; protection of joint use of intellectual property of members of the virtual department; integration of extensive educational practices into a holistic system of continuing adult education.

Currently, six virtual departments have been established, that represent the innovative digital space for the professional development of pedagogical, scientific-pedagogical and managerial staff of education. Virtual departments carry out scientific and practical communication of specialists in adult education in various fields and educational institutions, consumers of educational services. Among the advantages of the virtual department are the following: participants' awareness of each other's need for experience and resources, pooling resources on this basis to achieve common goals; electronic integration of the best developments; cooperation and coordination of remote partners; the ability to respond flexibly to changes in the environment, the labor market; implementation of interdisciplinary learning strategy; formation of flexible study groups, the possibility of individual learning.

The innovativeness of the Web portal is that it is an electronic resource and in the same time the open educational and scientific environment for professional and personal development of adults.

The LMS Adult Learning platform, that is the basis of this open educational and scientific environment, has a dynamic navigation structure of logical complexity and content that includes various modules:

- expert council: examination and approval of educational programs, teaching materials; providing consultations to participants of the educational process;
- virtual departments: andragogy http://uvu.org.ua/kafedra-osvity-doroslykh/, education management http://uvu.org.ua/kafedra-upravlinnia-osvitoiu/, vocational education http://uvu.org.ua/kafedra-profesiinoi-osvity/, psychology http://uvu.org.ua/kafedra-psykholohii/, digital technologies http://uvu.org.ua/kafedra-tsyfrovykh-tekhnolohii, New Ukrainian School http://uvu.org.ua/kafedra-nush/;
- electronic dean's office http://uvu.org.ua/struktura/elektronnyi-dekanat/: keeping records of students; formation of the schedule of educational process; development of schedules; formation of study groups; document management; certificates;
- information and consulting centre http://uvu.org.ua/ikcodn/ created at the request of teaching staff): 7x24 consultations; organization of flash courses; organization of webinars, seminars, conferences; individual work with participants of the educational process; marketing;
- department of scientific and methodical support: support and maintenance of the resource; maintenance of the educational environment; filling the web library, technical and methodical processing of materials of short term and special courses; organization of work in social networks; technical support of listeners;
- educational practices: acquaintance with the international experience of training organization; coverage of scientific achievements in the field of education and learning technologies.

Virtual departments include 62 teachers: 15 teachers from the regions, 16 – from Kyiv city, other teachers from the university.

Technical characteristics of the virtual university:

- Availability: The resource is available 24 hours a day, 7 days a week.
- Speed of work and correctness of adjustment: the resource reacts quickly enough to the entered inquiries, transitions between components, filling of forms of feedback; ranks first in the list of Google sites. In order to identify errors and eliminate them in a timely manner, a technical audit of the resource is carried out continuously. Continuous technical audit avoids code 404, which means that the page is unavailable for any reason. Continuous maintenance reduces the risk of search engines treating a resource as untrustworthy and reducing its ranking or exclusion. All pages of the resource are in working order.
- Availability of 'mirror': the resource has a 'mirror' on another server, which helps to save the audience (users) and improve its indexing.

It should be noted that the educational process is provided by training in the format of: flash courses; special courses; webinars; digital dialogues. Currently, there are 46 special courses and 4 flash courses. The list of special courses and flash courses in the virtual university as of 01.01.2022 http://uvu.org.ua/elektronni-resursy/spetsialni-kursy/.

Distance learning was organized for 1,137 students from 401 educational institutions in the period from 12.03.2020 to 01.02.2021 on the Web platform LMS AdL http://uvupo.ues.net.ua. Representatives of 23 regions of Ukraine and the city of Kyiv took part in advanced training courses. To provide distance learning for students, it was created 50 electronic classrooms for teachers, and 186 teaching materials have been posted in the web library. 950 people received certificates of advanced training; 1,362 people received certificates of participation in webinars [**?**].

The Ukrainian Open University of Postgraduate Education has a page in the Facebook, which includes 1.5 thousand regular participants and in total covers a virtual audience of about 40,000 users https://www.facebook.com/groups/217559579605133.

The originality of an innovative model of non-formal postgraduate education and Web portal is to provide conditions for continuous professional development of teachers in accordance with the requirements of the digital society, based on free choice of content and timing, diversification of learning through digital technology.

5. Conclusions and recommendations

The conducted research and the presented experience of the decision on support of distance learning allowed the authors to reach the following conclusions. The results of the teacher surveys revealed a number of problems faced by schools, teachers and school principals in connection with the introduction of quarantine measures in Ukraine. Threats and challenges as signs of crisis have become a determining condition for gaining new experience and opening new opportunities in ensuring the continuous professional development of teachers. Among the main ones: teachers' unwillingness to implement distance learning, gaps in knowledge

of digital teaching tools, insufficient awareness of digital educational resources in teaching subjects, limited access to digital resources, etc.

Particular attention should be paid to the digital competence of teachers, its constant development, which should be provided by teacher training institutions.

New realities of education during the quarantine period prompted to search for innovation solutions for the organization of the educational process and quality assurance of distance learning by teachers of secondary education in the context of digital transformation in Ukraine. We presented the Ukrainian experience in addressing the issue of teacher training not only on digital literacy, but also on professional activities in various fields.

The presented tools of the teacher survey can be used by the heads of educational institutions to identify problems and find solutions on the ground. The questionnaire can also serve as a tool to identify important topics for teacher training courses. We propose to conduct a survey of teachers on the problems of distance learning on a follow-up basis.

The experience of the Ukrainian Open University is a new solution for Ukraine and needs further development, development and renewal. That is why we see further prospects for the study of the problems outlined in the work in the further monitoring of the readiness and competence of teachers to use digital teaching aids; in identifying problems in the implementation of distance learning and finding more workable solutions. In our opinion, such aspects as the creation of short courses for teachers of various subjects in digital literacy, methodological and psychological support for teachers, motivation and encouragement to find creative solutions in distance learning in schools need attention.

References

[1] Concept of the development of digital economy and society in Ukraine for 2018-2020, 2018. URL: https://zakon.rada.gov.ua/laws/show/67-2018-%D1%80#n13.

[2] D. Trcek, Driving digital transformation through e-government, CEUR Workshop Proceedings 2422 (2019) 263–273.

[3] O. P. Pinchuk, O. M. Sokolyuk, O. Y. Burov, M. P. Shyshkina, Digital transformation of learning environment: Aspect of cognitive activity of students, CEUR Workshop Proceedings 2433 (2019) 90–101.

[4] N. V. Morze, O. V. Strutynska, Digital transformation in society: key aspects for model development, Journal of Physics: Conference Series 1946 (2021) 012021. doi:10.1088/1742-6596/1946/1/012021.

[5] M. P. Leshchenko, A. M. Kolomiiets, A. V. Iatsyshyn, V. V. Kovalenko, A. V. Dakal, O. O. Radchenko, Development of informational and research competence of postgraduate and doctoral students in conditions of digital transformation of science and education, Journal of Physics: Conference Series 1840 (2021) 012057. doi:10.1088/1742-6596/1840/1/012057.

[6] I. V. Ivaniuk, O. V. Ovcharuk, Results of an online survey of teachers' readiness and needs for the use of digital tools and ICT during quarantine: 2021, Analytical materials, Institute of Information Technologies and Learning Tools of the NAES of Ukraine, 2021. URL: https://lib.iitta.gov.ua/724564/.

[7] I. V. Ivaniuk, O. V. Ovcharuk, Results of an online survey of teachers' needs for raising the level of professionalism in digital and ICT use during quarantine, Analytical materials, Institute of Information Technologies and Learning Tools of the NAES of Ukraine, 2020. URL: https://lib.iitta.gov.ua/719908/.

[8] I. V. Ivaniuk, O. V. Ovcharuk, The response of Ukrainian teachers to COVID-19: challenges and needs in the use of digital tools for distance learning, Informational Technologies and Learning Tools 77 (2020) 282–291. doi:10.33407/itlt.v77i3.3952.

[9] O. Ovcharuk, Attitude of Ukrainian educators toward the use of digital tools for teaching and professional development: Survey results, CEUR Workshop Proceedings 2732 (2020) 746–755.

[10] Ukrainskyi vidkrytyi universytet pisliadyplomnoi osvity [Ukrainian Open University of Postgraduate Education], 2021. URL: https://uvu.org.ua.

[11] L. A. Kartashova, A. M. Gurzhii, V. O. Zaichuk, T. M. Sorochan, F. M. Zhuravlev, Digital twin of an educational institution: an innovative concept of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[12] D. Y. Bobyliev, E. V. Vihrova, Problems and prospects of distance learning in teaching fundamental subjects to future mathematics teachers, Journal of Physics: Conference Series 1840 (2021) 012002. doi:10.1088/1742-6596/1840/1/012002.

[13] N. P. Franchuk, T. V. Prydacha, Organization and conduct of classes in educational institutions during distance learning, Journal of Physics: Conference Series 1840 (2021) 012054. doi:10.1088/1742-6596/1840/1/012054.

[14] L. H. Havrilova, O. Y. Ishutina, V. V. Zamorotska, D. A. Kassim, Distance learning courses in developing future music teachers' instrumental performance competence, CEUR Workshop Proceedings 2433 (2019) 429–442.

[15] V. Kukharenko, T. Oleinik, Open distance learning for teachers, CEUR Workshop Proceedings 2393 (2019) 156–169.

[16] I. S. Mintii, T. A. Vakaliuk, S. M. Ivanova, O. A. Chernysh, S. M. Hryshchenko, S. O. Semerikov, Current state and prospects of distance learning development in Ukraine, CEUR Workshop Proceedings 2898 (2021) 41–55. URL: http://ceur-ws.org/Vol-2898/paper01.pdf.

[17] M. J. Syvyi, O. B. Mazbayev, O. M. Varakuta, N. B. Panteleeva, O. V. Bondarenko, Distance learning as innovation technology of school geographical education, CEUR Workshop Proceedings 2731 (2020) 369–382.

[18] T. A. Vakaliuk, O. M. Spirin, N. M. Lobanchykova, L. A. Martseva, I. V. Novitska, V. V. Kontsedailo, Features of distance learning of cloud technologies for the organization educational process in quarantine, Journal of Physics: Conference Series 1840 (2021) 012051. doi:10.1088/1742-6596/1840/1/012051.

[19] T. L. Hodovaniuk, T. M. Makhometa, I. M. Tiahai, M. O. Medvedieva, S. M. Pryshchepa, A. V. Voznyak, Educational trainings as one of the effective forms of digital competence development of secondary school teachers, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[20] O. Kuzminska, M. Mazorchuk, N. Morze, V. Pavlenko, A. Prokhorov, Study of Digital

Competence of the Students and Teachers in Ukraine, Communications in Computer and Information Science 1007 (2019) 148–169. doi:10.1007/978-3-030-13929-2_8.
[21] M. V. Moiseienko, N. V. Moiseienko, I. V. Kohut, A. E. Kiv, Digital competence of pedagogical university student: Definition, structure and didactical conditions of ormation, CEUR Workshop Proceedings 2643 (2020) 60–70. URL: http://ceur-ws.org/Vol-2643/paper01.pdf.
[22] N. V. Soroko, Methodology for teachers' digital competence developing through the use of the STEAM-oriented learning environment, CEUR Workshop Proceedings 2732 (2020) 1260–1271.
[23] The Council of the European Union, Council Recommendation of 22 May 2018 on key competences for lifelong learning (Text with EEA relevance), 2018. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01)&from=EN.
[24] O. G. Yaroshenko, O. D. Samborska, A. E. Kiv, Experimental verification of efficiency of the formation of information and digital competence of bachelors of primary education based on an integrated approach, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[25] O. Ovcharuk, I. Ivaniuk, N. Soroko, O. Gritsenchuk, O. Kravchyna, The use of digital learning tools in the teachers' professional activities to ensure sustainable development and democratization of education in European countries, E3S Web of Conferences 166 (2020) 10019. doi:10.1051/e3sconf/202016610019.
[26] O. Ovcharuk, O. Hrytsenchuk, Digital tools for creating and maintaining educational environment for democratic citizenship in european countries, Computer in school and family 158 (2020) 52–56.
[27] O. O. Hrytsenchuk, Information and educational learning environment as a tool of developing teachers' civic competence in the Netherlands, Ph.D. thesis, Institute of Information Technologies and Learning tools of NAES of Ukraine, Kyiv, Ukraine, 2020.
[28] A. Gurzhii, L. Kartashova, V. Lapinsky, New ukrainian school: digital resources as a necessary factor in maintaining continuity of education, in: Modern Achievements in Science and Education. XII International Conference, Netanya, Israel, 2018, pp. 195–199.
[29] L. Kartashova, N. Bakhmat, I. Plish, Development of teacher's digital competency in terms of information and educational environment of a secondary education establishment, Informational Technologies and Learning Tools 68 (2018) 193–205. doi:10.33407/itlt.v68i6.2543.
[30] L. Kartashova, M. Kyrychenko, T. Sorochan, Crisis management in the in-service training, Herald of the National Academy of Educational Sciences of Ukraine 2 (2020). doi:10.37472/2707-305X-2020-2-1-7-9.
[31] L. Petrenko, S. Kravets, O. Bazeliuk, L. Maiboroda, I. Muzyka, Analysis of the current state of distance learning in the vocational education and training institutions, E3S Web of Conferences 166 (2020) 10010. doi:10.1051/e3sconf/202016610010.
[32] S. V. Shokaliuk, Y. Y. Bohunenko, I. V. Lovianova, M. P. Shyshkina, Technologies of distance learning for programming basics on the principles of integrated development of key competences, CEUR Workshop Proceedings 2643 (2020) 548–562.
[33] O. M. Spirin, K. R. Kolos, O. A. Kovalchuk, O. O. Demianchuk, F. M. Zhuravlev, Build a technology for mass organization of distance learning for pupils in quarantine, in: S. Se-

merikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[34] 3D democracy: thinking, care, acting, 2021. URL: https://citizen.in.ua.
[35] PISA in Focus. Were the schools equipped, ready to study remotely? Programme for International Student Assessment, 2020. URL: http://pisa.testportal.gov.ua/wp-content/uploads/2020/11/PISA_in_Focus108-ukr_gotove.pdf.
[36] Open Access. Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, 2003. URL: https://openaccess.mpg.de/Berlin-Declaration.
[37] UNESCO, Steering AI and Advanced ICTs for Knowledge Societies, 2019. URL: https://en.unesco.org/system/files/unesco-steering_ai_for_knowledge_societies.pdf.
[38] UNESCO, Fighting COVID-19 through digital innovation and transformation, 2020. URL: https://en.unesco.org/covid19/communicationinformationresponse/digitalinnovation.
[39] UNESCO, Distance learning solutions, 2021. URL: https://en.unesco.org/covid19/educationresponse/solutions.

Computer modeling of the tournament of game algorithms in the process of learning of basics of algorithmization and programming by pre-service IT-specialists

Liudmyla E. Gryzun[1], Oleksandr V. Shcherbakov[1] and Svitlana H. Lytvynova[2]

[1]*Simon Kuznets Kharkiv National University of Economics, 9A Nauky Ave., Kharkiv, Ukraine*

[2]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

Abstract

The problems of contemporary IT specialists' training in terms of the high requirements to their computational thinking skills as well as the urgency of raising their motivation to mastering algorithmization and programming are discussed in the paper. It is emphasized by the authors that initial university courses should focus pre-service IT-specialists on the deep understanding of an algorithmic nature of any coding task, to realize basic characteristics of the algorithms, to understand their role in modern software development. Due to the contemporary demands, programming should rest on algorithms building and has to be a part of lager scale experiences in order to realize its full potential. One of such experiences offered by the authors in the paper is involving the students into specially arranged activity focused on efficient game algorithms creation and simulation of the tournament between the algorithms. The offered activity is elaborated based on the applying the gamification elements into the learning process. Basing on the core gamifiaction principles, there were thought over and arranged an activity involving the students into the creation of gamified products. In our case, the gamified product which the students had to develop in the process of learning of algorithmization and programming was the software platform which enables a computer simulation of the tournament between the different game algorithms which realize winning strategies. The peculiarities and the stages of the said activity are covered in details along with the description of the final software product. Analyzing the described functionality of the computer simulator of the algorithms tournaments based on the gamification ideas, we can emphasize its significant didactic facilities in the context of its using for IT-specialists training. In particular, the developed gamified product was probed in the process of other students' mastering algorithmization and programming as well as of the schoolchildren training during summer IT schools. The prospects of the research are outlined in the lines of using the obtained results for holding the empirical research for the verification of offered activity impact on the results of IT-specialists training.

Keywords

IT-specialists' training, computer modeling, tournament of algorithms, computer simulator, winning strategy

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1. Introduction

Rapid growing of IT industries and their spreading in all spheres of social life needs renewing approaches to modern computing education, which would provide national economy with advanced IT-specialists who are able not just to develop efficient software but also have special type of computational thinking.

In the international guidelines shaping the modern paradigms of global IT education, it is emphasized the transformation of computing which nowadays is not a single knowledge domain [1, 2, 3, 4, 5, 6]. According to the current state of IT education covered in the latest Computing Curricula Series Report [5, 6], we can conclude that computing area (as a result of rapid evolution) is not an isolated domain, but rather a family of knowledge domains which embraces a set of fundamental and applied study areas. They go on their developing that leads to emerging of new study areas which represent intersection of fundamental science, applied branches of science and traditional computer disciplines. In particular, according to recent studies, the advantages of computer science education nowadays lie in giving the students computational thinking skills which allow them to comprehend a problem in its complexity, to formalize it and develop possible solutions in a way understandable by a machine, a human (or both).

On the other hand, the contemporary evidence of educational practice testifies that IT-specialists' training at universities is facing the problems of raising students' motivation to mastering algorithmic basics of coding, which is considered to be a part of computational thinking [7]. It is defined by the psychologists [8], that computational thinking embraces four cornerstones one of which is and algorithm developing along with decomposition, pattern recognition and abstraction.

In this context it is important to mind that initial university courses should focus pre-service IT-specialists on the deep understanding of an algorithmic nature of any coding task, to realize basic characteristics of the algorithms, to understand their role in modern software development. It is essential at this level to cultivate the students' understanding that coding is not done in a vacuum: just knowing a programming language does not provide you with problem-solving skills necessary for real-life tasks. Programming should rest on algorithms building and has to be a part of lager scale (project-based) experiences in order to realize its full potential.

One of such experiences may be involving the students into specially arranged activity focused on efficient game algorithms creation and simulation the tournament between the algorithms. The purpose of such an activity including the elements of gamification is to give young developers understanding the difference between pure coding knowledge and the

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Lgr2007@ukr.net (L. E. Gryzun); oleksandr.shcherbakov@hneu.net (O. V. Shcherbakov);
s.h.lytvynova@gmail.com (S. H. Lytvynova)
https://kafis.hneu.net/grizun-lyudmila-eduardivna/ (L. E. Gryzun);
https://kafis.hneu.net/shherbakov-oleksandr-vsevolodovich/ (O. V. Shcherbakov);
https://iitlt.gov.ua/structure/departments/technology/detail.php?ID49 (S. H. Lytvynova)
0000-0002-5274-5624 (L. E. Gryzun); 0000-0002-6473-7629 (O. V. Shcherbakov); 0000-0002-5450-6635 (S. H. Lytvynova)
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algorithmization skills that allow to use computational thinking creatively and effectively.

The aim of the paper is to represent the case of the authors' practice of involving pre-service IT-specialists into computer simulation of the tournament between the different game algorithms which realize winning strategies.

2. Theoretical framework

According to a number of studies, gamification expects applying the game elements to encourage trainees' core innate needs for internal motivation [9, 10, 11]. These needs include, in particular: relatedness as the universal need to interact and be connected with others; competence as the universal need to be efficient and master a problem in a certain environment; autonomy: the universal need to control one's own activity.

The researchers also indicate that gamification methods are successful in fostering collaboration, especially when following the principles of self-determination theory [10]. It is also emphasized that applying only rewarding aspect of gamification (badges, bonuses or other rewards) [12], is not didactically beneficial, and instead gamification is recommended to consider the motivation of the participants, the goals of the course and gameful design together [13].

Gamification nowadays is widely used in educational practice of coding mastering both at school and university levels. Gamification refers to the use of game elements in a non-game context in order to increase communication between people and computers and to solve various problems effectively [14, 15, 16, 17, 18]. It is also emphasized that gamification can be described as using pieces of games to motivate learners, but the real definition of gamification involves using game-based mechanics, aesthetics, and game thinking to engage users, motivate action, promote learning, and solve problems. However, according to studies [19, 20], mostly gamification includes renaming grades for all assessments to "experience points" or "badges", a weekly compulsory and non-compulsory activities and a leaderboard, which is often integrated with an online management tools, and including other game elements without deep influence on the content of learning.

Along with such a common use of gamification method in programming learning, there are some studies which demonstrate the experience of a different gamification, involving the students into the creation of gamified products. Basing on the number of papers [17, 19], we learnt basic principles of arrangement of such an activity on design of gamified product which trig gamification mechanisms.

Gamification should have a special meaning for the trainees, the ability to inspire them to master the topic (course) and it should be autonomous providing a feeling of free choice [19]. It should also focus on meaningful victories, a sense of discovery, social interactions and include visually pleasing elements [20].

For the potential users of the gamified product it is essential to have a personal connection to it, they must feel that the game has a purpose for them individually (the final goal must be one that the users wish to achieve). The users must be able to clearly see and track their progress toward long and short term goals, in search of the final goal. To motivate the users to achieve these goals, gamified product should implement an accomplishment-based reward system. The prospect of winning a reward inspires users to work toward aims: the rewards

act as self-affirmation symbols as well as allowing users to identify with a group that works toward the same goals [21]. Leader boards should be incorporated to demonstrate the user his achievements compared to others in the same community and also create both competition and a sense of belonging to a similar minded group [21]. The reward system should be transparent and designed properly so as to maximize user's enjoyment.

It is also emphasized in the papers, that creating a gamified product it is important to mind that gaming is an unrestricted pass-time, and main objective is to motivate the users to go on playing the game and trying to overcome difficulties [19].

The techniques used in said research made the theoretical framework of our practical experience.

3. Computer simulator of the tournament between the different game algorithms

Basing on the covered principles, we thought over and arranged an activity involving the students into the creation of gamified products.

In our case, the gamified product which the students had to develop in the process of learning of algorithmization and programming was the software platform which enables a computer simulation of the tournament between the different game algorithms which realize winning strategies.

The students involved in the activity are pre-service specialists of the "Software engineering" who study the course of fundamentals of algorithmization during one term and the course of programming during two terms. The activity which was organized in its group form was offered to the students in the second term. So, the trainees had an opportunity to master algorithms and coding basics; learn common algorithms properties, methods, algorithmic solutions of classical informatics tasks etc., got familiar with some games and winning strategies for them.

On the preparation stage of the activity on creation the gamified product, the task for the students was specified as following: to develop a computer simulator of the tournament between the different game algorithms which realize winning strategies.

We would like to emphasize that the peculiarity of the task is to model the game process where the competitors are different algorithms but not a computer and humans (or humans controlled by a computer).

After the analysis of the subject domain and minding the principles of gamification (covered above), the use case diagram was built and functional requirements to the simulator were formulated.

In particular, the simulator has to provide users (students or schoolchildren who learn algorithmization and programming) with the opportunities to:

- choose a game (Tic-tac-toe, Battleship or other);
- determine the pitch dimensions and other game parameters;
- add a file with user's own algorithm which realizes the winning strategy of the game and wants to take part in tournament;
- simulate the tournament between available algorithms detecting the winner;

- visualize the progress of the tournament showing the moves of each participating algorithm;
- provide users with the results of the tournament at the leaderboard showing the name of the algorithm-winner;
- provide users with clear and friendly interface encouraging them to go on mastering the algorithms developing and achieving the victory among peers' algorithms.

After that the students were involved into direct activity on the computer simulator design.

Omitting the technical details, we could characterize the developed software as following. As a result, the computer simulator is a cross-platform software built in Python language which was learnt by the students within the course of programming. There were developed the modules and functions which enable to realize all the simulator functionality formulated above.

On the whole, the simulator is composed of three executing files: design.py, scripts.py and index.py.

The file scripts.py stores initial states of the game, default values of variables, and realized checks of winning combinations of the games.

The file design.py contains the interface and provides the proceeding of the simulator interaction with a user.

The file index.py is a main file for running the simulator. In terms of non-functional requirements, the user should make sure that the OS is installed Python programming language translator version not lower than 3.8, PyQt5 modules, Numpy and additional libraries from the list given in the requirements.txt file. For Windows, if you have a translator, just run the file Project121 (win32) .exe.

The executable file will automatically check for availability additional libraries and will install the missing modules. At restart, modules will no longer be loaded. If you are using the Linux family, launch the program is carried out from the window of the terminal emulator.

After the simulator running the user is invited to choose the game for the tournament. So far, it is realized the opportunity to hold the algorithms tournament for Tic-tac-toe and Battleship games (the others are being developed).

After the game choosing, the proper game's window is opened where a user can specify the parameters of the game. For example, after choosing the Tic-tac-toe game (figure 1), it is possible to set:

- the dimensions of the pitch where the algorithms will "play" (width and length which are integers less than 20),
- the number of figures in row to win (an integer that is not greater than minimum value of width and length),
- the number of rounds where a round is made by two games which differ by the first move of the algorithms that are competing.

In order to start the tournament, the user can choose the existing algorithms in the simulator or add his own algorithm realizing his own winning strategy. On this stage of the tournament it is possible to set up the speed of the algorithms visualization and switch on step-by-step mode of their realization.

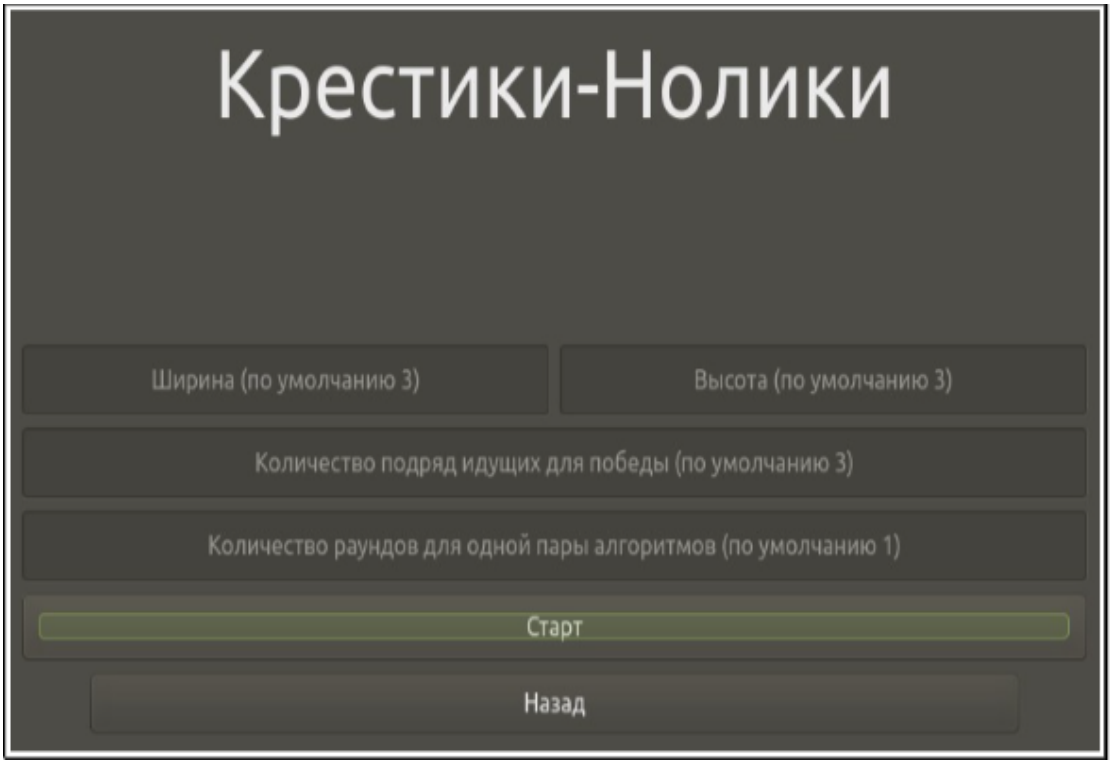

Figure 1: Tic-tac-toe game initial window where a user can set the game parameters.

The tournament on the comparing of winning strategies can start on condition of existing two or more algorithms. In order to add their own algorithm in the simulator to take part in the tournament, a user has to create file *.py with the developed function called *Algorithm*, according to the certain format. In particular, the function must depend on five parameters (*matrix, height, width, player, winCount*), where:

matrix — matrix (height, width), in which each element *matrix[i][j]* takes the value 1, if nobody has taken this cell yet, else this element of *matrix* will take proper symbol (“x” or “o”), latin symbols type;

height — height of the pitch, *int* type;

width — width of the pitch, *int* type;

player — the value which is put in the cell of the pitch by this algorithm, in other words, the value determines the type of this player (“x” or “o”);

winCount — the number of figures (“x” or “o”) in row which are necessary to win, *int* type.

The user’s function contains the algorithm of winning strategy: it has to process the data sending via its parameters, make a move (change one empty cell of the pitch (*matrix*)), and return a new state of the pitch. The format of the function with its example is provided by the simulator in special *Help* section for a user.

When the file *.py with the developed function *Algorithm* is ready, a user can add his algorithm to take part in the tournament via the button Add algorithm (figure 2). The episode of algorithm

adding is shown in the figure 3.

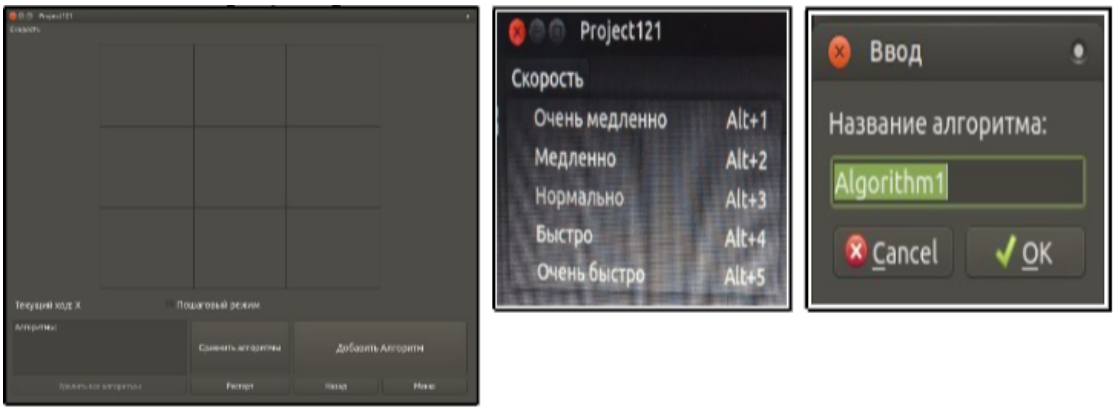

Figure 2: Tic-tac-toe tournament at the stage of choosing the algorithms and parameters of their visualization.

Figure 3: The episode of algorithm adding to take part in the tournament of algorithms.

Then a user can run the tournament with his algorithm participation.

Thus, the developed software provides the simulation of the algorithms tournament for the chosen game by comparing the algorithms' winning strategies.

The progress of the game is visualized in chosen speed showing the moves of each participating algorithm.

Finally, the simulator provides users with the results of the tournament at the leaderboard showing the name of the algorithm-winner.

The simulation of tournaments for Battleship game was realized by the students in similar way which gives potential users similar opportunities as for their algorithmic skills working out (figure 4).

However, the user has to create and add the file with two developed functions: *shipsPlacement* (which determines ships location) and *Algorithm* (which realizes the winning strategy).

It is important to emphasize that during the simulator developing the students had to test the work of their software on their own samples of algorithms as well as on the other their peers' algorithms. It made students themselves be involved into game activity testing gamified product and besides that, allowed them to involve other students into the process of creation of the algorithms which realize winning strategies for famous games. This circumstance showed great

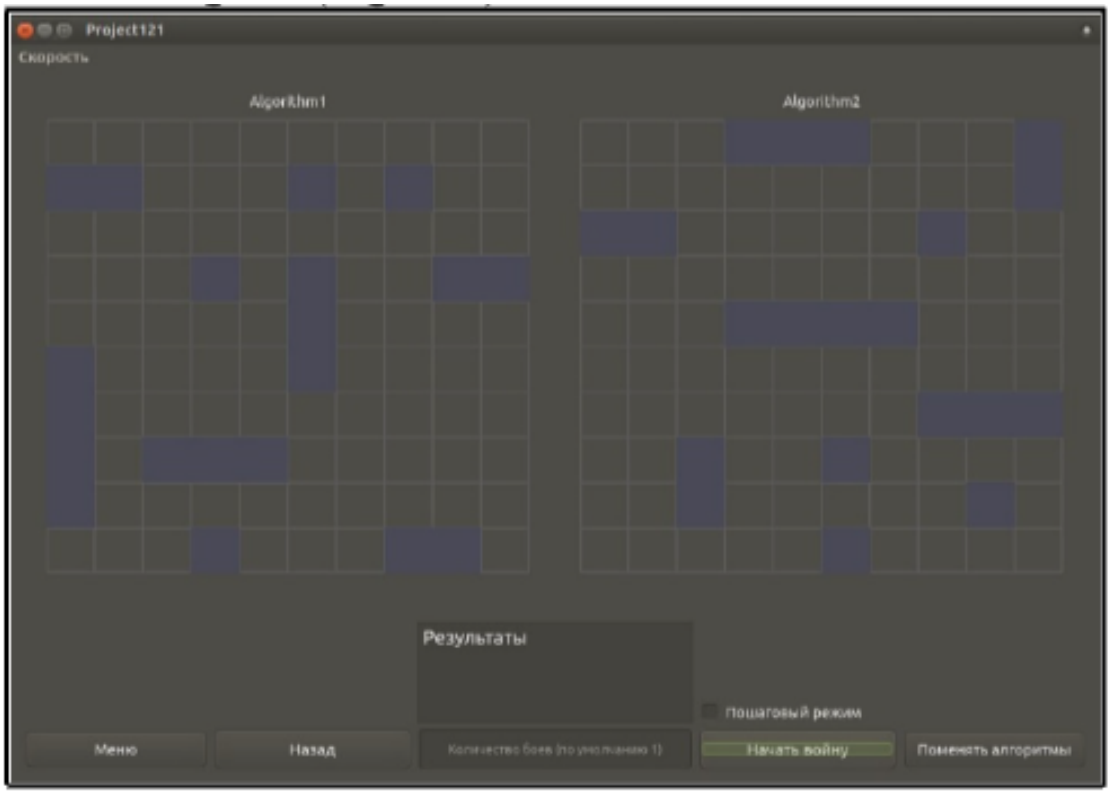

Figure 4: The episode of the tournament of the algorithms for the Battleship game.

benefit of gamification techniques using in the mastering of the said courses in their different variations.

Thus, as a result of the involving the students into specially arranged activity focused on game algorithms creation and development of simulator of the tournament between the algorithms we could conclude the impact of such an activity on the forming trainees' computational thinking.

It was prepared by us special program of monitoring the students' activity during different stages of their work upon the simulator including its testing and preparing the user's guidelines. Our monitoring, according to this program, testified raising the students' motivation and tendency to comprehend the essence of algorithms building. As it was predicted, we could notice their growing understanding of the role of algorithmization skills in the process of coding.

In addition, we held the survey which aimed at revealing students' hindsight and reflexion of their work upon the simulator. The survey included the set of questions and tasks, such as:

(1) How do you estimate your degree of attraction of algorithms basics in the progress of developing the said gamified product (according to the given scale)?
(2) Did you change your mind on the value of the fundamental knowledge on algorithms for coding? In which way?
(3) How do you estimate your level of engagement in analyzing feedback of your activities (according to the given scale)?

(4) What experience (besides alorithmization and coding) did you earn during the work upon the gamified product?
(5) How far does this experience seem to be essential for your future career?, and others.

Characterizing in brief the results of the survey, we can emphasize the following. 75% of the trainees agreed that the developing of gamified product encouraged them to attract algorithms basics in more concentrated way. Over the half of the students admitted changes in their understanding of practical value of the abstract fundamental knowledge. They also said that they were more engaged in analyzing feedback for activities in order to improve and earn more experience in the future. Finally, about 80% of the students admitted that such an activity provided them with precious experience of team work and communication with potential users.

The obtained results of our monitoring and survey may be taken as a basis for holding the empirical research for the verification of the offered activity impact on the results of IT-specialists' training, which makes a prospect of our research.

4. Conclusions

The problems of contemporary IT specialists' training in terms of the high requirements to their computational thinking skills as well as the urgency of raising their motivation to mastering algorithmization and programming are discussed in the paper. It is emphasized by the authors that initial university courses should focus pre-service IT-specialists on the deep understanding of an algorithmic nature of any coding task, to realize basic characteristics of the algorithms, to understand their role in modern software development. Due to the contemporary demands, programming should rest on algorithms building and has to be a part of lager scale experiences in order to realize its full potential.

One of such experiences offered by the authors in the paper is involving the students into specially arranged activity focused on efficient game algorithms creation and simulation of the tournament between the algorithms. The offered activity is elaborated based on the applying the gamification elements into the learning process.

Basing on the core gamifiaction principles, there were thought over and arranged an activity involving the students into the creation of gamified products. In our case, the gamified product which the students had to develop in the process of learning of algorithmization and programming was the software platform which enables a computer simulation of the tournament between the different game algorithms which realize winning strategies.

The peculiarities and the stages of the said activity are covered in details along with the description of the final software product. Analyzing the described functionality of the computer simulator of the algorithms tournaments based on the gamification ideas, we can emphasize its significant didactic facilities in the context of its using for IT-specialists training. In particular, the developed gamified product was probed in the process of other students' mastering algorithmization and programming as well as of the schoolchildren training during summer IT schools.

The prospects of the research are outlined in the lines of using the obtained results for holding the empirical research for the verification of offered activity impact on the results of IT-specialists' training.

References

[1] Association for Computing Machinery, IEEE Computer Society, Software Engineering Curricula 2014: Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering, Computing Curricula, 2015. URL: https://www.acm.org/binaries/content/assets/education/se2014.pdf.

[2] Association for Computing Machinery, IEEE Computer Society, Computer Engineering Curricula 2016: Curriculum Guidelines for Undergraduate Degree Programs in Computer Engineering, 2016. URL: https://www.acm.org/binaries/content/assets/education/ce2016-final-report.pdf.

[3] Task Group on Information Technology Curricula, Information Technology Curricula 2017: Curriculum Guidelines for Baccalaureate Degree Programs in Information Technology, Association for Computing Machinery, New York, NY, USA, 2017.

[4] Joint Task Force on Cybersecurity Education, Cybersecurity Curricula 2017: Curriculum Guidelines for Post-Secondary Degrees in Cybersecurity, 2017. URL: https://www.acm.org/binaries/content/assets/education/curricula-recommendations/csec2017.pdf.

[5] M. Geissler, D. Brown, N. McKenzie, S. Peltsverger, T. Preuss, M. Sabin, C. Tang, Information Technology Transfer Curricula 2020: Curriculum Guidelines for Two-Year Transfer Programs in Information Technology, Association for Computing Machinery, New York, NY, USA, 2020. URL: https://ccecc.acm.org/files/publications/IT-Transfer2020.pdf.

[6] Association for Computing Machinery, IEEE Computer Society, Computing Curricula 2020: Paradigms for Global Computing Education, 2020. URL: https://www.acm.org/binaries/content/assets/education/curricula-recommendations/cc2020.pdf.

[7] Z. Seidametova, Combining programming and mathematics through computer simulation problems, CEUR Workshop Proceedings 2732 (2020) 869–880.

[8] Introduction into computational thinking, 2021. URL: https://www.bbc.co.uk/bitesize/guides/zp92mp3/revision/1.

[9] K. Seaborn, D. I. Fels, Gamification in theory and action: A survey, International Journal of Human-Computer Studies 74 (2015) 14–31. doi:10.1016/j.ijhcs.2014.09.006.

[10] A. Knutas, J. Ikonen, U. Nikula, J. Porras, Increasing collaborative communications in a programming course with gamification: A case study, in: Proceedings of the 15th International Conference on Computer Systems and Technologies, CompSysTech '14, Association for Computing Machinery, New York, NY, USA, 2014, p. 370–377. doi:10.1145/2659532.2659620.

[11] V. L. Buzko, A. V. Bonk, V. V. Tron, Implementation of gamification and elements of augmented reality during the binary lessons in a secondary school, CEUR Workshop Proceedings 2257 (2018) 53–60.

[12] K. M. Kapp, The gamification of learning and instruction: game-based methods and strategies for training and education, Wiley, 2012.

[13] S. Deterding, The lens of intrinsic skill atoms: A method for gameful design, Human–Computer Interaction 30 (2015) 294–335. doi:10.1080/07370024.2014.993471.

[14] S. Deterding, D. Dixon, R. Khaled, L. Nacke, From game design elements to gamefulness: Defining "gamification", in: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, MindTrek '11, Association for Com-

puting Machinery, New York, NY, USA, 2011, p. 9–15. doi:10.1145/2181037.2181040.

[15] S. Deterding, M. Sicart, L. Nacke, K. O'Hara, D. Dixon, Gamification. using game-design elements in non-gaming contexts, in: CHI '11 Extended Abstracts on Human Factors in Computing Systems, CHI EA '11, Association for Computing Machinery, New York, NY, USA, 2011, p. 2425–2428. doi:10.1145/1979742.1979575.

[16] F. L. Khaleel, N. S. Ashaari, T. S. Meriam, T. Wook, A. Ismail, The study of gamification application architecture for programming language course, in: Proceedings of the 9th International Conference on Ubiquitous Information Management and Communication, IMCOM '15, Association for Computing Machinery, New York, NY, USA, 2015. doi:10.1145/2701126.2701222.

[17] F. L. Khaleel, N. S. Ashaari, T. S. M. Tengku Wook, A. Ismail, User-enjoyable learning environment based on gamification elements, in: 2015 International Conference on Computer, Communications, and Control Technology (I4CT), 2015, pp. 221–226. doi:10.1109/I4CT.2015.7219570.

[18] E. G. Fedorenko, N. V. Kaidan, V. Y. Velychko, V. N. Soloviev, Gamification when studying logical operators on the Minecraft EDU platform, CEUR Workshop Proceedings 2898 (2021) 107–118. URL: http://ceur-ws.org/Vol-2898/paper05.pdf.

[19] C. S. Deterding, Meaningful play: Getting gamification right, Video, 2011. URL: https://www.youtube.com/watch?v=7ZGCPap7GkY.

[20] J. Hoonhout, B. Meerbeek, Brainstorm triggers: game characteristics as input in ideation, in: CHI 2011 Workshop Gamification: Using Game Design Elements in Non-Game Contexts, Vancouver, Canada, 2011, pp. 49–54. URL: http://gamification-research.org/wp-content/uploads/2011/04/13-Hoonhout.pdf.

[21] J. Antin, E. Churchill, Badges in social media: A social psychological perspective, in: CHI 2011 Workshop Gamification: Using Game Design Elements in Non-Game Contexts, Vancouver, Canada, 2011, pp. 49–54. URL: http://gamification-research.org/wp-content/uploads/2011/04/03-Antin-Churchill.pdf.

ICT and current trends as a path to STEM education: implementation and prospects

Natalia S. Lukychova[1], Nataliia V. Osypova[2] and Galina S. Yuzbasheva[2]

[1]*Rakivskyi institution of general general secondary education of Beryslav city council of Beryslav district of Kherson region, 12 Nova Str., Rakivka, 74312, Ukraine*

[2]*Communal Higher Educational Establishment "Kherson Academy of Continuing Education" of Kherson Regional Council, 41 Pokrysheva Str., Kherson, 73034, Ukraine*

Abstract

The aim of the study is to build a model for the introduction of STEM education in institutions of general secondary education, to demonstrate the experience of using ICT in STEM education. Research objectives: to determine the role and place of information and communication technologies in the model of introduction of STEM education in general secondary education institutions for the formation of key competencies; to find innovative solutions to create conditions that will promote the interest of student youth in the choice of STEM professions. Object of research: the model of the introduction of STEM education in institutions of general secondary education Subject of research: information and communication technologies in the model of introduction of STEM education in institutions of general secondary education as a component of the school educational environment. Analysis of scientific publications makes it possible to determine the role and place of ICT in the model of introduction of STEM education in general secondary education institutions. The presented experience of the systemic implementation of STEM education in general secondary education institutions allows the formation of professional competencies of teachers in the field of STEM education and can be useful in their professional activities. The study shows that the systemic implementation of STEM technologies in the educational process increases the effectiveness of training, the level of motivation of participants in the educational process and the quality of knowledge in the subjects of the natural science cycle, and also contributes to the formation of key competencies of students.

Keywords

STEM, STEM education, ICT, STEM education implementation model, digital services, augmented reality, virtual reality, key competencies

1. Introduction

STEM is a popular trend of education that encompasses the natural Sciences, Technology, technical creativity (Engineering) and Mathematics. This is a direction in education, in which the curriculum enhances the science component in combination with innovative technologies [1].

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lukuchovanatalia7@gmail.com (N. S. Lukychova); nataliesunny@gmail.com (N. V. Osypova); galina.yuzbasheva@gmail.com (G. S. Yuzbasheva)

https://rakiv.edu.ks.ua/kerivnytstvo/ (N. S. Lukychova); http://academy.ks.ua/?p=17743 (N. V. Osypova); http://academy.ks.ua/?p=17729 (G. S. Yuzbasheva)

0000-0003-4956-6526 (N. S. Lukychova); 0000-0002-9929-5974 (N. V. Osypova)

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The key characteristics of STEM education's educational activities consist of the following features: integration of science, technology, engineering and mathematics; organization of educational activities based on the system of learning progression; providing contextual learning; innovation-based learning; organization of activities focused on designing and solving problems; use of authentic and formative assessment [2].

The tasks of STEM education are: formation of skills for solving complex practical problems, critical thinking, creative qualities and cognitive flexibility, organizational and communication skills, ability to assess problems and make decisions, readiness for conscious choice and mastery of future profession, financial literacy, holistic scientific worldview, values landmarks, general cultural, technological, communicative and social competencies, mathematical and natural literacy; comprehensive development of personality by identifying its inclinations and abilities; mastering the means of cognitive and practical activities; upbringing of a person who strives for lifelong education; formation of skills of practical and creative application of the acquired knowledge.

The main advantages of STEM education:

- the opportunity to develop ingenuity and creativity, which leads to new ideas and innovations;
- ensuring the sustainability of learning in a safe environment;
- encouragement of research and experimentation;
- encouraging students of all ability levels to work together in a team environment;
- encouraging the application of knowledge and skills that can be used in the real world;
- encouragement to use technic and innovative technologies;
- formation of problem-solving skills;
- encouragement to adapt to different scenarios [3].

Working with STEM is often called the work of the future as the sector continues to grow.

According to the 2018 US News and World Report, students study STEM fields twice as often as their parents, and 52 percent of parents surveyed believe that the number of STEM jobs in the United States will increase significantly in the coming years. Two out of five Americans say that the shortage of STEM workers is at a "crisis level" in the United States, and there is a need for more people to take on such roles. The distribution of demand for specialists in the fields of STEM, according to the Bureau of Labor Statistics of the United States in 2018 is shown in figure 1.

Science and industry are experiencing an acute shortage of IT specialists, programmers, engineers, specialists in high-tech production of bio- and nano-technologies.

State STEM education programs have been adopted in Australia, China, Great Britain, Israel, Korea, Singapore, and the United States to meet such requests.

Strengthening the role of STEM education is one of the priorities of modernization of education, an integral part of public policy to raise the level competitiveness of the national economy and human development capital, one of the main factors of innovation in education, that meets the demands of the economy and the needs of society [4].

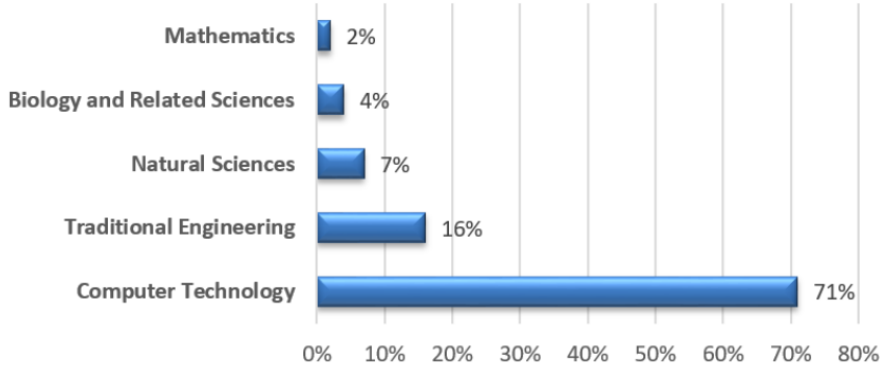

Figure 1: The distribution of demand for specialists in the fields of STEM, according to the Bureau of Labor Statistics of the United States in 2018.

2. Related work

A brief overview of the history of the STEM and STEAM is presented in [5]. This article traces a history of STEM and STEAM. It also provides an assessment of the risks inherent in current trends of STEAM roll-out in schools, from the lack of resources for professional development.

Review the implementation of STEM Education models in the early 21st century is presented in the work [6].

The aim of the study by Gencer et al. [7] is to explore integrated STEM models at theoretical level based on the literature examination about integrated program approaches.

The study of Li et al. [8] probes into the localization of STEM education based on the present situation in China. In the educational model of "STEM education + creator", this study finds out the model of integrating STEM education into the talent cultivation process by means of creator space.

Kramarenko et al. [9], Midak et al. [10], Semerikov et al. [11], Shapovalov et al. [12, 13, 14, 15], Shyshkina [16], Slipukhina et al. [17] define the conceptual and categorical apparatus on various aspects of STEM education, cover the introduction of STEM technologies in educational institutions.

Analysis of models of integration of formal and non-formal STEM education in Ukraine is offered by Polikhun et al. [18]. The authors reveal the features of the educational STEM environment and offer methodological approaches to the organization of STEM projects.

Sharko [19] considers the methodical problem of teaching students STEM disciplines.

Morze et al. [20] analyzes modern views on STEM education and features of its introduction into the educational process, the impact on student motivation; demonstrated the need to prepare students for the skills of the twenty-first century through the introduction of STEM education, starting from primary school. The key and subject competencies that can be formed in children while learning the basics of robotics are described.

Theoretical and practical aspects of informatization of education, in particular the use of information technology as one of the areas of implementation of STEM education, studied by Fedorenko et al. [21], Hlushak et al. [22], Morze and Kucherovska [23], Morze and Strutynska

[24, 25], Morze et al. [26, 27], Ramsky and Rezina [28], Semerikov et al. [29, 30], Spirin et al. [31, 32].

Erasmus+ project "STEM in Education" aims to encourage and inspire teachers of STEM – science, technology, engineering and mathematics – to teach using supporting Information and communications technology (ICT) [33].

Erasmus+ project entitled "Inclusive STEM Education to Enhance the capacity to aspire and imagine future careers" (I SEE) designs innovative approaches and teaching modules to foster students' capacities to imagine the future and aspire to STEM careers. The goal is not only to develop professional skills but also to foster students' identities as capable persons and citizens in a global, fragile and changing world [34].

The STEMkey Erasmus+ project "Teaching Standard STEM Topics with a Key Approach to Competence" develops training modules that are used in higher education programs for future STEM teachers, which transforms the learning abilities of future STEM teachers [35].

A large number of international scientific and practical conferences (Conference of Space Research Educators, STEM Annual Educational Conference, California STEAM Symposium, STEM Solutions Conference) confirms the relevance of STEM technologies in education and the interest of the scientific community in these innovative issues.

In Communal Higher Educational Establishment "Kherson Academy of Continuing Education" of Kherson Regional Council there is an extending experience in teachers' trainings in STEM education [36].

3. Problem setting

Education reforms in the field of science, technology, engineering and mathematics (STEM) are especially important for the competitiveness of Ukraine and other countries of the world.

In modern conditions of technology development, the issues of practical implementation of STEM approaches in education are relevant, in particular, the problem of the development of an information educational environment is one of the key ones.

The object of the research is the model of introduction of STEM education in institutions of general secondary education.

The subject of research is the information and communication technologies in the model of introduction of STEM education in institutions of general secondary education as a component of the school educational environment.

The purpose of the article is to build a model for the introduction of STEM education in institutions of general secondary education, to demonstrate the experience of using ICT in STEM education.

Research tasks:

- to analyze the main features and benefits of STEM education;
- to build a model for the introduction of STEM education in institutions of general secondary education;
- to determine the role and place of information and communication technologies in the model of introduction of STEM education in institutions of general secondary education for the formation of key competencies;

- to find innovative solutions to create conditions that will promote the interest of student youth in the choice of STEM professions;
- to demonstrate the experience of using ICT in STEM education in the practice of modern educational institutions, to summarize the obtained data and provide conclusions.

4. Model for the introduction of STEM education in institutions of general secondary education

The main conditions for the development of STEM education in secondary school are:

- development of values to achieve a common goal;
- team and leaders;
- STEM education model;
- STEM education development plan;
- learning and gaining new experience;
- expanding the circle of like-minded people and presenting the results.

The model for the Introduction of STEM Education in Institutions of General Secondary Education is presented in in figure 2.

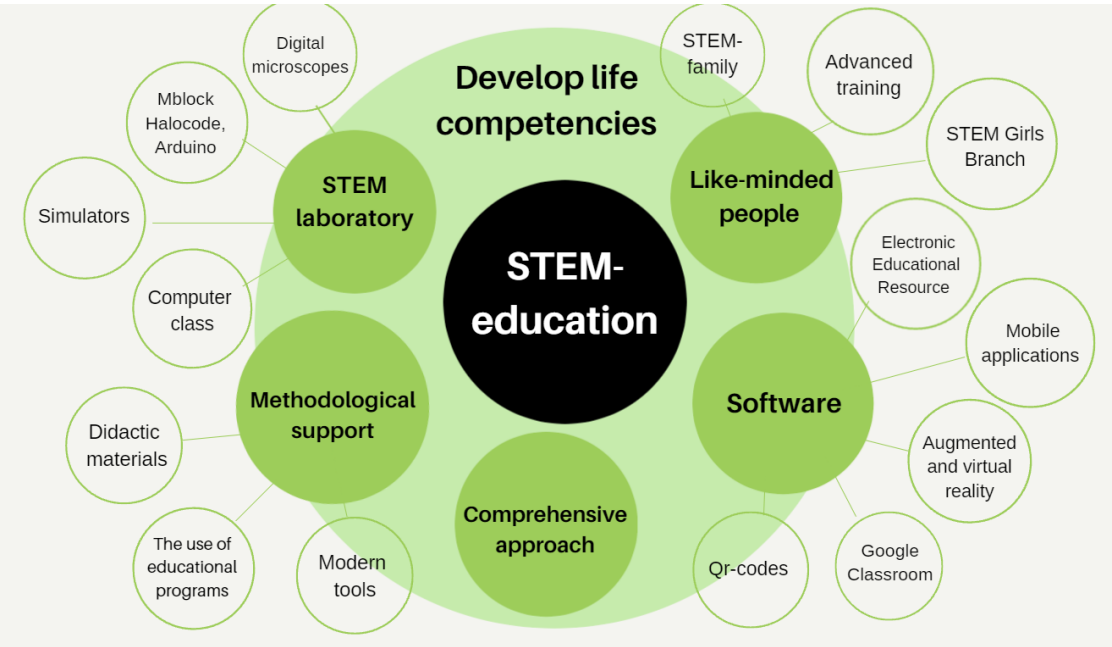

Figure 2: The model for the introduction of STEM education in institutions of general secondary education.

For the systematic implementation of STEM education in the institution it is necessary to: study the approaches and features of modern STEM education; introduce a policy of transformation of the institution with STEM; develop a strategy and implementation plan; determine resource provision and indicators.

The purpose of introducing STEM into the educational process: the formation of key competencies of students.

One of the most important components of the model for the introduction of STEM education in general education institutions of secondary education is the formation of a circle of like-minded people among the administration, teachers, students and their parents, including through joining the STEM Girls communities, the formation of a STEM family, professional development of teachers (participation in webinars, trainings, contests, olympiads).

Information and communication technologies act in STEM education both as a subject of study and as a means of teaching. Therefore, the creation of a unified information and educational environment that ensures the management of the educational process, the exchange of ideas and thoughts, and joint work on projects is a prerequisite for the implementation of STEM in an educational institution.

Such an environment includes:

- STEM laboratories with appropriate equipment (computers, tablets, electron microscopes, 3D printers, robotic constructors and platforms, etc.);
- software (distance learning systems, mobile applications, augmented and virtual reality applications, e-learning resources, cloud environments, etc.);
- methodological support (methods, forms, teaching aids: textbooks, manuals, didactic materials, etc.).

Changes should take place in all areas of activity of the educational institution: creation of infrastructure; content and assessment of student achievement; teacher training; ensuring continuous monitoring [37].

5. Practic ICT and current trends in education

In the conditions dictated by modernity, it is necessary to “keep an eye on the pulse” of new technologies. The development of society, science and technology puts the education system in front of the need to use new tools, forms and methods of teaching. The modern world dictates new rules that require students: critical thinking, communication, creativity and teamwork. Departure from old projects in the form of printouts to improvements, modern multimedia projects, ready-made products that students do themselves.

Students in the classroom should be able to implement the idea with further refinement and improvement. Proceed from the framework of standard and established concepts and show creativity. Teachers need to prepare children not just for monitoring, not for performance, but for a successful future.

The test for many was distance learning, which forced them to quickly adapt to work in the digital world. Teachers also faced the issue of distance work on an individual trajectory, finding tools to become distant assistants to students, support the learning process and increase motivation to work.

Information and communication technologies have radically transformed the educational space, qualitatively changed the environment, opened new opportunities and became a basic system forming factor in the development of education. Smartphones are simply indispensable

assistants in learning. And it's not just the use of e-classrooms through applications (such as Classroom, Universe, Matific), but also a lot of creative opportunities. It's no secret that the use of Qr-codes, augmented and virtual reality is now becoming popular. At the time of available technologies, it is not difficult to master and use them. Qr-code has firmly taken its place in education. The practice of use is also in new textbooks, notebooks, including the publishing house "Ranok", which provide electronic support and place access to electronic simulators near the test papers (the student has several attempts and the opportunity to download or send the result to the teacher).

Augmented reality technology promises to be no less common in education. It is becoming very popular nowadays, and we are showing more and more interest in it. Encyclopedias, fairy tales, and educational literature already contain "hidden worlds". Mobile applications are happy with the variety [38]. Augmented Reality (AR) technologies are able to project digital information (images, videos, text, graphics) outside the screens of devices and combine virtual objects with the real environment [39]. Virtual Reality (VR) with the help of a 360° image transports a person to an artificial world, where the environment is completely changed [40]. You can get acquainted with augmented reality with just a smartphone, but to dive into the virtual space you will need a special helmet or goggles [41].

These immersive teaching methods can potentially become a key tool in education and revolutionize the learning of both schoolchildren and students. Teachers can use virtual and augmented reality for students to interact with different objects in three-dimensional space [42].

Importantly, the introduction of elements of STEM education helps to form the following competencies: information, lifelong learning, initiative and entrepreneurship, social and civic, mathematical, information-digital and basic competencies in science and technology.

Unfortunately, some teachers are still apprehensive about adopting STEM approaches in education to their own arsenal. There are certain fears, "myths" and stereotypes. It is necessary to start attracting new educational trends with the "education" of the leadership in this matter, the involvement of activists. Get acquainted with the experience of implementation practitioners, analyze and choose your own implementation model.

6. Experience of STEM implementation in school

The path to STEM education at Rakivskiy institution of complete secondary education began with a combination of information technology, mathematics and art. Thanks to the knowledge and skills acquired through self-education and refresher courses, teachers introduce students to new trends in education: qr-code, cloud services, e-testing, learn to create e-textbooks and deepen their knowledge in STEM.

To deepen their skills, engage students in IT, and prepare for success, they have been trained and instructed in the Cisco Sandbox. The Network Academy not only gives a start to successful IT specialists, but also prepares conscious users, for whom, in our opinion, the future of STEM education.

The model of realization of STEM education became the own "formula of success", which helps to encourage students to independent and creative activity, provides attraction of "atypical"

forms of work.

Modern tools: online tests, online Olympiads (“Na Urok”, “Vseosvita”, interactive school “Ranok”), Google applications, Microsoft Education opportunities, platforms “Matific”, “My Class” and others help to motivate, raise interest in students, consolidate time in class and are excellent helpers for teachers in preparing for class. Implementation practice includes not only the use of modern educational learning platforms during classes, but also the use of: mobile applications, augmented and virtual reality, makering and design.

The use of educational programs, opportunities for virtual learning space, classes in the sandbox of the Cisco Network Academy (IoT and Cybersecurity course) enhances the prestige of rural schools, allows to take into account the eco-component, financial literacy and to use a gamified approach to learning.

Work on the implementation of ICT in Rakivskiy institution of complete secondary education began in 2018 with a pilot project of using the Electronic Educational Resource “MyClass” [43]. Rakivskyi institution is one of the 100 schools in Ukraine that have started implementing this resource. The resource has in reserve most of the school subjects, designed not only for work in the classroom, but also at home, monitoring, activity tracking and an interesting system of TOPs. The percentage of students involved on the platform exceeds 60%. Students actively work on the platform, compete with each other, organize competitions between classes, in addition to grades, they also have the opportunity to receive awards (“MyClass” diplomas for first places in the TOPs). It is nice that parents and teachers are also interested in the resource. As a result, the leading 3rd place among users-institutions of the Kherson region.

A year later, the school’s mathematics teachers began to actively use platforms such as Geogebra (for students in grades 7–11) and Matific (for students in grades 5–6, a digital math platform developed by education experts) to help implement practical application of knowledge in an interesting and cognitive form (figure 3).

GeoGebra is more than just a free dynamic geometric environment [44, 45]. The use of this tool makes complex drawings interesting and clear, “dry” mathematical processes – turns into almost scientific work. Especially children like working with 3D scenes, the ability to “explore” objects in full, for example, working with applications in geometry lessons, when studying geometric bodies and constructing their cross sections. A rather complex topic becomes more accessible, it saves time for understanding and helps in application, acquisition of skills. The processes are no longer boring, and children are given the opportunity to put into practice the acquired knowledge.

The Matific training platform, recommended by the Ministry of Education and Science of Ukraine, provides for three ways of use: assignment of tasks and tracking of successes; individual topics; use of planned tasks. The system allows you to work not only with interesting, interactive tasks, but also to move your own learning trajectory, gives the opportunity to compete in the “Arena” with classmates from around the world in mathematical dexterity. It has a good system of motivation, so students not only work on lessons, do homework (15–20 minutes), but also conquer bonus missions, find time for additional work, which brings success that is very pleasing.

Matific uses game principles to encourage students to learn through discovery, and has tools for teachers, including worksheets, lesson plans, and real-time reporting. The program is available not only online but also offline. The system works in a browser and can also be

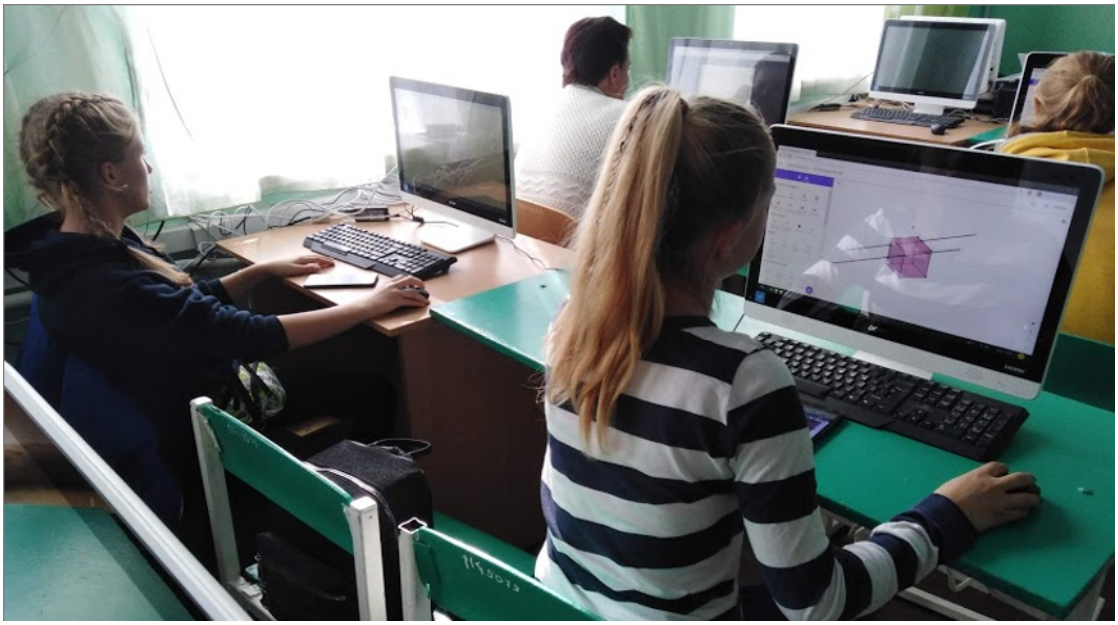

Figure 3: Using the GeoGebra environment to build models in geometry lessons.

downloaded as a mobile application (separate versions for teacher and student). It is possible to update the database to receive tasks and send results. Children like this form of activity, they are actively involved in the opportunity to work with the platform (in lessons and homework). The institution uses a platform for students of 2nd, 3rd, 5th and 6th grades. Matific provides an exciting opportunity to learn mathematical concepts that previously frightened and "disobeyed". It's fun, rewarding and open to all students (figure 4).

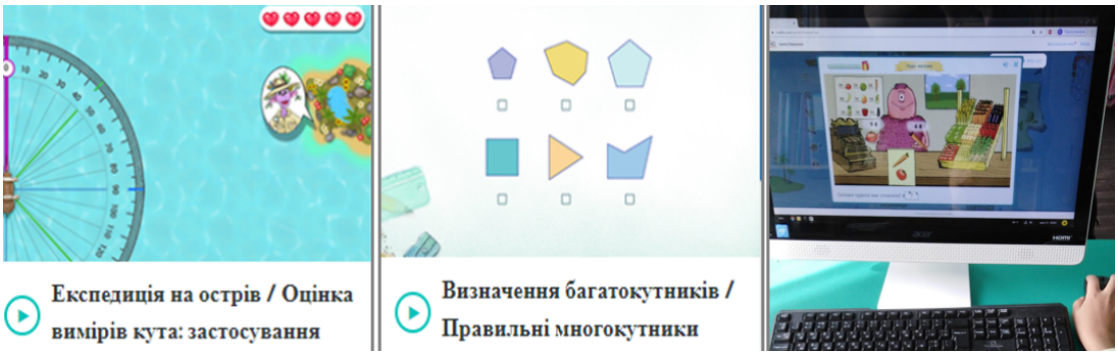

Figure 4: Using the Matific environment in Math lessons.

In addition to mastering learning platforms, the possibilities of QR codes are used: setting up access to students' electronic classrooms, for registration for quests, courses, etc., placement of schedules, applications, instructions and assessment of tasks. Such an organization is convenient and practical for both students and teachers (figure 5).

Figure 5: Using the QR codes in learning materials.

An additional motivation is the attractiveness of color and shape and the use of link abbreviations (which make it possible to monitor the work with codes). Students have quick access to learning materials and do not spend time searching and entering long links.

The use of Google Classroom allows you to organize activities in offices, set up joint activities [46], and is a tool for extracurricular activities, such as web investments. Google Classroom can combine several tools in one activity. For example, the Da Vinci Footprints website provides an opportunity to learn about machines of a well-known kind, offer augmented reality research (augmented reality supplement for Da Vinci Machines AR), travel the Internet, and present a real test of the invention, the Challenge of Creation [47].

The Google Classroom provides a wide range of related tools and extensions that automate routine operations, help diversify, and support the learning process.

An important aspect of the implementation of STEM education is the continuous professional development of teachers. Thus, teachers mastered the course on the secrets of distance learning "NonStop Education" 2.0 and Pitch "Immersion" in STEM at the Kherson Academy of Continuing Education. Workshops on the use of web tools in distance and blended learning and a course on immersive technologies were also useful.

Augmented and virtual reality applications play an important role in education. Augmented reality makes it possible to interact with the subject, to explore the properties that are useful not only in the study of mathematics (spatial figures), but also in the study of biology (cell structure, the structure of the human body).

Quiver – 3D Coloring App allows you to "revive" the child's colored coloring pages. The database contains images of plant and animal cells, maps, images of sea creatures, volcanoes that can be used in educational training. The appendix also contains materials useful for mathematicians: Platonic solids and materials for the study of magic numbers [48]. Quiver – 3D Coloring App is used in lessons I Explore the World (New Ukrainian School) and in extracurricular activities (figure 6).

A digital microscope is used to carry out research in STEM projects. The eyepiece through

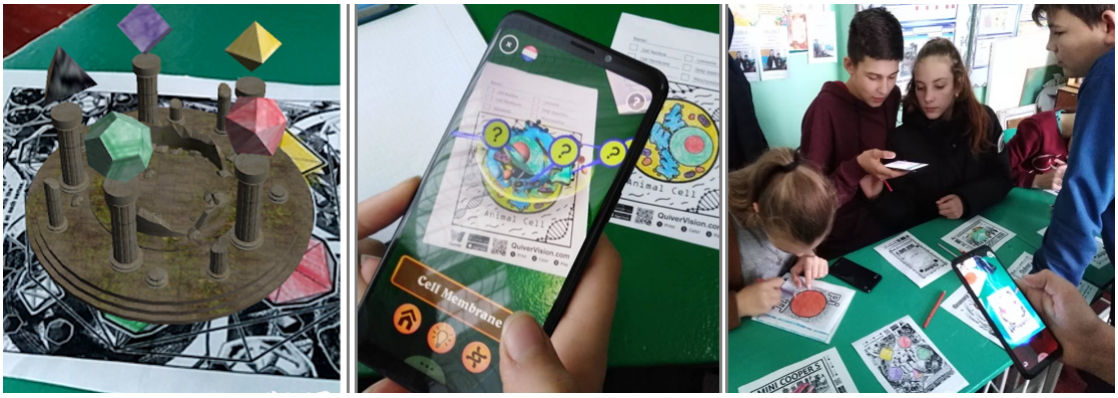

Figure 6: Using augmented reality applications.

which the object is observed has been replaced by a digital camera. Objects of natural origin are used for research; objects man-made; objects are studied, compared and their properties are distinguished. The studied objects are displayed on a personal computer monitor or on a projection screen, which allows you to perform research in group work, developing skills of teamwork. Digital microscopes can be used at different stages and types of lessons. Students have increased motivation and cognitive activity. Photos and videos taken during the work are used for editing videos, creating educational projects in computer science lessons (figure 7).

Figure 7: Using a digital microscope in STEM projects.

Cisco sandbox classes are conducted under the guidance of an instructor. The Cisco Networking Academy provides access to computer science courses for teachers and students. Thanks to the capabilities provided by Cisco, students can work without special equipment.

The All-Ukrainian action “STEM Spring 2020” provides access to courses of different levels of difficulty: from a beginner who works with ready-made devices, to a user who is able to model physical space, program IoT work and is interested in competitions. Packet Tracer simulator can be downloaded from the website. Students learn to model smart devices, program, create models of houses, rooms, etc.

Involvement in All-Ukrainian activities, in particular the marathon “Girls power tech” and the master class “ANYONE CAN CODE”, which gives an opportunity not only to study interestingly, acquire useful skills, but also to receive awards of success, plays an important role in strengthening students’ motivation for STEM technologies (stylish certificates, digital badges, valuable gifts).

Students are involved in learning the basics of programming through the use of wireless single-board computer Makeblock HaloCode, which the institution received as a result of winning the ideas of Hackathon 2019. Makeblock HaloCode is a single-board computer with built-in Wi-Fi for programming (includes a wide range of electronic modules). HaloCode offers a variety of features for working with AI & IoT applications with a few mouse clicks; it makes learning programming easy, fun and interesting. HaloCode allows you to use IoT applications and create simple, home devices. Provides access to the microphone module and support for Microsoft Cognitive Services. Sensors allow the use of HaloCode for the implementation of STEM projects [49].

Since 2020s, the direction of robotics has developed. Students use Makeblock and Arduino technologies in integrated stem projects, studying physical laws, programming, mathematics [50].

The use of the above-mentioned tools is good in combination, most of them are not limited to a specific subject or cycle of lessons. The success of STEM education lies in a comprehensive approach. However, ICTs are an important catalyst for the effective implementation of STEM education.

Analysis of the results of the implementation of STEM technologies for 3 years allows to identify an increase in performance and motivation to learn. The use of ICT helped to involve students in active work and mastering the subjects of the natural-mathematical cycle. Thanks to the method of blended learning, the “flipped classroom”, which began to be implemented from the 201-8-2019 school year, the students of the institution were ready to work under quarantine restrictions. Educational platforms, remote classes such as google classroom and webinar rooms were common-place. The only obstacles were limited access to quality internet coverage and difficult technical conditions in some families due to financial constraints. Indicators show that the use of ICT in the classroom helps to increase the level of academic achievement in distance and blended learning. For example, we offer monitoring of educational activities in mathematics (table 1, figure 8).

The result of active work with STEM directly is the victory in the competitions “Na Urok”, “Vseosvita”, “Kangaroo”, the diploma of the most active STEM Girls Branch 2020.

As part of the cooperation, the official status of the STEM Girls Branch was confirmed, and a Cooperation Agreement was signed with the Center for the Development of Corporate Social Responsibility – STEM Girls Community to strengthen and develop educational and scientific activities, including for further development and implementation of STEM education in Ukraine; Cisco Academy opened in the institution; the strategic plan of the Rakivskiy institution for the

Table 1
Monitoring the quality of mathematics studies in the institution.

Level	2017–2018	2018–2019	2019–2020	2020–2021
Initial	15%	15%	14%	14%
Average	62%	57%	49%	46%
Sufficient	23%	23%	35%	36%
High	0%	5%	3%	5%
Quality of knowledge	23%	28%	38%	41%

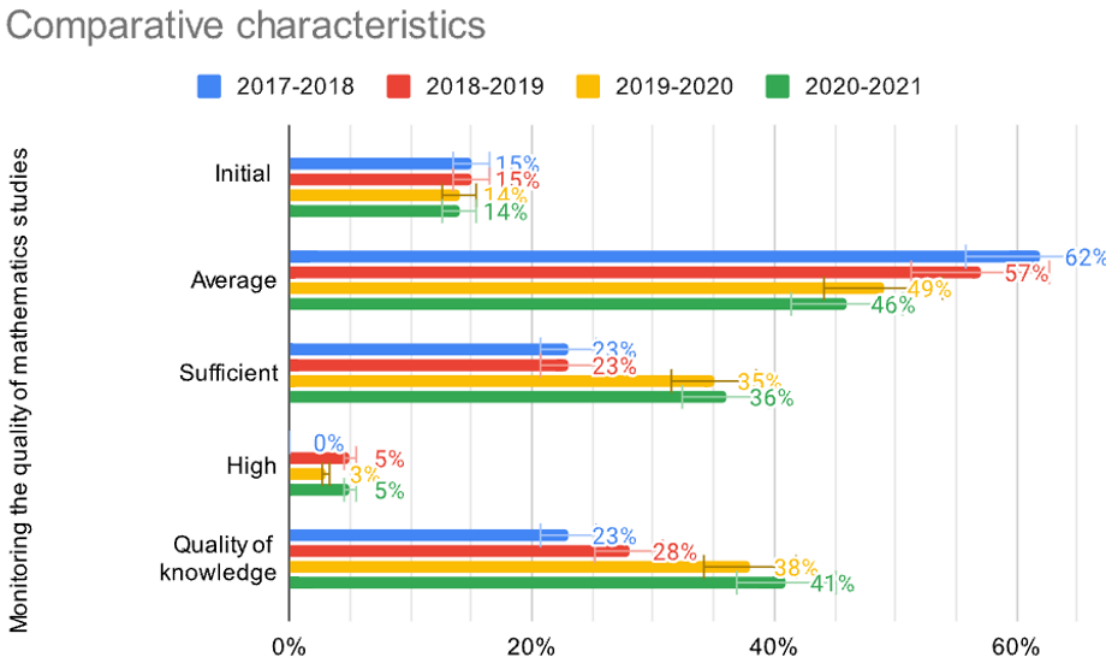

Figure 8: Monitoring the quality of mathematics studies in the institution.

next years is created.

An important condition for the implementation of STEM education is the presence of a team. The activity of a team of like-minded people allows you to find funding, develop and develop. To spread the experience, it is necessary to constantly cover the work on the site of the institution, to keep a blog so that the community monitors the success of the institution. It is necessary to promote STEM education, make it attractive for students and parents, overcome stereotypes and attract as large an audience as possible. Therefore, the institution: created its own YouTube channel; the page of the STEM family of the institution was published on Facebook; published the page of the STEM Girls Branch in social networks Facebook, Instagram (rakivkastream) and Tik-Tok (@girls_stem).

7. Conclusions and outlook

To prepare a successful graduate, it is necessary to develop life competencies, and the main conditions for their development are the formation of reading, mathematics and competence in the natural sciences. We consider it important to form a STEM family, which unites a community of teachers, children and their parents, helps to implement the idea of holding STEM weekend, STEM camps during the holidays, which includes involving all participants in the educational process in active STEM activities. Disclosure of the benefits of STEM and the destruction of gender stereotypes can enhance career guidance for choosing STEM professions.

For the effective implementation of STEM education it is necessary: development of scientific and methodological support and introduction of modern teaching aids; training and advanced training of scientific and pedagogical workers; expansion of the network of regional STEM centers; conducting scientific and applied research; analysis of the dynamics of STEM education development, identification of problems and forecasting of further tendencies of STEM education directions implementation [4].

References

[1] Institute for Modernization of Educational Content, Stem education, 2018. URL: https://imzo.gov.ua/stem-osvita/.

[2] S. Chamrat, The Definition of STEM and Key Features of STEM Education Learning Activity, STOU Education Journal 10 (2017). URL: https://so05.tci-thaijo.org/index.php/edjour_stou/article/view/123452.

[3] M. Lynch, 7 benefits of STEM education, 2019. URL: https://www.theedadvocate.org/7-benefits-of-stem-education/.

[4] Methodical recommendations for the development of STEM-education in general secondary and out-of-school education institutions in the 2020/2021 academic year, 2020. URL: https://drive.google.com/file/d/1qxDeN7-bycJXSBKTRqvBnO9Xuc5TFSgs/view?usp=sharing.

[5] L. G. Catterall, A brief history of STEM and STEAM from an inadvertent insider, The STEAM Journal 3 (2017) 5. URL: https://scholarship.claremont.edu/steam/vol3/iss1/5/. doi:10.5642/steam.20170301.05.

[6] Widya, R. Rifandi, Y. L. Rahmi, STEM education to fulfil the 21st century demand: a literature review, Journal of Physics: Conference Series 1317 (2019) 012208. doi:10.1088/1742-6596/1317/1/012208.

[7] A. S. Gencer, H. Doğan, K. Bılen, B. Can, Integrated STEM education models, Pamukkale Üniversitesi Eğitim Fakültesi Dergisi (PAU Journal of Education) 45 (2019) 38–55. URL: http://acikerisim.pau.edu.tr/xmlui/bitstream/handle/11499/32559/bilge%20can.pdf. doi:10.9779/PUJE.2018.221.

[8] Y. Li, Q. Zhang, W. Feng, H. Kang, Z. Bao, S. Wang, Educational model and practice of STEM education+creator, Educational Sciences: Theory & Practice 18 (2018) 2932–2940. doi:10.12738/estp.2018.6.192.

[9] T. H. Kramarenko, O. S. Pylypenko, V. I. Zaselskiy, Prospects of using the augmented

reality application in STEM-based mathematics teaching, CEUR Workshop Proceedings 2547 (2020) 130–144.
[10] L. Y. Midak, I. V. Kravets, O. V. Kuzyshyn, L. V. Baziuk, K. V. Buzhdyhan, J. D. Pahomov, Augmented reality as a part of STEM lessons, Journal of Physics: Conference Series 1946 (2021) 012009. doi:10.1088/1742-6596/1946/1/012009.
[11] S. O. Semerikov, M. M. Mintii, I. S. Mintii, Review of the course "Development of Virtual and Augmented Reality Software" for STEM teachers: implementation results and improvement potentials, CEUR Workshop Proceedings 2898 (2021) 159–177. URL: http://ceur-ws.org/Vol-2898/paper09.pdf.
[12] Y. B. Shapovalov, Z. I. Bilyk, A. I. Atamas, V. B. Shapovalov, A. D. Uchitel, The potential of using Google Expeditions and Google Lens tools under STEM-education in Ukraine, CEUR Workshop Proceedings 2257 (2018) 66–74.
[13] Y. B. Shapovalov, V. B. Shapovalov, V. I. Zaselskiy, TODOS as digital science-support environment to provide STEM-education, CEUR Workshop Proceedings 2433 (2019) 232–245.
[14] Y. B. Shapovalov, V. B. Shapovalov, F. Andruszkiewicz, N. P. Volkova, Analyzing of main trends of STEM education in Ukraine using stemua.science statistics, CEUR Workshop Proceedings 2643 (2020) 448–461.
[15] Y. B. Shapovalov, Z. I. Bilyk, S. A. Usenko, V. B. Shapovalov, K. H. Postova, S. O. Zhadan, P. D. Antonenko, Using of personal smart tools in STEM education, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[16] M. P. Shyshkina, The problems of personnel training for STEM education in the modern innovative learning and research environment, CEUR Workshop Proceedings 2257 (2018) 61–65.
[17] I. A. Slipukhina, A. P. Polishchuk, S. M. Mieniailov, O. P. Opolonets, T. V. Soloviov, Methodology of M. Montessori as the basis of early formation of STEM skills of pupils, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[18] N. I. Polikhun, K. G. Postova, I. A. Slipukhina, G. V. Onopchenko, O. V. Onopchenko, Implementation of STEM-education in terms of integration of formal and informal education of gifted students: guidelines, Institute of Gifted Children of the National Academy of Pedagogical Sciences of Ukraine, Kyiv, 2019.
[19] V. Sharko, Modernization of training system of STEM-courses of study as the methodical problem, Naukovi zapysky [Kirovohradskoho derzhavnoho pedahohichnoho universytetu imeni Volodymyra Vynnychenka]. Seriia: Problemy metodyky fizyko-matematychnoi i tekhnolohichnoi osvity 10 (2016) 160–165. URL: http://nbuv.gov.ua/UJRN/nz_pmfm_2016_10%283%29__37.
[20] N. V. Morze, M. A. Gladun, S. M. Dziuba, Formation of key and subject competences of students by robotic kits of STEM-education, Information Technologies and Learning Tools 65 (2018) 37–52. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/2041. doi:10.33407/itlt.v65i3.2041.
[21] E. H. Fedorenko, V. Y. Velychko, A. V. Stopkin, A. V. Chorna, V. N. Soloviev, Informatization

of education as a pledge of the existence and development of a modern higher education, CEUR Workshop Proceedings 2433 (2019) 20–32.
[22] O. M. Hlushak, V. V. Proshkin, O. S. Lytvyn, Using the e-learning course "Analytic Geometry" in the process of training students majoring in Computer Science and Information Technology, CEUR Workshop Proceedings 2433 (2019) 472–485.
[23] N. V. Morze, V. O. Kucherovska, Ways to design a digital educational environment for K-12 education, CEUR Workshop Proceedings 2879 (2020) 200–211.
[24] N. V. Morze, O. V. Strutynska, Digital transformation in society: key aspects for model development, Journal of Physics: Conference Series 1946 (2021) 012021. doi:10.1088/1742-6596/1946/1/012021.
[25] N. V. Morze, O. V. Strutynska, Model of the competences in educational robotics, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[26] N. Morze, O. Kuzminska, G. Protsenko, Public information environment of a modern university, CEUR Workshop Proceedings 1000 (2013) 264–272.
[27] N. Morze, L. Varchenko-Trotsenko, T. Terletska, E. Smyrnova-Trybulska, Implementation of adaptive learning at higher education institutions by means of Moodle LMS, Journal of Physics: Conference Series 1840 (2021) 012062. doi:10.1088/1742-6596/1840/1/012062.
[28] Y. Ramsky, O. Rezina, Study of Information Search Systems of the Internet, in: R. T. Mittermeir (Ed.), From Computer Literacy to Informatics Fundamentals, Springer Berlin Heidelberg, Berlin, Heidelberg, 2005, pp. 84–91. doi:10.1007/978-3-540-31958-0_11.
[29] S. O. Semerikov, A. M. Striuk, T. A. Vakaliuk, A. V. Morozov, Quantum information technology on the Edge, CEUR Workshop Proceedings 2850 (2021) 1–15. URL: http://ceur-ws.org/Vol-2850/paper0.pdf.
[30] S. O. Semerikov, I. O. Teplytskyi, V. N. Soloviev, V. A. Hamaniuk, N. S. Ponomareva, O. H. Kolgatin, L. S. Kolgatina, T. V. Byelyavtseva, S. M. Amelina, R. O. Tarasenko, Methodic quest: Reinventing the system, Journal of Physics: Conference Series 1840 (2021) 012036. doi:10.1088/1742-6596/1840/1/012036.
[31] O. Spirin, V. Oleksiuk, N. Balyk, S. Lytvynova, S. Sydorenko, The blended methodology of learning computer networks: Cloud-based approach, CEUR Workshop Proceedings 2393 (2019) 68–80.
[32] O. M. Spirin, K. R. Kolos, O. A. Kovalchuk, O. O. Demianchuk, F. M. Zhuravlev, Build a technology for mass organization of distance learning for pupils in quarantine, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[33] ISEE, The role of SELFIE in the Erasmus+ project 'STEM in Education', 2019. URL: http://web.archive.org/web/20201117104149/https://ec.europa.eu/education/schools-go-digital/selfie_news/the-role-of-selfie-in-the-erasmus-project-stem-in-education_en.
[34] Inclusive STEM Education to Enhance the capacity to aspire and imagine future careers, 2016. URL: https://iseeproject.eu/.
[35] New Erasmus+ Project STEMkey, 2020. URL: https://icse.eu/

new-erasmus-project-stemkey/.
[36] N. Kushnir, N. Valko, N. Osipova, T. Bazanova, Model of organization of the university ecosystem for the development of STEM-education, Journal of Information Technologies in Education (ITE) (2018) 77092. URL: http://ite.kspu.edu/index.php/ite/article/view/15.
[37] N. Morze, STEM: problems and prospects, 2016. URL: https://www.slideshare.net/ippo-kubg/stem-65590054.
[38] S. L. Malchenko, M. S. Tsarynnyk, V. S. Poliarenko, N. A. Berezovska-Savchuk, S. Liu, Mobile technologies providing educational activity during classes, Journal of Physics: Conference Series 1946 (2021) 012010. doi:10.1088/1742-6596/1946/1/012010.
[39] N. V. Rashevska, V. N. Soloviev, Augmented reality and the prospects for applying its in the training of future engineers, CEUR Workshop Proceedings 2257 (2018) 192–197.
[40] I. V. Barkatov, V. S. Farafonov, V. O. Tiurin, S. S. Honcharuk, A. A. Lozko, V. V. Marushchenko, K. V. Korytchenko, V. I. Barkatov, R. F. Muravlyov, 360° photographic panoramas as an effective multifunctional aid for teaching technology subjects, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[41] N. Osipova, H. Kravtsov, O. Hniedkova, T. Lishchuk, K. Davidenko, Technologies of virtual and augmented reality for high education and secondary school, CEUR Workshop Proceedings 2393 (2019) 121–131. URL: http://ceur-ws.org/Vol-2393/paper_258.pdf.
[42] N. Osypova, O. Kokhanovska, G. Yuzbasheva, H. Kravtsov, Augmented and virtual reality technologies in teacher retraining, CEUR Workshop Proceedings 2732 (2020) 1203–1216. URL: http://ceur-ws.org/Vol-2732/20201203.pdf.
[43] MiiKlas, 2021. URL: https://miyklas.com.ua.
[44] M. G. Drushlyak, O. V. Semenikhina, V. V. Proshkin, S. Y. Kharchenko, T. D. Lukashova, Methodology of formation of modeling skills based on a constructive approach (on the example of GeoGebra), CEUR Workshop Proceedings 2879 (2020) 458–472.
[45] T. H. Kramarenko, O. S. Pylypenko, I. O. Muzyka, Application of GeoGebra in Stereometry teaching, CEUR Workshop Proceedings 2643 (2020) 705–718.
[46] O. V. Bondarenko, S. V. Mantulenko, A. V. Pikilnyak, Google Classroom as a tool of support of blended learning for geography students, CEUR Workshop Proceedings 2257 (2018) 182–191.
[47] N. Lukichova, #DaVinci's footsteps, 2020. URL: https://naurok.com.ua/stem-vesna-ideya-davinci-s-footsteps-kvest-slidami-da-vinchi-167765.html.
[48] The best augmented reality applications for student research, 2020. URL: http://teach-hub.com/dodatky-dopovnenoji-realnosti/.
[49] HaloCode – Wireless Single Board Computer, 2022. URL: https://www.makeblock.com/steam-kits/halocode.
[50] N. Morze, Educational robotics as a promising area of STEM education, Open educational e-environment of modern university 5 (2018) 178–187. URL: http://nbuv.gov.ua/UJRN/oeeemu_2018_5_22.

Complex systems and physics education

Andrii O. Bielinskyi[1], Arnold E. Kiv[2], Yuliya O. Prikhozha[1], Mykola A. Slusarenko[1] and Vladimir N. Soloviev[1]

[1]Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine
[2]Ben-Gurion University of the Negev, P.O.B. 653, Beer Sheva, 8410501, Israel

Abstract

Synergetics as a scientific area of research is in demand by society. The context of synergetics makes it possible for scientists of different specializations to interact fruitfully in the language of systematic understanding and search for new solutions. The presented work raises the question of how the theory of self-organization can help in the reformation of the higher education system, why this is relevant, and what can lead to the training of both teachers and students within the framework of an interdisciplinary approach. In the future, we will highlight the most important characteristics of complex systems and the simplest and at the same time conceptually simplest methods for analyzing complexity. As part of the complex systems modeling course, which will first be presented to students of physics and mathematics, and then, possibly, to students of other specialties, we present signals of seismic activity, gravitational waves and magnetic activity, and demonstrate how we can identify critical or crash phenomena in such systems. This kind of analysis can serve as a good basis for the formation of professional skills and universal competencies.

Keywords

synergetics, complex systems, non-equilibrium, self-organization, interdisciplinarity

1. Introduction

In 2021, Syukuro Manabe, Klaus Hasselmann, and Giorgio Parisi were awarded the Nobel Prize in Physics "*for groundbreaking contributions to our understanding of complex physical systems*" [1]. That is a sign that the study of complex systems is of paramount importance. Nevertheless, we need to deal with the problems of their implementation in the educational process.

The education system in the world today is in a state of crisis. This is evidenced by the following trends: a further increase in the number of illiterate people in the world; the widespread decline in the quality of education; the growing gap between education and culture, education and science; alienation of the student from the educational process.

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krivogame@gmail.com (A. O. Bielinskyi); kiv.arnold20@gmail.com (A. E. Kiv); prihozhaya.yuliya93@gmail.com (Y. O. Prikhozha); nick03069719@gmail.com (M. A. Slusarenko); vnsoloviev2016@gmail.com (V. N. Soloviev)
https://www.researchgate.net/profile/Andrii-Bielinskyi (A. O. Bielinskyi); https://ieeexplore.ieee.org/author/38339185000 (A. E. Kiv); https://kdpu.edu.ua/personal/prihozhaya.html (Y. O. Prikhozha); https://kdpu.edu.ua/personal/masliusarenko.html (M. A. Slusarenko); https://kdpu.edu.ua/personal/vmsoloviov.html (V. N. Soloviev)
0000-0002-2821-2895 (A. O. Bielinskyi); 0000-0002-0991-2343 (A. E. Kiv); 000-0002-0259-1516 (Y. O. Prikhozha); 0000-0003-0288-5482 (M. A. Slusarenko); 0000-0002-4945-202X (V. N. Soloviev)
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This situation in the world at the present stage makes the problem of finding a new paradigm of education urgent, since the possibility of sustainable development of society, successful overcoming of global problems, regional and national conflicts characteristic of the present time of the development of civilization is closely related to the achieved level of education of all members of society [2]. But the education system is always based on a certain scientific understanding of the world and man, which determines the goals and objectives of education, its content, principles and methods.

The heyday of education in the XVII-XVIII centuries, which happened through the development and spread of classical mechanics of the New Time, led to the determination of the picture of the world, where the studied elements are unchangeable, and the laws of classical mechanics are universal and apply to all types of motion of matter.

In such a world there was no place for chance, and irreversibility and probability were usually associated with the incompleteness of knowledge. In this case, each phenomenon has a cause and at the same time there is a cause of other phenomena. Cause and effect form a chain that comes from the past, permeates the present and disappears in the future. This meant that all the processes taking place in the world were predetermined and led to the search for initial elements, having discovered which, it is possible to accurately predict the future.

Therefore, such ideological and methodological principles as rationalism, determinism, mechanismism and reductionism began to dominate in scientific knowledge, which also had a decisive influence on the education system: on the forms of knowledge acquisition, presentation of material, organizational principles of education.

The discovery by synergetics of the processes of self-organization in inanimate nature clearly shows that the transition from disorder to order, accompanied by the emergence of self-organization and stable structures, the replacement of old structures with new ones occurs according to specific internal laws inherent in certain forms of the movement of matter. Ultimately, it is the qualitative and quantitative criteria of self-organization that characterize the level of complexity and perfection of the corresponding forms of movement [3]. Based on these ideas, it is possible to develop a classification of types, forms, properties of matter according to their degree of complexity, perfection of organization, and thereby the degree of development. In this regard, development itself appears as a very complex, self-organizing process of movement from simple to complex, from less organized and perfect to more organized and perfect. In other words, development, in contrast to the movement that characterizes any changes in general, acts as a directed change associated with the emergence of a new one.

The post-non-classical stage of the development of science shows that rigid determinism and reductionism, which serve as the basis of the mechanistic view of the world, cannot be considered as universal principles of scientific knowledge, since an extensive class of phenomena and processes does not fit into the framework of linear, equilibrium and reversible schemes. In the world around us, a very real irreversibility plays an essential role, which is the basis of the majority of self-organization processes. Reversibility and rigid determinism in the world are applicable only in simple limiting cases, and irreversibility and randomness should be considered not as an exception, but as a general rule.

To integrate the synergetics approach into the educational process, it is important to instill in students ways of setting and solving problems of being and developing complex systems in various spheres: economic, social, natural, etc. It is equally important, at the beginning of

studying the methods of studying complex systems, to instill in students at first or repeat with them the concepts of self-organization, chaos, destructive phenomena, to voice the difference between complex and complicated systems, etc.

Complex systems are a field of research that is now acquiring the characteristic features of a well-formed area of science with its own object, conceptual apparatus, and methods of analysis [4]. The concept of a complex system is gradually becoming one of the fundamental concepts of modern science, or, more broadly, it is increasingly appearing in a general cultural context. The expansion of the scope of application of this concept, as well as the identification and awareness of an increasing number of phenomena where it is applicable, causes difficulties in its exact definition. Although the science of complex systems covers a broad interdisciplinary field of research, the methods and concepts of physics (dynamical systems theory, quantum mechanics, statistical physics) are central to it.

So, the processes of self-organization in non-equilibrium conditions correspond to the dialectical interaction between chance and necessity, fluctuations and deterministic laws. Near bifurcations, the main role is played by chaos, randomness, while deterministic connections dominate in the intervals between bifurcations. The ways of development of self-organizing systems are not predetermined. Probability appears not as a product of our ignorance, but as an inevitable expression of chaos at the points of bifurcations. This means the end of the classical ideal of omniscience and creates the need to revise the principle of mechanical rationalism as the dominant scientific explanation of reality. The traditional education system, based on the principles of classical science, cannot effectively fulfill the role of a means of mastering the world by a person.

Hence, there is a need to integrate the principles and ideas of the complex systems paradigm in the sphere of education.

2. Analysis of previous studies

Analysis of scientific sources and publications shows that today there is an opinion that synergetics could provide significant assistance in the search for a new paradigm of education. A synergistic approach to understanding patterns operating in nature is associated with the names of Haken [5, 6, 7, 8], Haken and Schiepek [9], Nicolis and Prigogine [10], Prigogine and Stengers [11, 12], Prigogine [13, 14]. Some scientists believe that synergetics, as a theory of self-organization of complex systems, describes the general (common) that is in their development, education is a complex system, and therefore synergetics, which today is developed by various branches of scientific knowledge, necessarily becomes its new philosophy. However, despite the existence of a sufficient number of works devoted to the application of synergetics in various spheres of human activity, the methodological and practical context of synergetics in the philosophy of education remains insufficiently developed. This is especially true for applying a synergistic approach to understanding the higher education system.

When forming interdisciplinary specialists, a significant component may be the humanitarization of education [15]. It is humanitarization that is designed to provide an educational synthesis of humanitarian, technical and natural science disciplines based on multi-level integration of the entire complex of knowledge. The growing trend of all scientific knowledge,

which manifests itself in the transition from focusing on individual disciplines studied in the course of higher education, to strengthening interdisciplinary ties, requires qualitatively new approaches to the content of education and reorientation in teaching. Humanitarization and interdisciplinarity of education involve not only the intensive introduction of humanities disciplines into purely technical higher educational institutions, but also the enrichment of Natural Science and technical disciplines with material that reveals the struggle of scientific ideas, the human destinies of scientists-discoverers, the dependence of socio-economic and scientific progress on personal and moral qualities of a person, his creative abilities. In contrast to the traditional interdisciplinary approach in education, the goal is not only to provide knowledge, but also to teach to hear and understand colleagues working in different specialties, to develop skills of dialogue between specialists in different branches of scientific knowledge. The need for such a dialogue is becoming more and more palpable. Since the theoretical physicist Hermann Haken introduced this concept into scientific use [5], the world has been accumulating some experience in the use of synergetics and in the study of social and educational systems.

As Andrushchenko and Svyrydenko [16] notes, "... domestic scientific schools are not always ready to accept the success of other schools and directions, when traditionalism and conservatism enter the fight against innovation; threats of marginalization of carriers of foreign experience in the educational or scientific environment are actualized". These processes in their content, scientists believe, contradict the logic of scientific cooperation, the spirit of partnership and exchange of views, in which the long-term experience of the closed educational system, its focus on ensuring the ideological function of education plays an important role. The nonlinear complexity of methodological renewal, thanks to the creativity of creative processes, creates new horizons for the emerging future [17]. This idea is supported by Kremen and Illyin [18], noting that the principles and ideas of synergetics have significant heuristic and methodological potential. In this regard, scientists believe that a synergistic approach to education and upbringing can be the basic one for solving many problems in the field of education.

When using and teaching approaches that are part of the synergetics paradigm, as already noted, chaos seems to be the engine of change. From the point of view of synergetics, personality development appears as a constant movement from one state of the system to another, in which chaos, chance, creation/destruction, passage of bifurcation points, etc.are natural states of the system, successively replacing each other, building a continuous chain of transformations [19]. Research conducted in schools and universities shows that interactive chaotic environments are very productive for developing creative thinking. The results of work in this area were presented by Davis-Seaver et al. [20], who analyzed the learning process at three levels – from a single point of balance, statement of fact, statement of a single point of view to learning on the verge of chaos, when there are many points of view, when reasoning develops in different directions, when students listen to the opinions of others and on this basis develop their own judgments. The role of the teacher is not to spread knowledge and evaluate the correctness of judgments, but to monitor the progress of reasoning and transfer the learning process from one level to another. As a result, the understanding becomes deeper, more versatile, and the incentives for learning are largely created by the energy of the group, and not by the diligence of the teacher. In the context of revealing a person's creative abilities, a synergistic approach to education seeks not to eradicate chaos, but to find the relationship between order and disorder that would be most fruitful [21].

The above-mentioned concept of chaos from the point of view of synergetics loses its negative connotation. As Prigogine and Stengers [12] notes, instability can be a condition for stable and dynamic development. Only systems that are far from equilibrium are able to organize and evolve spontaneously. Thus, there is no development without instability. And if the system is strict against the implementation of new units, new units ('innovators') die". In higher education, self-organizing systems are the Student, Teacher, their interrelation, etc. [22].

Jacobson and Wilensky [23], Wilensky and Jacobson [24] emphasize different research issues that need to be explored. They present such principles in studying complex phenomena as

- experiencing complex systems phenomena;
- making the complex systems conceptual framework explicit [25];
- encouraging collaboration, discussion, and reflection; the design of environments for learning about complex systems needs to take advantage of lessons learned from the extensive research on pedagogy that foster collaboration, discussion, and reflection [26];
- constructing theories, models, and experiments;
- learning trajectories for deep understandings and explorations.

With a given appropriate conceptual and representational scaffolding in the learning environment, students should be able to tap into their everyday experiences and channel and enhance these experiences to construct understandings of complex systems that are cognitively robust. Nowadays, students should have more possibilities to explore world through computational modeling which progressive scientists use almost everyday.

Jackson [27] and other, such as Pagels [28], have observed how the use of computational tools in science allows dramatically enhanced capabilities to investigate complex and dynamical systems that otherwise could not be systematically investigated by scientists. These computational modeling approaches include cellular automata, network and agent-based modeling, neural networks, genetic algorithms, Monte Carlo simulations, and so on that are generally used in conjunction with scientific visualization techniques. Examples of complex systems that have been investigated with advanced computational modeling techniques include climate change [29], urban transportation models [30, 31, 32], and economics [33, 34, 35, 36]. New communities of scientific practice have also emerged in which computational modeling techniques, in particular agent-based models and genetic algorithms, are being used to create synthetic worlds such as artificial life [37, 38] and societies [39] that allow tremendous flexibility to explore theoretical and research questions in the physical, biological, and social sciences that would be difficult or impossible in "real" or nonsynthetic settings.

Methodology of nonlinear synthesis based on scientific principles evolution and co-evolution of complex structures of the world, can form the basis of futurological research, designing various ways of human development into the future [40]. As the environmental, economic, and political problems of humanity have become global, complex and nonlinear, traditional ideas about individual responsibility are becoming questionable. We need to study and teach new models of collective behavior that take into account the different degrees of our individual abilities and understanding of what is happening.

We believe that the study of the apparatus of physics, graph theory, and computer science is now of paramount importance for the further development of both our society and the entire universe.

In further we need to understand how to grow an interest of students in constructing and revising computational models with multi-agent or qualitative modeling software, and how model building activities may enhance student conduct of real world experiments related to the phenomena under consideration [41, 42, 43].

3. The most important properties of complex systems to be studied

Based on the previously described characteristics and the direction in which we should move, it becomes clear that synergetics (the theory of complex systems) is the foundation of almost any system. Including pedagogical. Although the initial direction of research within this paradigm was physical systems, the latest objects of research on various manifestations of complexity also appear in the context of business organization and economics. For example, Wheatley [44] suggests that we view organizations as being more like living organisms than machines. As such, we need to modify traditional views on controlling organizations. Wheatley [44] argues that organizations are dynamic, nonlinear networks of relationships and cannot be separated into parts while maintaining their essential identity.

In complex systems, it is worth highlighting that they are

- dynamic;
- non-equilibrium and have the potential to change suddenly and may take one path out of an infinite number of others (bifurcate);
- open systems, that is interchange energy (and information) with their surroundings;
- depended. What happens next depends on what happened previously;
- systems where the whole is more than the sum of its parts;
- causal and yet indeterminate;
- irreversible, since the interaction of parts together is transforming;
- multi-agent. They composed of a diversity of agents that interact with each other, mutually affect each other, and in so doing generate novel, emergent behavior for the system as a whole. The system is constantly adapting to the conditions around it and over time it evolves;
- co-evolving and move spontaneously towards the edge of chaos.

3.1. Time series data

In order to maintain students' interest in studying complex systems and their corresponding data analysis tools, programming languages, etc. [45, 46], it is important to select truly interesting and complex systems (series). It is equally important that the studied systems are within the framework of the specialty that students are guided by. However, since we strive for an interdisciplinary approach, the study, for example, by biologists of the corresponding nonlinear methods on the example of the same socio-economic series or physical ones can also be beneficial for general development.

Complexity theory is subdivided into hard and soft complexity. Hard complexity theory stands for analytical analysis that concern with the nature of reality, while soft complexity aims

to describe social and living systems. Davis and Sumara [47] proposes such term as "complexity thinking" which lies somewhere in between hard and soft skills. We support such idea and would like to promote it among ordinary citizens who are not specialists and, particularly, among universities and their student. Focusing on interdisciplinarity, both hard and soft skills, teachers and students will be more creative and productive in their further research. Knowing about interconnections across different disciplines, there are much more possibilities for collaborative research between different faculties and there is larger probability that people will be able to find common topics for communication and will be engaged to cooperate.

The goal of this work is to present the basic characteristics of complex systems, which should be introduced to students during the course of studying complex systems, and the basic sets of methods that allow analyzing the varying randomness (complexity) of the system during the development of the studied signals.

In this paper, we present some of the most fundamental, applied, robust, and powerful methods on the example of three physical signals: seismic (SEI), gravitational wave (GW), and the distribution storm time (Dst) index.

SEI dataset constructed by Bladford [48]. Each event has 2048 points fixed at a seismic recording station in Scandinavia.

We used GW data GW150914 from Events of LIGO Open Science Center and select strain data (H1 and L1) after noise subtraction [49] (https://www.ligo.org/detections/GW150914.php).

The Dst index is an index of magnetic activity derived from a network of nearequatorial geomagnetic observatories that measures the intensity of the globally symmetrical equatorial electrojet ("ring current"). Dst is maintained at National Centers for Environmental Information [50] from 1957 to the present. Dst equivalent equatorial magnetic disturbance indices are derived from hourly scalings of low-latitude horizontal magnetic variation. They show the effect of the globally symmetrical westward flowing high altitude equatorial ring current, which causes the "main phase" depression worldwide in the H-component field during large magnetic storms.

In this paper, the time series of hourly values of the storm on March 13, 1989 is investigated. It is the strongest storm in the space age in several ways; the power system of the province of Quebec was out of order. The peak of the storm falls in the middle of the time series (point 1000).

In order to study changes of complexity dynamically, i.e., to get not only one value that will characterize the whole system, but an array of values, where each value will reflect the complexity of a signal in a specific period, we use sliding window approach [51].

In figure 1 is presented the dynamics of all physical signals that could be studied during physics classes. However, students of other faculties can also be interested.

3.2. Fat-tailed distribution

When studying complex systems, we inevitably encounter power distributions characterized by thick tails. A classic example is the power-law of dividing words by their frequency of use in a text, known as Zipf's law [52].

In economics, this is the law of wealth distribution among individuals [53]; in demography, the distribution of cities by their size [54]; in biology, the distribution of the size of forest patches [55]; in scientometry, the distribution of citations [56]. In general, a wide class of phenomena

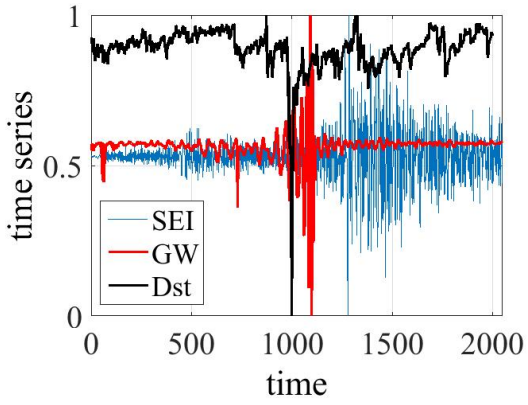

Figure 1: The signals of SEI, GW, and Dst in normalized scale.

is described in the framework of distributions with a degree dependence, but the researcher (student) will have to find out the nature of such a dependence, which can be caused by many factors: critical phenomena, processes with preference, self-organized criticality, multiplicative processes with connections, optimization and path-dependent nonergodic processes, the phase space of which decreases with evolution [57, 58, 59, 60, 61].

First of all, it will be important to build an empirical distribution for our data (figure 2). Having visualized the series we study in this paper, we can already be convinced of the non-Gaussian dynamics of the presented systems.

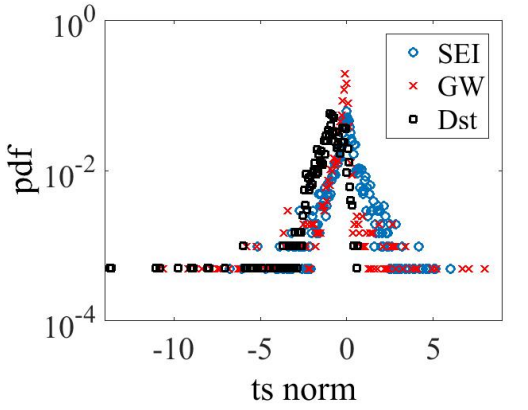

Figure 2: Probability density function (pdf) of the studied signals (normalized time series – ts norm).

In the course of our research, we have determined that the Lévy α-stable distribution most successfully covers the key statistical characteristics of both the economic [62, 63, 64] and those systems presented in this paper. Figures 3a to 3c show the window dynamics of the α index derived from the Lévy distribution that characterizes the "heaviness" of tails.

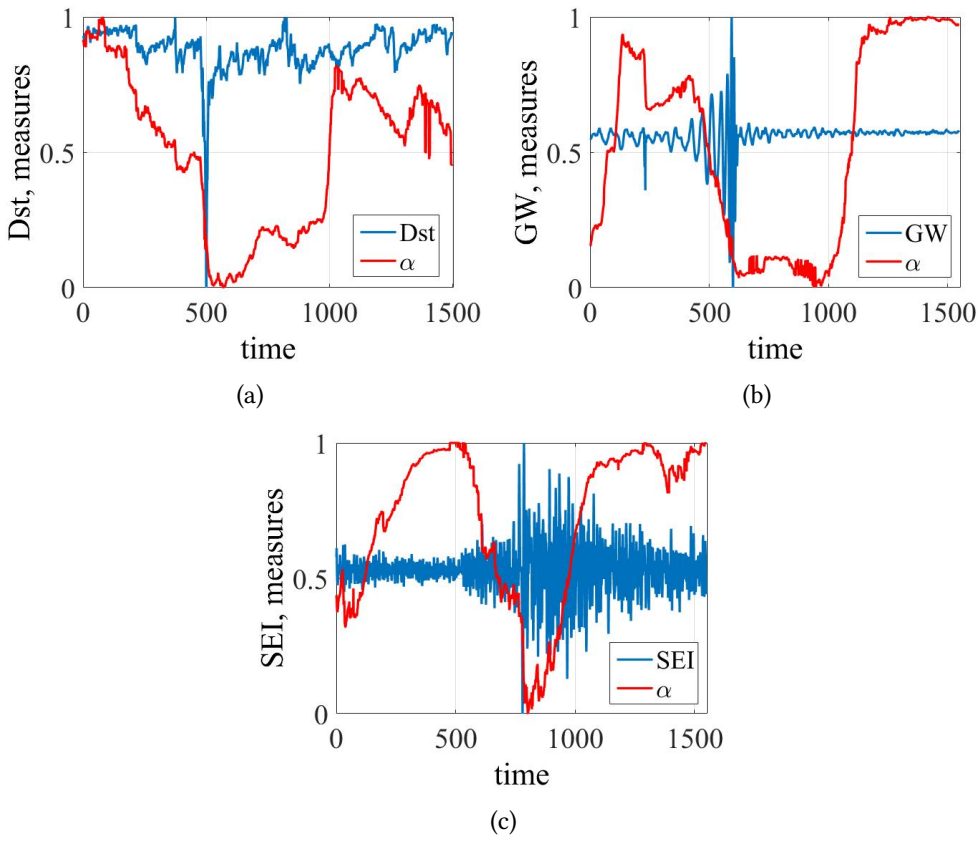

Figure 3: The dynamics of three signals and their α index of stability.

3.3. Multifractality

When studying various types of systems, we often encounter both fractal (self-similar) structures and sets of different fractal dimensions [65]. In such problems, it is necessary to take into account the entire range of critical indicators that characterize different moments in the distribution of observed quantities. Such properties usually relate to the term "multifractality" [66].

There are several different algorithms that allow the obtention of multifractal spectra from time series. The most famous is the MF-DFA [67, 68, 69].

Based on the MF-DFA procedure, we select the maximum value of such a quantitative characteristic of multifractality as the singularity strength [70], although in the corresponding section of fractal (multifractal) analysis, it would be necessary to characterize and demonstrate the dynamics of all multifractality indicators. The following figure shows the window dynamics of the maximum value of the singularity strength.

3.4. Network analysis

Equally important is the network analysis of complex systems. Today, networks play a central role in modeling complex systems, as they offer a way to describe different types of relationships

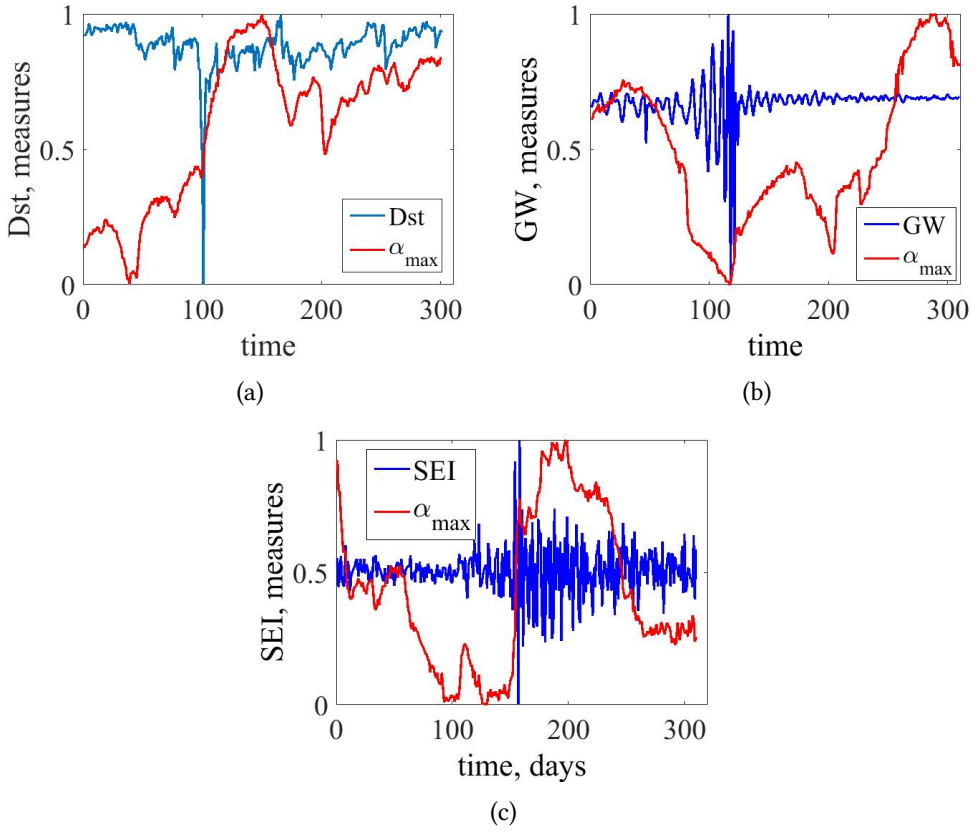

Figure 4: The dynamics of three signals and their index of stability.

between agents that act as endpoints in the network. Complex networks can characterize information, social, economic, biological, neural, and other systems [71, 72, 73, 74]. For example, a society can be represented as a network, where each individual (university, wealth, city) can be represented as nodes of a graph, and the connection between them through edges. For cities, edges can represent a road, where the possibilities of movement can vary, and therefore a different weight can be determined for each edge.

In general, the computer network model is a random graph, the law of mutual arrangement of edges and vertices for which is defined by the probability distribution.

The simplest of networked objects, so-called Erdös-Rényi, or random graphs. Such graphs can be characterized within the framework of the Poisson distribution, but most complex systems, as already noted, are characterized within the framework of distributions with heavy tails.

One of the most interesting characteristics of networks is the vertex degree. The vertex degree distribution for many real-world networks shows a power-law dependence. Such networks are called scale-independent. Scale-free networks are often characterized by very short average distances between randomly chosen pairs of nodes that may have a strong impact on the whole dynamics.

In addition to the topology of graphs, you can also study their quantitative characteristics.

In our case, using the window procedure, we get a variable graph representation of our signal over time. For the presented work, we calculated the maximum vertex degree of the graph (D_{max}), since this measure is one of the conceptually simplest measures, although many other measures can be represented. It is worth noting that there are also various algorithms for converting a time series to a graph. We would like to emphasize the visibility graph algorithms [64, 75, 76, 77, 78] (figure 5) and one based on recurrence analysis [79] (figure 6).

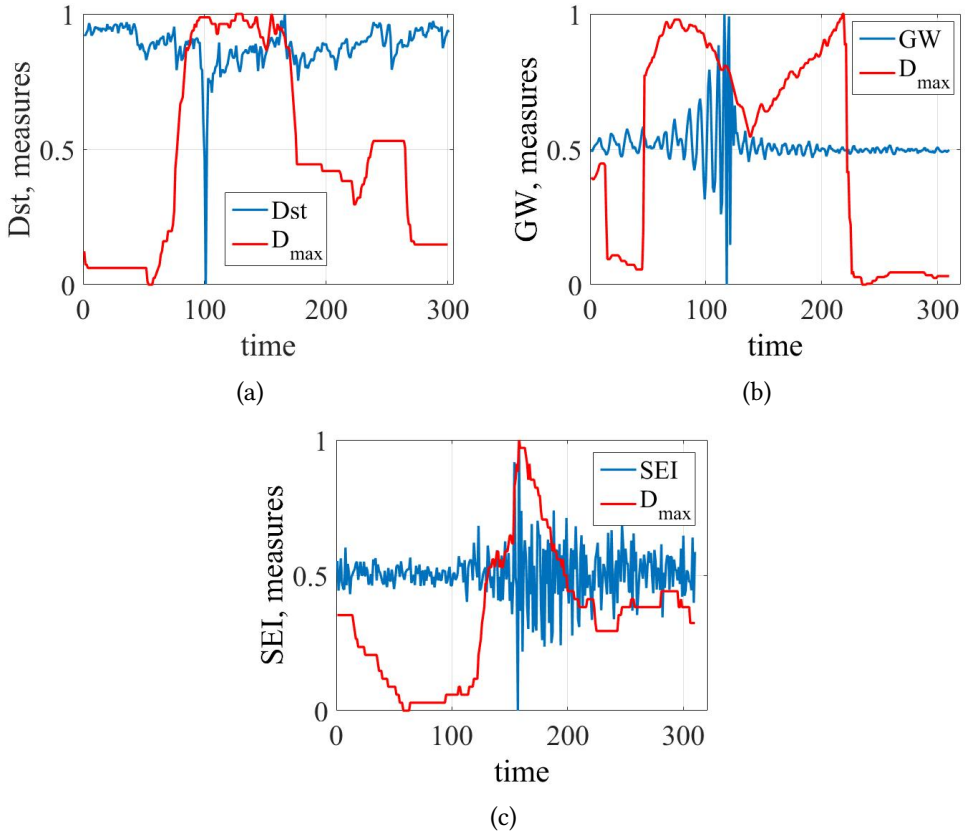

Figure 5: The dynamics of three signals and their D_{max} in accordance with the visibility graph.

3.5. Recurrence analysis

Processes in nature are characterized by pronounced recurrent behavior, such as periodicity or irregular cyclicity.

Moreover, the recurrence (repeatability) of states in the sense of passing a further trajectory quite close to the previous one is a fundamental property of dissipative dynamical systems. This property was noted in the 1880s by the French mathematician Henri Poincaré and subsequently formulated in the form of the "recurrence theorem", published in 1890 [80].

The essence of this fundamental property is that, despite the fact that even the smallest perturbation in a complex dynamical system can lead the system to an exponential deviation

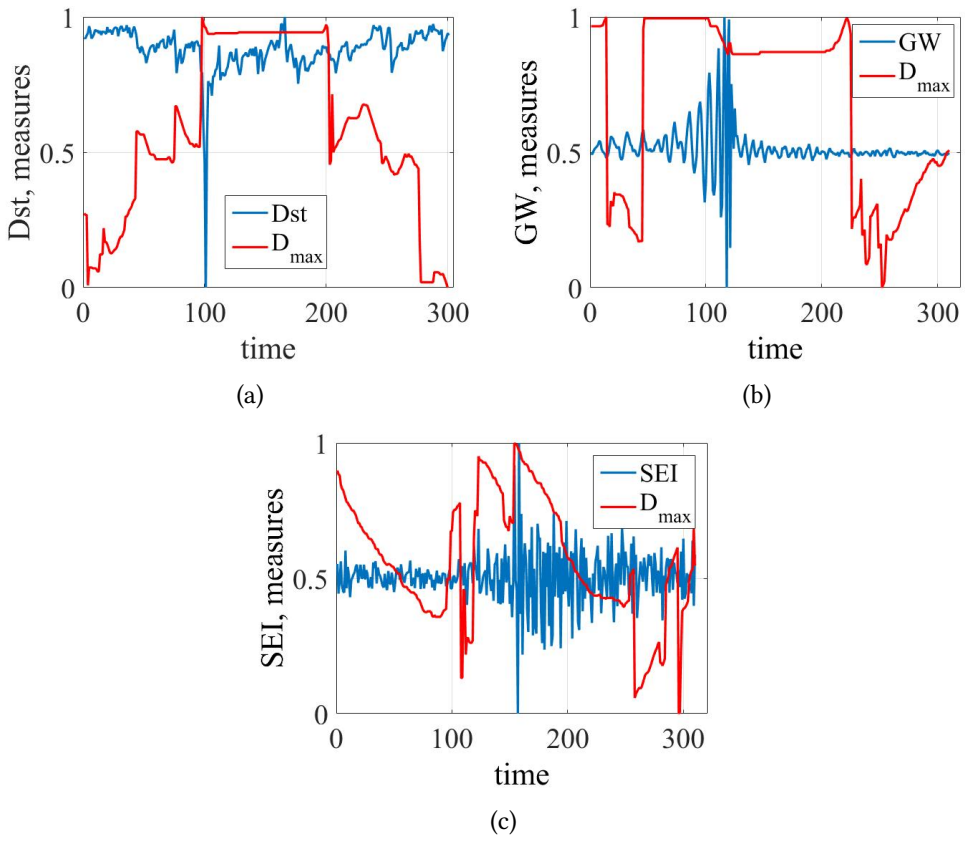

Figure 6: The dynamics of three signals and their D_{max} in accordance with the algorithm based on recurrence analysis.

from its state, after a while the system tends to return to a state that is somewhat close to the previous one, and goes through similar stages of evolution.

In 1987, Eckmann et al. [81] proposed a method for mapping the recurrence of phase space trajectories to $N \times N$ matrix. The appearance of a recurrence diagram allows us to judge the nature of processes occurring in the system, the presence and influence of noise, states of repetition and fading (laminarity), and the implementation of sudden changes (extreme events) during the evolution of the system. If you look at recurrent diagrams in more detail, you can find small-scale structures (textures) consisting of simple points, diagonal, horizontal, and vertical lines, which in turn correspond to chaotic, repetitive, or laminar states.

Using combinations of these states, Zbilut and Webber [82], Webber and Zbilut [83] developed a tool for calculating a series of measures based on the distribution of recurrent points on a recurrence matrix. Later, the toolkit for quantitative recurrent analysis was supplemented by Marwan and Kurths [84]. The tools of quantitative recurrent analysis include the recurrence rate, determined by the ratio of recurrent points to the total number of points on the recurrence matrix under study. In addition to the recurrence measure, in the course of analyzing complex systems, it would be possible to present such measures as determinism, divergence, entropy,

trend, and so on [78, 64, 51, 85, 86, 87, 88].

In this paper, we will focus on the recurrence rate and present it for the already specified series (figure 7).

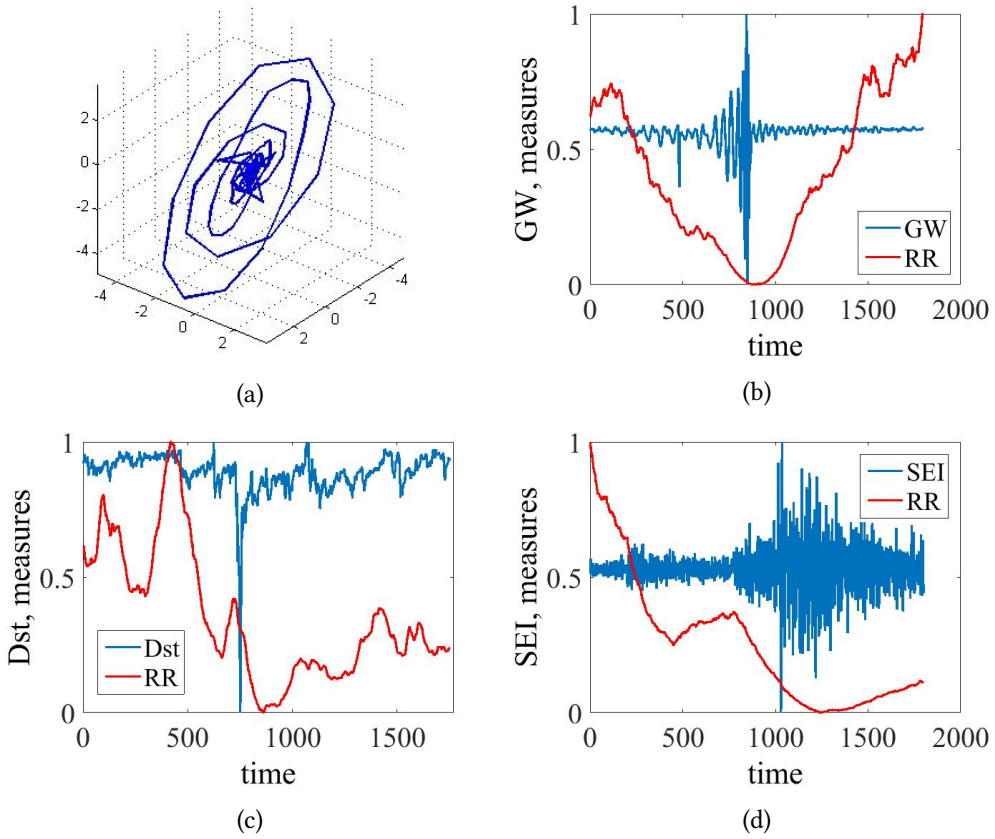

Figure 7: Phase space portrait of GW (a). The dynamics of RR for GW (b), Dst (c), and SEI (d).

3.6. Entropy and non-extensive statistics

The Boltzmann-Gibbs statistical entropy and the classical statistical mechanics associated with it are extremely useful tools for studying a wide range of simple systems that are characterized by a small range of space-time correlations (short memory), the additivity of noise, the presence of intense chaos, the ergodicity of dynamic processes, the Euclidean geometry of phase space, the locality of interaction between elements, the Gaussian probability distributions, etc.

The Boltzmann-Gibbs statistical entropy is a fundamental concept of the school section and the university course of thermodynamics and statistical physics.

In statistical mechanics, entropy denotes the number of possible configurations of a thermodynamic system. The notion of entropy can be associated with the uncertainty in the system [89, 90]. In 1948, Shannon [91] transformed classical statistical entropy to information entropy. Since then, a number of other types of information entropy have been developed [92, 93, 94, 95].

In order to study many real-world systems, it is necessary to go beyond the standard course of thermodynamics, statistical physics, and classical Shannon entropy. A whole range of natural, artificial and social systems, which, unlike those mentioned above, are characterized by a long range of spatio-temporal correlations and non-Gaussian processes.

Since the non-Gaussian and multifractal behavior of the studied systems was presented previously, we will depict the autocorrelation function in the figure 8a, as it should demonstrate an indicator decline. This fact will indicate the dependence of the following values on the previous ones.

It is also worth mentioning that such systems are characterized by multiplicative noise, the presence of weak chaos (vanishing maximum Lyapunov exponent), non-ergodicity of dynamic processes, hierarchy (usually multifractality) of the geometry of the phase space, the presence of asymptotically power-law statistical distributions. A fairly wide class of these complex systems (although not all) it is adequately described by non-additive statistics based on the Tsallis parametric entropy.

Figures 8b to 8d show the q-Gaussian distribution from the Tsallis statistics for the considered series in comparison with the classical Gaussian one.

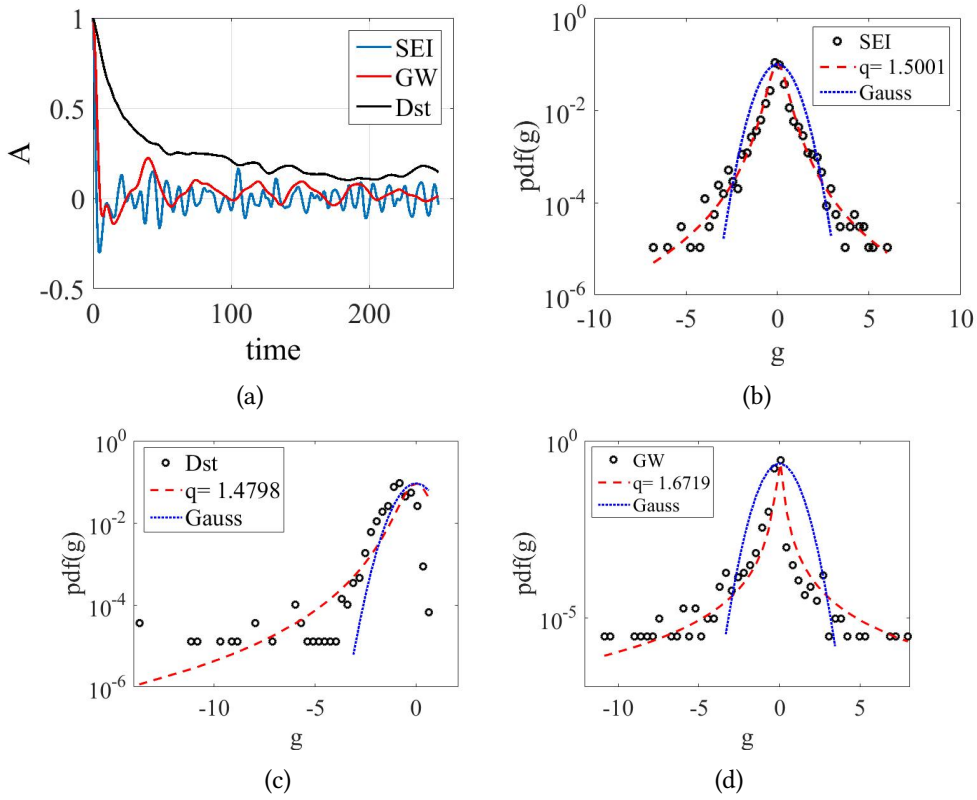

Figure 8: Autocorrelation plots for the studied signals (a). The pdf's of the three signals, Gaussian, and q-Gaussian functions (b-c).

3.7. Reversibility and irreversibility

The last characteristic that we would like to mention is time-reversibility. Temporary irreversibility is a key property of non-equilibrium systems.

Again, such systems are characterized by the presence of memory, while reversibility increases with more noisy and unpredictable signals. Thus, by calculating the irreversibility, we determine the degree of nonlinearity and predictability. It is important to note that the significant time reversibility excludes linear Gaussian processes as a model of generating dynamics. Within the framework of the systems we are considering, we need to think about methods of nonlinear dynamics and non-Gaussian ones [96, 97].

Over the past decade, various methods have been proposed for calculating the degree of irreversibility in systems [98, 99, 100, 101, 102, 103, 104, 105] and we have presented how to use some of them for crises identification [77]. For pedagogical purposes, along with the mentioned concept of multifractality and entropy, we would like to present irreversibility based on the multifractal approach [105] and permutation patterns [104]. The last mentioned approach could be taught within the section of entropy approaches if we were teaching students. However, the calculation of irreversibility based on graph theory is also possible [100, 101, 102].

Figures 9a to 9c show the mentioned measures of irreversibility for the studied signals.

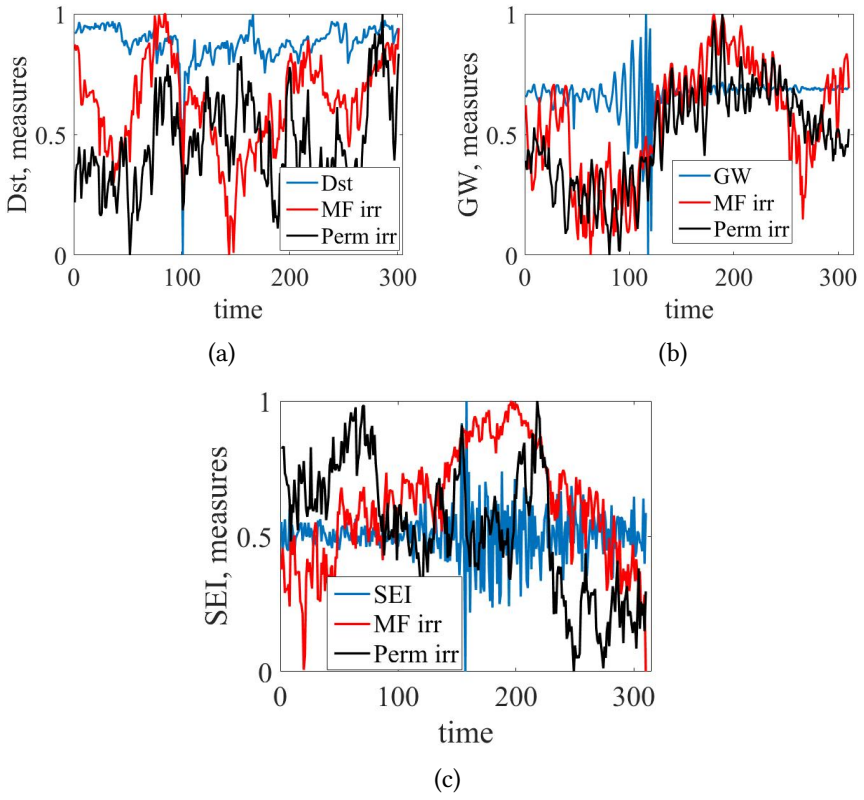

Figure 9: The dynamics of irreversibility measures along with the studied signals.

4. Conclusions

The analysis of the adaptive nature of many complex systems led to the creation of methods and the development of concepts that were successfully applied to describe formally similar phenomena in chemical, biological, social and other systems of agents of non-physical nature. It is sometimes argued that if physics is the science of the four fundamental forces that matter interacts with.

Remembering figures in the field of social sciences, it is still relevant to adapt theoretical material and practical tasks of various fields of physics and higher mathematics to those disciplines that students already study in the framework of social sciences.

In this paper, we have presented some of the most significant approaches on the example of SEI, GW, and Dst, but even more can be shown and much can be taught [106, 107]. The most important thing is not just to convey information, but to interest the student in the right way.

References

[1] Nobel Foundation, Press release: The nobel prize in physics 2021, 2021. URL: https://www.nobelprize.org/prizes/physics/2021/press-release/.

[2] N. V. Karlov, Preobrazovaniye obrazovaniya, Voprosy filosofii 11 (1998) 3–20.

[3] E. N. Knyazeva, S. P. Kurdyumov, Zakony evolyutsii i samoorganizatsii slozhnykh system, Nauka, Moscow, 1994.

[4] S. Thurner (Ed.), 43 Visions for Complexity, volume 3 of *Exploring Complexity*, World Scientific, Singapore, 2017. URL: http://pure.iiasa.ac.at/id/eprint/14000/.

[5] H. Haken, Synergetics: Introduction and Advanced Topics, 1 ed., Springer, Berlin, Heidelberg, 2004. doi:10.1007/978-3-662-10184-1.

[6] H. Haken, Synergetics, Physics Bulletin 28 (1977) 412.

[7] H. Haken, Synergetics: Formation of ordered structures out of chaos, Leonardo 15 (1982) 66–67. URL: http://www.jstor.org/stable/1574350.

[8] H. Haken, Can synergetics be of use to management theory?, in: Self-organization and management of social systems, Springer, 1984, pp. 33–41.

[9] H. Haken, G. Schiepek, Synergetik in der Psychologie: Selbstorganisation verstehen und gestalten, Hogrefe Göttingen, 2006.

[10] G. Nicolis, I. Prigogine, Exploring complexity: an introduction, W.H. Freeman New York, 1989.

[11] I. Prigogine, I. Stengers, Order Out of Chaos Man's New Dialogue with Nature, Bantam Books, 1984.

[12] I. Prigogine, I. Stengers, The End of Certainty, Free Press, 1997.

[13] I. Prigogine, The philosophy of instability, Futures 21 (1989) 396–400. doi:10.1016/S0016-3287(89)80009-6.

[14] I. Prigogine, From Being to Becoming Time and Complexity in the Physical Sciences, W.H. Freeman, 1980.

[15] O. Y. Panfilov, I. V. Romanova, Synerhetychnyy pidkhid v osmyslenni osvity, Bulletin

of the Yaroslav the Wise National University 3 (2019) 71–80. URL: http://fil.nlu.edu.ua/article/view/170335. doi:10.21564/2075-7190.42.170335.

[16] V. Andrushchenko, D. Svyrydenko, Akademichna mobilnist v ukrayinskomu prostori vyshchoyi shkoly: realiyi, vyklyky ta perspektyvy rozvytku, Vyshcha osvita Ukrayiny 2 (2016) 5–11.

[17] O. Rubanets, Kohnityvnyy aspekt metodolohichnoho onovlennya vyshchoyi shkoly, Vyshcha osvita Ukrayiny 3 (2016) 24–29.

[18] V. H. Kremen, V. V. Illyin, Synerhetyka v osviti: kontekst lyudynotsentryzmu, 2012.

[19] N. Kochubei, Neliniine myslennia v osviti, in: I. Predborska (Ed.), Filosofski abrysy suchasnoi osvity, volume 11, Universytetska kniha, 2006, pp. 29–41.

[20] J. Davis-Seaver, D. Leflore, T. Smith, Promoting critical thinking at the university level, National forum of teacher educational journal 10E (2000) 1–11. URL: http://www.nationalforum.com/Electronic%20Journal%20Volumes/Davis-Seaver%20Jane%20Promoting%20Critical%20Thinking%20at%20the%20University%20Level.pdf.

[21] V. Kremen, Pedahohichna synerhetyka: poniatiino-katehorialnyi syntez, Teoriia i praktyka upravlinnia sotsialnymy systemamy 3 (2013) 3–19.

[22] T. M. Taranenko, Synerhetychnyi pidkhid v orhanizatsii navchalno-vykhovnoho protsessu, Tavriiskyi visnyk osvity 1 (2014) 10–15.

[23] M. J. Jacobson, U. Wilensky, Complex systems in education: Scientific and educational importance and implications for the learning sciences, Journal of the Learning Sciences 15 (2006) 11–34. doi:10.1207/s15327809jls1501_4.

[24] U. Wilensky, M. Jacobson, Complex systems and the learning sciences, in: The Cambridge Handbook of the Learning Sciences, Second Edition, Cambridge University Press, 2014, pp. 319–338. doi:10.1017/CBO9781139519526.020.

[25] N. R. Council, How People Learn: Brain, Mind, Experience, and School: Expanded Edition, The National Academies Press, Washington, DC, 2000. URL: https://www.nap.edu/catalog/9853/how-people-learn-brain-mind-experience-and-school-expanded-edition. doi:10.17226/9853.

[26] National Research Council, Inquiry and the National Science Education Standards: A Guide for Teaching and Learning, The National Academies Press, Washington, DC, 2000. URL: https://www.nap.edu/catalog/9596/inquiry-and-the-national-science-education-standards-a-guide-for. doi:10.17226/9596.

[27] E. A. Jackson, The second metamorphosis of science: A second view, SFI Working Papers 96-05-059, Santa Fe Institute, 1995. URL: https://EconPapers.repec.org/RePEc:wop:safiwp:95-01-001.

[28] H. R. Pagels, The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity, Simon & Schuster, 1988.

[29] J. J. West, H. Dowlatabadi, On assessing the economic impacts of sea-level rise on developed coasts, in: T. E. Downing, A. A. Olsthoorn, R. S. J. Tol (Eds.), Climate, Change and Risk, 1 ed., 1998, p. 16.

[30] M. Balmer, K. Nagel, B. Raney, Large-scale multi-agent simulations for transportation applications, Journal of Intelligent Transportation Systems 8 (2004) 205–221. doi:10.1080/15472450490523892.

[31] D. Helbing, K. Nagel, The physics of traffic and regional development, Contemporary Physics 45 (2004) 405–426. doi:10.1080/00107510410001715944.
[32] M. Noth, A. Borning, P. Waddell, An extensible, modular architecture for simulating urban development, transportation, and environmental impacts, Computers, Environment and Urban Systems 27 (2003) 181–203. doi:10.1016/S0198-9715(01)00030-8.
[33] P. W. Anderson, K. J. Arrow, D. Pines (Eds.), The Economy As An Evolving Complex System, 1 ed., Addison-Wesley, 1988.
[34] W. B. Arthur, S. N. Durlauf, D. A. Lane (Eds.), The Economy As An Evolving Complex System II, 1 ed., Addison-Wesley, 1997.
[35] R. Axelrod, The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration, Princeton Studies in Complexity, Princeton University Press, 1997.
[36] J. M. Epstein, R. Axtell, Growing Artificial Societies: Social Science from the Bottom Up, volume 1, 1 ed., The MIT Press, 1996. URL: https://EconPapers.repec.org/RePEc:mtp:titles:0262550253.
[37] C. Langton (Ed.), Artificial life, Addison-Wesley, 1989.
[38] C. Langton (Ed.), Artificial life: Overview, MIT, 1995.
[39] J. M. Epstein, R. Axtell, Growing artificial societies: Social science from the bottom up, MIT, 1996.
[40] V. M. Vandyshev (Ed.), Problemy koevolyutsiyi, Philosophical Sciences, Sums'kyy Derzhavnyy Pedahohichnyy Universytet Imeni A. S. Makarenka, 2000.
[41] D. Abrahamson, U. Wilensky, Collaboration and equity in classroom activities using Statistics As Multi-Participant Learning-Environment Resource (S.A.M.P.L.E.R.), in: W. Stroup, U. Wilensky, C. D. Lee (Eds.), Patterns in group learning with next-generation network technology, 2005.
[42] D. Abrahamson, U. Wilensky, The stratified learning zone: Examining collaborative-learning design in demographically diverse mathematics classrooms, in: D. Y. White, E. H. Gutstein (Eds.), Equity and diversity studies in mathematics learning and instruction. Conference: annual meeting of the American Educational Research Associationannual meeting of the American Educational Research Association, 2005.
[43] S. Jackson, J. Krajcik, E. Soloway, Model-it: A design retrospective, in: M. J. Jacobson, R. B. Kozma (Eds.), Innovations in science and mathematics education: Advanced designs for technologies of learning, Lawrence Erlbaum Associates, Inc, 2000, pp. 77–115.
[44] M. J. Wheatley, Leadership and the New Science: Discovering order in a chaotic world, 3 ed., Berrett-Koehler Publishers, 2006.
[45] R. H. Shumway, D. S. Stoffer, Time Series Analysis and Its Applications. With R Examples, Springer Texts in Statistics, 4 ed., Springer, 2016.
[46] B. D. Fulcher, M. A. Little, N. S. Jones, Highly comparative time-series analysis: the empirical structure of time series and their methods, Journal of The Royal Society Interface 10 (2013) 20130048. doi:10.1098/rsif.2013.0048.
[47] B. Davis, D. Sumara, Complexity and education: Inquiries into learning, teaching, and research, Journal of Contemporary Issues in Education 1 (2006) 54–55.
[48] R. R. Bladford, Discrimination of Earthquakes and Explosions, Report AFTAC-TR-93-044 HQ, Air Force Technical Applications Center, Patrick Air Force Base FL 32925-6001, 1993. URL: https://apps.dtic.mil/sti/pdfs/ADA267638.pdf.

[49] B. P. Abbott, R. Abbott, T. D. Abbott, M. R. Abernathy, F. Acernese, K. Ackley, C. Adams, T. Adams, P. Addesso, R. X. Adhikari, V. B. Adya, C. Affeldt, M. Agathos, K. Agatsuma, N. Aggarwal, O. D. Aguiar, L. Aiello, A. Ain, P. Ajith, B. Allen, A. Allocca, P. A. Altin, S. B. Anderson, W. G. Anderson, K. Arai, M. A. Arain, M. C. Araya, C. C. Arceneaux, J. S. Areeda, N. Arnaud, K. G. Arun, S. Ascenzi, G. Ashton, M. Ast, S. M. Aston, P. Astone, P. Aufmuth, C. Aulbert, S. Babak, P. Bacon, M. K. M. Bader, P. T. Baker, F. Baldaccini, G. Ballardin, S. W. Ballmer, J. C. Barayoga, S. E. Barclay, B. C. Barish, D. Barker, F. Barone, B. Barr, L. Barsotti, M. Barsuglia, D. Barta, J. Bartlett, M. A. Barton, I. Bartos, R. Bassiri, A. Basti, J. C. Batch, C. Baune, V. Bavigadda, M. Bazzan, B. Behnke, M. Bejger, C. Belczynski, A. S. Bell, C. J. Bell, B. K. Berger, J. Bergman, G. Bergmann, C. P. L. Berry, D. Bersanetti, A. Bertolini, J. Betzwieser, S. Bhagwat, R. Bhandare, I. A. Bilenko, G. Billingsley, J. Birch, R. Birney, O. Birnholtz, S. Biscans, A. Bisht, M. Bitossi, C. Biwer, M. A. Bizouard, J. K. Blackburn, C. D. Blair, D. G. Blair, R. M. Blair, S. Bloemen, O. Bock, T. P. Bodiya, M. Boer, G. Bogaert, C. Bogan, A. Bohe, P. Bojtos, C. Bond, F. Bondu, R. Bonnand, B. A. Boom, R. Bork, V. Boschi, S. Bose, Y. Bouffanais, A. Bozzi, C. Bradaschia, P. R. Brady, V. B. Braginsky, M. Branchesi, J. E. Brau, T. Briant, A. Brillet, M. Brinkmann, V. Brisson, P. Brockill, A. F. Brooks, D. A. Brown, D. D. Brown, N. M. Brown, C. C. Buchanan, A. Buikema, T. Bulik, H. J. Bulten, A. Buonanno, D. Buskulic, C. Buy, R. L. Byer, M. Cabero, L. Cadonati, G. Cagnoli, C. Cahillane, J. C. Bustillo, T. Callister, E. Calloni, J. B. Camp, K. C. Cannon, J. Cao, C. D. Capano, E. Capocasa, F. Carbognani, S. Caride, J. C. Diaz, C. Casentini, S. Caudill, M. Cavaglià, F. Cavalier, R. Cavalieri, G. Cella, C. B. Cepeda, L. C. Baiardi, G. Cerretani, E. Cesarini, R. Chakraborty, T. Chalermsongsak, S. J. Chamberlin, M. Chan, S. Chao, P. Charlton, E. Chassande-Mottin, H. Y. Chen, Y. Chen, C. Cheng, A. Chincarini, A. Chiummo, H. S. Cho, M. Cho, J. H. Chow, N. Christensen, Q. Chu, S. Chua, S. Chung, G. Ciani, F. Clara, J. A. Clark, F. Cleva, E. Coccia, P.-F. Cohadon, A. Colla, C. G. Collette, L. Cominsky, M. Constancio, A. Conte, L. Conti, D. Cook, T. R. Corbitt, N. Cornish, A. Corsi, S. Cortese, C. A. Costa, M. W. Coughlin, S. B. Coughlin, J.-P. Coulon, S. T. Countryman, P. Couvares, E. E. Cowan, D. M. Coward, M. J. Cowart, D. C. Coyne, R. Coyne, K. Craig, J. D. E. Creighton, T. D. Creighton, J. Cripe, S. G. Crowder, A. M. Cruise, A. Cumming, L. Cunningham, E. Cuoco, T. D. Canton, S. L. Danilishin, S. D'Antonio, K. Danzmann, N. S. Darman, C. F. Da Silva Costa, V. Dattilo, I. Dave, H. P. Daveloza, M. Davier, G. S. Davies, E. J. Daw, R. Day, S. De, D. DeBra, G. Debreczeni, J. Degallaix, M. De Laurentis, S. Deléglise, W. Del Pozzo, T. Denker, T. Dent, H. Dereli, V. Dergachev, R. T. DeRosa, R. De Rosa, R. DeSalvo, S. Dhurandhar, M. C. Díaz, L. Di Fiore, M. Di Giovanni, A. Di Lieto, S. Di Pace, I. Di Palma, A. Di Virgilio, G. Dojcinoski, V. Dolique, F. Donovan, K. L. Dooley, S. Doravari, R. Douglas, T. P. Downes, M. Drago, R. W. P. Drever, J. C. Driggers, Z. Du, M. Ducrot, S. E. Dwyer, T. B. Edo, M. C. Edwards, A. Effler, H.-B. Eggenstein, P. Ehrens, J. Eichholz, S. S. Eikenberry, W. Engels, R. C. Essick, T. Etzel, M. Evans, T. M. Evans, R. Everett, M. Factourovich, V. Fafone, H. Fair, S. Fairhurst, X. Fan, Q. Fang, S. Farinon, B. Farr, W. M. Farr, M. Favata, M. Fays, H. Fehrmann, M. M. Fejer, D. Feldbaum, I. Ferrante, E. C. Ferreira, F. Ferrini, F. Fidecaro, L. S. Finn, I. Fiori, D. Fiorucci, R. P. Fisher, R. Flaminio, M. Fletcher, H. Fong, J.-D. Fournier, S. Franco, S. Frasca, F. Frasconi, M. Frede, Z. Frei, A. Freise, R. Frey, V. Frey, T. T. Fricke, P. Fritschel, V. V. Frolov, P. Fulda, M. Fyffe, H. A. G. Gabbard, J. R. Gair, L. Gammaitoni, S. G. Gaonkar, F. Garufi, A. Gatto, G. Gaur, N. Gehrels,

G. Gemme, B. Gendre, E. Genin, A. Gennai, J. George, L. Gergely, V. Germain, A. Ghosh, A. Ghosh, S. Ghosh, J. A. Giaime, K. D. Giardina, A. Giazotto, K. Gill, A. Glaefke, J. R. Gleason, E. Goetz, R. Goetz, L. Gondan, G. González, J. M. G. Castro, A. Gopakumar, N. A. Gordon, M. L. Gorodetsky, S. E. Gossan, M. Gosselin, R. Gouaty, C. Graef, P. B. Graff, M. Granata, A. Grant, S. Gras, C. Gray, G. Greco, A. C. Green, R. J. S. Greenhalgh, P. Groot, H. Grote, S. Grunewald, G. M. Guidi, X. Guo, A. Gupta, M. K. Gupta, K. E. Gushwa, E. K. Gustafson, R. Gustafson, J. J. Hacker, B. R. Hall, E. D. Hall, G. Hammond, M. Haney, M. M. Hanke, J. Hanks, C. Hanna, M. D. Hannam, J. Hanson, T. Hardwick, J. Harms, G. M. Harry, I. W. Harry, M. J. Hart, M. T. Hartman, C.-J. Haster, K. Haughian, J. Healy, J. Heefner, A. Heidmann, M. C. Heintze, G. Heinzel, H. Heitmann, P. Hello, G. Hemming, M. Hendry, I. S. Heng, J. Hennig, A. W. Heptonstall, M. Heurs, S. Hild, D. Hoak, K. A. Hodge, D. Hofman, S. E. Hollitt, K. Holt, D. E. Holz, P. Hopkins, D. J. Hosken, J. Hough, E. A. Houston, E. J. Howell, Y. M. Hu, S. Huang, E. A. Huerta, D. Huet, B. Hughey, S. Husa, S. H. Huttner, T. Huynh-Dinh, A. Idrisy, N. Indik, D. R. Ingram, R. Inta, H. N. Isa, J.-M. Isac, M. Isi, G. Islas, T. Isogai, B. R. Iyer, K. Izumi, M. B. Jacobson, T. Jacqmin, H. Jang, K. Jani, P. Jaranowski, S. Jawahar, F. Jiménez-Forteza, W. W. Johnson, N. K. Johnson-McDaniel, D. I. Jones, R. Jones, R. J. G. Jonker, L. Ju, K. Haris, C. V. Kalaghatgi, V. Kalogera, S. Kandhasamy, G. Kang, J. B. Kanner, S. Karki, M. Kasprzack, E. Katsavounidis, W. Katzman, S. Kaufer, T. Kaur, K. Kawabe, F. Kawazoe, F. Kéfélian, M. S. Kehl, D. Keitel, D. B. Kelley, W. Kells, R. Kennedy, D. G. Keppel, J. S. Key, A. Khalaidovski, F. Y. Khalili, I. Khan, S. Khan, Z. Khan, E. A. Khazanov, N. Kijbunchoo, C. Kim, J. Kim, K. Kim, N.-G. Kim, N. Kim, Y.-M. Kim, E. J. King, P. J. King, D. L. Kinzel, J. S. Kissel, L. Kleybolte, S. Klimenko, S. M. Koehlenbeck, K. Kokeyama, S. Koley, V. Kondrashov, A. Kontos, S. Koranda, M. Korobko, W. Z. Korth, I. Kowalska, D. B. Kozak, V. Kringel, B. Krishnan, A. Królak, C. Krueger, G. Kuehn, P. Kumar, R. Kumar, L. Kuo, A. Kutynia, P. Kwee, B. D. Lackey, M. Landry, J. Lange, B. Lantz, P. D. Lasky, A. Lazzarini, C. Lazzaro, P. Leaci, S. Leavey, E. O. Lebigot, C. H. Lee, H. K. Lee, H. M. Lee, K. Lee, A. Lenon, M. Leonardi, J. R. Leong, N. Leroy, N. Letendre, Y. Levin, B. M. Levine, T. G. F. Li, A. Libson, T. B. Littenberg, N. A. Lockerbie, J. Logue, A. L. Lombardi, L. T. London, J. E. Lord, M. Lorenzini, V. Loriette, M. Lormand, G. Losurdo, J. D. Lough, C. O. Lousto, G. Lovelace, H. Lück, A. P. Lundgren, J. Luo, R. Lynch, Y. Ma, T. MacDonald, B. Machenschalk, M. MacInnis, D. M. Macleod, F. Magaña Sandoval, R. M. Magee, M. Mageswaran, E. Majorana, I. Maksimovic, V. Malvezzi, N. Man, I. Mandel, V. Mandic, V. Mangano, G. L. Mansell, M. Manske, M. Mantovani, F. Marchesoni, F. Marion, S. Márka, Z. Márka, A. S. Markosyan, E. Maros, F. Martelli, L. Martellini, I. W. Martin, R. M. Martin, D. V. Martynov, J. N. Marx, K. Mason, A. Masserot, T. J. Massinger, M. Masso-Reid, F. Matichard, L. Matone, N. Mavalvala, N. Mazumder, G. Mazzolo, R. McCarthy, D. E. McClelland, S. McCormick, S. C. McGuire, G. McIntyre, J. McIver, D. J. McManus, S. T. McWilliams, D. Meacher, G. D. Meadors, J. Meidam, A. Melatos, G. Mendell, D. Mendoza-Gandara, R. A. Mercer, E. Merilh, M. Merzougui, S. Meshkov, C. Messenger, C. Messick, P. M. Meyers, F. Mezzani, H. Miao, C. Michel, H. Middleton, E. E. Mikhailov, L. Milano, J. Miller, M. Millhouse, Y. Minenkov, J. Ming, S. Mirshekari, C. Mishra, S. Mitra, V. P. Mitrofanov, G. Mitselmakher, R. Mittleman, A. Moggi, M. Mohan, S. R. P. Mohapatra, M. Montani, B. C. Moore, C. J. Moore, D. Moraru, G. Moreno, S. R. Morriss, K. Mossavi, B. Mours, C. M. Mow-Lowry, C. L. Mueller, G. Mueller, A. W. Muir, A. Mukherjee,

D. Mukherjee, S. Mukherjee, N. Mukund, A. Mullavey, J. Munch, D. J. Murphy, P. G. Murray, A. Mytidis, I. Nardecchia, L. Naticchioni, R. K. Nayak, V. Necula, K. Nedkova, G. Nelemans, M. Neri, A. Neunzert, G. Newton, T. T. Nguyen, A. B. Nielsen, S. Nissanke, A. Nitz, F. Nocera, D. Nolting, M. E. N. Normandin, L. K. Nuttall, J. Oberling, E. Ochsner, J. O'Dell, E. Oelker, G. H. Ogin, J. J. Oh, S. H. Oh, F. Ohme, M. Oliver, P. Oppermann, R. J. Oram, B. O'Reilly, R. O'Shaughnessy, C. D. Ott, D. J. Ottaway, R. S. Ottens, H. Overmier, B. J. Owen, A. Pai, S. A. Pai, J. R. Palamos, O. Palashov, C. Palomba, A. Pal-Singh, H. Pan, Y. Pan, C. Pankow, F. Pannarale, B. C. Pant, F. Paoletti, A. Paoli, M. A. Papa, H. R. Paris, W. Parker, D. Pascucci, A. Pasqualetti, R. Passaquieti, D. Passuello, B. Patricelli, Z. Patrick, B. L. Pearlstone, M. Pedraza, R. Pedurand, L. Pekowsky, A. Pele, S. Penn, A. Perreca, H. P. Pfeiffer, M. Phelps, O. Piccinni, M. Pichot, M. Pickenpack, F. Piergiovanni, V. Pierro, G. Pillant, L. Pinard, I. M. Pinto, M. Pitkin, J. H. Poeld, R. Poggiani, P. Popolizio, A. Post, J. Powell, J. Prasad, V. Predoi, S. S. Premachandra, T. Prestegard, L. R. Price, M. Prijatelj, M. Principe, S. Privitera, R. Prix, G. A. Prodi, L. Prokhorov, O. Puncken, M. Punturo, P. Puppo, M. Pürrer, H. Qi, J. Qin, V. Quetschke, E. A. Quintero, R. Quitzow-James, F. J. Raab, D. S. Rabeling, H. Radkins, P. Raffai, S. Raja, M. Rakhmanov, C. R. Ramet, P. Rapagnani, V. Raymond, M. Razzano, V. Re, J. Read, C. M. Reed, T. Regimbau, L. Rei, S. Reid, D. H. Reitze, H. Rew, S. D. Reyes, F. Ricci, K. Riles, N. A. Robertson, R. Robie, F. Robinet, A. Rocchi, L. Rolland, J. G. Rollins, V. J. Roma, J. D. Romano, R. Romano, G. Romanov, J. H. Romie, D. Rosińska, S. Rowan, A. Rüdiger, P. Ruggi, K. Ryan, S. Sachdev, T. Sadecki, L. Sadeghian, L. Salconi, M. Saleem, F. Salemi, A. Samajdar, L. Sammut, L. M. Sampson, E. J. Sanchez, V. Sandberg, B. Sandeen, G. H. Sanders, J. R. Sanders, B. Sassolas, B. S. Sathyaprakash, P. R. Saulson, O. Sauter, R. L. Savage, A. Sawadsky, P. Schale, R. Schilling, J. Schmidt, P. Schmidt, R. Schnabel, R. M. S. Schofield, A. Schönbeck, E. Schreiber, D. Schuette, B. F. Schutz, J. Scott, S. M. Scott, D. Sellers, A. S. Sengupta, D. Sentenac, V. Sequino, A. Sergeev, G. Serna, Y. Setyawati, A. Sevigny, D. A. Shaddock, T. Shaffer, S. Shah, M. S. Shahriar, M. Shaltev, Z. Shao, B. Shapiro, P. Shawhan, A. Sheperd, D. H. Shoemaker, D. M. Shoemaker, K. Siellez, X. Siemens, D. Sigg, A. D. Silva, D. Simakov, A. Singer, L. P. Singer, A. Singh, R. Singh, A. Singhal, A. M. Sintes, B. J. J. Slagmolen, J. R. Smith, M. R. Smith, N. D. Smith, R. J. E. Smith, E. J. Son, B. Sorazu, F. Sorrentino, T. Souradeep, A. K. Srivastava, A. Staley, M. Steinke, J. Steinlechner, S. Steinlechner, D. Steinmeyer, B. C. Stephens, S. P. Stevenson, R. Stone, K. A. Strain, N. Straniero, G. Stratta, N. A. Strauss, S. Strigin, R. Sturani, A. L. Stuver, T. Z. Summerscales, L. Sun, P. J. Sutton, B. L. Swinkels, M. J. Szczepańczyk, M. Tacca, D. Talukder, D. B. Tanner, M. Tápai, S. P. Tarabrin, A. Taracchini, R. Taylor, T. Theeg, M. P. Thirugnanasambandam, E. G. Thomas, M. Thomas, P. Thomas, K. A. Thorne, K. S. Thorne, E. Thrane, S. Tiwari, V. Tiwari, K. V. Tokmakov, C. Tomlinson, M. Tonelli, C. V. Torres, C. I. Torrie, D. Töyrä, F. Travasso, G. Traylor, D. Trifirò, M. C. Tringali, L. Trozzo, M. Tse, M. Turconi, D. Tuyenbayev, D. Ugolini, C. S. Unnikrishnan, A. L. Urban, S. A. Usman, H. Vahlbruch, G. Vajente, G. Valdes, M. Vallisneri, N. van Bakel, M. van Beuzekom, J. F. J. van den Brand, C. Van Den Broeck, D. C. Vander-Hyde, L. van der Schaaf, J. V. van Heijningen, A. A. van Veggel, M. Vardaro, S. Vass, M. Vasúth, R. Vaulin, A. Vecchio, G. Vedovato, J. Veitch, P. J. Veitch, K. Venkateswara, D. Verkindt, F. Vetrano, A. Viceré, S. Vinciguerra, D. J. Vine, J.-Y. Vinet, S. Vitale, T. Vo, H. Vocca, C. Vorvick, D. Voss, W. D. Vousden, S. P. Vyatchanin, A. R. Wade, L. E. Wade, M. Wade,

S. J. Waldman, M. Walker, L. Wallace, S. Walsh, G. Wang, H. Wang, M. Wang, X. Wang, Y. Wang, H. Ward, R. L. Ward, J. Warner, M. Was, B. Weaver, L.-W. Wei, M. Weinert, A. J. Weinstein, R. Weiss, T. Welborn, L. Wen, P. Weßels, T. Westphal, K. Wette, J. T. Whelan, S. E. Whitcomb, D. J. White, B. F. Whiting, K. Wiesner, C. Wilkinson, P. A. Willems, L. Williams, R. D. Williams, A. R. Williamson, J. L. Willis, B. Willke, M. H. Wimmer, L. Winkelmann, W. Winkler, C. C. Wipf, A. G. Wiseman, H. Wittel, G. Woan, J. Worden, J. L. Wright, G. Wu, J. Yablon, I. Yakushin, W. Yam, H. Yamamoto, C. C. Yancey, M. J. Yap, H. Yu, M. Yvert, A. Zadrożny, L. Zangrando, M. Zanolin, J.-P. Zendri, M. Zevin, F. Zhang, L. Zhang, M. Zhang, Y. Zhang, C. Zhao, M. Zhou, Z. Zhou, X. J. Zhu, M. E. Zucker, S. E. Zuraw, J. Zweizig (LIGO Scientific Collaboration and Virgo Collaboration), Observation of gravitational waves from a binary black hole merger, Phys. Rev. Lett. 116 (2016) 061102. doi:10.1103/PhysRevLett.116.061102.

[50] The disturbance storm time index, 2021. URL: https://www.ngdc.noaa.gov/geomag/indices/dst.html.

[51] V. Soloviev, A. Belinskij, Methods of nonlinear dynamics and the construction of cryptocurrency crisis phenomena precursors, CEUR Workshop Proceedings 2104 (2018) 116–127.

[52] G. K. Zipf, Human behavior and the principle of least effort, The Economic Journal 60 (1950) 808–810. URL: http://www.jstor.org/stable/2226729.

[53] V. Pareto, Cours d'Économie Politique, volume 1, 1896.

[54] F. Auerbach, Das gesetz der bevölkerungskonzentration, petermanns, Geographische Mitteilungen 59 (1913) 74–76.

[55] L. A. Saravia, S. R. Doyle, B. Bond-Lamberty, Power laws and critical fragmentation in global forests, Scientific Reports 8 (2018) 17766. doi:10.1038/s41598-018-36120-w.

[56] M. Brzeziński, Power laws in citation distributions: Evidence from Scopus, Working Papers 2014-05, Faculty of Economic Sciences, University of Warsaw, 2014. URL: https://ideas.repec.org/p/war/wpaper/2014-05.html.

[57] C. Domp, The Critical Point: A Historical Introduction To The Modern Theory Of Critical Phenomena, 1 ed., CRC Press, 1996. doi:10.1201/9781482295269.

[58] D. Sornette, Critical Phenomena in Natural Sciences. Chaos, Fractals, Selforganization and Disorder: Concepts and Tools, Springer Series in Synergetics, 2 ed., Springer-Verlag, 2006. doi:10.1007/3-540-33182-4.

[59] P. Bak, C. Tang, K. Wiesenfeld, Self-organized criticality: An explanation of the 1/f noise, Phys. Rev. Lett. 59 (1987) 381–384. doi:10.1103/PhysRevLett.59.381.

[60] B. B. Mandelbrot, An informational theory of the statistical structure of languages, Communication Theory (1953) 486–502.

[61] B. Corominas-Murtra, R. Hanel, S. Thurner, Understanding scaling through history-dependent processes with collapsing sample space, Proceedings of the National Academy of Sciences 112 (2015) 5348–5353. URL: https://www.pnas.org/content/112/17/5348. doi:10.1073/pnas.1420946112.

[62] A. Bielinskyi, S. Semerikov, V. Solovieva, V. Soloviev, Levy's stable distribution for stock crash detecting, SHS Web of Conferences 65 (2019) 06006. doi:10.1051/shsconf/20196506006.

[63] A. Bielinskyi, I. Khvostina, A. Mamanazarov, A. Matviychuk, S. Semerikov, O. Serdyuk,

V. Solovieva, V. N. Soloviev, Predictors of oil shocks. econophysical approach in environmental science, IOP Conference Series: Earth and Environmental Science 628 (2021) 012019. doi:10.1088/1755-1315/628/1/012019.

[64] A. Bielinskyi, O. Serdyuk, S. Semerikov, V. Soloviev, Econophysics of cryptocurrency crashes: an overview, SHS Web of Conferences 107 (2021) 03001. doi:10.1051/shsconf/202110703001.

[65] H. E. Stanley, P. Meakin, Multifractal phenomena in physics and chemistry, Nature 335 (1988) 405–409. doi:10.1038/335405a0.

[66] K. R. Sreenivasan, C. Meneveau, The fractal facets of turbulence, Journal of Fluid Mechanics 173 (1986) 357–386. doi:10.1017/S0022112086001209.

[67] J. W. Kantelhardt, S. A. Zschiegner, E. Koscielny-Bunde, S. Havlin, A. Bunde, H. Stanley, Multifractal detrended fluctuation analysis of nonstationary time series, Physica A: Statistical Mechanics and its Applications 316 (2002) 87–114. doi:10.1016/S0378-4371(02)01383-3.

[68] D. B. de Freitas, M. M. F. Nepomuceno, J. R. D. Medeiros, Multifractal signatures of gravitational waves detected by ligo, 2019. arXiv:1912.12967.

[69] I. Eghdami, H. Panahi, S. M. S. Movahed, Multifractal analysis of pulsar timing residuals: Assessment of gravitational wave detection, The Astrophysical Journal 864 (2018) 162. doi:10.3847/1538-4357/aad7b9.

[70] Y. Ashkenazy, D. R. Baker, H. Gildor, S. Havlin, Nonlinearity and multifractality of climate change in the past 420,000 years, Geophysical Research Letters 30 (2003) 4. doi:10.1029/2003GL018099.

[71] M. E. J. Newman, The structure and function of complex networks, SIAM Review 45 (2003) 167–256. doi:10.1137/s003614450342480.

[72] S. Boccaletti, G. Bianconi, R. Criado, C. I. del Genio, J. Gómez-Gardeñes, M. Romance, I. Sendiña-Nadal, Z. Wang, M. Zanin, The structure and dynamics of multilayer networks, Physics Reports 544 (2014) 1–122. doi:10.1016/j.physrep.2014.07.001, the structure and dynamics of multilayer networks.

[73] S. Boccaletti, V. Latora, Y. Moreno, M. Chavez, D.-U. Hwang, Complex networks: Structure and dynamics, Physics Reports 424 (2006) 175–308. doi:10.1016/j.physrep.2005.10.009.

[74] M. Baiesi, M. Paczuski, Scale-free networks of earthquakes and aftershocks, Physical Review E 69 (2004). doi:10.1103/physreve.69.066106.

[75] B. A.-S. Juan, L. Guzmán-Vargas, Earthquake magnitude time series: scaling behavior of visibility networks, The European Physical Journal B: Condensed Matter and Complex Systems 86 (2013) 1–10. URL: https://ideas.repec.org/a/spr/eurphb/v86y2013i11p1-1010.1140-epjb-e2013-40762-2.html. doi:10.1140/epjb/e2013-40762-2.

[76] S. Kundu, A. Opris, Y. Yukutake, T. Hatano, Extracting correlations in earthquake time series using visibility graph analysis, Frontiers in Physics 9 (2021) 179. doi:10.3389/fphy.2021.656310.

[77] A. Bielinskyi, S. Hushko, A. Matviychuk, O. Serdyuk, S. Semerikov, V. Soloviev, The lack of reversibility during financial crisis and its identification, SHS Web of Conferences 107 (2021) 03002. URL: https://doi.org/10.1051/shsconf/202110703002. doi:10.1051/shsconf/202110703002.

[78] V. N. Soloviev, A. Belinskiy, Complex systems theory and crashes of cryptocurrency market, in: V. Ermolayev, M. C. Suárez-Figueroa, V. Yakovyna, H. C. Mayr, M. Nikitchenko, A. Spivakovsky (Eds.), Information and Communication Technologies in Education, Research, and Industrial Applications, Springer International Publishing, Cham, 2019, pp. 276–297. doi:10.1007/978-3-030-13929-2_14.

[79] R. V. Donner, M. Small, J. F. Donges, N. Marwan, Y. Zou, R. Xiang, J. Kurths, Recurrence-based time series analysis by means of complex network methods, International Journal of Bifurcation and Chaos 21 (2011) 1019–1046. doi:10.1142/S0218127411029021.

[80] H. Poincaré, Sur le problème des trois corps et les équations de la dynamique, Acta Math 13 (1890) 1–270.

[81] J.-P. Eckmann, S. O. Kamphorst, D. Ruelle, Recurrence plots of dynamical systems, Europhysics Letters (EPL) 4 (1987) 973–977. doi:10.1209/0295-5075/4/9/004.

[82] J. P. Zbilut, C. L. Webber, Embeddings and delays as derived from quantification of recurrence plots, Physics Letters A 171 (1992) 199–203. doi:10.1016/0375-9601(92)90426-M.

[83] C. L. Webber, J. P. Zbilut, Dynamical assessment of physiological systems and states using recurrence plot strategies, Journal of Applied Physiology 76 (1994) 965–973. doi:10.1152/jappl.1994.76.2.965.

[84] N. Marwan, J. Kurths, Nonlinear analysis of bivariate data with cross recurrence plots, Physics Letters A 302 (2002) 299–307. doi:10.1016/s0375-9601(02)01170-2.

[85] V. Derbentsev, S. Semerikov, O. Serdyuk, V. Solovieva, V. Soloviev, Recurrence based entropies for sustainability indices, E3S Web of Conferences 166 (2020) 13031. doi:10.1051/e3sconf/202016613031.

[86] Z. Fan, Q. Chen, G. Sun, N. Mastorakis, X. Zhuang, Nonlinear analysis of gravitational wave signals based on recurrence quantification analysis, MATEC Web of Conferences 210 (2018) 05011. doi:10.1051/matecconf/201821005011.

[87] M. Lin, G. Zhao, G. Wang, Recurrence quantification analysis for detecting dynamical changes in earthquake magnitude time series, International Journal of Modern Physics C 26 (2015) 1550077. doi:10.1142/S0129183115500771.

[88] A. Banerjee, B. Goswami, Y. Hirata, D. Eroglu, B. Merz, J. Kurths, N. Marwan, Recurrence analysis of extreme event-like data, Nonlinear Processes in Geophysics 28 (2021) 213–229. URL: https://npg.copernicus.org/articles/28/213/2021/. doi:10.5194/npg-28-213-2021.

[89] R. Clausius, XVI. On a mechanical theorem applicable to heat, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 40 (1870) 122–127. doi:10.1080/14786447008640370.

[90] L. Boltzmann, Weitere Studien über das Wärmegleichgewicht unter Gasmolekülen, volume 67, Vieweg+Teubner Verlag, 1970, pp. 115–225. doi:10.1007/978-3-322-84986-1_3.

[91] C. E. Shannon, A mathematical theory of communication, Bell System Technical Journal 27 (1948) 379–423. doi:10.1002/j.1538-7305.1948.tb01338.x.

[92] L. P. Karakatsanis, G. P. Pavlos, M. N. Xenakis, Tsallis non-extensive statistics, intermittent turbulence, SOC and chaos in the solar plasma. Part two: Solar flares dynamics, Physica A: Statistical Mechanics and its Applications 392 (2013) 3920–3944. doi:10.1016/j.physa.

2013.05.010.
[93] M. Javaherian, S. Mollaei, Multiscale Entropy Analysis of Gravitational Waves, Adv. High Energy Phys. 2021 (2021) 6643546. doi:10.1155/2021/6643546.
[94] Y. E. Litvinenko, A maximum entropy argument for the slopes of power-law particle spectra in solar flares, The Astrophysical Journal 880 (2019) 20. doi:10.3847/1538-4357/ab2760.
[95] A. Posadas, J. Morales, A. Posadas-Garzon, Earthquakes and entropy: Characterization of occurrence of earthquakes in Southern Spain and Alboran Sea, Chaos: An Interdisciplinary Journal of Nonlinear Science 31 (2021) 043124. doi:10.1063/5.0031844.
[96] A. J. Lawrance, Directionality and reversibility in time series, International Statistical Review / Revue Internationale de Statistique 59 (1991) 67–79. URL: http://www.jstor.org/stable/1403575.
[97] L. Stone, G. Landan, R. M. May, Detecting TimeArrow: a method for identifying nonlinearity and deterministic chaos in time-series data, Proceedings of the Royal Society of London. Series B: Biological Sciences 263 (1996) 1509–1513. doi:10.1098/rspb.1996.0220.
[98] C. S. Daw, C. E. A. Finney, M. B. Kennel, Symbolic approach for measuring temporal "irreversibility", Phys. Rev. E 62 (2000) 1912–1921. doi:10.1103/PhysRevE.62.1912.
[99] M. B. Kennel, Testing time symmetry in time series using data compression dictionaries, Phys. Rev. E 69 (2004) 056208. doi:10.1103/PhysRevE.69.056208.
[100] L. Lacasa, A. Nuñez, E. Roldán, J. M. R. Parrondo, B. Luque, Time series irreversibility: a visibility graph approach, Eur. Phys. J. B 85 (2012) 217. doi:10.1140/epjb/e2012-20809-8.
[101] J. F. Donges, R. V. Donner, J. Kurths, Testing time series irreversibility using complex network methods, EPL (Europhysics Letters) 102 (2013) 10004. doi:10.1209/0295-5075/102/10004.
[102] R. Flanagan, L. Lacasa, Irreversibility of financial time series: A graph-theoretical approach, Physics Letters A 380 (2016) 1689–1697. doi:10.1016/j.physleta.2016.03.011.
[103] M. Costa, A. L. Goldberger, C.-K. Peng, Broken asymmetry of the human heartbeat: Loss of time irreversibility in aging and disease, Phys. Rev. Lett. 95 (2005) 198102. doi:10.1103/PhysRevLett.95.198102.
[104] M. Zanin, A. Rodríguez-González, E. Menasalvas Ruiz, D. Papo, Assessing time series reversibility through permutation patterns, Entropy 20 (2018). URL: https://www.mdpi.com/1099-4300/20/9/665. doi:10.3390/e20090665.
[105] C. Jiang, P. Shang, W. Shi, Multiscale multifractal time irreversibility analysis of stock markets, Physica A: Statistical Mechanics and its Applications 462 (2016) 492–507. doi:10.1016/j.physa.2016.06.092.
[106] Y. Chen, W. B. Manchester, A. O. Hero, G. Toth, B. DuFumier, T. Zhou, X. Wang, H. Zhu, Z. Sun, T. I. Gombosi, Identifying solar flare precursors using time series of SDO/HMI images and SHARP parameters, Space Weather 17 (2019) 1404–1426. doi:10.1029/2019sw002214.
[107] H. Liu, C. Liu, J. T. L. Wang, H. Wang, Predicting solar flares using a long short-term memory network, The Astrophysical Journal 877 (2019) 121. doi:10.3847/1538-4357/ab1b3c.

Agile methodology in higher education quality assurance system for SDGs 4, 8 and 9 achievement: national experience

Artem E. Artyukhov[2], Iurii Iu. Volk[1] and Tetiana A. Vasylieva[1]

[1]Sumy State University, 2 Rymskogo-Korsakova Str., Sumy, 40007, Ukraine

Abstract

This paper is focused on considering agile methodology as an instrument to use in education quality assurance. We propose the Scrum method applicable for education quality assurance based on adapted Manifesto for Agile Education Quality Assurance and twelve principles behind it. The Scrum procedure is described and roles are distributed for two real-life cases of external and internal educational program quality evaluation. We illustrate that proposed Scrum procedure perfectly fits existing practices and can be used to enhance both external and internal quality assurance processes in higher education. We consider achievement of SDG 4 targets through proposed methodology as the necessary step to take in achieving SDGs 8 and 9. It is concluded that stakeholders feedback about their satisfaction by economic and innovative factors should be included in each sprint review procedure in proposed Scrum methodology. We discuss SDG 4 achieving within multilayered DIKW+DM hierarchy as a framework for education quality assurance that allow to join information processing, knowledge acquisition and corresponding decision-making algorithm.

Keywords

education quality, agile methodologies, scrum, sustainability

1. Introduction

Application of agile methodologies in education is a widely discussed topic nowadays. Due to the constant changing labor market demands, higher education institutions are forced to adapt approaches aimed at flexible learning. This matter is especially at hand due to worldwide orientation at life-long education: agility is of crucial importance for keeping the same pace as constantly changing requirements of society. Recent interest in application of agile methodologies to form innovative pedagogical tools is logical reaction of educational institutions aimed to address these challenges.

When building a model for generating knowledge and testing the “quality of education" system, one should also pay attention to the trends dictated by the world community. These

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a.artyukhov@pohnp.sumdu.edu.ua (A. E. Artyukhov); y.volk@mss.sumdu.edu.ua (I. Iu. Volk); tavasilyeva@fem.sumdu.edu.ua (T. A. Vasylieva)

https://personal.sumdu.edu.ua/artyukhov/en/ (A. E. Artyukhov); https://pom.sumdu.edu.ua/en/department/personal-pages/252-iurii-i-volk (I. Iu. Volk); https://biem.sumdu.edu.ua/en/director-biem (T. A. Vasylieva)

0000-0003-1112-6891 (A. E. Artyukhov); 0000-0002-0262-762X (I. Iu. Volk); 0000-0001-9534-1251 (T. A. Vasylieva)

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trends have been outlined as Sustainable Development Goals in United Na- tions Millennium Development Goals and 2030 Agenda for Sustainable Development. Given that there is a separate Sustainable Development Goal (SDG) 4 dedicated to quality education, it is important to establish a link in the proposed approach SDG 4 and other SDGs. This idea is the basis of the presented material. Considering that the result of achieving SDG 4 is, among other things, the growth of economic indicators among stakeholders, it should be noted that there is a specific connection between SDG 4, SDG 8 and SDG 9. The role of university education is to ensure economic growth and create an innovative infrastructure in connection with the main stakeholders, which determines the need to consider mentioned relationship between SDGs.

However, labor market's main interest is not the education process itself, but its outcomes in form of trained graduate possessing skill-set suitable for current position or able to quickly adapt to position's specifics. Despite the small contribution in form of direct pedagogical innovations, employers are highly motivated to participate in education quality assurance activities. Therefore, the need arises to form educational quality assurance system that accounts interests of all stakeholders and allow them to collaborate in efficient and flexible framework. This paper attempts to provide Ukrainian higher education institutions (HEIs) with such quality assurance methodology developed upon agile philosophy and principles.

2. Literature review

Agile methodologies in education have their constant attention in forms of direct application to learning process [1, 2, 3]. As stated in [4], "By using Agile methodologies to design, structure and steer courses as a whole, or punctual activities and projects, instructors are offering a valuable framework and environment for students to develop valuable competencies that can serve to increase their performance in their work life and their development as responsible citizens living in a sustainable way". However, as we defined in the introduction, the aim of this article to propose not a learning tool, but education quality assurance method based on agile philosophy.

To determine the trending direction of research, a bibliometric analysis was carried out using data from the Scopus scientometric database (https://www.scopus.com/) using the VOSViewer (https://www.vosviewer.com/) and SciVal (https://www.scival.com/home) tools. The main task of bibliometric analysis is to determine the relationship between agile methodology and various aspects of the educational sphere. Bibliometric analysis was carried out using query "agile quality of education".

Analysis of the relationship between different keywords by specified query (figure 1) highlights the areas of application of agile in education. These keywords actually create a set of indicators for quality assurance in education. Individual clusters within the keyword map are of particular interest. The "scrum" cluster (figure 2) can be used as the basis to create an algorithm for assessing educational program quality. The "decision making" cluster (figure 3) is a prototype for testing the education quality system based on the DIKW model [5] and on the agile approach at the decision-making stage which in its turn is based on data, information and knowledge received.

The relevance of the proposed topic in terms of practical implementation is confirmed by

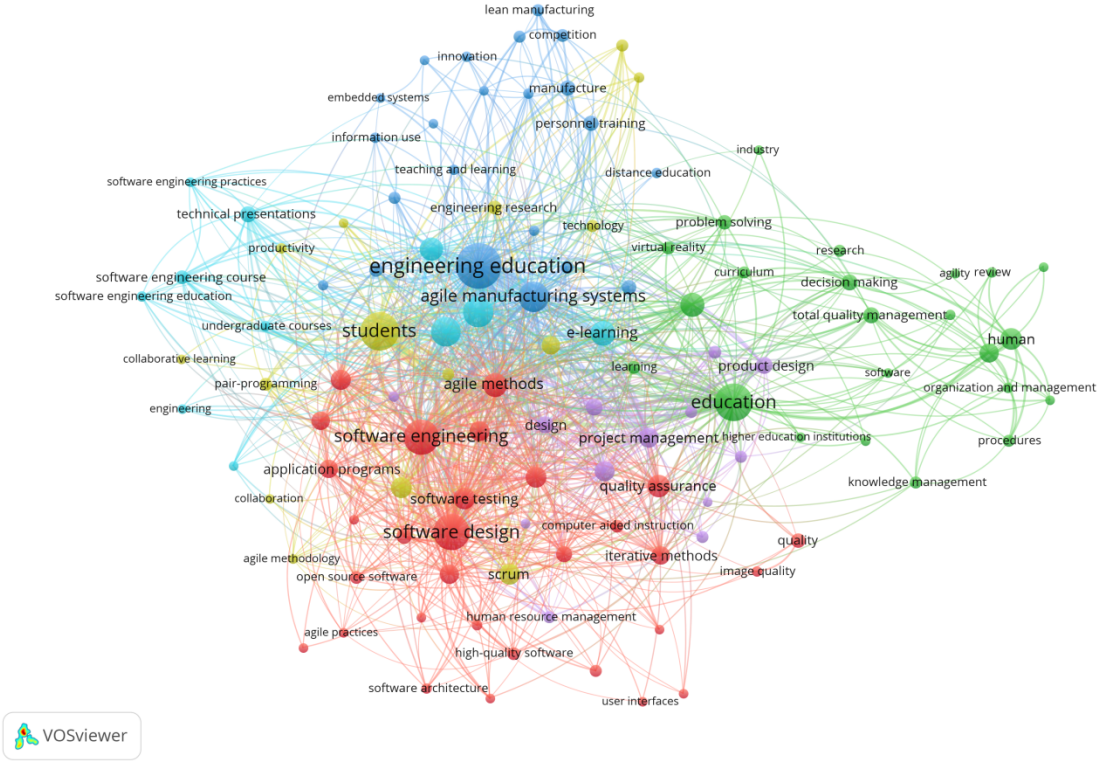

Figure 1: Keywords corresponding to the query “agile quality of education”.

the results of bibliometric analysis shown in figure 4. Topic clusters show the main points of influence of the quality of education including economic factors: learning environment, educational innovation, information quality, business model innovation , sustainable business etc.

These data allow to create a testing model with specific outcomes, which can be used to determine the degree of performance of the system “quality of education”.

As for the analysis of various indicators impact on the system “quality of education”, we refer to specific literary sources, systematizing them in following way:

- marketing and knowledge management as a basis for modeling the system “quality of education” [6, 7, 8, 9];
- main stakeholders the influence of the on the educational environment [10, 11, 12];
- ensuring the quality of education in general and personnel training quality [13, 14, 15, 16];
- socio-economic factors of the education influence [17, 18];
- quality of education and sustainable development [19, 20]].

Thus, the bibliometric analysis in general and the analysis of specific literary sources allow us to define a niche where it is possible to use the agile approach for ensuring the quality of education in relation to socio-economic indicators

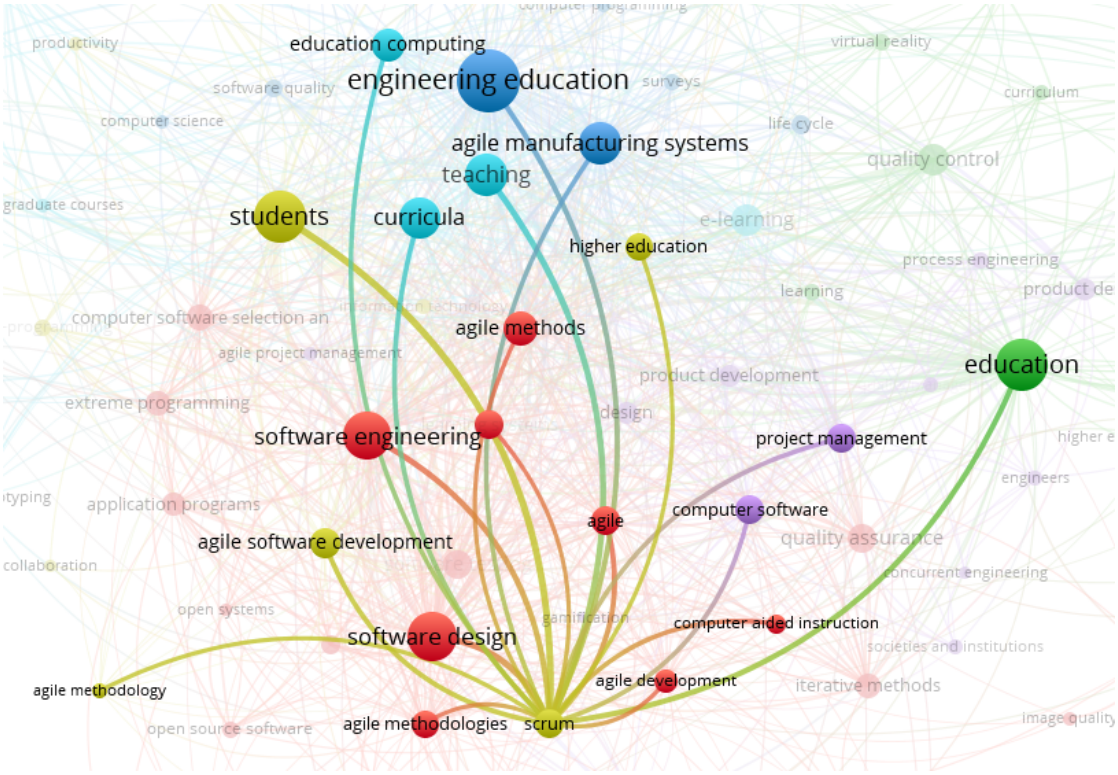

Figure 2: Cluster “scrum”.

3. Modelling of university quality education system utilizing agile methodology

Before we introduce direct agile applications in university quality assurance system, let us briefly discuss Agile Manifesto in terms of education quality. It can be formed as legacy of Manifesto for Agile Software Development [21] with corresponding alignment of twelve principles behind it [22]. Therefore, the Manifesto for Agile Education Quality Assurance can be adapted as follows:

- Individuals and interactions are valued over processes and tools (same as in software development);
- Education quality is valued over comprehensive regulatory framework;
- Stakeholder collaboration is valued over requirements discussion;
- Responding to change is valued over following a plan (same as in software development).

Introduced manifesto is based on following twelve principles:

1. Highest priority of education quality assurance is to satisfy all stakeholders through continuous improvement of learning quality.

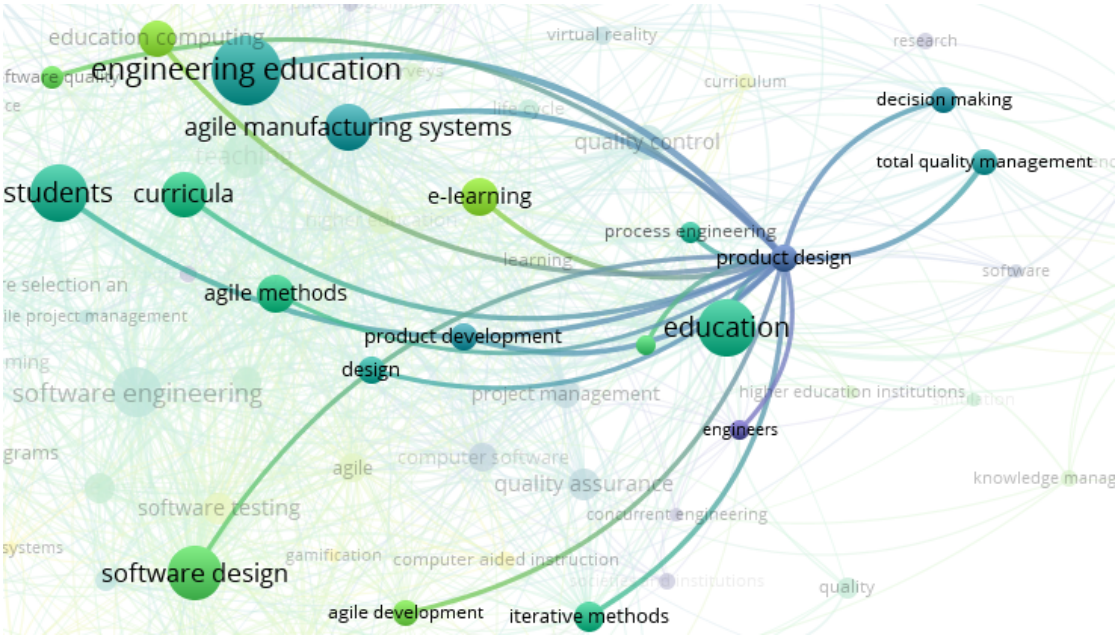

Figure 3: Cluster “decision making”.

2. Welcome changes in education quality criteria, even at formed systems.
3. Deliver evaluation results frequently, both internally and externally.
4. Frequent collaboration between all stakeholders: students, university management and employers.
5. Build the system around motivated individuals giving them the environment and support they need, and trust them to get the job done.
6. Face-to-face conversation is the most effective method of communication within quality assurance system.
7. Student level of knowledge is the primary measure of education quality.
8. Sustainable development is maintained throughout the whole system functioning.
9. Continuous attention to technical excellence and good design enhances agility
10. Simplicity – the art of maximizing the amount of work not done – is essential
11. Self-organization of the team fosters the best practices for education quality assurance.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

Note that some principles outlined for software development at [22] are perfectly applicable for education quality assurance and hence they are incorporated in unchanged form.

Hereby we propose few insights on how to build education quality assurance system based on agile principles and applicable for any Ukrainian higher education institution.

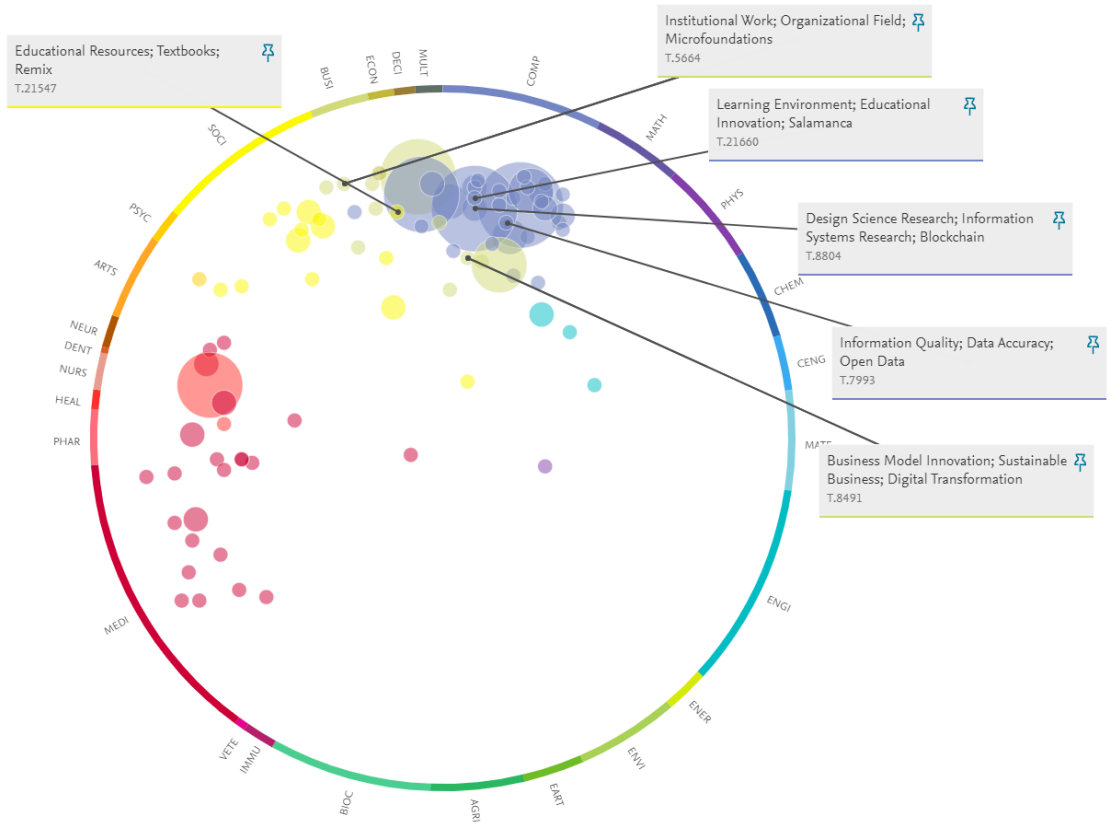

Figure 4: Top 25% topics by prominence defined by query “agile quality of education”.

3.1. Scrum method for education quality assurance

Scrum is the agile methodology widely used in project management and systems development. First published in [23] it has since gained significant development. Nowadays scrum is one of the most preferable agile methodologies with benefits in transparency, risk management and flexibility.

In this paper we propose scrum method for education quality assurance. This method allows organizing education quality assurance procedure in comprehensive way. It can be scaled from overall university performance evaluation (including both educational and scientific components) down to single educational program assessment on the department level. Figure 1 represents the diagram of proposed scrum method.

The process is comprised of the following steps:

1. *Forming of Educational Quality Assurance Backlog.* It is closely coupled with internal or external quality criteria (e.g. National Agency for Education Quality Assurance of Ukraine (NAQA) educational program quality criteria).
2. *Forming Evaluation Sprint Backlog.* Basically, Scrum team selects tasks (activities) from

Activities backlog formed on previous step to include in the next sprint (e.g. check academic integrity environment in the university).

3. *Performing Evaluation Sprint.* Along with direct fulfillment of sprint backlog tasks, team evaluates total Activities backlog completion taking new tasks for new sprint and/or including tasks failed on previous sprint (e.g. re-evaluate unclear points explained by university management).
4. Each spring gets reviewed and based on this retrospective team implements *sprint's deliverables* (e.g. recommendations for educational programs improvement).

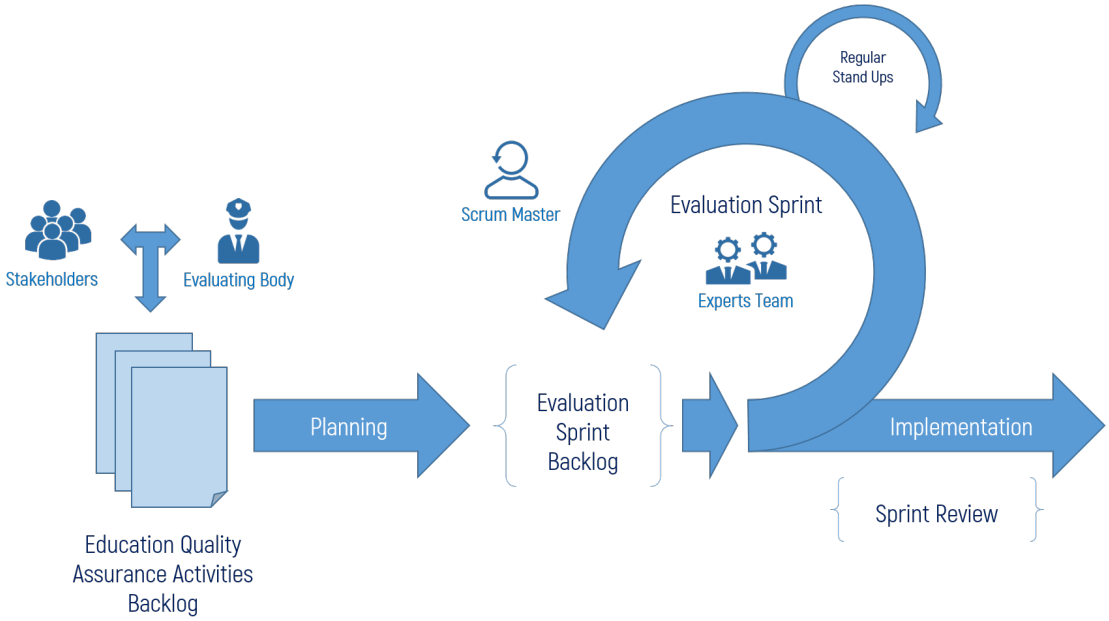

Figure 5: Scrum method for education quality assurance.

- **Stakeholders** provide their vision of education quality since they are highly motivated in high quality education due to direct economical connection to the graduates landscape. They also provide initial self-assessment report which is used as the base for activities backlog forming.
- **Evaluating Body** such as NAQA mostly contribute to forming of structured quality assurance backlog providing universal evaluation criteria and independent experts staff for external quality assurance. However, internal quality assurance department might also act as evaluating body in case of scaling Scrum method to internal quality assurance procedure.
- **Experts Team** perform the evaluation activities during each sprint in transparent and sharable way. Most of their evaluation activities should be backed by deliverables, e.g. meeting reports and grades. Scrum Master supervises their work.

- **Scrum Master** maintains the control over the sprint duration and ensures that tasks from sprint evaluation backlog are fulfilled. Regular Stand-up meetings during the spring help to keep all the stakeholders and team informed about each other's activities.

To illustrate the viability of proposed scrum method let us provide examples for external and internal quality of educational program assurance procedures. Based on existing practices (NAQA Evaluation procedure and internal assessment of educational program) we define Educational Quality Assurance Backlog, divide it by sprints and distribute roles according to positions of engaged staff. Figure 6 should be considered as key to be used with scrum method given in figure 5.

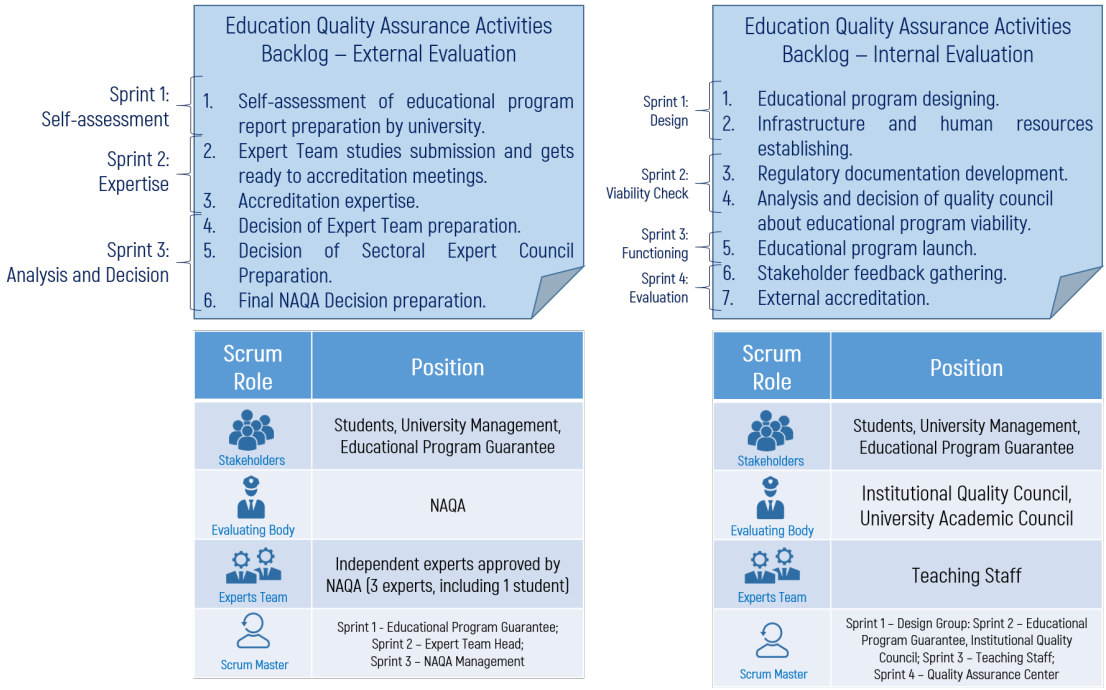

Figure 6: Scrum backlogs and roles for external and internal quality assurance procedures.

As figure 6 demonstrates, such distribution of roles and formation of Education Quality Assurance Backlog fully fits into scrum method described by figure 5. We should note that figure 6 was constructed based on existing evaluation procedures: external evaluation of educational programs by NAQA and internal evaluation of educational programs within the university.

Another important note to take here is that after reviewing the Sprint activities the evaluation outcomes (grades, recommendations to improve some parts of the program, staff evaluation reports) are than used as deliverables for university. Sprint review procedure is also closely coupled with stakeholders feedback collection about their satisfaction by economic outcomes (in terms of graduates competencies) that are provided by educational program and level

of innovation that industry gets from implementing educational program. Thus, proposed methodology connects clear SDG 4 tasks behind the quality assurance system and not so obvious in this context SDGs 8 and 9.

As can be seen from figure 6, external accreditation of educational program is included in Sprint 4 of internal evaluation procedure. This may seem counterintuitive on the first glance, but is backed by logic of educational program development, which is much more complex project than its accreditation.

3.2. University quality education system aimed at SDG achievement

SDG 4 is a combination of ten targets addressing problems of education quality and equality on different levels of education. The first two targets (4.1, 4.2) are intended to ensure equal access of all children to early childhood development and primary education with effective learning outcomes. This is followed by targets 4.3 and 4.4 stating the need to ensure equal access for all women and men to technical education and availability of quality employment for all graduates. Target 4.5 addresses the problems of educational access for vulnerable groups including people with disabilities, indigenous peoples and children in vulnerable situations. Target 4.6 is aimed to reduce both youth and adult illiteracy and innumeracy. Target 4.7 raises the need to focus educational content on the knowledge and skills promoting sustainable development, human rights, gender equality and culture of peace along with global citizenship. Additional targets 4A, 4B and 4C lay the timeframe and suggest means to fulfill targets 4.1–4.7 [24].

However, the quantitative measurements of the stated targets fulfillment is complicated despite the indicators formulated by SDG 4. According to [25], "Education quality, equality, inclusion, gender equality may be unmeasurable with current indictors, but if metrics are useful to enhance human rights agendas and develop strategies to tackle considerable injustices, then research and critical discussion is needed concerning what indicators might help develop policy, practices and accountability to realise the vision of SDG4. A frequent riposte to the complexity of ideas of quality, equality and inclusion in education is that they are actually unmeasurable."

Therefore, combining efforts aimed to achievement of the stated targets leads to the idea of the development of quality education system focused on SDG4 principles and aimed at fulfilling targets 4.1–4.7.

Figure 8 illustrates multidirectional pipeline focused on achieving SDGs 4, 8 and 9 through the university engagement. Each of the six stages is carried out in the presented sequence when the "initial data" for following stages are the results of the previous. Each of the stages is associated with the fulfilling of different SDG targets. In addition to SDG 4 and SDG 7, which connection with university activities was covered in [19], the diagram shows other SDGs that can be achieved during the implementation of the algorithm, in particular SDGs 8 and 9 discussed above. One can see that a cycle of university activities is organized between the main elements (nodes). Each stakeholder has the ability to influence the nature of the model implementation at a certain stage. In this case, stakeholders are initiators of error search and proposing changes on the stage testing phase (algorithm modernization, conditions for performing a particular stage, conditions for moving to the next stage, etc.) This fact is demonstrated in the description of the model testing algorithm. The model assumes that at the beginning of the algorithm implementation (when developing the technical task for each stage — the regulatory framework

of the university), the stages can be carried out in parallel. However, the effective implementation of the algorithm can be continued only when the result is achieved at the "Quality education system" stage.

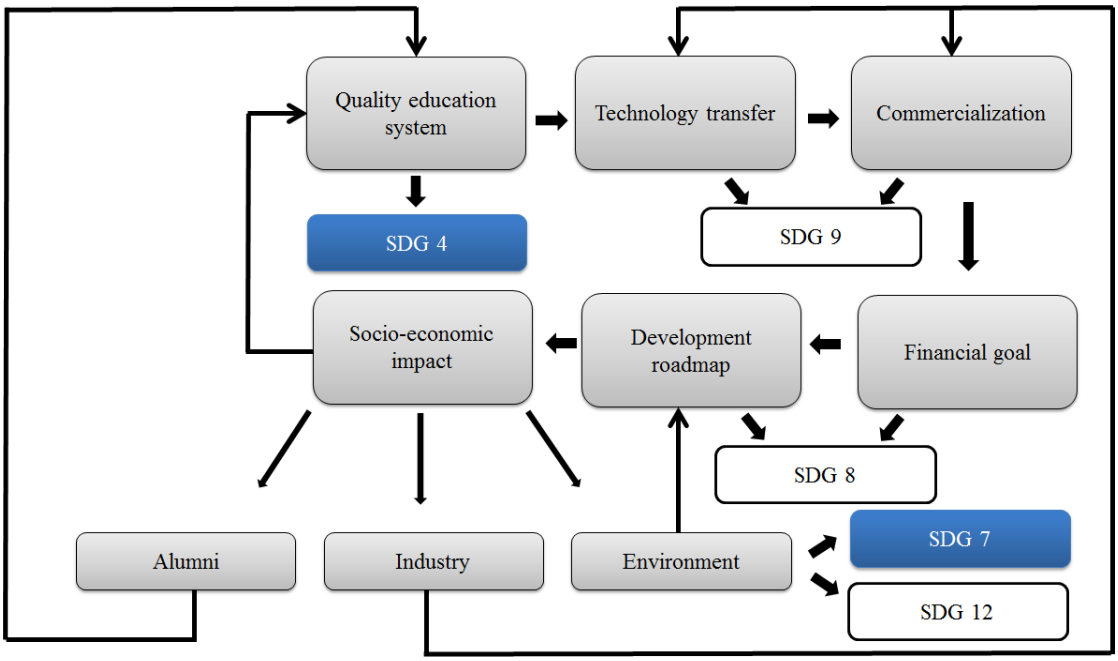

Figure 7: From quality education to innovations and economic growth.

One of the ideas of achieving SDG 4 on level of university is to use DIKW+DM hierarchy. Its aim is the modification of known DIKW information hierarchy to get multilayered framework for education quality assurance that allow to join information processing, knowledge acquisition and corresponding decision-making algorithm.

The agile approach is not recommended for all layers of the DIKW hierarchy. At the stage of collecting data, analyzing them, systematizing and obtaining an array of information, the data is not corrected due to their constancy. Only at the stage of knowledge generation as a tool for subsequent decision-making, it becomes necessary to assess certain factors degree of influence and revise the system's functioning model. At the same time, the procedure of internal quality control by the university and external quality control by independent educational agencies and external stakeholders is implemented. The report on the monitoring of the quality system is a guiding document for further revision of system structure, content, interrelation of elements and the degree of their mutual influence. This part of the model is tested and refined through an agile approach.

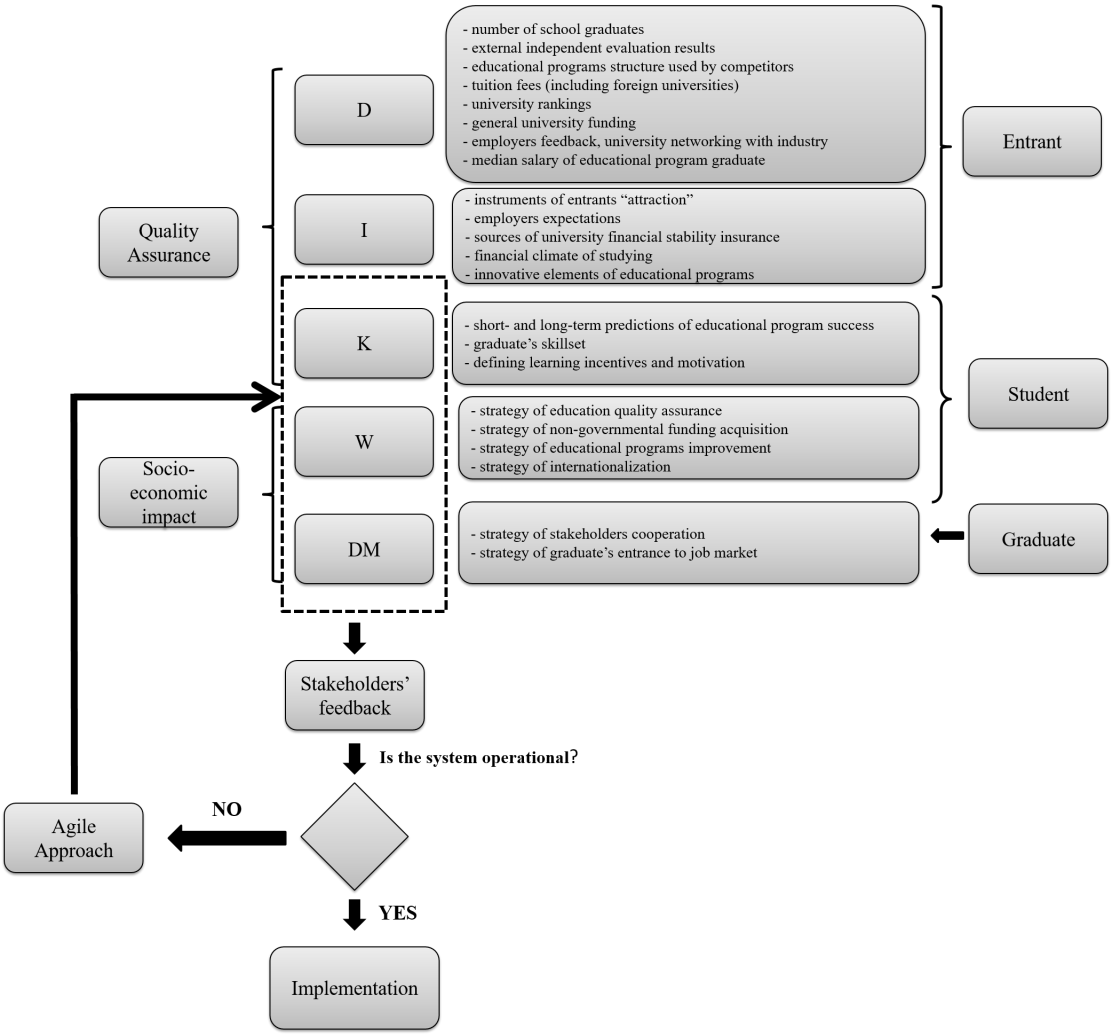

Figure 8: DIKW+DM Model incorporating agile approach on the system testing phase.

4. Conclusions

Therefore, in this paper we proposed Manifesto for Agile Education Quality Assurance and twelve principles behind it based on Manifesto for Agile Software Development. We used these principles to propose scrum method for education quality assurance. We defined the overall scrum procedure and distributed roles participating in planning, spring execution and implementation phases. It was illustrated that Scrum method perfectly fits existing procedure and staff roles and can be adopted with minimal adjustments by national HEIs.

A consistent approach to the optimal implementation method of quality assurance main tasks at the university allows solving other problems simultaneously. Achieving SDG 4 targets all continues the quality assurance journey beyond the educational process. The creation of

innovative infrastructures and the achievement of economic growth (thus fostering SDGs 8 and 9 achievement) are important outcomes of an effective model for ensuring the quality of education. Based on feedback from stakeholders about the degree of their "economic" and "innovative" satisfaction, subtasks are formed within the framework of internal and external assurance sprints of education quality assurance procedure.

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References

[1] M. J. D'Souza, P. Rodrigues, Extreme pedagogy: An agile teaching-learning methodology for engineering education, Indian Journal of Science and Technology 8 (2015) 828–833. doi:10.17485/ijst/2015/v8i9/53274.

[2] P. Salza, P. Musmarra, F. Ferrucci, Agile methodologies in education: A review, in: Agile and Lean Concepts for Teaching and Learning, Springer Singapore, 2018, pp. 25–45. doi:10.1007/978-981-13-2751-3_2.

[3] D. Parsons, K. MacCallum, Agile education, lean learning, in: Agile and Lean Concepts for Teaching and Learning, Springer Singapore, 2018, pp. 3–23. doi:10.1007/978-981-13-2751-3_1.

[4] A. López-Alcarria, A. Olivares-Vicente, F. Poza-Vilches, A systematic review of the use of agile methodologies in education to foster sustainability competencies, Sustainability 11 (2019). URL: https://www.mdpi.com/2071-1050/11/10/2915. doi:10.3390/su11102915.

[5] O. Dammann, Data, information, evidence, and knowledge: A proposal for health informatics and data science, Online Journal of Public Health Informatics 10 (2019). URL: https://journals.uic.edu/ojs/index.php/ojphi/article/view/9631. doi:10.5210/ojphi.v10i3.9631.

[6] B. A. Brimah, W. D. Olanipekun, A. G. Bamidele, M. Ibrahim, Knowledge management and its effects on financial performance: Evidence from Dangote Flour Mills, Ilorin, Financial Markets, Institutions and Risks 4 (2020) 34–42. doi:10.21272/fmir.4(2).34-42.2020.

[7] H. Yarovenko, Y. Bilan, S. Lyeonov, G. Mentel, Methodology for assessing the risk associated with information and knowledge loss management, Journal of Business Economics and Management 22 (2021) 369–387. doi:10.3846/jbem.2021.13925.

[8] K. Onopriienko, V. Onopriienko, Y. Petrushenko, I. Onopriienko, Environmental education for youth and adults: a bibliometric analysis of research, E3S Web of Conferences 234 (2021) 00002. doi:10.1051/e3sconf/202123400002.

[9] S. Kvitka, G. Starushenko, V. Koval, H. Deforzh, O. Prokopenko, Marketing of ukrainian higher educational institutions representation based on modeling of webometrics rank-

ing, Marketing and Management of Innovations (2019) 60–72. doi:10.21272/mmi.2019.3-05.
[10] F. Vidic, Entrepreneurial orientation and knowledge creation and their impact on company performance, SocioEconomic Challenges 2 (2018) 37–48. doi:10.21272/sec.3(2).37-48.2018.
[11] I. Kobushko, O. Jula, M. Kolesnyk, Improvement of the mechanism of innovative development of small and medium-sized enterprises, SocioEconomic Challenges 1 (2017) 60–67. doi:10.21272/sec.2017.1-07.
[12] L. Sineviciene, O. Shkarupa, L. Sysoyeva, Socio-economic and political channels for promoting innovation as a basis for increasing the economic security of the state: Comparison of ukraine and the countries of the european union, SocioEconomic Challenges 2 (2018) 81–93. doi:10.21272/sec.2(2).81-93.2018.
[13] O. Pavlenko, V. Martynets, O. Dreval, D. Smolennikov, Analysis of influence of the quality of specialist training on social and economic development, Quality - Access to Success 21 (2020) 81–86.
[14] V. Levchenko, A. Boyko, T. Savchenko, V. Bozhenko, Y. Humenna, R. Pilin, State regulation of the economic security by applying the innovative approach to its assessment, Marketing and Management of Innovations (2019) 364–372. doi:10.21272/mmi.2019.4-28.
[15] C. G. Cosmulese, V. Grosu, E. Hlaciuc, A. Zhavoronok, The influences of the digital revolution on the educational system of the EU countries, Marketing and Management of Innovations (2019). doi:10.21272/mmi.2019.3-18.
[16] I. S. and, Towards the assurance of transparency and quality of higher education in Ukraine: National qualification framework, Business Ethics and Leadership 2 (2018). doi:10.21272/bel.2(1).96-105.2018.
[17] S. Lyeonov, O. Liuta, Actual problems of finance teaching in ukraine in the post-crisis period, in: The Financial Crisis, Springer International Publishing, 2016, pp. 145–152. doi:10.1007/978-3-319-20588-5_8.
[18] I. Didenko, J. Paucz-Olszewska, S. Lyeonov, A. Ostrowska-Dankiewicz, Z. Ciekanowski, Social safety and behavioral aspects of populations financial inclusion: A multicountry analysis, Journal of International Studies 13 (2020) 347–359. doi:10.14254/2071-8330.2020/13-2/23.
[19] A. Artyukhov, I. Volk, T. Vasylieva, S. Lyeonov, The role of the university in achieving SDGs 4 and 7: a Ukrainian case, E3S Web of Conferences 250 (2021) 04006. doi:10.1051/e3sconf/202125004006.
[20] A. Vorontsova, T. Vasylieva, Y. Bilan, G. Ostasz, T. Mayboroda, The influence of state regulation of education for achieving the sustainable development goals: case study of Central and Eastern European countries, Administratie si Management Public 34 (2020) 6–26. doi:10.24818/amp/2020.34-01.
[21] Manifesto for Agile Software Development, 2001. URL: https://agilemanifesto.org/.
[22] Principles behind the Agile Manifesto, 2001. URL: https://agilemanifesto.org/principles.html.
[23] K. Schwaber, SCRUM development process, in: Business Object Design and Implementation, Springer London, 1997, pp. 117–134. doi:10.1007/978-1-4471-0947-1_11.
[24] United Nations, 4 Ensure inclusive and equitable quality education and promote lifelong

learning opportunities for all, 2022. URL: https://sdgs.un.org/goals/goal4.
[25] E. Unterhalter, The many meanings of quality education: Politics of targets and indicators in SDG4, Global Policy 10 (2019) 39–51. doi:10.1111/1758-5899.12591.

Experience in training specialists with mathematical computer modeling skills, taking into account the needs of the modern labor market

Nataliia V. Morze[1], Iryna V. Mashkina[1] and Mariia A. Boiko[1]

[1]Borys Grinchenko Kyiv University, 18/2 Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine

Abstract

Today in most countries there is a lack of qualifications in areas, which require specialists with mathematical competencies, despite the high unemployment rate in many countries. At the same time, it is generally recognized that most likely those sciences are developing, the fundamental results of which can be formulated mathematically. Using mathematical methods, researchers draw important conclusions that could hardly be obtained otherwise. Digital transformation of all industries requires specialists with a sufficient level of mathematical competence and skills in ICT tools, including computer modeling using the approach called Inquiry-Based Mathematics Education (IBME).

Keywords

mathematical competence, STEM education, computer modeling, IBME, labor market

1. Introduction

Modern society, digital transformation of all industries require the development of business mindset, innovation, STEM education and science education. These needs of the labor market can be met only with professionals who have an adequate level of mathematical competence.

In the last few years, Ukrainian universities have faced the problem of mathematics' training. Young people do not wish to teach mathematics and have a low level of preparation when they enter the university to master the program in mathematics.

We see a real problem with the study and teaching of mathematics in high school and in universities. One of the reasons for this situation, in our opinion, is the low motivation of students. This happens because students do not see a suitable labor market. There are two ways to solve this problem:

1. Change the methodology of teaching mathematics from passive learning to active activities. This means students are involved in solving theoretical and practical problems using

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n.morze@kubg.edu.ua (N. V. Morze); i.mashkina@kubg.edu.ua (I. V. Mashkina); m.gladun@kubg.edu.ua (M. A. Boiko)

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0000-0003-3477-9254 (N. V. Morze); 0000-0003-0667-5749 (I. V. Mashkina); 0000-0003-0293-5670 (M. A. Boiko)

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the inquiry.

2. Teach students a business mindset. This means the development of their own projects that can become Startups. All with the help of mathematics.

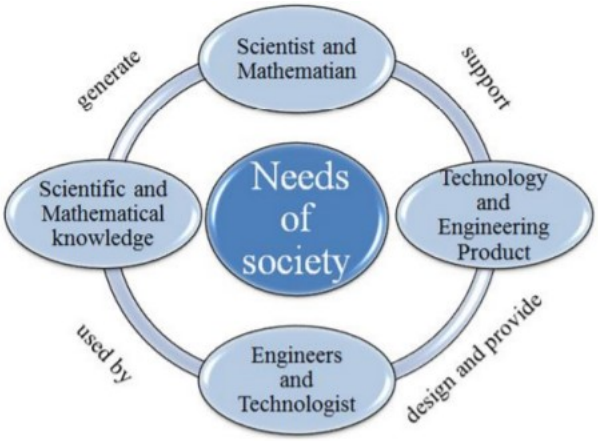

Figure 1: Needs of society.

The problem of the quality of natural and mathematical education in Ukraine as a part of the general world educational space is multidimensional, and numerous academic and journalistic works of domestic and foreign authors are devoted to various aspects of this problem.

The aim of this paper is to show IBME approaches in teaching mathematical modeling considering the demand in the labor market in professions requiring mathematical competence and to analyze European and national approaches to stimulate their use in accordance with the needs of the labor market, and to identify competencies that contribute to an increase in a skilled workforce considering the formation of mathematical competence.

The modern labor market imposes requirements on graduates of higher educational institutions related to the possession of professional (hard skills) and flexible (soft skills) skills, hard skills are determined by professional knowledge, skills that can be clearly demonstrated, necessary for solving specific professional tasks are formed in the learning process.

Knowledge of mathematics is critical for many areas of business: finance, IT, construction, accounting, architecture, mechanical engineering, logistics, medicine, trade and others.

Firstly, mathematical knowledge allows you to learn about the world, and, if necessary, work in other spheres of human activity. For example, a mathematician can easily work as an analyst in various modern companies. This is evidenced by the examples and lives of graduates of other specialities of Borys Grinchenko Kyiv University.

Secondly, the need of modern society for mathematicians, and not only for programmers and economists, is constantly increasing. This affects wages and the ability to work both in Ukraine and abroad.

2. Related work

The shortage of specialists in the labor market with established mathematical competence has been investigated by many scientists. In particular, Levanon [1] analyzed the main analysis on labor shortages in the United States and other advanced economies. The author notes that the risk of labor shortages in mathematics majors is much higher due to the rapid increase in available data at the company level or big data, currently leading to the rapidly growing demand for workers who can help turn this data into business decisions. According to employment forecasts by the Bureau of Labor Statistics, the math professions are expected to grow by 28 percent in 2014-2024 – one of the fastest-growing occupation groups in the entire economy.

To meet the needs of modern society in mathematics, we see the importance of forming mathematical competence [2]. In particular, Onoprienko [3] considers the formation of mathematical competence through competence-oriented problems.

The system approach is presented in the works of Fayzullaev [4], Khomiuk [5], Striuk et al. [6]. The formation of professional and mathematical competence of students in the field of technical training on the basis of interdisciplinary integration of mathematics and computer science is considered by Vasileva et al. [7]. Astafieva et al. [8] substantiated the approaches to the effective use of the advantages and minimized the disadvantages and losses of e-learning as a means of forming the mathematical competence of students in the context of a research-oriented educational process.

To increase the motivation of students in the study of mathematics, one way is to demonstrate the connection with real life. The method of studying processes or phenomena by creating their mathematical models and studying these models is mathematical modeling. A great contribution to the study of teaching mathematical modeling has also been made by Flehantov and Ovsiienko [9], Kaiser [10], Lvov et al. [11], Riyanto et al. [12], Teplytskyi [13].

3. Research methods

Teachers of the Department of Computer Science and Mathematics also conduct ongoing research in the direction of the quality of science and mathematics education. As part of an international project ERASMUS+ Platinum a survey of employers of the modern labor market in Ukraine and graduates of the University was conducted in order to compare on the one hand the needs of employers in specialists with mathematical competencies, on the other – self-assessment of graduates on the level of relevant competencies, Inquiry-Based Mathematics Education (IBME) used in the teaching of mathematical disciplines, in which students are invited to work in ways similar to how mathematicians and scientists work. In our project, we conducted a survey of employers and business leaders.

The task of the survey was to analyze what qualities employers expect and what students lack when they get a job. The survey was attended by employers in Kyiv, whose areas of activity are different in figure 2.

To the question “Do your company employ specialists with higher education, an important component of whose professional training were mathematical disciplines?” all respondents answered “yes”. At the same time, 68.8% of participants answered in the affirmative about the

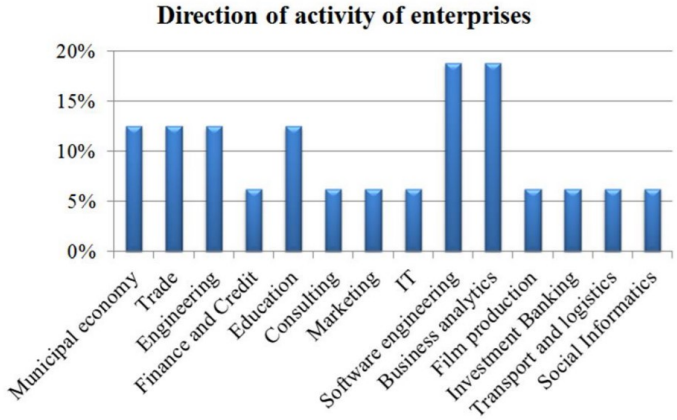

Figure 2: The direction of activity of the surveyed employers.

need for such specialists at their enterprise, 12.5% need professional mathematicians and 12.5% need situationally and then specialists are involved on a project basis.

The labor market needs for specialists in whom mathematical competencies are formed is also indicated by the answer to the question "Are you satisfied with the level of mathematical training of specialists working at your enterprise?" 43.8% answered "yes", 43.8% -"need a special preparation for the tasks of the organization", 12.5% – "suits, because a personnel policy is being carried out to select the appropriate stuff".

The survey also shows us which competencies are important for mathematicians from the point of view of the job market: the importance of competencies for mathematics specialists for business; use the Web resources to solve professional problems; ability to apply mathematical knowledge and models in real-life contexts.

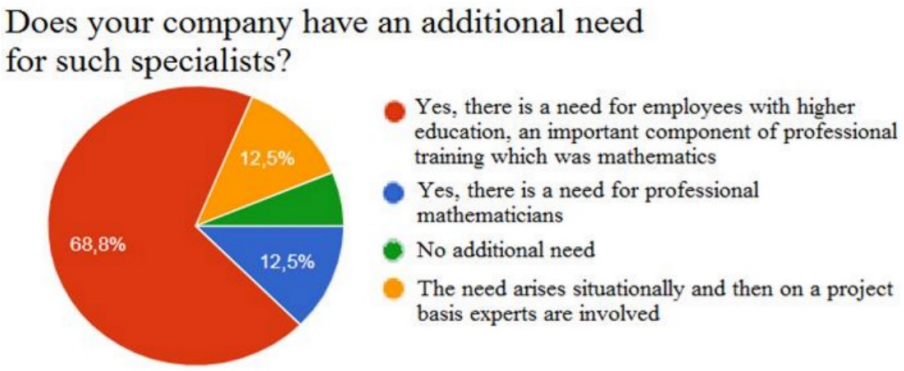

Figure 3: The result of a survey on the need for mathematicians.

As part of the project, we conducted a survey of our graduates of programs in mathematics. One of the questions in the survey was about what skills they needed.

In particular, they noted that they lack: the ability to adapt mathematical knowledge to the

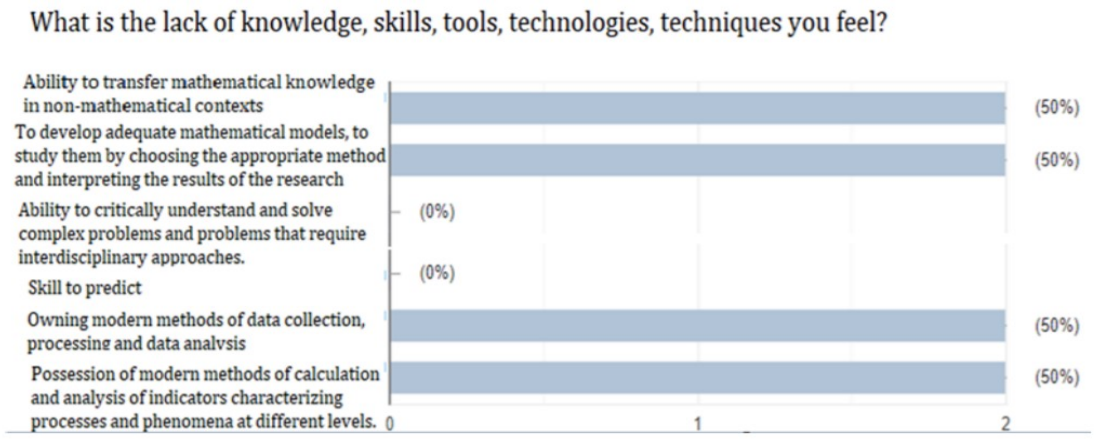

Figure 4: The result of a survey on the lack of knowledge, skills, tools, technologies.

context, the ability to use modelling in practice and research.

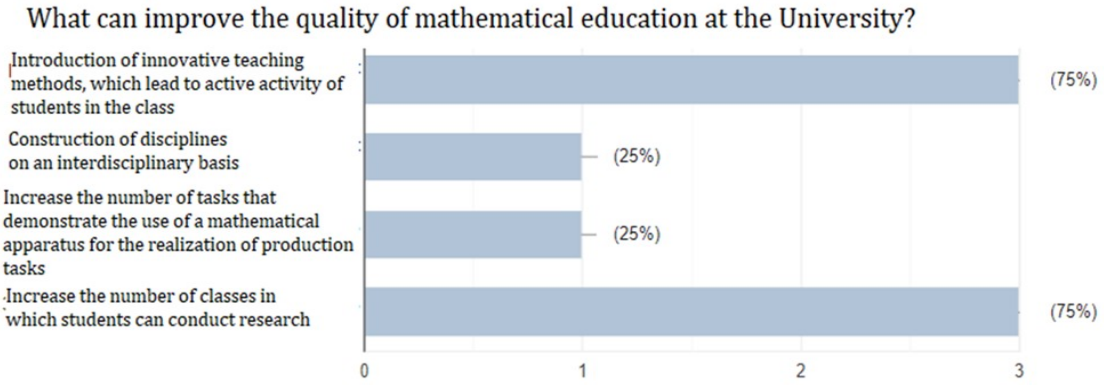

Figure 5: The result of a survey about improving the quality of mathematical education.

Another question was “What can improve the quality of teaching mathematics?”. The answers were: innovative teaching methods, elevation of research-based learning.

The results of a survey of teachers, graduates and employers showed that Mathematical Education needs:

- Changes in teaching: using IBL, active learning, flipped learning.
- Design and redesign of practical problems for teaching mathematics (creation of a system of modeling problems)
- Improving motivation to study mathematics. This means to demonstrate applied mathematics and to involve students in business activities using modeling tasks.

That is why the University began to implement:

- The new innovative method of teaching mathematics (based on the introduction of IBL – inquiry-based learning)
- Develop business mindset for business professions, but for mathematics too. This means:
  - to teach mathematical modeling related to the inquiry;
  - to use mathematical models to solve practical problems;
  - to implement innovations by involving the students to develop the startups.

The first stage of the development of the university into a business university is the creation of a student business incubator. The challenge for universities is to change approaches to teaching mathematics.

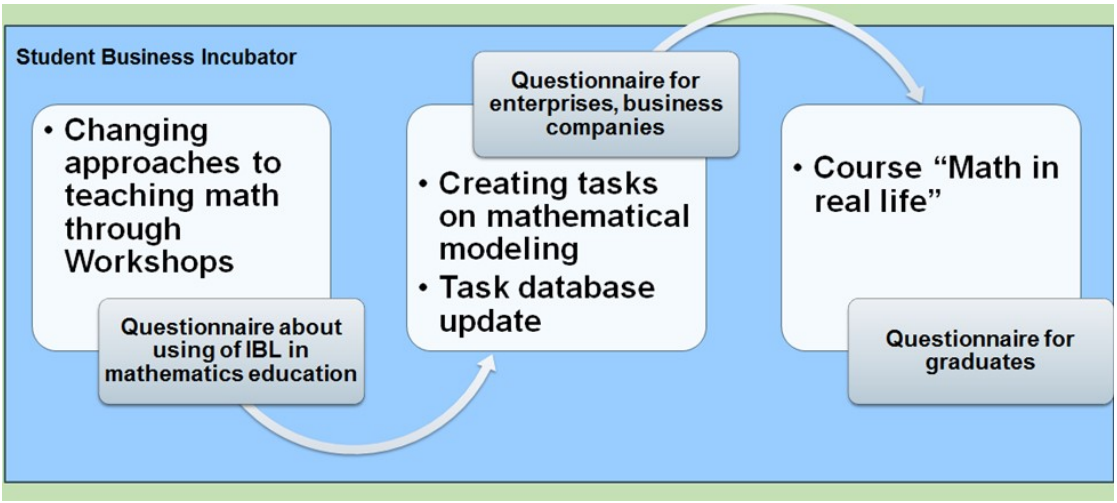

Figure 6: Development of student business incubator.

4. Application of IBME approaches in computer mathematical modeling

The problem of modeling is that the student must use the basic knowledge gained in the study of previous disciplines, and gain new knowledge needed to study the process and further modeling. The inquiry approach provides insight into the use of fundamental concepts and knowledge but plays a special role in acquiring new approaches and methods of knowledge. In the course of work on the PLATINUM project, we identified the main features that are present when solving modeling problems.

Ability to form several hypotheses, understanding the conditions of the problem.

- There are several ways to solve the problem.
- The presence of a technical, natural science, economic sense of the problem in the context of professional orientation.

- The complexity of mathematical knowledge, methods and procedures are based on "analysis by synthesis".

IBME teaching encourages students to take a different look at previously studied material, see fundamental concepts applied, and find knowledge gaps that they have forgotten or overlooked. If in teaching fundamental mathematical disciplines a query is used to obtain new knowledge (hypotheses, consequences, etc.), then in mathematical modeling the query is used at each stage of modeling.

Students have to formulate a mathematical model, hypotheses are put forward (students put forward their own hypotheses).

At this stage, students offer different hypotheses and, during the discussion, they will come to a choice. It is necessary to answer the questions: what is the problem?

- the problem is open and students must develop their own protocols;
- the problem is partially open and students have to deal with limited materials;
- the situation for students is new. They need to find a way to solve the problem.

The teacher provides the relevant material to make a request:

- What are the components of the system process, how do they interact?
- Which compounds are harmful, which interfere, which are neutral, and which are useful?
- What parts and what can be replaced and what not?

An important stage of modeling is the *interpretation of the results* in terms of the relevant subject area. And the ability to formulate a problem based on a real situation, just means that the problem is based on the properties of the mathematical model of this situation, which allows it to be interpreted. Thus, the design of problems, based on the query, can be considered as a technology of mathematical modeling, which directs the study of the mathematical model by finding the most realistically interpreted results.

Our observations highlight that students can:

- participate in research on the basis of inquiries;
- use existing models in their queries;
- participate in a query that results in a revision of the model, use models to construct explanations,
- use models to "unify" their understanding and argue.

Students use ICT tools to interpret the simulation results, as exploring the model takes time and effort. In addition, a model is created, as a rule, it is a simplified prototype of a modeled process (or system), the use of ICT technologies makes it possible to study the model by increasing the number of parameters and additional conditions that affect it.

Task. Students were asked to simulate the development of a viral disease at the university. Dynamics of the number of cases $I(t)$ by days is presented in table 1. $S(t)$ - the number of healthy, not yet sick students.

Students make an analysis of the development of the disease and forecast its development for the future.

Table 1
Statistics of the sick and recovered

Day	2	3	4	5	6	7	8	9	10	11	12	13	14
$S(t)$	762	740	650	40	250	120	80	50	20	18	15	13	10
$I(t)$	1	20	80	220	300	260	240	190	120	80	20	5	2

Viruses epidemic model

Among students due to contact with an infected possible transmission of infection to a healthy student and how consequence, his illness. Infected students with get well over time. After recovery, students can acquire immunity and no longer get sick. Students do not come into contact with other infected people outside the school. Contacts with teachers are not taken into account.

Model parameters:

- The number of students in the institution.
- The likelihood of illness.
- The likelihood of recovery.

The mathematical model of the development of the epidemic can be represented by a system of three differential equations first order

$$\begin{cases} \frac{dS}{dt} = -aSI \\ \frac{dI}{dt} = aSI - bI \\ \frac{dR}{dt} = bI \end{cases} \tag{1}$$

1st equation – the rate of illness in healthy students, the number of which decreases, the likelihood of illness;

2nd equation – the rate of change in the number of cases, recovered and recovered with probability b;

3rd equation – the rate of change in the number of students who have been ill and recovered.

$$R(t) = 763 - S(t) - I(t) \tag{2}$$

is the number infected recovered and not yet ill. It is necessary to determine the probability coefficients of states a and b.

Linear interpolation gives values for a and b coefficients 0.0036 and 0.94, respectively.

Simulation algorithm

Let us construct a procedure for calculating the right-hand side of the system.

The results are presented in figure 10. The graphs compare the theoretical curves and experimental values shown by the “o” markers.

Model exploration inquiry method

1. Plot the function $R(t)$, reflecting the dynamics of the number of students who have had a viral disease.

```
>> S = [ 762 740 650 400 250 120 80 50 20 18 15 13 10];
I = [1 20 80 220 300 260 240 190 120 80 20 5 2];
days = [0 3 4 5 6 7 8 9 10 11 12 13 14];
for k = 1:10
 y(k) = (1/I(k+2))*(I(k+3)-I(k+1))/2;
 x(k)=S(k+2);
end
plot(x,y,'o')
>>
```

Figure 7: Experimental dependence graph.

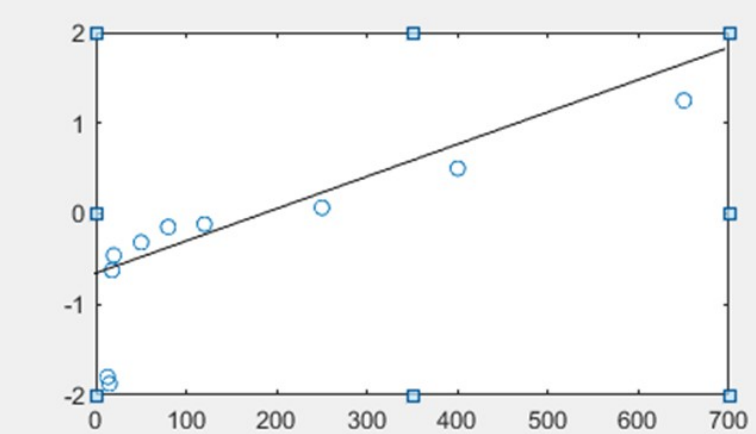

Figure 8: Linear interpolation.

2. Suppose that you have succeeded in analyzing an epidemic for a population of a small town. Build a mathematical model.
3. Get the curves of the development of the epidemic. What are the benefits of knowing the peak of the epidemic?

Students can present their own experiences. In order to interpret the simulation results, students can use various ICT tools: spreadsheets, application packages MATLAB, Mathcad, FreeMat, Mathematica and others. Students choosing their way of interpreting the results.

5. Conclusions

Employers and analysts argue that due to changes in the nature of activities, traditional approaches to professional skills training may be ineffective in the future. Given the growing pace of change and uncertainty in the workplace, young people will be better prepared, even for entry-level positions and, of course, for career advancement, if they have a basic understanding of the scientific, mathematical, social and even cultural aspects of working within their jobs. professional competencies. This leads to a change in approaches to the teaching and

viral.m | viral1.m

```
clear, clc
S = [ 762 740 650 400 250 120 80 50 20 18 15 13 10];
I = [1 20 80 220 300 260 240 190 120 80 20 5 2];
days = [0 3 4 5 6 7 8 9 10 11 12 13 14];
y0 = [762 1 0];
dt = [0 14];
[t, y] = ode45('viral', dt, y0, [],  [0.0026 0.51]);
subplot(2,1,1)
plot(t, y(:,1), days, S, 'o', 'LineWidth', 2)
title('Function graph for the risk group','FontName','Arial Unicode MS')
ylabel('number of students at risk','FontName','Arial Unicode MS')
subplot(2,1,2)
plot(t, y(:,2), days, I, 'o', 'LineWidth', 2)
title('Function graph of the infected','FontName','Arial Unicode MS')
ylabel('number of infected','FontName','Arial Unicode MS')
xlabel('time, days', 'FontName','Arial Unicode MS')
```

Figure 9: Main m-file of computer modelling.

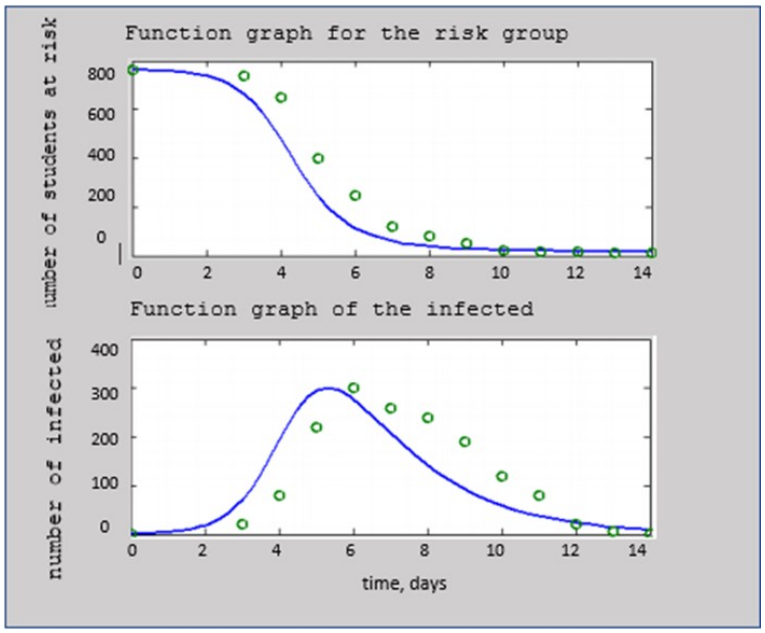

Figure 10: Results of modelling.

learning of mathematical disciplines, increasing the emphasis on the integration of academic and professional education.

Mathematical competence is an integrated dynamic property of the student's personality, which characterizes his ability and willingness to use mathematical methods of modeling in professional activities. Mathematical competence integrates mathematical knowledge and skills, as well as general cultural and professional competencies that are projected into the subject area of mathematics – their core is the ability and willingness of the graduate to apply this knowledge in professional activities.

To solve the problems of mathematical modeling, students must translate real situations, which are usually presented in text form, into mathematical models. To complete the translation process, the problem solver must first understand the real situation. Thus, reading comprehension can be considered as an important part of solving modeling problems, and the development of reading comprehension can lead to increased competence in modeling. In addition, it was found that ease of understanding and engagement increases interest in learning material, and thus improving reading comprehension can also increase interest in modeling.

Motivation of students plays a decisive role in the process of teaching mathematics. One of the important motivational variables is the interest of students both in the educational material and in the use of the acquired competencies in professional activities, and computer modeling has a very important role.

Standards and expectations from students should be high, but this is only part of the solution. The more important part is developing teaching techniques and methods that will help all students (not just a small fraction) to achieve these high expectations and standards. This will require some changes in teaching and learning mathematics.

Effective education must pay clear attention to the connection of the real-life context with the subject content for the student, and this requires more "interconnected" approaches to teaching mathematics disciplines.

Teaching query-based modeling improves students' research skills and helps build math competence. The model query activates students' conceptual knowledge if they have it and finds out gaps in knowledge that have been forgotten or lost. Work on the PLATINUM project has increased the interaction of teachers who teach basic disciplines of higher mathematics and applied disciplines.

Acknowledgments

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References

[1] G. Levanon, Wanted: Math majors – mathematical jobs facing tough labor shortages, 2016. URL: https://www.conference-board.org/blog/postdetail.cfm?post=5200.

[2] S. V. Shokaliuk, Y. Y. Bohunenko, I. V. Lovianova, M. P. Shyshkina, Technologies of distance learning for programming basics on the principles of integrated development of key competences, CEUR Workshop Proceedings 2643 (2020) 548–562.

[3] O. V. Onoprienko, Competence-oriented tasks as a means of forming mathematical competence of students, Primary School 3 (2013) 23–26.

[4] J. Fayzullaev, A systematic approach to the development of mathematical competence among students of technical universities, European Journal of Research and Reflection in Educational Sciences 8 (2020) 42–47. URL: http://www.idpublications.org/wp-content/uploads/2020/03/Full-Paper-A-SYSTEMATIC-APPROACH-TO-THE-DEVELOPMENT-OF-MATHEMATICAL-COMPETENCE-A pdf.

[5] V. V. Khomiuk, Strukturna model formuvannia matematychnoi kompetentnosti maibutnikh inzheneriv [Structural model of formation of mathematical competence of future engineers] (2015) 160–168. URL: http://nbuv.gov.ua/UJRN/nvkogpth_2015_5_26.

[6] M. I. Striuk, S. O. Semerikov, A. M. Striuk, Mobility: A systems approach, Information Technologies and Learning Tools 49 (2015) 37–70. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1263. doi:10.33407/itlt.v49i5.1263.

[7] L. N. Vasileva, T. V. Kartuzova, A. V. Merlin, N. I. Merlina, N. I. Svetlova, Formation of professional-mathematical competence of students in the field of technical training based on interdisciplinary integration of mathematics and computer science, Mediterranean Journal of Social Sciences 6 (2015) 90. URL: https://www.richtmann.org/journal/index.php/mjss/article/view/6028.

[8] M. M. Astafieva, O. B. Zhyltsov, V. V. Proshkin, O. S. Lytvyn, E-learning as a mean of forming students' mathematical competence in a research-oriented educational process, CEUR Workshop Proceedings 2643 (2020) 674–689.

[9] L. Flehantov, Y. Ovsiienko, The simultaneous use of Excel and GeoGebra to training the basics of mathematical modeling, CEUR Workshop Proceedings 2393 (2019) 864–879.

[10] G. Kaiser, The teaching and learning of mathematical modeling, in: J. Cai (Ed.), Compendium for Research in Mathematics Education, The National Council of Teachers of Mathematics, Inc., 2017, pp. 267–291.

[11] M. Lvov, L. Shishko, I. Chernenko, E. Kozlovsky, Mathematical models and methods of supporting the solution of the geometry tasks in systems of computer mathematics for educational purposes, CEUR Workshop Proceedings 2393 (2019) 41–52.

[12] B. Riyanto, Zulkardi, R. I. I. Putri, Darmawijoyo, Mathematical learning through modeling task in senior high school: Using nutrition context, Journal of Physics: Conference Series 1097 (2018) 012102. doi:10.1088/1742-6596/1097/1/012102.

[13] I. O. Teplytskyi, Physics models in the course "The basics of computer simulation", ACNS Conference Series: Social Sciences and Humanities 1 (2022) 01002. URL: https://doi.org/10.55056/cs-ssh/1/01002. doi:10.55056/cs-ssh/1/01002.

Digital transformation of vocational schools: problem analysis

Vasyl I. Kovalchuk[1], Svitlana V. Maslich[2], Larysa G. Movchan[3], Valerii V. Soroka[1], Svitlana H. Lytvynova[4] and Olena H. Kuzminska[5]

[1]*Oleksandr Dovzhenko Hlukhiv National Pedagogical University, 24 Kyievo-Moskovska Str., Hlukhiv, 41400, Ukraine*

[2]*Bilotserkivskiy institute of continuous professional education of University of Educational Management, 52/4 Levanevskoho Str., Bila Tserkva, 09108, Ukraine*

[3]*Vinnytsia Humanities Pedagogical College, 13 Nahirna Str., Vinnytsia, 21019, Ukraine*

[4]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[5]*National University of Life and Environmental Sciences of Ukraine, 15 Heroyiv Oborony Str., Kyiv, 03041, Ukraine*

Abstract

Modern society is characterized by a significant impact of information technologies on all spheres of human life. In a special way, the processes of digital transformation affect educational institutions, including vocational (vocational and technical) ones. Now vocational (vocational and technical) education occupies an important place in the sector of the country's economy, prioritizing effective training of highly qualified labourers in the state policy of Ukraine. Nowadays, the professional activity of labourers incorporates an intellectual component related to working with electronic devices, artificial intelligence systems, etc. Monitoring of the labor market shows that a skilled worker of the XXI century should be able to think critically, process information analytically, and work with mechatronics systems. The analysis of the European experience in training qualified workers reflects a certain lag of domestic institutions in terms of digital supply. At the same time, the level of teachers' digital competence at vocational (vocational and technical) education institutions needs improving. As a result, the issues of digital transformation for educational institutions are urgent and topical. Provision of modern digital equipment, formation and development of digital competence of all participants in the educational space are becoming the main tasks of teaching stuff in the current conditions. In a special way, the tasks set become relevant during the period of quarantine restrictions, when educational institutions mainly work on distance and mixed forms of teaching.

Keywords

education, vocational training, digital transformation, digital technologies, key competencies, distance learning

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1. Introduction

Modern society is characterized by a significant impact of digital technologies on all spheres of human life. According to research conducted by Gartner analysts, by the end of 2021, the number of digital devices in the world will have reached 6.22 billion units, including more than 4.3 billion smartphones, 495 million desktops, 866 million laptops and 535 million tablets [1]. Now the number of the Internet users is also rapidly increasing. So, according to the statistics, now the Internet is used by more than 60% of world's population, which is more than 4.5 billion people [2]. The process of digitalization is inexorable, and has touched the educational domain to such an extent that now it seems impossible to facilitate the modern teaching process without any digital devices.

The use of innovative forms, teaching methods, and the latest pedagogical technologies determines the improvement of the quality of education and is an important tool in the process of forming key, subject, and professional competencies of vocational school students. At the same time, digitalization of education has become a priority of its development, which is stipulated by both globalization processes and the spread of coronavirus infection COVID-19, and, as a result, the transfer of the educational process to distance and mixed forms of learning [3, 4].

1.1. Theoretical background

The use of digital technologies in education has greatly influenced its forms and methods, since they have changed the way people communicate ideas, learn and work. Still, digitalization of all social spheres, including educational is a new phenomenon and requires new knowledge and skills to master different digital activities for various purposes. Since our research deals with digitalization of education at vocational schools (VS), the participants of it VS teachers and students are representatives of different generations who have different experiences of digital teaching-learning [5].

In [6] shown the ways digital technologies can enhance learning outcomes, students learning skills, their motivation to solve problems, thus making them more responsible for the outcome of their study, develop their team-working skills etc. Thus, embedding digital technologies in the curriculum is an important step to educational improvements.

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v.i_kovalchuk@ukr.net (V. I. Kovalchuk); smaslich@ukr.net (S. V. Maslich); larisa.movchan.ua@gmail.com (L. G. Movchan); valmortal@gmail.com (V. V. Soroka); s.h.lytvynova@gmail.com (S. H. Lytvynova); o.kuzminska@nubip.edu.ua (O. H. Kuzminska)
http://tpgnpu.ho.ua/index.php/struktura/kafedra-po-ta-tsgv/40-vykladachi-po-ta-tshv/198-kovalchuk-v-i (V. I. Kovalchuk); https://cutt.ly/SIYaIev (S. V. Maslich); https://scholar.google.com.ua/citations?user=V887pCYAAAAJ (L. G. Movchan); https://cutt.ly/jEN0rf3 (V. V. Soroka); https://iitlt.gov.ua/structure/departments/technology/detail.php?ID=49 (S. H. Lytvynova); https://nubip.edu.ua/node/3983 (O. H. Kuzminska)
0000-0002-5006-573X (V. I. Kovalchuk); 0000-0002-8606-0949 (S. V. Maslich); 0000-0003-0913-3240 (L. G. Movchan); 0000-0001-7869-6173 (V. V. Soroka); 0000-0002-5450-6635 (S. H. Lytvynova); 0000-0002-8849-9648 (O. H. Kuzminska)
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Leshchenko et al. [7], Morze and Strutynska [8], Pinchuk et al. [9], Siemens [10], Trcek [11] emphasized the need of digital transformations in education due to complex societal changes and globalization processes, raising students' need for corresponding skills to enter a global labour market.

Windham [12] studies the influence of informational technologies on the new generation, calling them Net Geners, because they grow up together with Web, prioritize technological understanding for future achievements. This idea is also reinforced by curricula, that offer special subjects for digital literacy and the whole range of digital devices students use for study, browsing information and communication.

McLoughlin and Lee [13] address the problems of the gap between the generation of digital students and teachers, as well as implications of digital education. They argue that digital education raises students' participation and collaboration as well as independence in the learning process, which should be taken as a new starting point for changes.

Siemens [10] also sticks to the opinion that changes in the education are necessary and are caused by the discrepancy of teachers' and students' digital background. He says that educational establishments should undergo changes to accommodate the mode of learning and teaching and prepare student for active participation in the constantly changing world. He emphasizes the necessity for the students to be ready to work in the conditions of labour force mobility and lifelong learning to be able to change career paths in future.

Mentis [14] considers the digital literacy from a teacher-teacher perspective and shows that also teachers have different digital background and can perform their assignments differently with unequal performance opportunities to which refer their education, their current work and personal conditions. It means, that even seemingly the same digital tools in the hands of different participants can have different performance results and the need for seeking ways for its improvement will always exist.

In this respect, interesting is the research by Salajan et al. [15], who on the basis of the survey of both students and teachers of dentistry faculty on their feedback about applying digital technologies for educational purposes, suggested, that students admitted to be proficient in using digital technologies for study, while teachers felt less confident in coping with them.

1.2. Problem statement

Vocational education (VE) is an inseparable and significant part of educational domain which is also an important stage to higher education but also supplies the labour market with qualified workers. According to the Ministry of education and science of Ukraine, as of 01.01.2021, 239.8 thousand students received professional education at 708 domestic VS [16]. However, despite a large number of VS, in general, there is a problem of non-compliance of professional training of their graduates with the needs of employers, economy and society. Also, the Concept of implementation of the state policy in the sphere of vocational education "Modern vocational education" for the period up to 2027, emphasizes that the problem of non-compliance of training of future skilled workers in the VS to the needs of the labor market also manifests itself in "non-compliance of the content of education and teaching methods with the requirements of the modern labor market and the needs of the individual" [17]. That is why, starting from 2019, the professional education system is undergoing a number of reforms aimed at improving its

quality and, accordingly, providing the labor market with highly qualified workers. One of the directions of reform is the digitalization of the educational process.

Since the center of any educational process is a student, all changes and reforms in this system have always been made with respect of its optimization, accessibility and enhancing knowledge. At the same time, digital technologies are the most rapidly developed and expensive ones. This arouses the following issues to address:

1) the ability of its participants (teachers and students) to maintain a digital education process effectively;
2) ensuring the feasibility of this process through available digital tools.

Although qualitative approaches can provide valuable information for improving education, there are limited qualitative studies related to technology use in vocational education. The research is aimed to study the problems of digital transformations of vocational schools of Ukraine, ways of enhancing digital literacy of all the participants of the educational process and define the changes to be done for the effectiveness of this process.

1.3. Methods

The article is based on the following methods: theoretical method of analysis and synthesis of the latest research on the issue of applying digital technologies in the educational process, which enabled to single out the main problems of digitalization of education at a current stage and the vectors of its improvement. The statistical analysis of digital equipment and software supply of vocational schools of Vinnytsia, Khmelnytskiy, Kyiv and Sumy regions was conducted to define the problems hindering the effectiveness of digitalization of education at the current stage. The received data included questionnaires, classroom observations, opinion surveys and were interpreted using the main theses of the competence-based approach, systemic, synthetic methods to explore the students' and teachers' perception of the problem and their experience of using digital technologies for educational purposes.

2. Results and discussion

"Today's system of education and science must undergo dramatic digital changes to meet global trends in digital development so that each person could successfully realize his/her potential" [6]. This particularly applies to VS, since a large number of craft professions are associated with the use of digital technologies. For example, these are professions of transport (car computer diagnostics), agricultural sphere (tractors, combine harvesters equipped with digital harvesting systems), public catering (working with cash registers, R-Keeper systems), tourism industry (processing electronic sources of information, providing electronic services for tourism), etc. On the one hand, in order to ensure the quality of educational services, VS teachers must acquire soft skills (ability to work with digital resources during their lessons), on the other – be able to use digital technologies in the context of professional activities of future skilled workers. Moreover, the latter applies not only to teachers of special disciplines or masters of industrial training, but also to all teachers working in groups of the corresponding direction. This is due to the integrity and dynamism of the educational process. For example, when studying

the subject “Information Technologies” future mechanicals specializing in repair of wheeled vehicles, must perform laboratory and practical work on the topics “Work with programs for diagnosing engines (electrical equipment, transmission, undercarriage of a car, car control mechanism, additional and special car systems)”.

In most research digitalization of education is referred as implementation of digital technologies in the educational process. If educational technology is seen as a broad concept incorporating pedagogical, educational and informational communicative technologies, then they must conform to the requirements to the technological process and be systematic, effective, optimal, predicted and reproducible [18].

Authors of [19] also refers to digital technology as educational one being “the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources”.

Suffice it to note that lately, in conditions of the quarantine, traditional classrooms have shifted to students’ and teachers’ homes, blurring the border between a study and a private space. Therefore, when we speak about digitalization of education, we also refer to its presence in our private life, partially due to learning from home which digital technologies facilitate [5]. Here, we should not forget that learning from home and teaching from home have a lot of so called technical similarities, the role of students and teachers are still different.

The previous research shows, that incorporating digital technologies at the educational process will make it more inclusive both for students and teachers. She argues that digital technologies enabled both parties to be “consumers and producers of information” [20]. Sadik [21] also emphasizes greater participatory practices through greater students’ involvement in their own learning.

However, some scientists argue soundly that there exists a significant discrepancy between the teachers’ and students’ digital skills that brings them to different levels of performance. This idea was first proposed by Prensky [22], who calls the modern generation of students “digital natives”, since they were born at the digital age and have been dealing with digital technologies since their early childhood, while teachers have obtained this knowledge much later, thus are “digital immigrants”. Therefore, teaching digital natives requires a lot of changes.

Palfrey and Gasser [23] suggest, that conventional education methods and forms may become so much outdated that it will become difficult to approach students with their totally new mode of thinking and learning. So, the main concern of modern teachers is to acquire necessary knowledge and skills to keep up with digitalized world and thus education. Although stakeholders of this process are both students and teachers, the last have a challenging task to implement digital transformations in the educational process and to make it beneficiary for both parties.

Taking into consideration this binary challenge, it is important to emphasize the importance of teachers’ digital literacy. A modern teacher should be able to create presentations, maintain websites, blogs, and communicate with all participants in the educational process online, which requires a high level of information literacy and digital competence.

The research shows that students also have a different digital experience, therefore it is necessary to make sure that both participants of this digital educational process (teachers and students) have the similar level of digital literacy to cope with the tasks and challenges of this process.

The above mentioned "Draft Concept of digital transformation of education and science up to 2026" outlines the problems of transformation of the educational and scientific domain that call for immediate solutions. Taking into account the specifics of vocational schools, we have identified the main problems of their digital transformation. To them refer:

1) the outdated database of digital equipment (in some cases – missing or insufficient);
2) mostly low level of digital competencies of all participants in the educational process;
3) lack of a high-quality digital educational environment.

Suffice it to note that the outdated base of digital equipment (and its lack or shortage) also refers to educational establishments of all levels. Figure 1 indicates, that this issue is in suspension and little is done for its realization and necessary software for optimization of cooperation only 33% of respondents admitted to having special software and using digital devises for teaching and learning (figure 1).

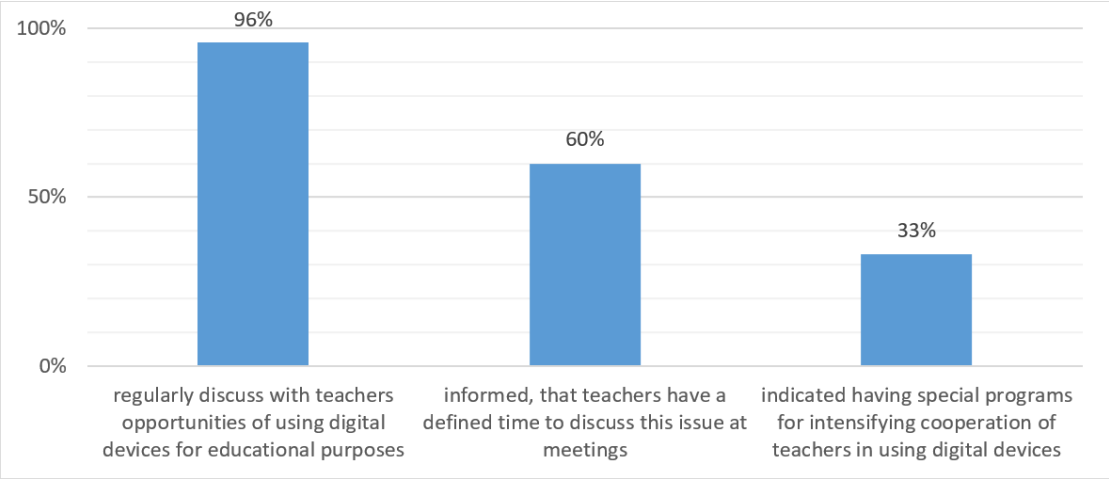

Figure 1: Results of VS principals' survey on teachers' use of digital technologies at lessons (based on materials of [24]).

We have conducted separate studies on the availability of computer equipment at VS in Vinnytsia region. In 28 institutions surveyed, 8 persons share 1 computer. Suffice it to note that the use of computer equipment in (VS) is of priority when studying the subjects "Computer Science", "Information Technologies", as well as when mastering such professions as "Information processing and software operator", "Tourism agent", "Digital book-keeping accountant", "Manager's secretary", etc. However, studying other subjects and mastering other professions, students are also expected to work at the computer. This means that each classroom, as well as the workshop (laboratory) of industrial training, should be provided with computers (laptops) with free access for students.

It goes without saying that the quality of computer equipment (hardware and software) influences the effectiveness of working with it. According to the survey, over the past 5 years, the (VS) of Vinnytsia, Khmelnytsky, Kiev and Sumy regions purchased 36% of the total number of available computers, 64% of printers and multifunction devices. Hardware and software of

a digital device are known to be interdependent: when installing software one should follow minimum hardware requirements. In turn, each new version of the operating system requires more powerful hardware. Figure 2 shows the upgrade levels of operating systems (OS) installed on computers in VS of Vinnytsia region.

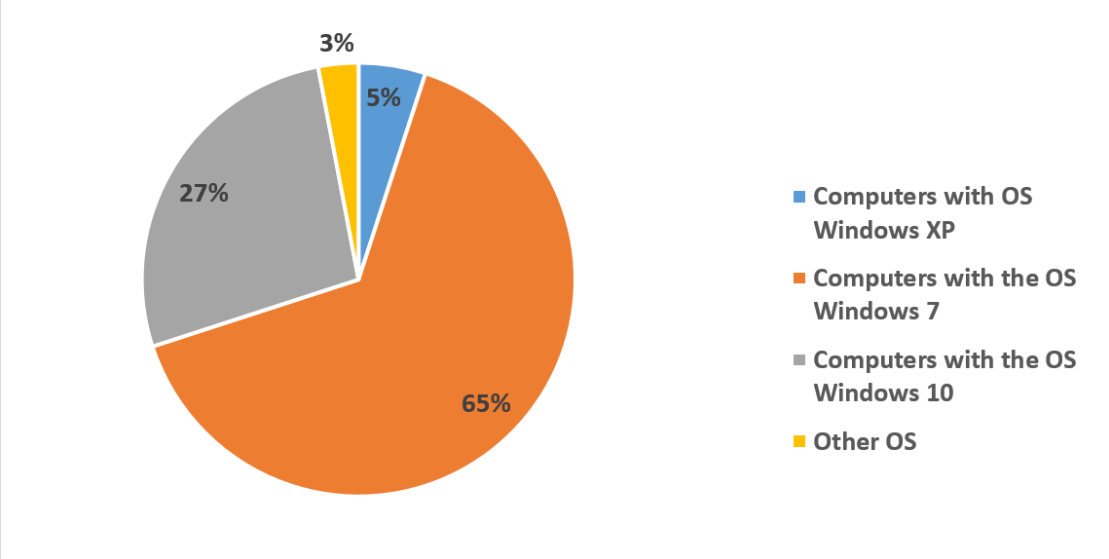

Figure 2: Using OS in VS.

As we see, only 27% of all computers in VS have a modern OS Windows 10 compatible with modern software, interfaces of the Internet study platforms. We can also notice a tendency of retreat from outdated software, yet it is much unclear taking into consideration these 65% of other OS. In addition, 28% of the surveyed VS teachers in these regions admitted to use their own laptops when conducting lessons for the students of these educational institutions, 45% noted that the equipment they work with needs upgrading, and only 8% of teachers who took part in the survey noted that they did not have any problems with updating the database of computer equipment.

In a special way, the problem of lacking high-quality computer equipment has worsened during the spread of coronavirus infection COVID-19, when all educational institutions, including VS switched to distance learning. Initially it was a default situation when the educators could not maintain teaching online because of their either low digital literacy or absence of the necessary equipment. This resulted in teachers using their private personal digital devices to maintain the educational process. Moreover, their number had to correspond to the number of all participants in the educational process, which caused complications. Our research among the participants of the educational process – teachers and students of VS in Vinnytsia, Khmelnitsky, Kiev and Sumy regions (1054 people) – indicate that the majority of respondents during quarantine training from home (distant training or mixed forms), had problems with free access to computer equipment, often used mobile devices for work, which were ineffective for performing certain tasks (figure 3).

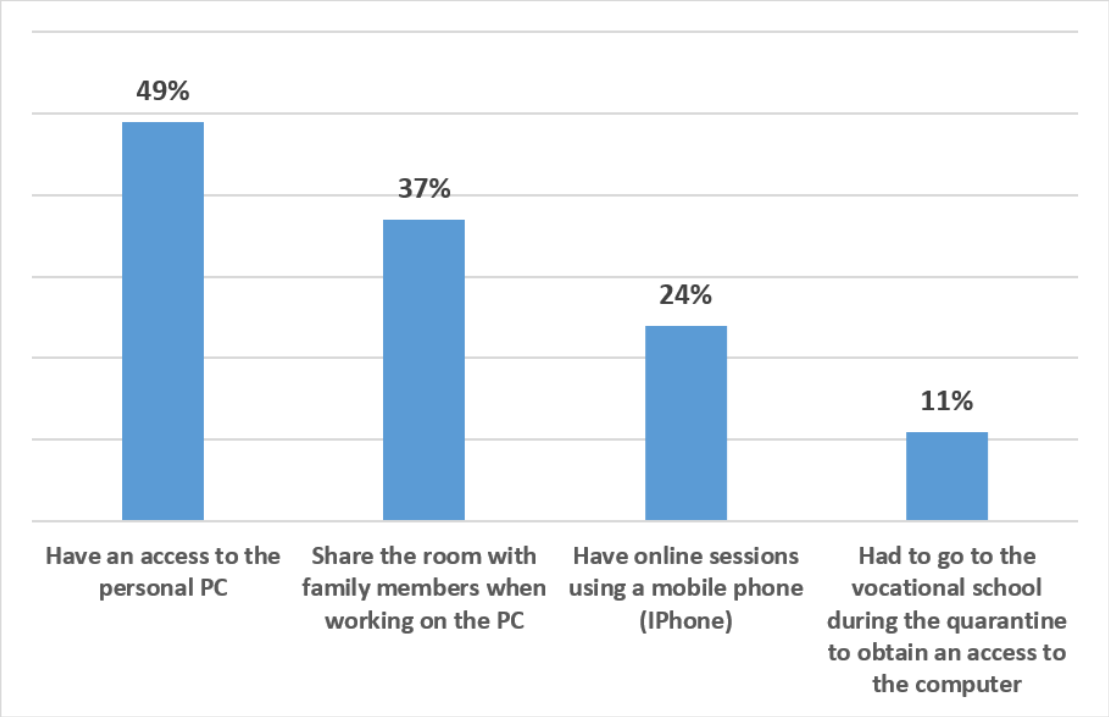

Figure 3: Accessibility of digital devices for students and teachers during the educational process at VS.

Here, suffice it to note that one of the obstacles to the high-quality educational process organization in remote and mixed forms was insufficient Internet coverage. Unlike cities where this problem practically does not exist, rural areas faced problems with the Internet access in 54% of the cases, according to students' survey.

Apparently, nowadays, there are many problems in the state regarding the digitalization of the education, which are primarily related to material and technical support. Along the way, we note that this issue is topical for the entire global educational domain, and a large number of countries are working to solve it. The Ukrainian government, the Ministry of education and science of Ukraine, and the executive council bodies are also implementing a number of reforms to overcome existing difficulties in digitalizing the educational sphere.

Among the measures on improving the quality of educational services while intensifying the material and technical base of VS is the creation of educational and practical centers for modern vocational education (Order No. 846 of the Ministry of education and science of Ukraine dated 26.07.2021). Thus, the creation of educational and practical centers for the profession of "Information and software processing operator" (SVEI "Kozyatyn interregional higher professional school of railway transport", Vinnytsia region, SVEI "Bilotserkivsky professional Lyceum", Kyiv region) provides for a subvention from the state budget for the purchase of digital equipment.

Improving the material base is also possible through participation in grant programs. Since 2006, Vinnytsia region has been exercising a regional program for the development of information and innovative technologies in educational institutions of the region, the purpose of

which is to provide monetary remuneration for the purchase of digital equipment. Annually, educational institutions of the region, including VS participate in the contest for the best project in the field of development and application of information and innovative technologies in management activities, educational process and research work. The theme of the submitted projects indicates the motivation of contest participants to the use of digital technologies in educational institutions and the simultaneous possibility of implementing projects both during lessons and in extracurricular activities, which expands the range of using digital equipment (table 1). For example, for the period 2008–2021, through participation in the grant program, the state educational institution "Vinnytsia higher vocational school of the service sector" purchased equipment (computers and multimedia tools) for the sum of 295,000 UAH.

Table 1
Grant awarded projects submitted within the Regional program for the development of information and innovative technologies (Vinnytsia region, 2020–2021).

VS	Topic of the project submitted for the contest	Year
SVEI "Vinnytsia interregional higher professional school"	"Laboratory for network and information security of the training and practical center for modern IT technologies" of the State Technical University "Vinnytsia IHVS"	2020
Higher art vocational school No. 5 in Vinnytsia	"Creation of an educational cluster of 3D modeling of ceramic, wood and metal items"	2020
SVEI "Vinnytsia higher professional school of the service sector"	"Creating an interactive career counseling center"	2020
SEI "Center of vocational education No. 1 in Vinnytsia"	"Deployment of an innovative educational and digital learning environment by the Google G Suite for Education Service System" in the SEI "Center for vocational education No. 1 in Vinnytsia"	2021
SVEI "Vinnytsia interregional higher professional school"	"Video studio of distance education of an institution of professional (vocational and technical) education"	2021
SEI "Brailov vocational lyceum"	"Safety and comfort in the digital environment of a vocational education institution"	2021

The next problem of digital transformation which VS face, is primarily the low level of digital competencies of all participants of the educational process. To define the concept of digital competence, we will use the Framework Program of updated key competencies for lifelong learning, according to which, the concept of key competencies is understood as necessary "for all people to increase personal potential and development, expand employment opportunities, social integration and active citizenship", namely, the concept of "digital competence" is interpreted as "confident, critical and responsible use and interaction with digital technologies for training, professional activities (work) and participation in society" [25]. For clarification, we note that digital competence covers 3 areas of digital technologies use: training, professional activity and participation in the social life.

There exist many mechanisms for determining digital competence. There is the European framework of digital competence of teachers, developed for the teachers to determine their own level of digital knowledge and find out the necessary needs for further improvement. This

document contains criteria that enable to determine both the teacher's professional digital competence and that of the student. The Ukrainian platform "Diya", in its turn, contains tests to determine the digital literacy of citizens, among them – "Digital Programs for teachers". In April 2021 the Ministry of education and science launched a project to introduce an online tool called SELFIE for assessing the digitalization state of an educational institution, the level of digital competencies of participants in the educational process. It is clear that in the rapidly digitalizing world, teachers also need to adapt to new realities.

However, the acquisition of new competencies does not only mean mastering new techniques, but also rethinking the traditional idea of the role and tasks of the teacher. He must be open to inevitable changes in modern education for the new generation, as the website of the Media Center in Baden – Württemberg notes [26].

During this period, in most educational institutions, educational methodology departments developed recommendations for conducting classes using remote technologies and posted them on the websites on the "Methodological room" page.

In addition to methodological assistance, teachers of the VS have completed a large number of trainings, master classes, webinars, etc. on improving the level of digital literacy over the past period (table 2).

A significant contribution to the development of digital competencies of teachers of VS was made by the Ministry of education and science of Ukraine through the implementation of the European program "EU4Skills: the best skills for Modern Ukraine", aimed at implementing reforms in VS. Within the framework of this program, teachers of pilot institutions had the opportunity to participate in training programs to improve the level of digital competencies.

The transition to distance learning led to updating teachers' needs in mastering software tools, namely, the needs:

1) to conduct training sessions online using programs for organizing video conferences – Zoom, Google Meet, Microsoft Teams, etc.;
2) place and upload training materials in online services (Google Classroom, Microsoft Office 365);
3) maintain educational websites and blogs.

Our research suggests that teachers' digital skills during the quarantine have significantly increased due to 2 factors:

1) the above mentioned measures of raising teachers' digital literacy;
2) teachers' intensive use of digital devices for teaching.

During this period, they mastered the skills of working with Zoom, Google Meet, Microsoft Teams, Google Classroom, etc., as evidenced by the results of our survey. The survey involved 312 teachers of Vinnytsia, Kyiv and Khmelnytsky regions VS – 196 teachers and 116 masters of industrial training (figure 4).

The research shows, that teachers find a lot of positive aspects of digitalization of education. They can find and share necessary pictures, charts, graphs with students instantaneously, which saves time for other activities. This cannot be done in the classroom without any Internet access and a computer. Sharing a screen is another advantage, because students can

Table 2
Special measures taken to improve the level of teachers' digital competence

Institution	Measures
University of Educational Management of the NAES of Ukraine	Special courses: • "Electronic educational platforms for distance learning of general secondary education"; • "Digital remote testing systems"; • "Using Zoom and Google Meet to conduct online classes"; • "G Suite: an effective tool for building the information and educational environment of an educational institution"; • "Features of creating electronic educational resources to maintain the distance educational process"; • "Google services for organizing distance learning"; • "Information culture of the head of a vocational education institution in the era of digitalization"; • "Innovative technologies in informal education as a component of teachers' self-development"; • "Vectors of digitalization of teachers' professional development"; • "Teacher's professional development in an innovative educational environment".
Institute of vocational education of the NAES of Ukraine	Webinars: • "Practice of students' self-organizing independent work"; • "Organization of distance learning by means of LMS Moodle"; • "Creating SMART complexes in the distance learning system"; • "Organization of distance learning in vocational education institutions"; • "Organizational and pedagogical conditions of distance professional training"; • "Teacher's self-educational activity in the context of distance learning"; • "Using mobile applications in distance learning"; • "Organizational and pedagogical conditions for the development of SMART complexes".

immediately download it and have necessary information close at hand. So, teachers welcomed this opportunity and mastered it envisaging its significant benefits. Another advantage is learning materials and tools accumulation which can be improved in the process and used for the next generation of students. Such activities for teachers of VS, as well as for teachers of other educational institutions, appeared to be new and required enhanced methodological support and urgent professional development.

Returning to the main problems of digital transformation of VS, the third problem is the lack of a high-quality digital educational environment. The analysis of regulatory documents (standards of general secondary, professional (vocational-technical) education) enables to assert

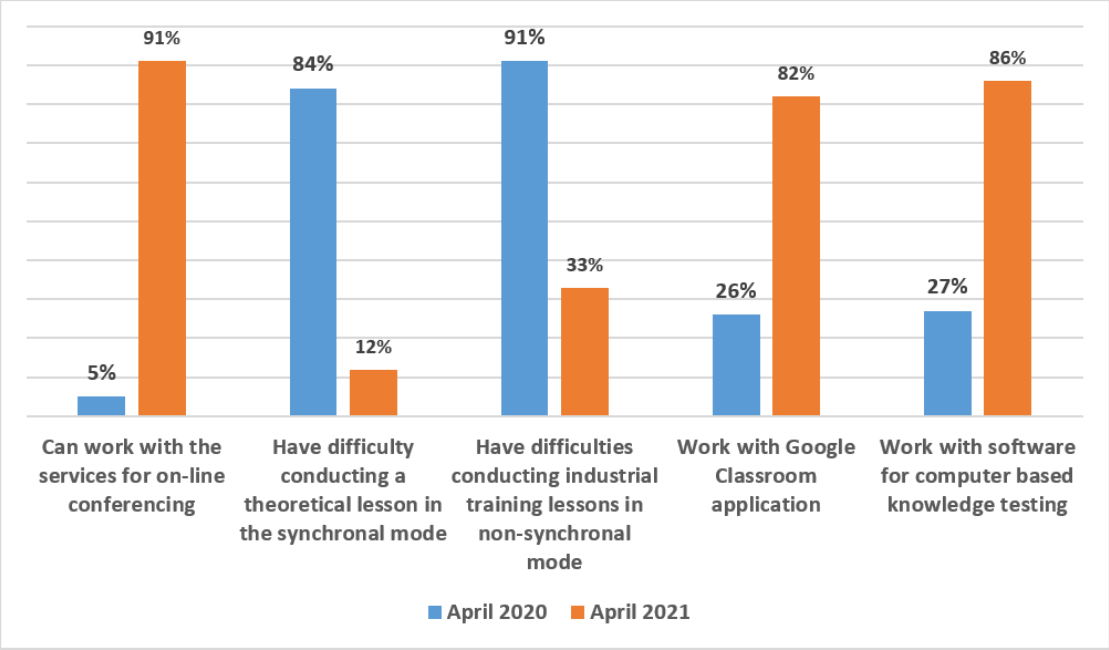

Figure 4: Improvement of VS teachers' software skills of maintaining distant and mixed forms of education (2020–2021).

that the information and educational environment (digital educational environment) combines a complex of information educational resources, including digital educational resources, a set of technological environments, information and communication technologies, a system of modern pedagogical technologies that provide training in a modern information educational environment.

Rapid development of technology creates new challenges for professional training of skilled workers. For example, nowadays, Germany possesses 309 industrial robots per 10 thousand skilled workers. This means that a specialist working at the relevant enterprise must develop skills in working with automation systems, artificial intelligence, be able to control robotic systems, and have developed technological thinking. And, if not long ago specialists in robotics and artificial intelligence were trained only at higher education institutions, now in the world practice has it a priority of professional education. In this sense, the experience of organizing professional training in Germany draws attention. Such experience testifies to the state's response to professional training of workers in the context of rapid technological development.

One of the most promising professions of our time is mechatronics, a branch of applied robotics science that combines mechanics and electronics. Mechatronic systems are used in various fields: cosmonautics, aviation, mechanical engineering, food processing, etc., and require highly qualified specialists to maintain them. There is no doubt, that mastering mechatronic programs, studying artificial intelligence systems, and robotic devices requires expensive equipment and the formation of appropriate professional skills of teachers and masters of industrial training. An effective method of training in such conditions, as the German experience shows, is dual training. It is the dual form of training that eliminates the problem of non-compliance of training

laborers with employer's needs, because the process of professional training takes place directly in production (or in the service sector) with the involvement of specialists in the relevant field in the training process.

Training of future specialists in mechatronics in Germany is carried out by Siemens, and this form of training is part of vocational education in Germany: every year Siemens trains up to 500 thousand skilled workers for the German economy. Simultaneously, students have the opportunity to study on expensive equipment (in Germany, businesses invest up to 50 billion euro per year to train specialists in artificial intelligence and robotics, while at the University of North Carolina, such annual training of one student costs from 25 thousand to 44 thousand dollars) [27].

In Ukraine, the training of future mechatronics specialists has generally remained the prerogative of higher education institutions [28]. However, taking into account the world experience and the needs of the economy, some VS see prospects for training specialists in this area, which is supported by the Ministry of education and science of Ukraine through the implementation of relevant programs, one of which is the EU program "EU4Skills: best skills for Modern Ukraine", which, for example, higher vocational school No. 21 of the city of Mykolaiv received half a million UAH for the equipment of industrial training workshops and laboratories for professional training of future electricians, for their mastering renewable energy and mechatronics systems. Within the framework of the program "EU4Skills: best skills for modern Ukraine", the institution has specialized laboratories for "robotics and smart home devices", "power electrical equipment" and "electric lighting and start-up equipment". According to the data, the carried out activities contributed to improving the level of professional training, taking into account today's requirements, creating an innovative educational environment for professional training [29].

The process of digitalization also largely applies to the transport industry. Currently, transport systems are undergoing significant changes in operation, and therefore repair. Unmanned control technologies, neural networks, and artificial intelligence are the reality of the present and the prospect of the future. In addition, the introduction of the latest technologies for regulating traffic has led to the emergence of intelligent transport systems, which are a mixture of computer, information technology and telecommunications developments along with knowledge in the automotive and transport sectors. Intelligent transport systems are defined as the use of computer, Information and communication technologies for driving vehicles, including their repair and maintenance [30]. Specialists in the repair and maintenance of this type of transport systems must have technological thinking, skills in working with electronic equipment and control systems. However, training in this sphere also faces a number of problems: the lack of highly qualified teachers-practitioners, the lack of the latest professional literature, the imperfection of the material base, difficulties in organizing industrial practice and industrial training. Therefore, in order to improve the level of professional training, the organization of the educational process according to new, productive educational technologies for the motor transport profile should cover the following elements, which can be applied to all the disciplines of vocational training [31]:

- supply of the educational process with information sources;
- introduction of innovative production technologies with high educational potential;

- creation of an innovative climate among teachers aimed at comprehensive professional development;
- close cooperation with stakeholders, social partners, and employers with their involvement in organizing the professional training process;
- material and technical support in accordance with modern requirements;
- availability of a modern highly equipped enterprise as a social partner for conducting training qualified labor resources;
- available prospects for the introduction of advanced educational technologies;
- training of future specialists in accordance with the needs of the labor market.

Obviously, training future qualified workers requires the implementation of the latest approaches to professional training, the introduction of modern forms and methods of training. It is not important without sufficient state provision, because digital equipment should be in the hand of everyone. The next important aspect is ensuring digital literacy of both stakeholders of the educational process: teachers and students, which can be done on the basis of VC as well. Thus, VS can be both offer and receive educational services. Thus, as the research shows, among the educational technologies decisive in the education of the future, we should highlight [32]:

- corporate online training (a training model that allows students to move along their own route using adaptive formats);
- competence measuring (assessment of competency and individual learning progress);
- flipped learning technology (a form of blended learning with advanced homework assignments);
- alternative learning styles (learning styles that offer students a more interactive experience – writing code in a browser, completing online tasks);
- online training based on competencies (involves combining training modules, taking into account flexibility and adaptability to the changing labor market), etc.

3. Conclusion

The conducted research enables to state that digital transformation of vocational schools is an urgent process aroused both by the distant learning due to COVID-19 restrictions and primarily by the global modernization through digitalization of production processes. The process of digital transformation of vocational education implies a high level of digital competency of all its participants, which calls for the search of and realization of effective forms of teaching and learning applying digital technologies. A digital divide between teachers and students arouses the necessity of systemic measures to eliminate it: raising teachers' digital knowledge and skills, students' and teacher's mastering various educational software and digital tools to apply them for educational purposes.

Considering applicable and practical nature of vocational education, it should be realized on a competency-based, student-centered approach, so that a student acquires necessary skills to maintain complex automated digital processes at production etc.

Since digital technologies are considered as those rapidly developing and expensive, their application requires their constant upgrading as well as upgrading of corresponding skills of

working with them and sustain the educational process. Thus, it is possible only on the level of interested parties – governmental, regional or municipal or other future employers who can provide VS with necessary equipment and upgrade the software. Having access to high quality digital equipment and necessary skills to work with it will raise students' and teachers' confidence and motivation.

Further research may be dedicated to studying person's behavior in the conditions of the virtual educational space, development of digital etiquette etc.

References

[1] The number of computers used worldwide will reach 6.2 billion in 2021, 2021. URL: https://news.finance.ua/ua/news/-/490338/kilkist-vykorystovuvanyh-kompyuteriv-u-vsomu-sviti-dosyagne-6-2-mlrd-v-2021-rotsi.

[2] S. Kemp, Digital 2020: 3.8 billion people use social media, 2020. URL: https://wearesocial.com/uk/blog/2020/01/digital-2020-3-8-billion-people-use-social-media/.

[3] T. B. Bykova, M. V. Ivashchenko, D. A. Kassim, V. I. Kovalchuk, Blended learning in the context of digitalization, CEUR Workshop Proceedings 2879 (2020) 247–260. URL: http://ceur-ws.org/Vol-2879/paper12.pdf.

[4] V. Tkachuk, Y. Yechkalo, S. Semerikov, M. Kislova, Y. Hladyr, Using Mobile ICT for Online Learning During COVID-19 Lockdown, in: A. Bollin, V. Ermolayev, H. C. Mayr, M. Nikitchenko, A. Spivakovsky, M. Tkachuk, V. Yakovyna, G. Zholtkevych (Eds.), Information and Communication Technologies in Education, Research, and Industrial Applications, Springer International Publishing, Cham, 2021, pp. 46–67. doi:10.1007/978-3-030-77592-6_3.

[5] N. G. Ugur, Digitalization in higher education: A qualitative approach, International Journal of Technology in Education and Science (IJTES) 4 (2020) 18–25. URL: https://www.ijtes.net/index.php/ijtes/article/view/24. doi:10.46328/ijtes.v4i1.24.

[6] The Concept of digital transformation of education and science: the Ministry of Education and Science invites to public discussion, 2021. URL: https://cutt.ly/8YUZk1f.

[7] M. P. Leshchenko, A. M. Kolomiiets, A. V. Iatsyshyn, V. V. Kovalenko, A. V. Dakal, O. O. Radchenko, Development of informational and research competence of postgraduate and doctoral students in conditions of digital transformation of science and education, Journal of Physics: Conference Series 1840 (2021) 012057. doi:10.1088/1742-6596/1840/1/012057.

[8] N. V. Morze, O. V. Strutynska, Digital transformation in society: key aspects for model development, Journal of Physics: Conference Series 1946 (2021) 012021. doi:10.1088/1742-6596/1946/1/012021.

[9] O. P. Pinchuk, O. M. Sokolyuk, O. Y. Burov, M. P. Shyshkina, Digital transformation of learning environment: Aspect of cognitive activity of students, CEUR Workshop Proceedings 2433 (2019) 90–101.

[10] G. Siemens, PLEs – I acronym, therefore I exist, 2007. URL: http://web.archive.org/web/20080105101901/http://www.elearnspace.org/blog/archives/002884.html.

[11] D. Trcek, Driving digital transformation through e-government, CEUR Workshop Proceedings 2422 (2019) 263–273.
[12] C. Windham, The student's perspective, in: D. Oblinger, J. Oblinger (Eds.), Educating the Net Generation, 2005, pp. 5.1–5.16. URL: https://www.educause.edu/research-and-publications/books/educating-net-generation/students-perspective.
[13] C. McLoughlin, M. J. W. Lee, The 3 p's of pedagogy for the networked society: Personalization, participation, and productivity, International Journal of Teaching and Learning in Higher Education 20 (2008) 10–27. URL: https://www.isetl.org/ijtlhe/pdf/IJTLHE395.pdf.
[14] M. Mentis, Navigating the e-learning terrain: Aligning technology, pedagogy and context, Electronic Journal of e-Learning 6 (2008) 217–226. URL: https://www.learntechlib.org/p/175519.
[15] F. D. Salajan, D. J. Schönwetter, B. M. Cleghorn, Student and faculty inter-generational digital divide: Fact or fiction?, Comput. Educ. 55 (2010) 1393–1403. doi:10.1016/j.compedu.2010.06.017.
[16] Professional education, 2022. URL: https://mon.gov.ua/ua/tag/profesiyno-tekhnichna-osvita.
[17] On approval of the Concept of state policy implementation in the sphere of vocational (vocational and technical) education "Modern vocational (vocational and technical) education" for the period up to 2027, 2019. URL: https://zakon.rada.gov.ua/laws/show/419-2019-%D1%80#Text.
[18] O. I. Yankovych, Educational technologies in the history of higher pedagogical education of Ukraine (1957–2008), Pidruchyki ta posibnyki, Ternopil, 2008.
[19] Reflections on the 2008 AECT definitions of the field, TechTrends 52 (2008) 24–25. URL: https://thenextnewthing.files.wordpress.com/2009/11/aect-definitions-of-the-field.pdf. doi:10.1007/s11528-008-0108-2.
[20] M. Farkas, Participatory technologies, pedagogy 2.0 and information literacy, Library Hi Tech 30 (2012) 82–94. doi:10.1108/07378831211213229.
[21] A. Sadik, Digital storytelling: a meaningful technology-integrated approach for engaged student learning, Educational Technology Research and Development 56 (2008) 487–506. doi:10.1007/s11423-008-9091-8.
[22] M. Prensky, Digital Natives, Digital Immigrants Part 1, On the Horizon 9 (2001) 1–6. doi:10.1108/10748120110424816.
[23] J. Palfrey, U. Gasser, Generation Internet: Die Digital Natives: Wie sie leben - Was sie denken - Wie sie arbeiten, Carl Hanser Verlag GmbH & Co. KG, 2008.
[24] M. Bondar, How many students are provided with computers in schools and how it affects their academic performance: research, 2021. URL: https://education.24tv.ua/skilki-uchniv-zabezpecheni-kompyuterami-yak-tse-ukrayina-novini_n1522470.
[25] Annex to the Proposal for a Council Recommendation on Key Competences for Lifelong Learning, 2018. URL: https://ec.europa.eu/education/sites/education/files/annex-recommendation-key-competences-lifelong-learning.pdf.
[26] C. Redecker, European Framework for the Digital Competence of Educators: DigCompEdu, Science for Policy report EUR 28775 EN, Joint Research Centre (JRC), Luxembourg, 2017. doi:10.2760/178382.
[27] I. Nekhai, PTU po-nemetcki. Kak v Germanii gotoviat rabochikh i chto khotiat izmenit

iz-za AI i robotov, 2018. URL: https://cutt.ly/lYUJ6PQ.
[28] Y. O. Modlo, S. O. Semerikov, E. O. Shmeltzer, Modernization of professional training of electromechanics bachelors: ICT-based competence approach, CEUR Workshop Proceedings 2257 (2018) 148–172. URL: http://ceur-ws.org/Vol-2257/paper15.pdf.
[29] Half a million for workshop equipment for electricians, the study of renewable energy and mechatronics – case study of Vocational School No. 21. of the city of Mykolaiiv, 2020. URL: https://u.to/TZenGw.
[30] Intellectual transport systems. Module 4. Sustainable development of transport system; materials collection for city politicians, 2009. URL: https://city2030.org.ua/sites/default/files/documents/GIZ_SUTP_SB4e_Intelligent-Transport-Systems_UA.pdf.
[31] V. I. Kovalchuk, V. V. Soroka, Training of specialists in automobile sphere under conditions of digitalization, in: Training of specialists in automobile sphere under conditions of digitalization, 2021, pp. 2–20. doi:10.36074/pcaifswal.ed-2.01.
[32] V. I. Kovalchuk, Trends in the development of education in the era of the information society, strategies for the intensification of higher humanitarian education in Ukraine and the EU countries, NULP of Ukraine, Kiev, 2017, pp. 7–134.

Social dimension of higher education: definition, indicators, models

Liubov F. Panchenko[1], Hennadii O. Korzhov[1], Andrii O. Khomiak[1], Vladyslav Ye. Velychko[2] and Vladimir N. Soloviev[3]

[1]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37 Peremohy Ave., Kyiv, 03056, Ukraine

[2]Donbas State Pedagogical University, 19 Batyuk Str., Sloviansk, 84122, Ukraine

[3]Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine

Abstract

The article deals with the problem of strengthening the social dimension of higher education. It discusses the definition of social dimension, its indicators, models of student retention and student engagement. The article argues that students should act as active researchers of the topic of social dimension and present the ways to update the content of university courses for Sociology majors, such as "Mathematical and statistical methods of social information analysis", "Social statistics and demography", "Multivariate data analysis", "Structural equation modeling" and other courses for bachelors, master students, and PhDs in Sociology.

Keywords

higher education, social dimension, education statistics, students training, EUROSTUDENT, social statistics, modeling, educational and migration backround of students, cloud technologies, R, NodeXL

1. Introduction

1.1. Setting of a problem

The social dimension of higher education has been the focus of attention of the European educational community since 2001 [1]. In general terms, the social dimension means compliance with the principles of equality, accessibility and diversity in the higher education system. The Rome Ministerial Communiqué (2020) [2] proposes a definition of vulnerable, disadvantaged and underrepresented groups of students, and sets out the principles that oblige public authorities and higher education institutions to develop the relevant concepts, or to improve their policies and strategies for strengthening the social dimension of higher education. Such principles

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lubov.felixovna@gmail.com (L. F. Panchenko); korzhovgena@yahoo.com (H. O. Korzhov); andrii.khomiak@gmail.com (A. O. Khomiak); vladislav.velichko@gmail.com (V. Ye. Velychko); vnsoloviev2016@gmail.com (V. N. Soloviev)

https://fsp.kpi.ua/ua/faculty/panchenko/ (L. F. Panchenko); https://fsp.kpi.ua/ua/faculty/korzhov/ (H. O. Korzhov); https://scholar.google.com/citations?user=OIBWahAAAAAJ (A. O. Khomiak); https://ddpu.edu.ua/cc/velychko (V. Ye. Velychko); https://kdpu.edu.ua/personal/vmsoloviov.html (V. N. Soloviev)

0000-0002-9979-0625 (L. F. Panchenko); 0000-0001-5459-0702 (H. O. Korzhov); 0000-0002-6661-4510 (A. O. Khomiak); 0000-0002-5227-9168 (V. Ye. Velychko); 0000-0002-4945-202X (V. N. Soloviev)

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include the continuous monitoring and collection of data for evidence-based statistics on the topic of the social dimension of European higher education. The recent Eurostudent VII Conference in Hannover, 2021 [3] featured the issue of the social dimension, the comparison of the results of monitoring of this issue among European countries, and he definition of common and special social dimensions. Consequently, the inclusion of the social dimension into national strategies for the transformation of higher education remains a priority for the countries of the European Education Area.

As an associate member of the EU, Ukraine is aiming to develop its higher education system in compliance with European priorities. Therefore, training of the specialists who can develop the social dimension of higher education is important task of Ukrainian universities.

Based on the conceptualization of the social dimension in higher education, its indicators and models, the article is aimed to show the paths of including this topic in the training sociology majors in Ukrainian universities.

1.2. Related work

The various aspects of computer modeling in education were summarized by Ukrainian scientists within CoSinE workshop (2019–2021). Semerikov et al. [4] studied computer simulation of neural networks; Bilousova et al. [5] discussed computer simulation in computational mathematics; Soloviev et al. [6] presented cognitive process modelling using complexity theory methods.

Burke [7], Hauschildt et al. [8, 9, 10], Mishra and Diesner [11], Salmi [12, 13], Unger [14] studied various questions of social dimension.

The problems of social and economic conditions of student life in Europe are summarized by Hauschildt et al. [8, 9], Unger [14] as part of EUROSTUDENT.

Many scholars are interested in the problems that arise in model building on student retention and student engagement: Tinto [15, 16, 17, 18, 19, 20], Spady [21, 22], Tight [23], Burke [7], Kerby [24], Kricorian et al. [25].

We share the Tight [23] view that modern student's success a not limited to learning. A wide range of issues related to their families, friends, social environment influences their ability to successfully complete studies and integrate. It is important that students participate in the study of the problem of the social dimension, even as researchers.

That is why the purpose of our study is to find ways to include content on social dimension of the higher education in the training of sociology majors. This training follows modern strategies of [26, 27]:

- Shifting the focus of statistical tasks within the curriculum from mathematical calculations to tasks of a practical nature.
- Integration of statistical thinking and statistical literacy into the curriculum of different disciplines;
- Development of problem solving skills: students are offered open problems and the teacher takes on the role of a "facilitator" in the learning process.
- Using real life examples in project work;
- Developing strategies to increase students' motivation;
- Using multidimensional models for understanding social phenomens.

The issues of preparing sociology students and PhDs to use statistical models and education statistics data are discussed in papers [28, 29, 30, 31].

2. Results

In London Communiqué, ministers agreed on the following definition of the social dimension: ”We share the societal aspiration that the student body entering, participating in and completing higher education at all levels should reflect the diversity of our populations. We reaffirm the importance of students being able to complete their studies without obstacles related to their social and economic background. We therefore continue our efforts to provide adequate student services, create more flexible learning pathways into and within higher education, and to widen participation at all levels on the basis of equal opportunity” [32].

The Rome Ministerial Communiqué (2020) [33] proposes a definition of vulnerable, disadvantaged and underrepresented groups of students.

- *Underrepresented students.* A group of learners is underrepresented in relation to certain characteristics (e.g. gender, age, nationality, geographic origin, socio-economic background, ethnic minorities) if its share among the students is lower than the share of a comparable group in the total population. This can be documented at the time of admission, during the course of studies or at graduation. Individuals usually have several underrepresented characteristics, which is why combinations of underrepresented characteristics (“intersectionality”) should always be considered. Furthermore, underrepresentation can also have impact at different levels of higher education – study programme, faculty or department, higher education institution, higher education system. This definition is complementary to the London Communiqué, ”that the student body entering, participating in and completing higher education at all levels should reflect the diversity of our populations”, but does not fully cover it.
- *Disadvantaged students:* Disadvantaged students often face specific challenges compared to their peers in higher education. This can take many forms (e.g. disability, low family income, little or no family support, orphan, many school moves, mental health, pregnancy, having less time to study, because one has to earn ones living by working or having caring duties). The disadvantage may be permanent, may occur from time to time or only for a limited period. Disadvantaged students can be part of an underrepresented group, but do not have to be. Therefore, disadvantaged and underrepresented are not synonymous.
- *Vulnerable students:* Vulnerable students may be at risk of a disadvantage (see above) and in addition have special (protection) needs. For example, because they suffer from an illness (including mental health) or have a disability, because they are minors, because their residence permit depends on the success of their studies (and thus also on decisions made by individual teachers), because they are at risk of being discriminated against. These learners are vulnerable in the sense that they may not be able to ensure their personal well-being, or that they may not be able to protect themselves from harm or exploitation and need additional support or attention.

EUROSTUDENT is an international survey project collecting data on the social and economic conditions of student life in Europe. The dataset of this project covers many of important

aspects of student life: access to higher education, students' demographic characteristics, their educational background, types and modes of study, time budget, students' income, employment, types of housing, international mobility. The seventh round of the EUROSTUDENT project started in June 2018 and finished in 2021. The purpose of project was to provide data on the social dimension of European higher education for researchers, ministers, teachers, students, policy-makers, and others. Data were collected in 18 countries in 2019. The version presented during the Hannover Conference covered 20 countries and the final version is to be released in August 2021. Author was a (virtual) participant of the Hannover conference that took place on May 18–19, 2021. After discussion, Eurostudent VII participants presented some ideas for imaging and innovating the social dimension of higher education after the pandemic (in two words, figure 1).

Figure 1: Imaging and innovating the social dimension of higher education after the pandemic (in two words). Source: https://twitter.com/EUROSTUDENTtwt/status/1394684695594639365

Unger [14] in his conference report showed the relation between social dimension measurement and EUROSTUDENT VII data. EUROSTUDENT provides the following data:

- On many underrepresented groups (by sex, educational background, access (routes), migration background, disability);
- On disadvantaged students (students with kids, disability, non-native speakers, delayed transition, working, financial difficulties);
- On vulnerable students (direct: minors etc., and indirect: satisfaction, integration, difficulties in study).

This data set allows to combine various parameters of the student body; different routes to enter a university; drop-out intention; likelyhood to complete the studies by study intensity, drop-out intention, satisfaction, various difficulties. EUROSTUDENT data not provided: specific

national (minority) groups or issues; ethnicity, details on gender and sexual orientation; students from alternative care.

Social dimension is directly connected to student retention. Undergraduate retention is an institution of higher education's ability to "retain a student from admission until graduation" [34]. The earliest studies of undergraduate retention in the United States occurred in the 1930s and focused on what was referred to at the time as student mortality [35]. In 1975 Vincent Tinto presented student integration model. By Tinto [15], students who socially integrate into the campus community increase their commitment to the institution and are more likely to graduate.

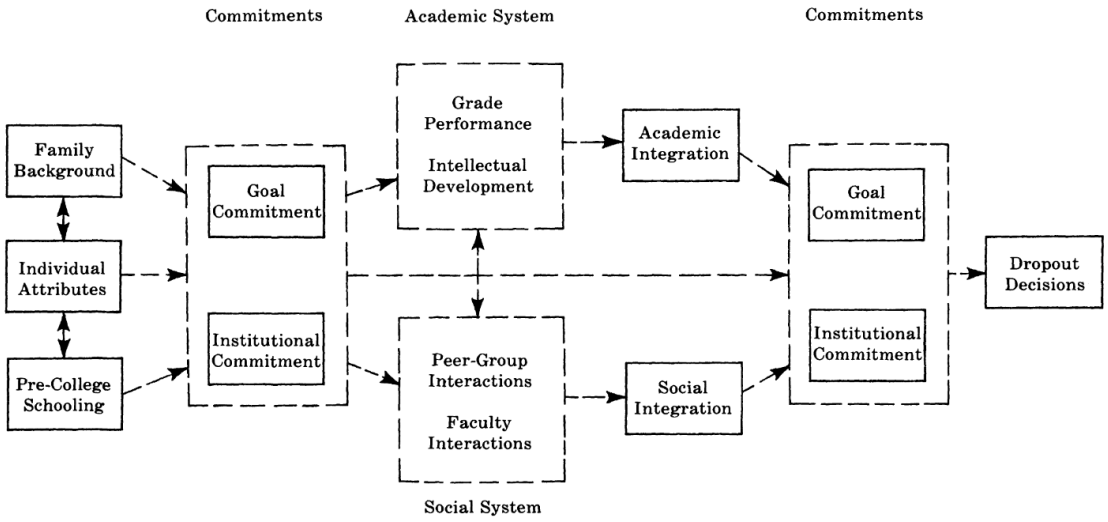

Figure 2: Tinto's model of dropout process [15, p. 95].

Tinto's student integration model has changed over the course of the 45 years from when it was originally introduced [15, 16, 17, 18, 19, 20]. In the recent versions motivational variables have included. The following motivational theories from educational psychology and social psychology have been applied to theoretical developments and practice of undergraduate retention: articular theory, attribution theory of motivation; expectancy theory, goal setting theory, self-efficacy beliefs, academic self-concept, motivational orientations and optimism [34].

Tight [23] remarks that "student retention is the older of the two concerns, at least in research terms, and was formerly also known by other, more negative, synonyms, such as student withdrawal, attrition and dropout. Student engagement, through which the student is involved in the higher education experience as deeply as possible, though a more recent concern, represents an obvious positive response to the problem of student retention. In other words, the more engaged a student is – with their higher education and the institution from which they are receiving it – the less likely they are to voluntarily leave higher education before they have completed their studies". The researcher provided bibliographic search using Scopus (2018) the numbers of times the exact words 'student retention' and 'student engagement' appeared in the titles of published English language (figure 3).

The conclusions of the research and the data collected during this study will enrich the

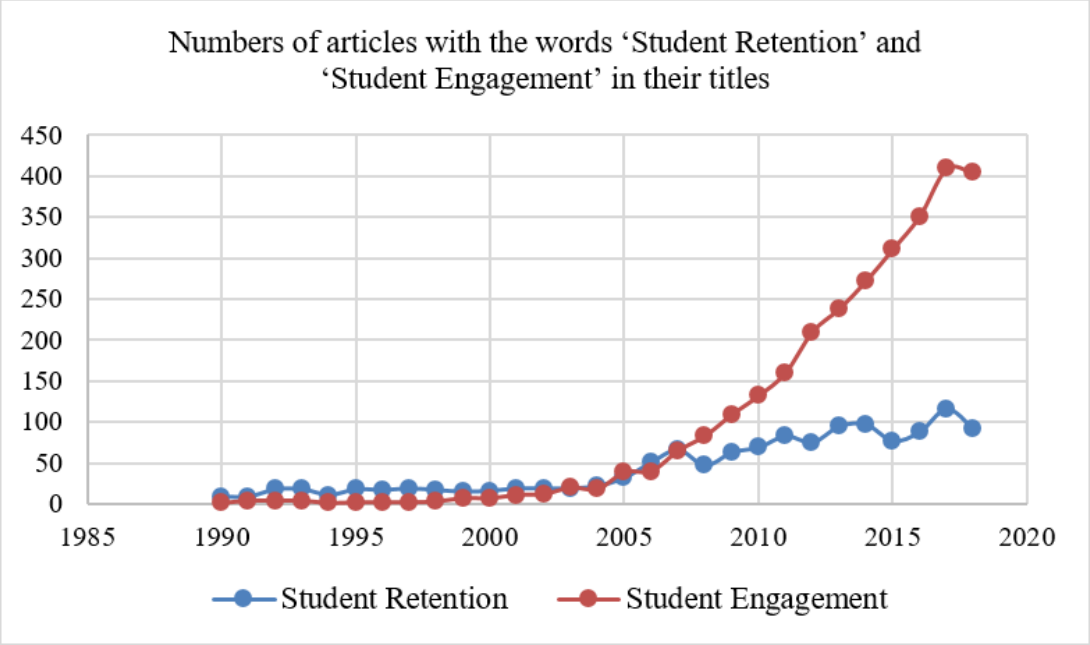

Figure 3: Numbers of articles with the words ‘Student Retention’ and ‘Student Engagement’ in their titles [23].

content of university courses. In particular, this applies to the NTUU ”IS KPI” course on Social Statistics (and Education Statistics, which is a component of the said course); to the courses on the Methods and Methodology of Sociological Research and Data Analysis, to the PhD courses on Multidimensional Research Methods; Master courses on Cross-National Research in Sociology, and Quantitative Methods of Social Processes Analysis.

An important problem in data analysis teaching is the development of student’s motivation. One example of the development of positive educational motivation, in our view, is the use of interesting data sets relevant to learner’s area. Social statistics course is a second-year course for sociology majors. This course is preceded by a mathematical methods course, so there is every reason to use these methods when analyzing social statistics data.

One of the most important sections of social statistics is education statistics. One of the main objectives of the statistical study of education is the social and economic life of students.

Social dimension is important topic of measurement in education statistics. Consider how we can use the EUROSTUDENT data in teaching the analysis of education statistics.

Therefore, first, we recommend that students visite the following page: http://database.eurostudent.eu/. There they will see the following parameters:

A. Demographics
B. Transition and access
C. Types and modes of study
D. Socio-economic background

E. Housing situation
F. Students' expenses
G. Students' resources
H. Employment and time budget
I. International student mobility
J. Assessment of studies

Table 1
Students' satisfaction with their current study programme: Organisation of studies (Slovakia) (based on Eurostudent VI data).

	Female (in %)	Male (in %)
Organization of studies: (very) satisfied	53.8	58.6
Cat.3 – unlabelled	24.2	24.6
not satisfied (at all)	22	16.8

In all figures and tables, the following abbreviations are used to refer to the participating countries: AL Albania; AT Austria; CH Switzerland; CZ Czech Republic; DE Germany; DK Denmark; EE Estonia; FI Finland; FR France; GE Georgia; HR Croatia; HU Hungary; IE Ireland; IS Iceland; IT Italy; LT Lithuania; LV Latvia; MT Malta; NL The Netherlands; NO Norway; PL Poland; PT Portugal; RO Romania; RS Serbia; SE Sweden; SI Slovenia; SK Slovakia; TR Turkey.

Students must select focus-group. These groups are:

- All students
- Age group
- Sex
- Educational background
- Type of higher education institution
- Type of study programme
- Field of study
- Study intensity
- Transition route
- Educational origin
- Dependency on income source
- Students in paid employment
- Financial difficulties
- Migration background
- Impairments
- Housing situation
- Access route

Table 2
Students' satisfaction with their current study programme: Study facilities (Slovakia) (based on Eurostudent VI data).

	Student without impairments (in %)	Student with impairments (in %)
Study facilities: (very) satisfied	63.3	50.2
Cat.3 – unlabelled	23.1	27.9
not satisfied (at all)	13.7	21.9

We can obtain actual tables by combining features "Assessment of studies", "Sex" and "Impairments" for a single country or several countries. We can observe and discuss gender differences and differences related to impairments (tables 1-2).

Using Eurostudent VI Appendix C3 Metadata, we can compare the percentage of student aged 30 and older in European countries (figure 4) and percent of students with impairments (figure 5).

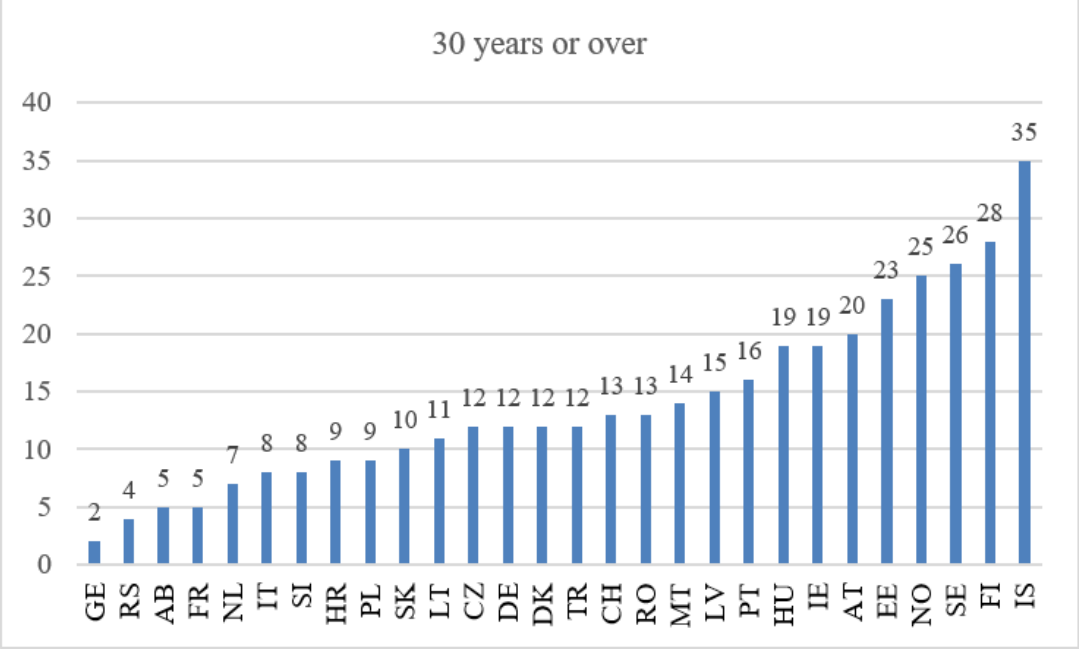

Figure 4: Percentage of students aged 30 and older (based on Eurostudent VI data).

It is interesting to compare these data with the data of the State Statistics Committee of Ukraine.

We can also apply correlation analysis, hypothesis testing, and discriminant analysis to these data by raising relevant research questions (i.e. educational and migration background and others).

In the table 3 we summarized the path to integrate the topic "Social dimention of higher

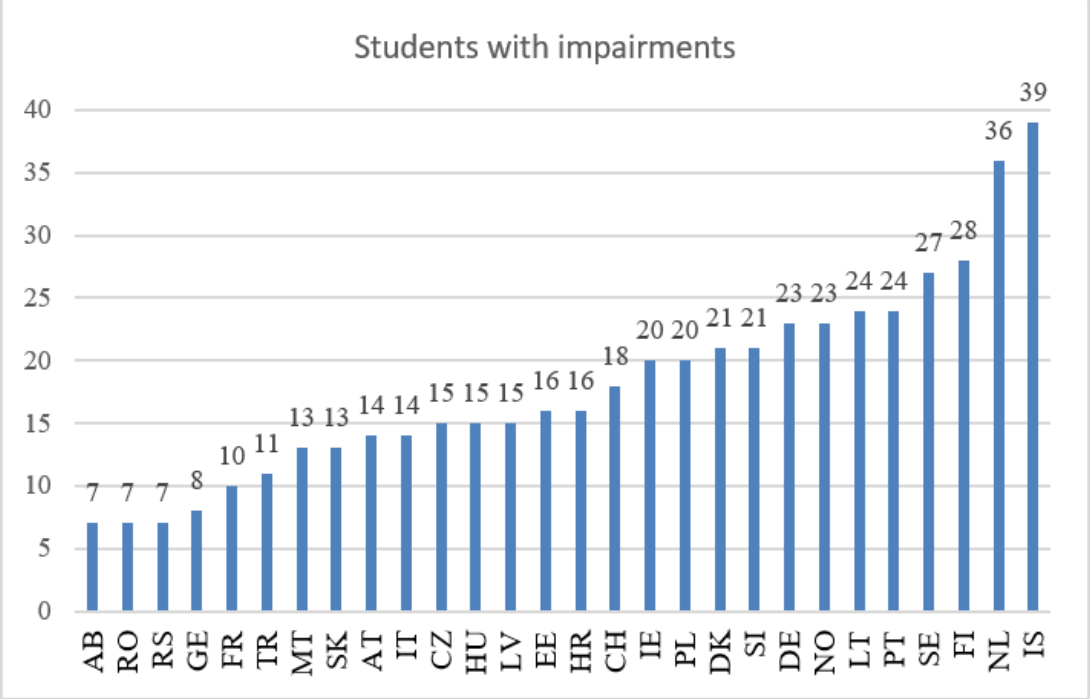

Figure 5: Percent of students with impairments (based on Eurostudent VI data).

education" into sociology students training (on example of National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute").

Here are two examples.

In the course "Structural equation modeling" students are asked to analyze the model built by researchers from Luxembourg with Eurostudent VII microdata (figure 6) [36]. Research questions of this model are as follows: "How do individual characteristics impact the dropout intention via student commitment and integration? Does institutional support mediate this effect/relationship?". Original conclusions obtained by researchers are: 1) gender as an individual characteristic showed no effect on any of the factors; 2) social integration regarding fellow students had no effect on study commitment, while social integration regarding University teachers showed the expected positive effect. As a case study, it is proposed to test this model in other countries and discuss the results.

The course "Social networks analysis" is selective and enrolled by students of various specialties. During the course, students learn to receive data from social networks and analyze them. One of the cases is the search queries about topics of the social dimension of higher education in Twitter, in particular with the hashtag #Eurostudent. The graph of the network with clusters is presented in figure 7. The data were obtained in the free version NodeXL for the period 25–29 November 2021. Students analyze this data using cloud tools: R environment, NodeXL, Gephi; they calculate and interpret key social networks metrics, at the user, group and network levels; visualize a graph of the network. For example, one of didactics task: to find and describe the

Table 3
Integration of topic "Social dimension of higher education" into sociology student training.

Discipline name	Level of education	Year taught	Content
Mathematical and statistical methods of sociological data analysis	Bachelor	1-2	Integration of the SD topic into practical classes and individual projects: descriptive statistics, correlation, regression. Use of Eurostudent YI, YII, Eurostat, Ukrstat databases
Methodology and methods of sociological research	Bachelor	1-2	Integration of the the SD topic into practical classes and group projects: survey, focus-group with underpresented studemts, data ethics, expert survey.
Social statistics and demography	Bachelor	2	Integration of the SD topic into practical classes and individual projects: education statistics unit. Use of Eurostudent YI, YII, Eurostat databases and others.
Social networks analysis	Bachelor	4	Twitter data analysis about topic social dimention in R Studio, NodeXL, Gephi. Twitter search with #Eurostudent
Multidimensional data analysis	Master	2	Integration the SD topic into practical classes and individual projects: Anova, discriminant analisys, factor analysis, cluster analysis models.
Actual problem of sociology research	PhD	2	Integration of the SD topic into theoretical and practical classes and individual projects: focus-group interview, data ethics, Eurostudent YII microdata, Ukrstat.
Structural equation modeling	PhD	2	Integration the SD into practical classes and individual projects: student retention and student engagement SEM models, Eurostudent YII microdata, Ukrstat.

social mediators of the network: the actors with both high betweenness and high in-degree centrality values (German Centre for Higher Education Research and Science Studies (DZHW); Praxis Centre for Policy Studies (Praxis), Estonia).

3. Conclusions and perspectives of further research

Strengthening the social dimension of higher education is a priority task in the EHEA [10, 12, 37]. The students from vulnerable, disadvantaged and underrepresented groups are not sufficiently and systematically researched in Ukraine [38]. This includes the groups of students directly involved in the armed conflict, i.e. young people from the uncontrolled regions of Crimea and Donbas; students from internally displaced families, children of the participants of the anti-terrorist operation, students with special educational needs, foreign students, and female students in STEM (Science, Technology, Engineering and Mathematics).

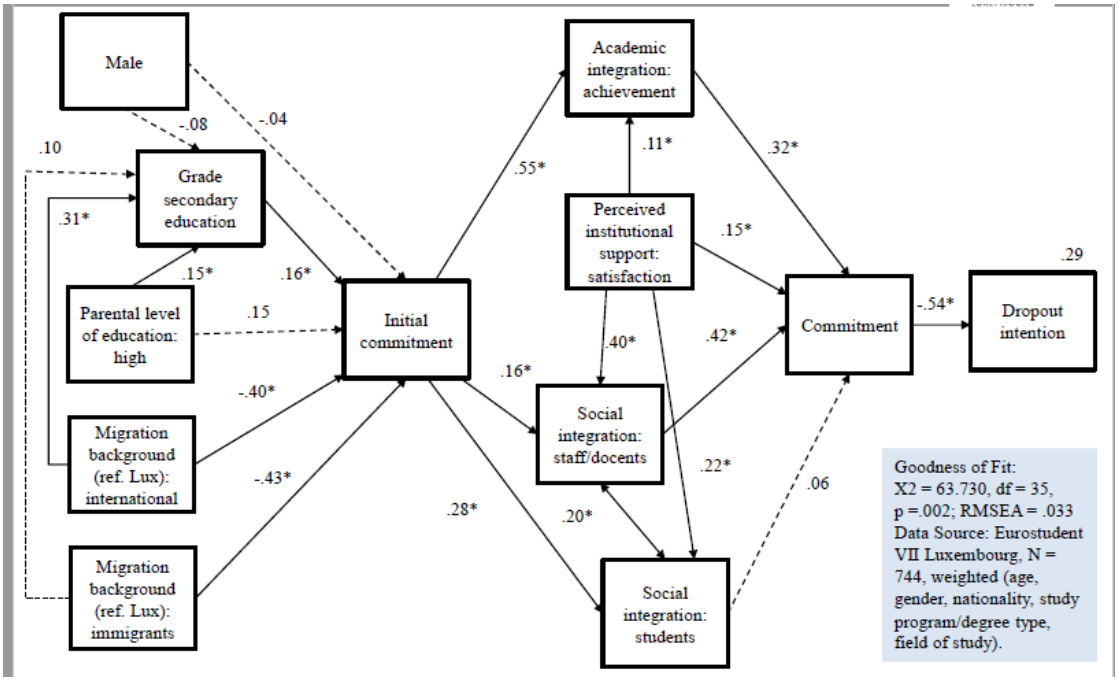

Figure 6: SEM model "Roles of individual characteristics and institutional support in students' higher education drop out intention in Luxembourg" [36].

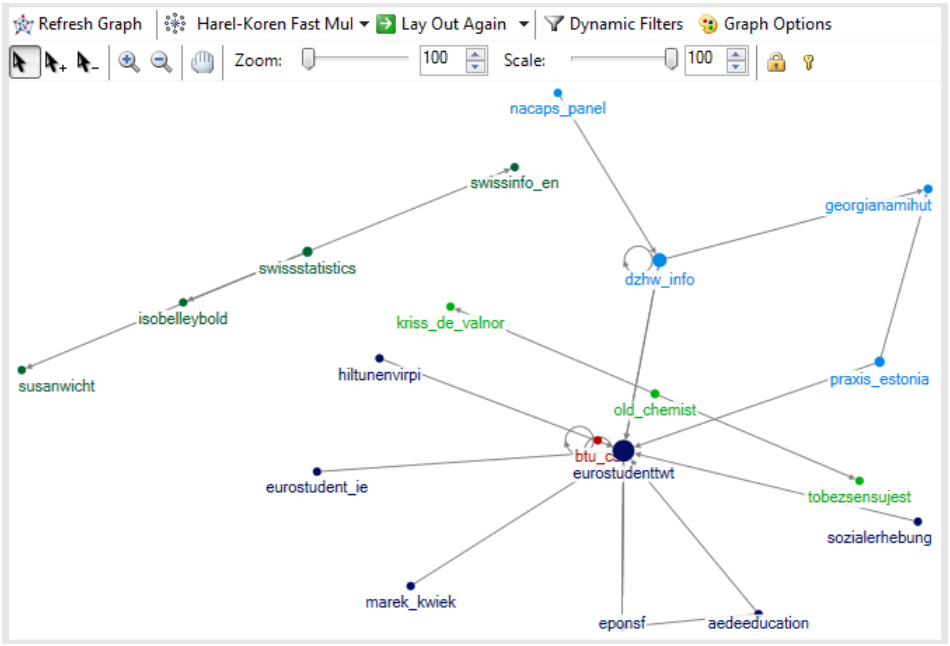

Figure 7: Twitter search with hashtag #Eurostudent. Network was obtained in the free version NodeXL for the period 25–29 November 2021 in the course "Social network analysis".

Modeling methodology helps to determine the effectiveness of educational innovations in different contexts of social dimension, and to study phenomena in their interrelations and latent factors.

This article presented the ways to update the content of the following university courses for sociology bachelors, master students, PhDs: “Mathematical and statistical methods of social information analysis”, “Social statistics and demography”, “Multivariate methods data analysis”, “Structural equation modeling”.

Further work in this direction includes the creation and study of structural equations model on student engagement and student integration with the help of Eurostudent data set.

References

[1] Prague Communiqué (Towards a European Higher Education Area): Communiqué of the Meeting of European Ministers of Education, 2001. URL: http://www.ehea.info/page-ministerial-conference-prague-2001.

[2] Rome Ministerial Communiqué (Conference of Ministers of Higher Education of the European Higher Education Area ”Embrace the challenge, create new opportunities and cancel differences” (Rome, Italy, 19.11.2020), 2020. URL: http://www.ehea.info/Upload/Rome_Ministerial_Communique.pdf.

[3] EUROSTUDENT VII final conference (Hanover, Germany, 18-19 may 2021), 2021. URL: https://eua.eu/partners-news/672-eurostudent-vii-final-conference,-18-%E2%80%93-19-may.html.

[4] S. Semerikov, I. Teplytskyi, Y. Yechkalo, O. Markova, V. Soloviev, A. Kiv, Computer simulation of neural networks using spreadsheets: Dr. Anderson, welcome back, CEUR Workshop Proceedings 2393 (2019) 833–848. URL: http://ceur-ws.org/Vol-2393/paper_348.pdf.

[5] L. Bilousova, O. Kolgatin, L. Kolgatina, Computer simulation as a method of learning research in computational mathematics, CEUR Workshop Proceedings 2393 (2019) 880–894.

[6] V. Soloviev, N. Moiseienko, O. Tarasova, Modeling of cognitive process using complexity theory methods, CEUR Workshop Proceedings 2393 (2019) 905–918.

[7] A. Burke, Student Retention Models in Higher Education: A Literature Review, College and University 94 (2019) 12–21. URL: https://www.aacrao.org/research-publications/quarterly-journals/college-university-journal/issue/c-u-vol.-94-no.-2-spring.

[8] K. Hauschildt, E. M. Vogtle, C. Gwosc, Social and Economic Conditions of Student Life in Europe: Eurostudent VI 2016-2018: Synopsis of Indicators, W. Bertelsmann Verlag, Bielefeld, 2018. URL: https://www.eurostudent.eu/download_files/documents/EUROSTUDENT_VI_Synopsis_of_Indicators.pdf. doi:10.3278/6001920cw.

[9] K. Hauschildt, C. Gwosć, H. Schirmer, F. Wartenbergh-Cras, Social and Economic Conditions of Student Life in Europe: EUROSTUDENT VII Synopsis of Indicators 2018–2021, wbv Media GmbH & Co. KG, Bielefeld, 2021. URL: https://www.eurostudent.eu/download_files/documents/EUROSTUDENT_VII_Synopsis_of_Indicators.pdf. doi:10.3278/6001920dw.

[10] K. Hauschildt, C. Gwosć, H. Schirmer, F. Cras, The social dimension of student life in the European higher education area in 2019. Selected indicators from Eurostudent

VII, 2019. URL: https://www.eurostudent.eu/download_files/documents/Eurostudent_brochure_WEB.pdf.
[11] S. Mishra, J. Diesner, Capturing signals of enthusiasm and support towards social issues from twitter, in: Proceedings of the 5th International Workshop on Social Media World Sensors, SIdEWayS'19, Association for Computing Machinery, New York, NY, USA, 2019, p. 19–24. doi:10.1145/3345645.3351104.
[12] J. Salmi, Social Dimension Within a Quality Oriented Higher Education System, in: A. Curaj, L. Deca, R. Pricopie (Eds.), European Higher Education Area: The Impact of Past and Future Policies, Springer, Cham, 2019, pp. 300–312. doi:10.1007/978-3-319-77407-7_10.
[13] J. Salmi, Violence, integrity and education, Global Crime 10 (2009) 396–415. doi:10.1080/17440570903248445.
[14] M. Unger, What can EUROSTUDENT data tell us about the social dimension?, in: Eurostudent VII Final Conference, 19.05.2021, 2021.
[15] V. Tinto, Dropout from higher education: A theoretical synthesis of recent research, Review of Educational Research 45 (1975) 89–125. doi:10.3102/00346543045001089.
[16] V. Tinto, Leaving college: Rethinking the causes and cures of student attrition, 2d ed., The University of Chicago Press, Chicago, 1994.
[17] V. Tinto, Taking Retention Seriously: Rethinking the First Year of College, NACADA Journal 19 (1999) 5–9. URL: https://meridian.allenpress.com/nacada-journal/article-pdf/19/2/5/2223517/0271-9517-19_2_5.pdf. doi:10.12930/0271-9517-19.2.5.
[18] V. Tinto, Linking learning and leaving: Exploring the role of the college classroom in student departure, Reworking the student departure puzzle, Vanderbilt University Press, Nashville, 2000, pp. 81–94. URL: https://silo.tips/download/linking-learning-and-leaving-exploring-the-role-of-the-college-classroom-in-stud#.
[19] V. Tinto, Student retention and graduation: Facing the truth, living with the consequences, Occasional Paper 1, The Pell Institute, Washington, 2004. URL: http://www.pellinstitute.org/publications-Student_Retention_and_Graduation_July_2004.shtml.
[20] V. Tinto, Research and practice of student retention: What next?, Journal of College Student Retention: Research, Theory & Practice 8 (2006) 1–19. doi:10.2190/4YNU-4TMB-22DJ-AN4W.
[21] W. G. Spady, Dropouts from higher education: An interdisciplinary review and synthesis, Interchange 1 (1970) 64–85. doi:10.1007/BF02214313.
[22] W. G. Spady, Dropouts from higher education: Toward an empirical model, Interchange 2 (1971) 38–62. doi:10.1007/BF02282469.
[23] M. Tight, Student retention and engagement in higher education, Journal of Further and Higher Education 44 (2020) 689–704. URL: https://eprints.lancs.ac.uk/id/eprint/131095/1/tight.pdf. doi:10.1080/0309877X.2019.1576860.
[24] M. B. Kerby, Toward a new predictive model of student retention in higher education: An application of classical sociological theory, Journal of College Student Retention: Research, Theory & Practice 17 (2015) 138–161. doi:10.1177/1521025115578229.
[25] K. Kricorian, M. Seu, D. Lopez, E. Ureta, O. Equils, Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets, International Journal of STEM Education 7 (2020) 1–24. doi:10.1186/s40594-020-00219-2.

[26] S. Tishkovskaya, G. Lancaster, Teaching strategies to promote statistical literacy: review and implementation, in: ICOTS 8 proceedings: International Conference on Teaching Statistics 2010, Ljubljana, Slovenia, International Association for Statistical Education, Auckland, New Zealand, 2010. URL: http://icots.info/8/cd/pdfs/contributed/ICOTS8_C193_TISHKOVSKAY.pdf.

[27] L. F. Panchenko, Training sociology students in computer analysis of demographic processes and structure, Information Technologies and Learning Tools 65 (2018) 166–183. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/2034. doi:10.33407/itlt.v65i3.2034.

[28] L. Panchenko, H. Korzhov, T. Kolomiiets, M. Yenin, PhD student training: principles and implementation, Journal of Physics: Conference Series 1840 (2021). doi:10.1088/1742-6596/1840/1/012056.

[29] L. Panchenko, N. Samovilova, Secondary data analysis in educational research: opportunities for PhD students, SHS Web of Conferences 75 (2020) 04005. doi:10.1051/shsconf/20207504005.

[30] L. Panchenko, Methodology of using structural equation modeling in educational research, CEUR Workshop Proceedings 2393 (2019) 895–904.

[31] L. F. Panchenko, V. Y. Velychko, Structural equation modeling in educational research: a case-study for PhD training, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[32] London Communiqué (Towards a European Higher Education Area: Responding to the Challenges of Globalization): Communiqué of the Conference of European Ministers responsible for Higher Education; London, 16-19 May 2007, 2007. URL: http://www.ehea.info/Upload/document/ministerial_declarations/2007_London_Communique_English_588697.pdf.

[33] Annex II Rome Ministerial Communiqué, Principles and Guidelines to Strengthen the Social Dimension of Higher Education in the EHEA, Produced by the BFUG Advisory Group 1 for Social Dimension. Edited by Co-Chairs Schmidt Scukanec Ninoslav (Croatia) and Napier Robert (ESU), 24 June 2020, 2020. URL: http://www.ehea.info/Upload/BFUG_DE_UK_73_9_b_PaG_SD.pdf.

[34] C. Demetriou, A. Schmitz-Sciborski, Integration, motivation, strengths and optimism: Retention theories past, present and future, in: R. Hayes (Ed.), Proceedings of the 7th National Symposium on Student Retention, 2011, Charleston, The University of Oklahoma, Norman, OK, 2011, pp. 300–312. URL: http://web.archive.org/web/20130223222447/http://studentsuccess.unc.edu/files/2012/11/Demetriou-and-Schmitz-Sciborski.pdf.

[35] J. B. Berger, G. Blanco Ramírez, S. Lyon, Past to present: A historical look at retention, in: A. Seidman (Ed.), College Student Retention: Formula for Student Success, Rowman & Littlefield, Lanham, MD, 2012, pp. 7–34.

[36] A. Hadjar, C. Haas, I. Gewinner, The roles of individual characteristics and institutional support in students' higher education dropout intention in Luxembourg, 2021. URL: https://wwwde.uni.lu/content/download/136307/1556785/file/Spady_Tinto_4May2021.pdf, Presentation of report in Eurostudent VII conference, Hannover.

[37] Eurydice (European Education and Culture Executive Agency), Chapter 4: So-

cial dimension, in: The European Higher Education Area in 2020, Bologna Process Implementation Report, Publications Office of European Union, Luxembourg, 2020. URL: https://eacea.ec.europa.eu/national-policies/eurydice/sites/default/files/ehea_bologna_2020_chapter04.pdf. doi:doi/10.2797/851121.

[38] Strategy for the development of higher education in Ukraine for 2021-2030, 2020. URL: https://mon.gov.ua/storage/app/media/rizne/2020/09/25/rozvitku-vishchoi-osviti-v-ukraini-02-10-2020.pdf.

Designing a rating system based on competencies for the analysis of the university teachers' research activities

Nataliia V. Morze, Oksana P. Buinytska and Valeriia A. Smirnova

Borys Grinchenko Kyiv University, 18/2 Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine

Abstract

One of the indicators of the influence and competitiveness of university is participation in international and local rankings. In the methodologies of the most authoritative rankings, the quality and transparency of Universities is assessed by indicators of the university teachers' publishing activity. The article analyzes the experience of designing systems that analyses university teachers research activities, tools and components of evaluating the effectiveness of research, designed a structural and functional model of rating system for the analysis the university teachers' research activities taking into account research and digital competencies. The developed model provides performance of the basic functions and allows for systematic monitoring of openness, transparency, efficiency of the research component of university teachers' professional activity. The model was based on key indicators for evaluating the effectiveness of research – citation indicators of the three most important scientometric databases – Scopus, Web of Science, Google Scholar. The connection between the indicators presented in the model forms a portrait of the university teachers' scientific activity, gives an overall assessment of productivity, influence and contribution to the research direction of the university as a whole. The article describes 1 stage of implementation of the presented model by developing a "Rating of Transparency of Structural Units", the effectiveness of experimental ranking. The study has established the positive impact of the implementation of the rating system, identified the main activities to increase the visibility, presence, dissemination of research results, the systematic implementation of which contributes to the optimal representation of the scientist in the rating evaluation of the research component of the university teachers professional activities, improving the digital competence of teachers and positively affects the quality indicators of the university scientific work in local and international rankings, as the existence of the system and the formation of ratings is an incentive for university teachers to present and disseminate their own publishing activities in the international online scientific community.

Keywords

publication activity, scientist profile, scientometric databases, rating system, research activity, research competence, digital competence

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n.morze@kubg.edu.ua (N. V. Morze); o.buinytska@kubg.edu.ua (O. P. Buinytska); v.smirnova@kubg.edu.ua (V. A. Smirnova)

http://eportfolio.kubg.edu.ua/teacher/152 (N. V. Morze); http://eportfolio.kubg.edu.ua/teacher/21 (O. P. Buinytska); http://eportfolio.kubg.edu.ua/teacher/222 (V. A. Smirnova)

0000-0003-3477-9254 (N. V. Morze); 0000-0002-3611-2114 (O. P. Buinytska); 0000-0001-9965-6373 (V. A. Smirnova)

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1. Introduction

The main priority of each university is to provide quality educational services, increase competitiveness in the educational market and to attract the most promising students. Participation in international and domestic rankings is an important tool for measuring the competitiveness of Universities. In the methodologies of the most authoritative rankings, the quality and transparency of Universities are assessed by indicators of publishing activity of researchers. Indicators of the scientific citations' quality according to Google Scholar Citations and citations in influential scientific journals are taken into account in international rankings – "Academic ranking of world universities" (ARWU), "QS Top University Ranking", webometric ranking of world universities "Webometrics", "Transparent ranking: Top Universities by Google Scholar Citations" and Ukrainian – "University ranking by Scopus indicators", "Top-200 Ukraine", "Consolidated rating of higher education institutions of Ukraine", "Bibliometrics of Ukrainian science" [1]. To ensure optimal representation of the university in international and Ukrainian rankings, it is necessary to develop and implement a rating system for the analysis the research activities of university teachers to monitor and qualitatively analyze the effectiveness of research activities of university teachers and timely develop systemic measures to increase openness, transparency results of research activities, wide dissemination in the international scientific network communities for popularization and collaboration.

The purpose of the study is to build a structural and functional model of a rating system for the analysis the research component of university teachers' activities based on key indicators of research and digital competencies.

2. Research of the experience of the analysis of research activity of the university teachers in the European space of higher education

Delgado López-Cózar et al. [2], Martín-Martín et al. [3], Bykov and Spirin [4], Bykov et al. [5], Semerikov et al. [6], Vakarenko [7] studied the features of the analysis of research results using open scientometric and bibliometric systems.

Theoretical bases of rating assessment of teachers' activity of the Ukrainian Universities were studied by Dzoba [8], Reheilo [9], Yaroshenko [10]. Yaroshenko [10] emphasized the need to modernize indicators of the teachers' research activities, in accordance with the modern realities of university education, summarizes the main characteristics of the rating assessment of the teachers: purpose, objectives, functions and ranking principles. Reheilo [9] considered the main conceptual principles of evaluating the effectiveness of the teachers' research activities, analyzed the principles, structural components and indicators of evaluation of the teachers' scientific activities in the European higher education area.

Issues of assessing the quality of research results were studied by Kostenko et al. [11], Shynenko et al. [12], Gasparyan et al. [13].

Hohunskyi et al. [14] determined that the use of profiles by scientists in Google Scholar, ORCID, Mendeley, Academia, ResearchGate increases the visibility of publications in the information space and has a positive effect on increasing citation rates.

In [11] the information-analytical system "Bibliometrics of the Ukrainian Science", developed by Social communication research center, which is the register of bibliometric profiles of researchers and research teams in the most authoritative scientometric databases, as Scopus, Web of Science and Google Scholar. The system allows to analyze the local scientific potential, to carry out a comparative analysis of the effectiveness of Ukrainian scientists in the fields of science, cities, affiliation, agencies, etc. by constructing rating tables on the value of h-indices in Scopus, Web of Science or Google Scholar databases [15]. Open profiles of a scientist in scientometric databases are a passport of a scientist in the European space of higher education, which reflects his authority and influence on the development of a particular field.

Spivakovsky et al. [16] describes the experience of designing an information system to analyze the research activities of university teachers, tested on the basis of Kherson State University and Kherson State Maritime Academy. The system implements tools for constructing teachers' ratings by the main indicators of scientific citation in the databases Scopus, Web of Science, Google Scholar, Semantic Scholar, Tutor Network. Ratings are built in the context of structural units, departments and scientific journals. The rating of departments is based on the maximum value of citation profiles of all employees in the department in these databases [17].

The project Open Ukrainian Citation Index (OUCI), developed by the State Scientific and Technical Library of Ukraine, was studied by Nazarovets [18]. OUCI is a search engine and database of scientific citations that contains meta-data of all publications that use Cited-by service from Crossref and support the Initiative for Open Citations. The OUCI database contains metadata of scientific publications that receive DOI from Crossref and takes into account citations between publications. OUCI is designed to simplify the search and analysis of research results and expand the presentation and visibility of Ukrainian scientific publications in international search engines, such as Dimensions, Lens.org, 1findr, Scilit, etc [19]. The implemented analytical tool allows to assess the state and dynamics of the development of scientific potential in terms of fields of knowledge, years, to select the appropriate scientific journal for publication.

A common practice among universities is the implementation of rating systems to assess the professional activity of university teachers, as part of the system of quality assurance in education, one of the areas of which is research. Borys Grinchenko Kyiv University has introduced the "E-portfolio" system, which reflects the detailed picture of the teacher's activity with certain quantitative and qualitative indicators of activity. The system allows not only to create an e-portfolio of the teacher, but also to form rating tables of indicators for assessing the main activities of each university teacher [20].

Borys Grinchenko Kyiv University has introduced the Corporate Standard of Research Activity of Employees and the Corporate Standard of Digital Competence of Teachers, which present and correlate the performance indicators of university teachers' research activity and their corresponding indicators of the levels of formation of teachers' digital competence (figure 1).

One of the indicators of university teacher's compliance with the Corporate Standard of Research Activities of the staff of Borys Grinchenko Kyiv University [21] is the indicator of scientific recognition, which is determined by the values of citation indices in the scientometric databases Scopus, Web of Science, Google Scholar. The key to optimal presentation of research results in scientometric databases is a sufficient level of digital competence, which lies in the ability to effectively use open digital systems in own research, create, update, supplement the articles of the scientist profile in scientometric databases, distribute research results in scientific

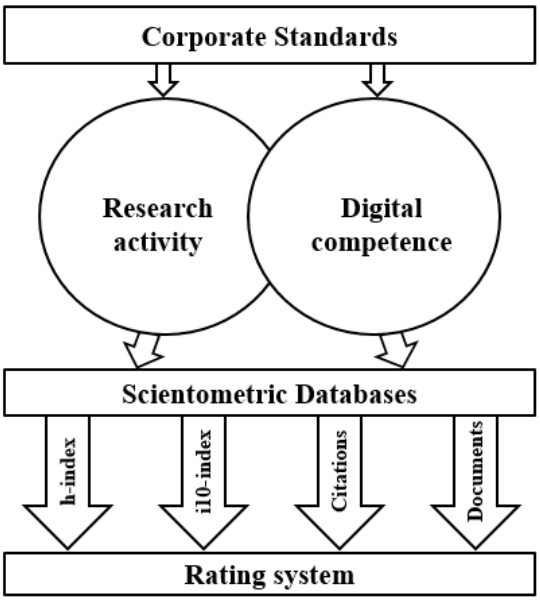

Figure 1: Correlation of indicators of the Corporate Standard of Research Activity and the Corporate Standard of Digital Competence of the staff of Borys Grinchenko Kyiv University.

Table 1
Comparative table of indicators of the Corporate Standard of Research Activity and the Corporate Standard of Digital Competence of the staff of Borys Grinchenko Kyiv University.

Corporate Standard of Research Activity	Corporate Standard of Digital Competence
Scientific recognition: Scientometric indicators from databases Scopus, Web of Science and Google Scholar • h-index • i10-index • Number of citations • Number of publications	• Actualization of scientist profiles in scientometric databases; • Dissemination of research results; • Systematic use of digital tools in conducting and disseminating research results.

web-communities and social networks [22] (table 1).

Analyzing the experience of developing rating systems for the analysis the activities of university teachers, it was determined that the most common quantitative indicators of evaluation of research activities are publications in journals included in influential scientometric databases; values of citation indices in scientometric databases – Scopus, Web of Science, Google Scholar, etc. [20].

3. Tools for determining the publishing activity of the university teachers

The most common tools for assessing the publishing activity of the university teachers are the determination of citation indices in scientometric databases. Scopus and Web of Science databases allow scientometric analysis of a scientist's productivity by analyzing the dynamics of the number of publications in influential international publications, the influence and demand of scientific work, analyzing the dynamics of bibliographic references and citation indices by years [23].

Scopus and Web of Science have powerful analytical tools SciVal and InCites. The tools allow for a comprehensive analysis of the effectiveness of research on a wide range of indicators: impact, productivity, collaboration, open access, the impact of journals, etc. in a visualized form; identify promising areas of research, expand the range of scientific collaboration and cooperation.

An alternative to commercial systems is the free Google Scholar system, which indexes full-text scientific publications from many disciplines in various databases. The main advantage of Google Scholar is its freeness and the fact that its index is not limited to a certain list of journals, unlike commercial scientometric databases like Scopus, Web of Science, but more broadly covers the web space, it indexes publications on sites electronic journals, repositories, electronic conferences, personal blogs of scientists, etc. For efficient indexing, web resources must be based on platforms with special meta tags (EPrints, DSpace, Open Conference System) [24], from which the Google Scholar system receives basic publication metadata or publication files designed according to certain requirements for document formatting, design of titles, personal data of the authors, the main content of the article, the list of sources used, etc [4]. The Google Scholar system allows researcher to create a personal profile and add system-indexed publications to it. The Google Scholar researcher's profile has tools for analyzing statistics on citations of publications by year, allows you to track the total number of citations, h-index and i10-index, which are calculated based on the total number of publications and the number citations of individual indicators for the entire period of scientific work and for the last 5 years in digital form and in the form of a comparative histogram [23].

A comparison of the available indicators for evaluating the effectiveness of the researcher's research activities in the profiles of the most common scientometric databases is given in table 2.

The analysis of indicators confirms that for a full-fledged comprehensive assessment of the effectiveness of research in various areas it is necessary to use a set of indicators of important scientometric databases.

4. Research results

4.1. Structural and functional model of the rating system for the analysis the research activity of the university teachers

The most important scientometric databases that demonstrate the effectiveness of the university teachers' research activity are Scopus, Web of Science and Google Scholar, in which the values of bibliographic citation are used as quantitative indicators of evaluation and analysis. At the same

Table 2
Comparative table of scientometric indicators in the scientists' profiles.

	Scopus	Scival	Web of Science	Publons	InCites	Google Scholar	ResearchGate
Number of publications	+	+	+	+	+	-	+
Citation	+	+	+	+	+	+	+
h-index	+	+	+	+	+	+	+
i10-index	-	-	-	-	-	+	-
Average citation value	-	-	+	-	+	-	-
Altmetric indicators (recommendations, readings)	+	-	+	-	-	-	+
Without self-citation	+	+	+	-	+	-	+
Visualization	+	+	+	+	+	+	-
Analysis of indicators	+	+	+	+	+	+	+
Reports	+	+	+	-	+	-	-
Making connections	+	+	+	+	+	+	+

time, it is important for university teachers to comply with the Corporate Standard of Research Activity and the Corporate Standard of Digital Competence, as the level of research and digital competence directly affects the quality of research and therefore the university's ranking in international and local rankings. That is why the basis of the model of the rating system for the analysis the research activity of the university teachers are these three scientometric databases.

The main principles in developing the methodology of the rating system for the analysis the research activity of the university teachers were objectivity, measurability and transparency. That is why as indicators of the effectiveness of university teachers' research activities were selected indicators of citing scientific publications in open teachers' profiles in Scopus, Web of Science and Google Scholar that is easy to get and check – the number of bibliographic references, the h-index and i10-index.

The rating system for the analysis the research activity of the university teachers performs the following functions:

- informational – the formation of a single information base of indicators of research effectiveness of university teachers for quality assessment;
- visualization – presentation of information in a visualized form to improve perception, reporting;
- motivational – the formation of an atmosphere of healthy competition, activation of the scientific potential of the university;
- competence – encouraging teachers to create, update, actualization information in their own profiles in scientometric databases;
- analytical – analysis of the current state of the research component of the departments and the university as a whole, identification of factors influencing the effectiveness of teachers' research activities, identification and analysis of relationships;
- prognostic – forecasting of perspective trajectories of the university development, system measures development for increasing the indicators of efficiency of the university teachers'

research activity;
- managerial – information basis for making managerial decisions.

The implementation of certain functions is possible in the presence of the following structural components of the rating system for the analysis the research activity of the university teachers.

The administrative component provides for the delimitation of access rights to the rating system – administrator, teacher, guest. Administrator rights include the start of rating formation, marking of incorrectly filled profiles, export of reports. The rating is available to university teachers and unauthorized users only for review and analysis.

Organizational component. For each lecturer of the Borys Grinchenko Kyiv University, a profile in the "E-portfolio" system is automatically generated, from which data on affiliation and scientific citation are obtained.

The technological component (figure 2) includes obtaining scientometric indicators from Scopus databases, Web of Science and the Google Scholar system and teachers' personal data. The "E-portfolio" system of the Borys Grinchenko Kyiv University automatically synchronizes the values of bibliographic references, h-index and i10-index for the last 5 years from the bibliographic profile of the scientist in the Google Scholar system, a link to which the teacher can add to his portfolio.

Scientometric indicators from the Scopus and Web of Science profiles are entered the "Database of activity registers", the data from which are automatically synchronized in the teachers' profile in the "E-portfolio" system. The relationship between the systems is implemented through APIs. The values of scientometric indicators from the Scopus, Web of Science and Google Scholar databases available in the profile are obtained during the formation of the "Rating of Transparency of Structural Units", which is one of the results of the designed model.

Effective component – based on the collected data on the affiliation and scientometric indicators of teachers are formed rating tables of research effectiveness of the university as a whole and in terms of departments and departments, based on which the ability to export reports.

Communication of all components is provided in the Borys Grinchenko Kyiv University Digital Campus.

Thus, the structural and functional model of the rating system system based on competencies for the analysis the research activity of the University teachers will have the following form (figure 3):

4.2. Development of a transparency rating and methodology for its construction

Based on the presented model, a rating was developed, which is one of the indicators of system performance. As a result of experimental implementation, a "Rating of Transparency of Structural Units" by citation indicators in Google Scholar was developed, which ranks teachers according to their indicators of publishing activity (figure 4).

The proposed model of the rating system was implemented as a web-oriented client-server architecture. PHP programming language using the MVC architectural model was used in the development of the server software. The web user interface is implemented using HTML, CSS and JavaScript.

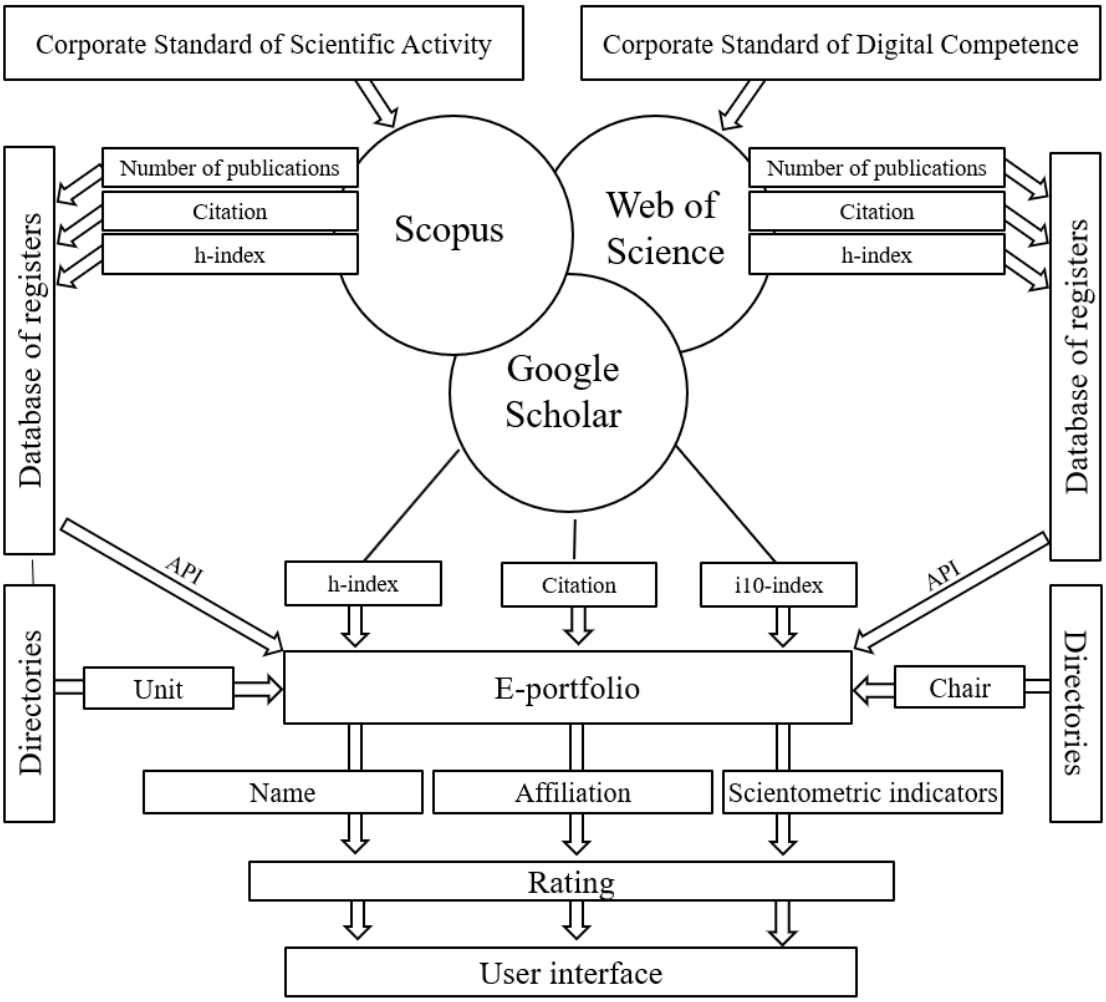

Figure 2: Technological component of the structural-functional model of the rating system for the analysis the research activity of the university teachers.

The average citation rate per university teacher was determined in order to build the ranking of the structural units, as this approach reflects the contribution of each individual teacher to the scientific achievement of the structural unit and the performance of the research team as a whole. The ranking of structural units and chairs in the "Rating of Transparency of Structural Units" is carried out in descending order of the value of the average citation rate per 1 university teacher. In the case of the same average citation rates, the structural units and chairs are sorted in descending order of the total number of citations of teacher profiles. The choice of the Google Scholar system is due to the fact that, unlike the scientometric databases Scopus and Web of Science, it has a wider coverage and includes publications from these databases and has a high level of correlation in citation values with Scopus, Web of Science, which confirmed by the results of research [3, 25], which provides a greater presence of University teachers in the ranking.

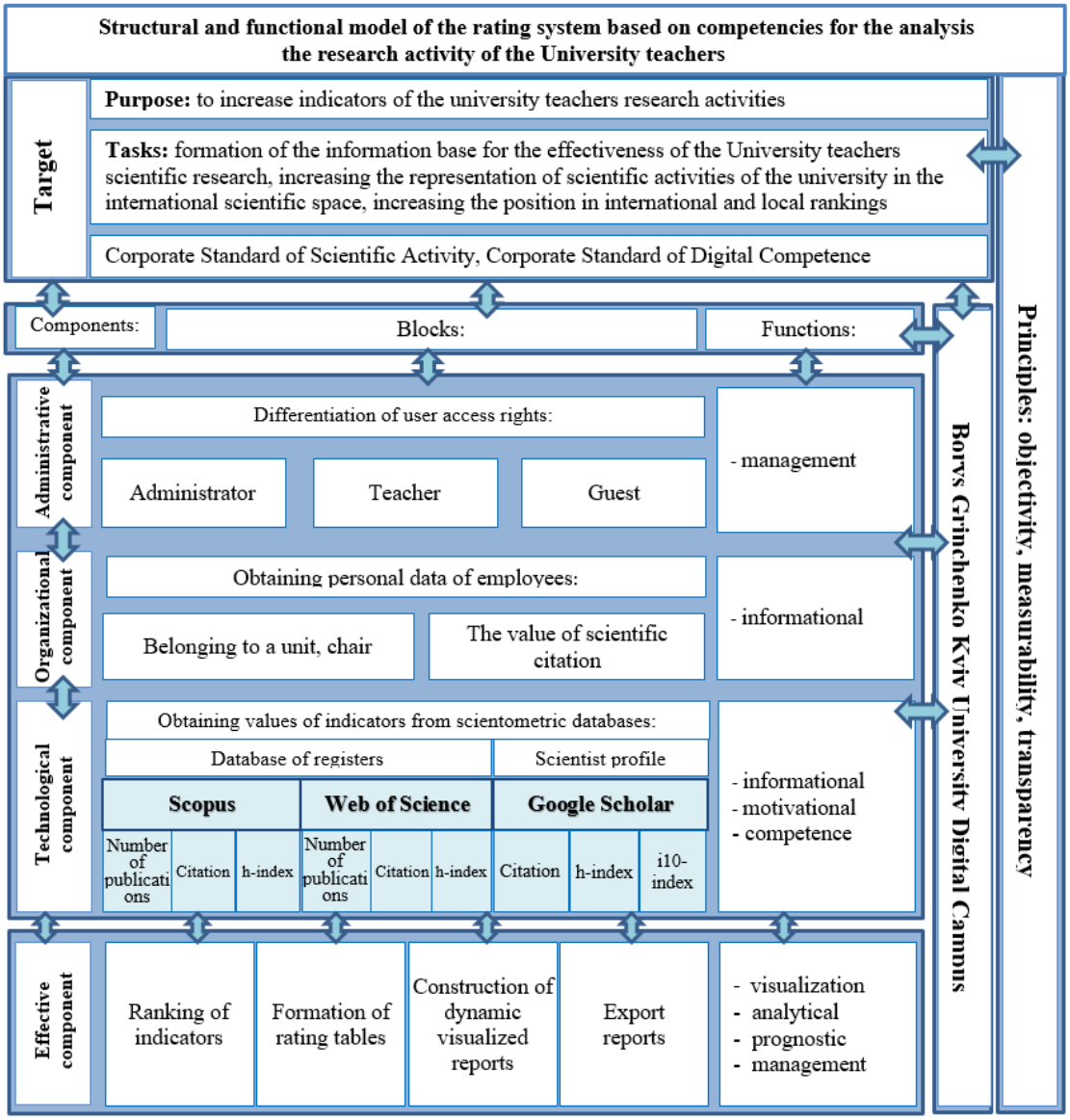

Figure 3: Structural and functional model of the rating system based on competencies for the analysis the research activity of the university teachers.

In the context of chairs, a list of teachers is displayed, ranked in descending order of the value of the total number of bibliographic references according to the Google Scholar (figure 5). The detailed table of research performance indicators contains the values of the total number of bibliographic references, h-index, i10-index and the link to the profile in the Google Scholar.

Creating a database of scientific profiles of researchers in Google Scholar allowed to implement the designation of incorrectly configured profiles in one place.

For further analysis of rating positions and indicators of the university teachers' research

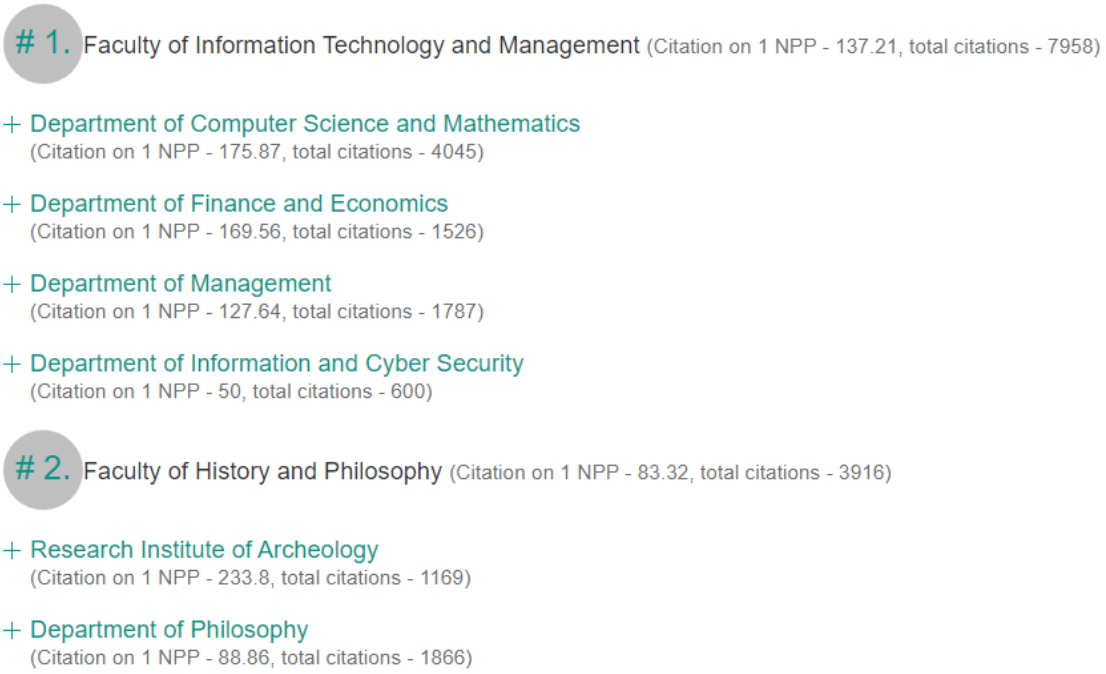

Figure 4: "Rating of Transparency of Structural Units" by citation indicators in Google Scholar.

– Department of Computer Science and Mathematics
(Citation on 1 NPP - 175.87, total citations - 4045)

№	Name	Citation	h-index	i10 index	
1	Morse Natalia Viktorivna	2249	21	63	Link to a Google Scholar account
2	Lytvyn Oksana Stepanovna	689	14	23	Link to a Google Scholar account
3	Wember Victoria Pavlovna	357	10	12	Link to a Google Scholar account
4	Boyko Maria Anatoliyivna	133	7	3	Link to a Google Scholar account
5	Proshkin Vladimir Vadimovich	122	6	2	Link to a Google Scholar account

Figure 5: Ranking of the university teachers by citation indicators in Google Scholar.

activities, construction of visualized reports on the effectiveness of research activities, it is planned to implement the 2nd stage of research – expanding the rating for other indicators presented in the model – the number of publications and citation indices in Scopus and Web of Science databases, establishing relationships to increase the university teachers' publishing activity.

4.3. Influence of the rating indicators on the improvement of the university teachers' research activity

The research took place in several stages: preparatory, design, experimental (implementation).

At the preparatory level, the theoretical foundations of rating of evaluation the university teachers' activity were investigated. At the design stage, a structural and functional model of the rating system for the analysis the research activity of the university teachers was designed, "Rating of Transparency of Structural Units" by citation indicators in Google Scholar was developed and a preliminary rating was built. For two months, the administration and university teachers had the opportunity to review and analyze the data of the previous rating, after which an experimental rating was built.

The analysis of preliminary and experimental ratings (figures 6, 7), built with an interval of 2 months, confirmed the positive dynamics of research performance. The availability of the system and the formation of ratings is an incentive for teachers to update their e-portfolio profiles, create profiles in scientometric databases, in the absence, update information in scientometric profiles, including Google Scholar, supplement indexed publications, dissemination of research results, their discussion in the international online scientific community, thus developing skills in using digital technologies in organizing research and disseminating results.

Unit	Average citation rate per 1 teacher			Total number of citations		
	April	June	Dynamics	April	June	Dynamics
FITM	137,42	137,21	-0,21	7558	7958	400
HIS	63,95	76,28	12,33	3709	4348	639
FHP	60,8	83,32	22,52	2736	3916	1180
FHPES	57,26	49,2	-8,06	2634	2263	-371
PI	56,06	62,24	6,18	3532	3921	389
Research Laboratory	50,71	52,86	2,15	710	740	30
IJ	20,82	22,16	1,34	1145	1263	118
IIST	20,57	22,76	2,19	1111	1252	141
FLIR	20,49	19,12	-1,37	881	822	-59
IP	13,83	15,83	2	2255	2628	373
IA	10,18	12,47	2,29	1059	1235	176
University	**46,55**	**50,31**	3,76	27330	30346	**3016,00**

Figure 6: Google Scholar citation rates in preliminary and experimental ratings.

According to the results of the study, it was found that the optimal presentation of the results of university teachers' research activities in ranking is facilitated by:

- implementation of open access, transparency, openness of research results;
- preference for publications, assigning articles a unique DOI identifier, which facilitates publication identification and provides a permanent publication link, regardless of changes in the publication web address;
- creating profiles and periodically adding new scientific developments to scientometric and bibliometric databases such as Google Scholar, ResearchGate, Mendeley, and the like;

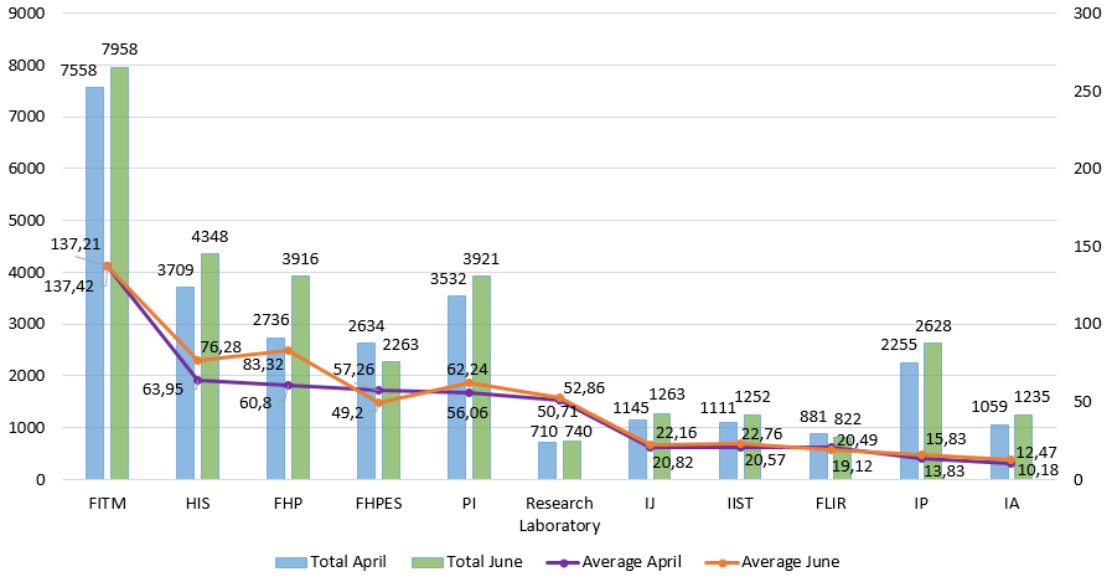

Figure 7: Diagram of indicators of preliminary and experimental ratings.

- use of ORCID scientist identifier to correctly identify the affiliation of the article to the author's profile;
- implementation of dissemination activities to increase visibility and presence in the international online scientific community.

Currently, work is underway to refine and expand the rating for other indicators of Scopus, Web of Science, presented in the model to obtain a full rating system; systems of analytics and statistics with the formation of dynamic visualization of the effectiveness of the scientific potential of the university.

5. Conclusions

For optimal presentation of the university's activity in international and Ukrainian rankings, ensuring the competitiveness of the university, it is important to systematically monitor the openness, transparency of the effectiveness of the university teachers' research activities. An effective tool for monitoring is the development and implementation of a rating system for research analysis.

The system is based on the three most important scientometric databases – Scopus, Web of Science, Google Scholar and provides the main functions – information, visualization, motivation, competence, analytical, prognostic and managerial. The rating system is implemented as a web-oriented client-server architecture. One of the components implemented in the system at the 1st stage of the study is "Rating of Transparency of Structural Units" by citation indicators in Google Scholar. According to the results of the study, recommendations were developed to improve the quality of research activities. The formation of the ranking has confirmed the

importance of designing a system to analyze research activities, improve the quality of scientific research, disseminate research results in the international educational space, to analyze teachers' own professional development, monitor the scientific growth of university teaching staff and obtain visualized analyses in real time. The prospects for further research is considered in the adding other research activity indicators to the ranking, realisation of real-time updates to the rating system, integration of modern business intelligence systems to build visualised statistics to analyse the effectiveness of the research component of the university's activities.

The systematic implementation of measures to ensure open access to own research results, to increase the visibility, transparency and dissemination of the results of research activities in the Internet space contributes to the optimal representation of the scientist's activities in the rating evaluation of the research component of the professional activities of university teachers, improving the professional competence of teachers and positively influencing on the indicators of quality of university's scientific work in local and international rankings.

References

[1] O. Buinytska, B. Hrytseliak, V. Smirnova, Rating as assessment tool of quality and competitiveness of university, Open educational e-environment of modern University 4 (2018) 16–32. doi:10.28925/2414-0325.2018.1632.

[2] E. Delgado López-Cózar, E. Orduña-Malea, A. Martín-Martín, Google scholar as a data source for research assessment, in: W. Glänzel, H. F. Moed, U. Schmoch, M. Thelwall (Eds.), Springer Handbook of Science and Technology Indicators, Springer International Publishing, Cham, 2019, pp. 95–127. doi:10.1007/978-3-030-02511-3_4.

[3] A. Martín-Martín, E. Orduna-Malea, M. Thelwall, E. Delgado López-Cózar, Google scholar, web of science, and scopus: A systematic comparison of citations in 252 subject categories, Journal of Informetrics 12 (2018) 1160–1177. doi:10.1016/j.joi.2018.09.002.

[4] V. Bykov, O. Spirin, Information and analytical support of scientific and pedagogical research based on electronic bibliometric systems, in: Reporting scientific-practical conference of the Institute of Information technologies and learning tools of the National Academy of Pedagogical Sciences of Ukraine, 2016, pp. 1–3. URL: https://lib.iitta.gov.ua/106914/.

[5] V. Bykov, O. Spirin, A. Biloshchytskyi, O. Kuchansky, O. Dikhtiarenko, O. Novytskyi, Open digital systems for assessment of pedagogical research results, Information Technologies and Learning Tools 75 (2020) 294–315. doi:10.33407/itlt.v75i1.3589.

[6] S. O. Semerikov, V. S. Pototskyi, K. I. Slovak, S. M. Hryshchenko, A. E. Kiv, Automation of the export data from Open Journal Systems to the Russian Science Citation Index, CEUR Workshop Proceedings 2257 (2018) 215–226. URL: http://ceur-ws.org/Vol-2257/paper21.pdf.

[7] O. Vakarenko, Scientometric databases: from system of obtaining information to instrument for evaluating scientific research, Science of Ukraine in the world information space 15 (2018) 9–15. doi:10.15407/akademperiodyka.372.009.

[8] O. H. Dzoba, Rating assessment of scientific and pedagogical workers: theoretical and methodical aspects within a market approach, Scientific Bulletin of Ivano-Frankivsk

National Technical University of Oil and Gas (Series: Economics and Management in the Oil and Gas Industry) 1(19) (2019) 84–95. URL: https://eung.nung.edu.ua/index.php/ecom/article/view/229. doi:10.31471/2409-0948-2019-1(19)-84-95.

[9] I. Reheilo, Theoretical bases of estimation and development of scientific and pedagogical workers of universities in the context of realization of scientific activity, in: Y. Skyba (Ed.), Theoretical bases of development of scientific and pedagogical potential of universities of Ukraine in the context of expansion of institutional autonomy: preprint (analytical materials) (Part I), IVO NAPS of Ukraine, Kyiv, 2020, pp. 72–103. doi:10.31874/978-617-7486-40-3-2020.

[10] O. Yaroshenko, Theoretical bases of rating as a tool for evaluating the activities of scientific and pedagogical staff of ukrainian universities, in: Y. Skyba (Ed.), Theoretical bases of development of scientific and pedagogical potential of universities of Ukraine in the context of expansion of institutional autonomy: preprint (analytical materials) (Part I), IVO NAPS of Ukraine, Kyiv, 2020, pp. 57—-71. doi:10.31874/978-617-7486-40-3-2020.

[11] L. Kostenko, T. Symonenko, O. Zhabin, Project "Bibliometrics of Ukrainian science": idea, realization, plans, Bulletin of the Book Chamber 5 (2019) 30–33.

[12] M. A. Shynenko, A. V. Kilchenko, S. M. Tukalo, Application of scientific metric indicators to evaluate the performance of scientific and pedagogical research, in: Reporting scientific-practical conference of the Institute of Information technologies and learning tools of the National Academy of Pedagogical Sciences of Ukraine, Kyiv, Ukraine, 2021, pp. 89–93.

[13] A. Y. Gasparyan, M. Yessirkepov, A. Duisenova, V. I. Trukhachev, E. I. Kostyukova, G. D. Kitas, Researcher and author impact metrics: Variety, value, and context, Journal of Korean Medical Science 33 (2018) e139. doi:10.3346/jkms.2018.33.e139.

[14] V. D. Hohunskyi, V. O. Yakovenko, T. O. Liashchenko, T. V. Otradska, General mechanisms of citation system of scientific articles, Bulletin of NTU "KhPI 1173 (2016) 14–18. URL: http://dspace.opu.ua/jspui/handle/123456789/1774.

[15] Bibliometrics of Ukrainian science, 2022. URL: http://nbuviap.gov.ua/bpnu/.

[16] A. Spivakovsky, M. Vinnyk, M. Poltoratskiy, Y. Tarasich, Y. Spivakovska, G. Gardner, K. Panova, Information system of scientific activity indicators of scientific organizations: Development status and prospects, CEUR Workshop Proceedings 2393 (2019) 220–228. URL: http://ceur-ws.org/Vol-2393/paper_260.pdf.

[17] Rating of departments of Kherson State University, 2021. URL: http://publication.kspu.edu/rating/departments/.

[18] S. Nazarovets, Open Ukrainian Citation Index (OUCI) project: idea, working principle and development prospects, Intellectual Property in Ukraine 3 (2019) 10–13. URL: http://eprints.rclis.org/34365/.

[19] Open Ukrainian Citation Index, 2022. URL: https://ouci.dntb.gov.ua/.

[20] N. Morze, O. Buinytska, Rating indicators system of evaluation teacher's activities in modern universities, Scientific journal of National Pedagogical Dragomanov University 26 (2017) 34–44. URL: http://enpuir.npu.edu.ua/handle/123456789/19082.

[21] Corporate Standard of Research Activity of the staff of Borys Grinchenko Kyiv University, 2018. URL: https://kubg.edu.ua/images/stories/Departaments/vdd/documenty/rozdil_8/nakaz_212_02.04.2018.pdf.

[22] Corporate Standard of Digital Competence of Teachers of Borys Grinchenko Kyiv Univer-

sity, 2021. URL: https://kubg.edu.ua/images/stories/Departaments/vdd/nakaz__421_11.06.21.pdf.

[23] V. Smirnova, Research on open digital information systems for analysis of research activity results of higher education institutions academic staff, Open educational e-environment of modern university 9 (2020) 134–144. doi:10.28925/2414-0325.2020.9.11.

[24] L. Luparenko, The use of electronic open journal systems in scientific and pedagogic research: Results of experiment, CEUR Workshop Proceedings 2732 (2020) 1113–1128. URL: http://ceur-ws.org/Vol-2732/20201113.pdf.

[25] A. Martín-Martín, E. Orduna-Malea, E. Delgado López-Cózar, Coverage of highly-cited documents in Google Scholar, Web of Science, and Scopus: a multidisciplinary comparison, Scientometrics 116 (2018) 2175–2188. doi:10.1007/s11192-018-2820-9.

Methods for predicting the assessment of the quality of educational programs and educational activities using a neuro-fuzzy approach

Andriy V. Ryabko[1], Oksana V. Zaika[1], Roman P. Kukharchuk[1], Tetiana A. Vakaliuk[2,3,4] and Viacheslav V. Osadchyi[5]

[1]*Olexander Dovzhenko Glukhiv National Pedagogical University, 24 Kyievo-Moskovska Str., Glukhiv, 41400, Ukraine*

[2]*Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine*

[3]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[4]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

[5]*Bogdan Khmelnitsky Melitopol State Pedagogical University, 20 Hetmanska Str., Melitopol, 72300, Ukraine*

Abstract

In the process of self-assessment and accreditation examination, assessment is carried out according to a scale that covers four levels of compliance with the quality criteria of the educational program and educational activities. Assessing the quality of education is complicated by the fact that the value of quality criteria is due to a large number of factors, possibly with an unknown nature of influence, as well as the fact that when conducting pedagogical measurements it is necessary to work with non-numerical information. To solve these problems, the authors proposed a method for assessing the quality of educational programs and educational activities based on the adaptive neuro-fuzzy input system (ANFIS), implemented in the package Fuzzy Logic Toolbox system MATLAB and artificial neural network direct propagation with one output and multiple inputs. As input variables of the system ANFIS used criteria for evaluating the educational program. The initial variable of the system formed a total indicator of the quality of the curriculum and educational activities according to a certain criterion or group of criteria. The article considers a neural network that can provide a forecast for assessing the quality of educational programs and educational activities by experts. The training of the artificial neural network was carried out based on survey data of students and graduates of higher education institutions. Before the accreditation examination, students were offered questionnaires with a proposal to assess the quality of the educational program and educational activities of the specialty on an assessment scale covering four levels. Student assessments were used to form the vector of artificial neural network inputs. It was assumed that if the assessments of students and graduates are sorted by increasing the rating based on determining the average grade point average, the artificial neural network, which was taught based on this organized data set, can provide effective forecasts of accreditation examinations. As a result of comparing the initial data of the neural network with the estimates of experts, it was found that the neural network does make predictions quite close to reality.

Keywords

evaluation criteria, educational program, educational activities, prognostication, rating, ANFIS, artificial neural networks

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1. Introduction

In assessing the quality of education, as well as in conducting pedagogical research, we are faced with information that has non-numerical characteristics that are difficult to formalize. For example, the number of computers, the number of students, the area of educational premises in a higher education institution are measurable, but the evaluation of the educational program and educational activities according to the educational program is carried out according to non-numerical criteria. The institution in the process of self-assessment, and subsequently the experts in the process of accreditation examination, must assess according to the assessment scale, which covers four levels of compliance with the criteria: A, B, E, F.

As a result, there is a need to build methods for quantitative description of processes and subjects related to assessing the quality of the educational program and educational activities. Of particular importance is the quality of education, which means some total indicator that reflects the results of the educational institution, as well as compliance with the needs and expectations of society (different social groups) in the formation of individual competencies. The methods of quantitative evaluation of the educational program and educational activities under this program will allow the higher education institution to identify existing shortcomings and potential problems, as well as provide an opportunity to address them before the accreditation examination.

Assessing the quality of educational programs and educational activities is complicated by the fact that the value of this indicator depends on many factors, possibly with an unknown nature of influence. Also in this case there is a specificity of the "product" of education – a graduate of an educational institution, which should be considered as a complex system. There are various methods and algorithms for assessing the quality of educational activities. In this study, we propose a method of assessing the quality of educational programs and educational activities based on the neuro-fuzzy approach, due to the active development of analytical systems, based on the technology of artificial intelligence. The most popular and proven of these technologies are neural networks, which successfully solve a variety of "fuzzy" tasks – prediction, classification, recognition of handwritten text, language, images [1, 2, 3, 4, 5, 6]. In such problems, where traditional technologies are powerless, neural networks often act as the only effective solution. In this work, artificial neural networks are used to solve the problem of assessing the quality of educational programs and educational activities.

Mandatory conditions for accreditation are compliance with the educational program and educational activities of the higher education institution under this educational program with the

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ryabko@meta.ua (A. V. Ryabko); ksuwazaika@gmail.com (O. V. Zaika); kyxap4yk1@ukr.net (R. P. Kukharchuk); tetianavakaliuk@gmail.com (T. A. Vakaliuk); osadchyi@mdpu.org.ua (V. V. Osadchyi)
http://pfm.gnpu.edu.ua/index.php/struktura1/2015-04-01-14-50-26 (A. V. Ryabko);
http://pfm.gnpu.edu.ua/index.php/struktura1/2015-04-01-14-50-26 (O. V. Zaika);
http://pfm.gnpu.edu.ua/index.php/struktura1/2015-04-01-14-50-26 (R. P. Kukharchuk);
https://sites.google.com/view/neota (T. A. Vakaliuk); http://osadchyi.mdpu.org.ua (V. V. Osadchyi)
0000-0001-7728-6498 (A. V. Ryabko); 0000-0002-8479-9408 (O. V. Zaika); 0000-0002-7588-7406 (R. P. Kukharchuk); 0000-0001-6825-4697 (T. A. Vakaliuk); 0000-0001-5659-4774 (V. V. Osadchyi)
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criteria established by law. In particular, the forms and methods of teaching should contribute to the achievement of the stated goals of the educational program and program learning outcomes.

Since the educational program and educational activities must meet the requirements of a student-centered approach and the principles of academic freedom, the hypothesis of the study is that based on a sample of students and graduates of higher education, the quality of educational programs and educational activities, which will be able to adequately perform a comprehensive assessment of the quality of the educational program and educational activities.

Intelligent data processing using a neural network allows forming forecast probabilities of values of future results of accreditation examination in a higher education institution, which can contribute to the improvement of measures to improve the educational program. The results of forecasting can be used by the management of faculties and graduating departments as informative and recommendatory. In addition, guarantors of educational programs based on forecasts can plan activities and individual work with teachers to positively change the forecast. Thanks to the analysis of the received data it is possible to reveal weak points of the educational process that will give the chance to modernize it.

With this in mind, the article aims to substantiate, develop and implement a mathematical model of a comprehensive assessment of the quality of educational programs and educational activities based on the methods of the neuro-fuzzy approach.

1.1. Theoretical background

Assessing the quality of educational activities according to clearly defined criteria and methodologies is an important task in the process of accreditation of educational programs, which are used to train applicants for higher education in Ukraine. In the process of preparing for accreditation and preparation of materials for self-assessment of the educational program, there are problems in determining the objectivity of self-assessment and finding potential problems and shortcomings of educational activities. Due to this problem, the urgent task is to find mathematical tools that could be used by managers of higher education institutions in their approaches to determining the quality of educational services offered.

The paradigm shift in educational philosophy and practice has led to focusing primarily on student learning outcomes. The educational process should be results-oriented - what exactly students know and can actually do. Accordingly, student-centered learning is an approach in which students influence the content, activities, materials, and pace of their learning. This model of learning puts the student at the center of the learning process [7].

EU initiatives call for increased efficiency, international attractiveness, and competitiveness of higher education institutions. A study by Wächter et al. [8] considers different approaches to quality, quality assurance, and ratings, analyzes recent research, critically analyzes these approaches in a comparative perspective, provides recommendations and policy options for parliament.

The problem of determining a set of effective indicators that are easy to determine and can be applied to both large public universities and small regional private colleges, from university programs to alternative programs is also relevant for the United States [9].

Cherniak et al. [10] investigated the possibility of assessing the quality of qualimetry objects by graph analytical method, ie to apply the principle of determining the area and volume under

curved surfaces both in the plane and in space, which are created by combining estimates of individual quality indicators on a dimensionless scale. It is shown that, as a rule, mathematical dependences are nonlinear and their research is reduced to the development of universal methods that could be applied to objects of qualimetry, regardless of their nature, complexity, importance, and more. Having unit quality indicators in a single (dimensionless) rating scale, it is proposed to determine a single comprehensive quality indicator of the object of qualimetry using the method of integration, which takes into account the evaluation of unit quality indicators [10].

Pârvu and Ipate [11] propose a mathematical model based on a set of indicators that are adapted to the classification structure of intellectual capital, which is unanimously recognized worldwide, namely to the external and internal structure and competence of employees. The Rompedet method, an original product of the Romanian school of management [12], was used as a mathematical calculation tool.

When assessing the quality of education, we are faced with a huge number of different criteria, each of which may consist of many sub-criteria, therefore, the task of assessing the quality of education in its mathematical formulation is multi-criteria. Problem situations that are modeled and described by linear models and depend on many factors play an important role, so solving a multicriteria decision-making problem is often accompanied by solving multicriteria linear programming problems, or in other words, vector optimization problems.

Given these problems, mathematical models of integrated quality assessment using methods that are based on the convolution of criteria were also of interest for our study. Models and methods of multicriteria optimization are considered in the work of Kondruk and Malyar [13], in particular, the method of additive convolution of criteria and the method of multiplicative and minimax convolution of criteria. The method of multiplicative convolution of partial criteria to a single generalized indicator, which provides as a normalized divisor to use the maximum (minimum) values of partial criteria, obtaining which does not cause significant difficulties, ie is carried out on many available design solutions is considered in [14]. Chervak [15] uses one of the methods of solving the Paretian multicriteria optimization problem as a mathematical tool of the decision-making process. To organize the selection problems on the same admissible set of alternatives, the concept of the super criterion of any criterion is introduced; if the criterion is a super criterion of this criterion on this set, then the last criterion is a subcriteria of the first. It is shown that the solution of the problem of multicriteria selection by the Paretian convolution is reduced to the solution of the problems of scalar or lexicographic optimization.

The theory of artificial neural networks and models of deep learning is considered in the fundamental works of Goodfellow et al. [16], Müller et al. [17], Sivanandam et al. [18], system design based on a neuro-fuzzy approach [19, 20].

The use of neural networks to classify the status of a graduate of a higher education institution based on selected academic, demographic, and other indicators is considered by Lesinski et al. [21]. A multilayer neural network with feedback is used as a model. The model was taught based on more than 5,000 records of entrance exams and university databases. Nine input variables consisted of categorical and numerical data that contained information about high school education, test results, assessment of high school teachers, parental assessment, and others. Based on these inputs, the multilayer neural network predicted the success of university entrants. With the help of the neural network, it was possible to predict the success of graduates and achieve the best performance with an accuracy of classification exceeding 95%. Black et al.

[7] examining the relationship between quality and success of high school students in college found no convincing evidence that exposure characteristics of high school diminish over time teaching students.

To address the issue of determining the quality of educational training, Mahapatra and Khan [22] developed the EduQUAL methodology and proposed an integrative approach using neural networks to assess the quality of education. Four neural network models based on a feedback algorithm are used to predict the quality of education for different stakeholders. This study showed that the P-E Gap model is the best model for all stakeholders [22].

The need to introduce neural network technology in educational courses of educational institutions indicates by Belyux and Sitkar [23]. Educational neural networks are often used for forecasting. For example, students must choose courses that interest them for the next semester. Due to limitations, including lack of sufficient resources and the overhead of several courses, some universities may not be able to teach all courses of the student's choice. Universities need to know each student's requirements for each course each semester for optimal course planning. Kardan et al. [24] used a neural network to model student choice behavior and apply the resulting function to predict the final enrollment of students for each course. The results showed high prediction accuracy based on experimental data. Arsad et al. [25], Osadchyi et al. [26], Okubo et al. [27] prove that the use of neural networks in predicting educational processes will allow obtaining results with a much higher level of accuracy and less time. According to Naser et al. [28], an artificial neural network can correctly predict the success of more than 80% of future students.

Chaban and Kukhtiak [29] analyze the problem of the social system, which consists of many students and teachers of higher education to create effective learning pairs "teacher-student". Elements of the theory of artificial intelligence based on artificial neural networks were used to form the mentioned learning pairs. Bukreyev and Serdyuk [30] propose to use a recurrent neural network (RNN) to predict students' final grades using journal data stored in educational systems.

Liu et al. [31] propose a method for assessing the quality of preparation for graduate school, which is based on the algorithm of neural network backpropagation and stress testing. This method creates a publicly available list of indicators consisting of 19 criteria in 4 groups of criteria, such as attitudes towards teaching, teaching content, approach to teaching, and the main characteristics of teachers. After the neural network algorithm is used to determine the optimal parameters of the evaluation model, a sensitivity test is used to identify indicators that have a significant impact on the quality of education. Also, scenario analysis is used to study the impact of the quality of education in pre-defined situations, providing theoretical and empirical support for assessing the quality of postgraduate teaching, improving the quality of education, and professional growth of teachers [31].

Educational institutions are constantly striving to improve the services they offer, their goal is to have the best teaching staff, improve the quality of teaching and academic success of students. Knowledge of the factors influencing student learning can help universities and learning centers adapt their curricula and teaching methods to students' needs. One of the first measures taken by educational institutions in the context of the COVID-19 pandemic was the creation of virtual learning environments [32]. To understand the factors influencing the university learning process in virtual learning environments, Rivas et al. [33] applied several automatic learning

methods to publicly available data sets, including tree-like models and various types of artificial neural networks.

The availability of educational data supported by learning platforms provides opportunities to study student behavior and solve problems in higher education, optimize the educational environment and ensure decision-making using an artificial neural network [34].

Cader [35] uses a deep neural network to assess students' acquisition of knowledge and skills. It is noted that the obstacle to the application of the method in teaching is the relatively small amount of data in the form of available estimates required for neural network training. A new method of data augmentation is proposed – asynchronous data augmentation through pre-categorization, which solves this problem. Using the proposed method, it is possible to carry out neural network training even for small amounts of data [35].

Do and Chen [36] present a neuro-fuzzy classifier that used the results of previous exams and other related factors as input variables and classified students based on their expected learning outcomes. The results showed that the proposed approach achieved high accuracy compared to the results obtained based on other known approaches to classification, in particular, Naive Bayes, neural networks, and others.

Fazlollahtabar and Mahdavi [37] proposed a neuro-fuzzy approach based on evolutionary techniques to obtain the optimal learning pathway for both teacher and student. The neuro-fuzzy approach allows providing recommendations to the teacher for making pedagogical decisions based on the student's learning style. On the other hand, the neural network approach is used for the student to create a personalized curriculum profile based on the individual needs of the student in a fuzzy environment [37].

Taylan and Karagözoğlu [38] use a systematic approach to designing a fuzzy inference system based on a class of neural networks to assess student achievement. The developed method uses a fuzzy system, supplemented by neural networks, to enhance some of its characteristics, such as flexibility, speed, and adaptability, called the adaptive fuzzy inference system (ANFIS). The results of the ANFIS model are as reliable as statistical methods, but they encourage a more natural way of interpreting student learning outcomes.

In comparison with these works, this study fills a gap in the methods of a comprehensive assessment of the quality of educational programs and educational activities based on a neuro-fuzzy approach.

1.2. Methods

In this study, methods of mathematical modeling and computational experiment based on statistical processing of data assessments of the quality of educational programs and educational activities were used. The essence of the methodology of mathematical modeling is to replace the original object with its mathematical model and study it with the help of computer technology. Processing, analysis, and interpretation of calculation results were carried out by constant comparison with the results of statistical processing of expert estimates. In the course of the research, refinements were made and the mathematical model was revised and the cycle of the computational experiment was repeated.

The methodology for assessing the quality of the curriculum and educational activities is built using methods and tools of artificial intelligence, implemented in the package Fuzzy

Logic Toolbox system MATLAB in the form of adaptive neuro-fuzzy output ANFIS (Adaptive Neuro-Fuzzy Inference System).

Participants in the experiment – full-time master's students (22 people) and graduates of higher education institutions of the previous term of study are the same specialties (32 people) – a total of 54 people. This number of respondents is due to the number of indicators of quality criteria because the data format of the artificial network in MATLAB supports square matrices, in this case, 54x54. Before the accreditation examination, students were offered questionnaires with a proposal to assess the quality of the educational program and educational activities of the specialty on an assessment scale covering four levels: F, E, B, A. Student assessments were used to form the vector of artificial neural network inputs. After the accreditation examination, the expert assessments were used to check the quality of the prediction of the artificial neural network.

To ensure the representativeness of the sample, the study of its design was carried out based on randomization. The decision on the statistical deviation of the null hypothesis regarding the differences between the averages, thus, was also associated with the procedure of random sampling.

The rating scale covers four levels of compliance by the requirements of the legislation (F, E, B, A) [39]. Also, the legislation establishes 10 criteria for assessing the quality of the educational program [39]:

1) design and objectives of the educational program (4);
2) structure and content of the educational program (9);
3) access to the educational program and recognition of learning outcomes (4);
4) teaching and learning according to the educational program (5);
5) control measures, evaluation of applicants for higher education and academic integrity (4);
6) human resources (6);
7) educational environment and material resources (6);
8) internal quality assurance of the educational program (7);
9) transparency and publicity (3);
10) learning through research (6).

In turn, each of these criteria has from 3 to 9 indicators (the number is indicated in parentheses). Together, all 10 criteria contain 54 indicators.

2. Results

At the first stage of the study, the collection and statistical processing of data on the results of the assessment of students and graduates of higher education educational programs and educational activities on the educational program for each criterion.

In the second stage, a computational experiment was performed. The cycle of the computational experiment was carried out in several stages:

1) the choice of approximation and mathematical formulation of the problem (construction of a mathematical model of the phenomenon under study);

2) development of a computational algorithm for solving the problem;
3) implementation of the algorithm in the form of a program for the PC;
4) settlements on the PC;
5) processing, analysis and interpretation of calculation results, comparison with the results of statistical processing of expert estimates and, if necessary, refinement or revision of the mathematical model, i.e. return to the first stage and repeat the cycle of the computational experiment.

Assessing the quality of the curriculum and learning activities is complicated by the fact that each of the 10 criteria, in turn, consists of several indicators (3-9) and is due to many factors, possibly with an unknown nature of influence, which is also non-numerical. To assess the quality of the curriculum and training activities, it is proposed to use a two-tier system based on the ANFIS package and artificial neural networks to predict assessment scores.

The ANFIS hybrid system is a combination of the Sugeno neuro-fuzzy inference method with the ability to train a five-layer artificial neural network (ANN) of direct propagation with a single output and multiple inputs, which are fuzzy linguistic variables. As input variables of the ANFIS system, we use the criteria for evaluating the quality of the educational program of 10 groups of factors $V_i (i = 1, ..., 10)$.

The output variable of the ANFIS system is a numerical assessment of the quality of the curriculum and training activities and is defined as a function $y = f(V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_10)$.

Layer 1 of the ANFIS system for the linguistic evaluation of input parameters uses the term set of all possible values of the linguistic variable. $A_{Vi} = \{$“F”, “E”, “B”, “A”$\}$. In symbolic form we write: $A_{Vi} = \{F < i >, E < i >, B < i >, A < i >\}$. The term set of the original linguistic variable y is the set of values of quality assessments of the curriculum and educational activities: $T_y = \{F, E, B, A\}$. The outputs of the nodes of layer 1 are the values of the membership functions at specific values of the input variables.

Layer 2 is non-adaptive and defines the preconditions of fuzzy production rules. Production rules – a form of representation of human knowledge in the form of a sentence type – if (condition), then (action). The rules provide a formal way to present recommendations, guidance, or strategies. They are ideal in cases where the knowledge of the subject area arises from the empirical associations accumulated during the work on solving problems in a particular field.

Each node of this layer is connected to those nodes of layer 1, which form the prerequisites of the corresponding rule. To solve this problem, four fuzzy production rules are formulated: $P = \{p_1, p_2, p_3, p_4\}$, because according to the features of the ANFIS network, the number of network rules must correspond to the dimension of the term set of the source variable y.

Nodes perform a fuzzy logical operation “I” (min). The outputs of the nodes of this layer are the degree of truth (fulfillment) of the preconditions of each of the four fuzzy production rules, which are calculated by the formulas:

$$\begin{cases} w_1 = \min(\mu_{F1}(V_1), \mu_{F2}(V_2), \mu_{F3}(V_3), \mu_{F4}(V_4)) \\ w_2 = \min(\mu_{E1}(V_1), \mu_{E2}(V_2), \mu_{E3}(V_3), \mu_{E4}(V_4)) \\ w_3 = \min(\mu_{B1}(V_1), \mu_{B2}(V_2), \mu_{B3}(V_3), \mu_{B4}(V_4)) \\ w_4 = \min(\mu_{A1}(V_1), \mu_{A2}(V_2), \mu_{A3}(V_3), \mu_{A4}(V_4)) \end{cases} \quad (1)$$

Layer 3 normalizes the degree of implementation of each of the fuzzy production rules (calculation of the relative degree of implementation of the rules) as follows:

$$\overline{w}_h = \frac{w_h}{\sum_{i=1}^{h} w_i} \tag{2}$$

where $h = 1, \ldots, 4$ is production rule number. Layer 4 calculates the contribution of each fuzzy production rule to the output of the network according to the formula.

$$y_h(v, V) = \overline{w}_h(v_h^{(0)} + v_h^{(1)}V_1 + v_h^{(2)}V_2 + v_h^{(3)}V_3 + v_h^{(4)}V_4 + v_h^{(5)}V_5) \tag{3}$$

where $v_h^{(0)}$ - coefficients of the initial function ($i = 0, \ldots, 5$).

Layer 5 summarizes the contributions of all the rules:

$$y = \sum_{i=1}^{4} y_i \tag{4}$$

Training of the ANFIS network was carried out for 24 epochs by a hybrid method. During training, the type of membership functions, the type of initial function, and their coefficients are selected. As a result of training a fuzzy network for four rules, Gaussian functions were adopted as membership functions, and a linear function was adopted as the initial function. As a result of training, membership functions and their coefficients were also obtained.

To assess each of the 10 groups of factors that affect the quality of the curriculum and educational activities by the evaluation criteria, 10 modules are used, which are implemented using artificial neural networks. Thus, it is necessary to design neural networks, a mathematical model of a comprehensive assessment of the quality of the educational program and educational activities based on the methods of the neuro-fuzzy approach. For this purpose, the Neural Network Toolbox was used. To form neural networks, it is necessary to determine their topology, learning mechanism, and testing procedure. Also, the training of an artificial neural network requires input data – a sample of answers of students and graduates with reliable quality indicators, determined based on these criteria.

An artificial neural network for the analysis of indicators of the quality of the educational program and educational activities will have the number of input neurons (according to the number of indicators for all criteria) 54; output neurons – 54. Input signals were determined based on students' assessments of each indicator of this quality criterion, while the scale F, E, B, A were translated into numerical 1; 2; 3; 4 respectively. Part of the data is given in table 1.

It is important that the neural network can predict expert assessments if student and graduate assessments are to be ranked in ascending order based on the determination of the grade point average. According to the hypothesis, we assume that students with higher academic performance are better acquainted with the goals, structure, and content of the educational program, the process and characteristics of teaching and learning according to the educational program, control measures, assessment system, and all other aspects of educational activities. assessments of the quality of the educational program and educational activities will be more objective.

Table 1
Input signals (T) based on students' assessments of quality criteria.

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	3	4	3	3	4	3	4	...	4
2	4	3	3	3	4	3	3	...	4
3	3	3	4	3	4	4	3	...	4
...	...	...	...	...	...	...	...	...	...
54	4	3	3	3	4	3	3	...	4

After starting the MATLAB system, you need to enter the tool command on the command line, which will open the window for entering data and creating a neural network (Neural Network / Data Manager). Clicking the New button opens the Create Network or Data window. After selecting the Data tab in the Name field you must enter a new name of the input data "P", and in the Value field the values of the input data, in which the numbers 1-54 are indicators of quality criteria, and 55-108 – students' and graduates' indicators quality criteria.

The configuration of the neural network of direct propagation is chosen based on a heuristic rule: the number of neurons of the hidden layer is equal to half of the total number of input and output neurons. The artificial neural network for the analysis of quality indicators of the educational program and educational activity will have the number of input neurons 2 (according to the dimensionality of the data – indicators of quality criteria and student evaluation); source neurons 54, therefore, the number of hidden neurons is 28 (figure 1).

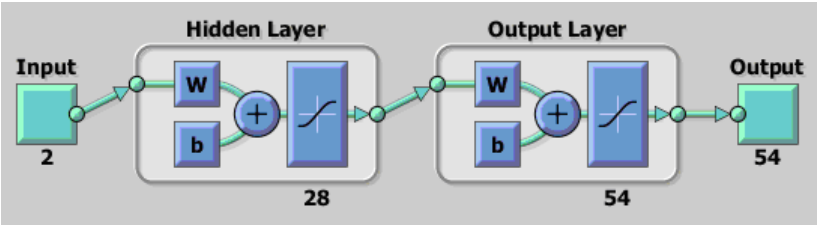

Figure 1: The structure of the neural network.

The array of input data is a matrix that contains assessments of quality indicators according to the criteria for evaluating the curriculum and educational activities – presented by students and graduates. Network type is feed-forward with back propagation. At the next stage, training and coaching of the network were carried out. After the training ended, the Neural Network / Data Manager window received two types of data: Output Data (O) and Error Data (E). By clicking the Export button in the manager window and then clicking Export again in the window, you can transfer the received data to the MATLAB workspace, where it will be presented in a presentable form.

You can calculate that the average network error is 0.0321, which indicates the efficiency of the system.

After learning the network, you can proceed to data forecasting. Returning to the Network

Table 2
Output signals (O).

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	3.1985	3.252	3.3058	3.3541	3.3933	3.4235	3.4475	…	3.9704
2	3.4521	3.3478	3.2644	3.2035	3.1633	3.1404	3.1319	…	3.9997
3	3.1516	3.1812	3.219	3.2627	3.3062	3.3417	3.3638	…	3.9992
…	…	…	…	…	…	…	…	…	…
54	4	3.4192	3.3522	3.3128	3.291	3.2798	3.2756	…	3.9716

Table 3
Errors (E).

Indicators of quality criteria	Student grades								
	1	2	3	4	5	6	7	...	54
1	-0.199	0.748	-0.306	-0.354	0.607	-0.424	0.552	…	0.0000237
2	0.548	-0.348	-0.264	-0.203	0.837	-0.140	-0.132	…	0.029607
3	-0.152	-0.181	0.781	-0.263	0.694	0.658	-0.364	…	0.00027
…	…	…	…	…	…	…	…	…	…
54	0.58076	-0.3522	-0.3128	-0.2909	0.7202	-0.2755	-0.2769	…	0.028442

Table 4
Neural network forecast and expert evaluation.

Indicators of quality criteria	Forecast	Estimates
1	3.999977	4
2	3.974844	4
3	3.999750	4
4	3.999379	3
5	3.956661	4
6	3.991731	4
7	3.985698	4
…	…	…
54	3.970182	4

and Data Manager window (Neural Network / Data Manager), you need to create additional input by clicking the New button. Going to the Data tab, the name of the data changes, for example, to P1, and the values are set as follows: values 1-54 still indicate the numbers of indicators of quality criteria of the educational program and educational activities, and 56-109 evaluations of students and graduates quality, and the last column – the projected estimates of experts.

Comparing the data issued by the system and the real data, we can see that the neural network does make predictions that are quite close to reality. Compared with expert estimates, the average absolute error is 0.0321, the relative error is 7.08%.

3. Discussion

The study aimed to demonstrate the possibility of predicting the assessment of the quality of educational programs and educational activities can be adequately addressed through an artificial neural network and obtain a comprehensive assessment of the quality of educational programs and educational activities based on a possible neuro-fuzzy approach. The mathematical model involves the use of neural networks and is based on the technology of analytical processing of statistical data. Standard methods of mathematical statistics are used to analyze the estimates received from respondents.

The assumption that based on a sample of students and graduates of higher education the quality of the educational program and educational activities can prepare a sample for setting up and teaching artificial neural networks is confirmed by ordering the quality of the curriculum of students and graduates. teaching. In practice, this allows you to predict the results and identify existing shortcomings and eliminate them before the accreditation examination. However, the difficulty of this method is to choose the architecture of the neural network and prepare a training sample to configure the neural network. In particular, in the future, it is planned to increase the volume of the input vector of the artificial neural network, and the form is based on estimates of teachers, stakeholders, and experts.

4. Conclusions

As a result of a mathematical model of a comprehensive evaluation of the quality of educational programs and educational activities based on the methods of neuro-fuzzy approach, first managed to work out a mechanism for obtaining a quantitative evaluation of educational programs and educational activities in this program that will allow the institution of higher education detect shortcomings and potential problems and solve them before the accreditation examination. Secondly, based on a sample of students and graduates of higher education to evaluate the quality of educational programs and educational activities, you can prepare a training sample for setting up and learning an artificial neural network that can adequately perform a comprehensive assessment of educational programs and educational activities. This can be done by arranging the assessments of the quality of the curriculum and the educational activities of students and graduates in ascending order based on the determination of the average grade point average. It is emphasized that these methods are effective provided they meet the requirements of a student-centered approach and the principles of academic freedom.

Based on a sample of students and graduates of higher education, the quality of the educational program and educational activities was prepared to prepare a training sample for setting up and teaching artificial neural network, which was able to adequately perform a comprehensive assessment of the quality of educational programs and educational activities. A comparison of the results of the operation of an artificial neural network of direct propagation with one output and several inputs with real data shows that the neural network does make predictions close to reality. Compared with expert estimates, the average absolute error was 0.0321; the relative error was 7.08%.

The results of the study can be used in the practice of higher education institutions to predict

the results and identify existing shortcomings and eliminate them before the accreditation examination.

We see prospects for further research in the application of software products based on the theory of neural networks to automate the processes of the organization, control, and analysis of the educational process; introduction of neural network software for direct training of students in certain disciplines.

References

[1] O. Markova, S. Semerikov, M. Popel, CoCalc as a learning tool for neural network simulation in the special course "Foundations of mathematic informatics", CEUR Workshop Proceedings 2104 (2018) 388–403. URL: http://ceur-ws.org/Vol-2104/paper_204.pdf.

[2] A. O. Tarasenko, Y. V. Yakimov, V. N. Soloviev, Convolutional neural networks for image classification, CEUR Workshop Proceedings 2546 (2019) 101–114.

[3] G. Kirichek, V. Harkusha, A. Timenko, N. Kulykovska, System for detecting network anomalies using a hybrid of an uncontrolled and controlled neural network, CEUR Workshop Proceedings 2546 (2019) 138–148.

[4] V. Porokhnya, O. Ostapenko, Neural network and index forecasting of the strategies of development of the armed forces of Ukraine depending on their own economic opportunities and encroachments of the aggressor states, CEUR Workshop Proceedings 2422 (2019) 111–120.

[5] L. Horal, I. Khvostina, N. Reznik, V. Shiyko, N. Yashcheritsyna, S. Korol, V. Zaselskiy, Predicting the economic efficiency of the business model of an industrial enterprise using machine learning methods, CEUR Workshop Proceedings 2713 (2020) 334–351.

[6] N. Valko, V. Osadchyi, Education individualization by means of artificial neural networks, E3S Web of Conferences 166 (2020) 10021. doi:10.1051/e3sconf/202016610021.

[7] S. E. Black, J. Lincove, J. Cullinane, R. Veron, Can you leave high school behind?, Economics of Education Review 46 (2015) 52–63. doi:10.1016/j.econedurev.2015.02.003.

[8] B. Wächter, M. Kelo, Q. Lam, P. Effertz, C. Jost, S. Kottowski, University quality indicators: a critical assessment, Technical Report, Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies, 2015. URL: https://www.europarl.europa.eu/RegData/etudes/STUD/2015/563377/IPOL_STU%282015%29563377_EN.pdf. doi:10.2861/426164.

[9] K. Hammerness, K. Klette, Indicators of quality in teacher education: Looking at features of teacher education from an international perspective, in: Promoting and sustaining a quality teacher workforce, volume 27 of *International Perspectives on Education and Society*, Emerald Group Publishing Limited, 2015, pp. 239–277. doi:10.1108/S1479-367920140000027013.

[10] O. Cherniak, N. Sorocolat, I. Kanytska, Graph analytical method for determining the complex quality indicator of qualimetry objects, Innovative Technologies and Scientific Solutions for Industries 4 (2020) 169–175. doi:10.30837/ITSSI.2020.14.169.

[11] I. Pârvu, D. M. Ipate, Mathematical model of measuring the quality of services of the

higher education institutions, Journal of Applied Economic Sciences 2 (2007). URL: https://EconPapers.repec.org/RePEc:ush:jaessh:v:2:y:2007:i:1(2)_fall2007:5.
[12] C. Isac, D. Nita, C. Dura, Optimizing franchising investment decision using Electre and Rompedet methods, The IUP Journal of Managerial Economics 8 (2010) 7–32.
[13] N. E. Kondruk, M. M. Malyar, Bagatokryterialna optymizaciya linijnyh system [Multicriteria optimization of linear systems], RA AUTDOR-ShARK, Uzhgorod, Ukraine, 2019. URL: https://dspace.uzhnu.edu.ua/jspui/handle/lib/24042.
[14] Y. I. Grycyuk, M. Y. Grycyuk, Osoblyvosti multyplikatyvnogo zgortannya chastkovyh kryteriyiv v uzagalnenyj pokaznyk [Features of multiplicative folding of partial criteria into the generalized indicator], Naukovyj visnyk NLTU Ukrayiny 24 (2014) 341–352. URL: https://cyberleninka.ru/article/n/osoblivosti-multiplikativnogo-zgortannya-chastkovih-kriteriyiv-v-uzagalneniy-pokaznik.
[15] O. Y. Chervak, Teoriya optymalnogo vyboru. Pidkryteriyi paretivskoyi zgortky kryteriyiv [The theory of optimal choice. Sub-criteria for convolution of Pareto criteria], Naukovyj visnyk Uzhgorodskogo universytetu 30 (2010) 28–30. URL: https://dspace.uzhnu.edu.ua/jspui/handle/lib/7372.
[16] I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, Adaptive Computation and Machine Learning series, MIT Press, 2016. URL: http://www.deeplearningbook.org.
[17] B. Müller, J. Reinhardt, M. T. Strickland, Neural Networks: An Introduction, Physics of Neural Networks, 2 ed., Springer-Verlag Berlin Heidelberg, 1995. doi:10.1007/978-3-642-57760-4.
[18] S. N. Sivanandam, S. Sumathi, S. N. Deepa, Introduction to neural networks using Matlab 6.0, Tata McGraw-Hill Education, New Delhi, 2006.
[19] S. D. Shtovba, Proektirovanie nechetkikh sistem sredstvami MatLab [Fuzzy systems design of by means of MatLab], Goryachaya Liniya–Telekom, Moscow, 2007. URL: http://pistunovi.inf.ua/shtovba_proek_nechet_sistem__matlab.pdf.
[20] S. D. Shtovba, O. D. Pankevych, Fuzzy technology-based cause detection of structural cracks of stone buildings, CEUR Workshop Proceedings 2105 (2018) 209–218.
[21] G. Lesinski, S. Corns, C. Dagli, Application of an artificial neural network to predict graduation success at the united states military academy, Procedia Computer Science 95 (2016) 375–382. doi:10.1016/j.procs.2016.09.348.
[22] S. S. Mahapatra, M. S. Khan, A neural network approach for assessing quality in technical education: an empirical study, International Journal of Productivity and Quality Management 2 (2007) 287–306. doi:10.1504/IJPQM.2007.012451.
[23] K. V. Belyux, T. V. Sitkar, Vykorystannya glybynnyx nejronnyh merezh v naukovyh doslidzhennyah ta osviti [The use of deep neural networks in research and education], in: Shlyax u nauku: pershi kroky, 2020, pp. 379–384. URL: http://dspace.tnpu.edu.ua/jspui/bitstream/123456789/16319/1/Conf_Shlax_nayky.pdf#page=110.
[24] A. A. Kardan, H. Sadeghi, S. S. Ghidary, M. R. F. Sani, Prediction of student course selection in online higher education institutes using neural network, Computers & Education 65 (2013) 1–11. doi:10.1016/j.compedu.2013.01.015.
[25] P. M. Arsad, N. Buniyamin, J.-l. A. Manan, A neural network students' performance prediction model (nnsppm), in: 2013 IEEE International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA), 2013, pp. 1–5. doi:10.1109/ICSIMA.2013.

6717966.
[26] V. Osadchyi, V. Kruglyk, D. Bukreyev, Development of a software product for forecasting the entrance of applicants to higher educational institutions, Ukrainian Journal of Educational Studies and Information Technology 6 (2018) 55–69. URL: https://uesit.org.ua/index.php/itse/article/view/204. doi:10.32919/uesit.2018.03.06.
[27] F. Okubo, T. Yamashita, A. Shimada, H. Ogata, A neural network approach for students' performance prediction, in: Proceedings of the Seventh International Learning Analytics & Knowledge Conference, LAK '17, Association for Computing Machinery, New York, NY, USA, 2017, p. 598–599. doi:10.1145/3027385.3029479.
[28] S. A. Naser, I. Zaqout, M. A. Ghosh, R. Atallah, E. Alajrami, Predicting student performance using artificial neural network: In the faculty of engineering and information technology, International Journal of Hybrid Information Technology 8 (2015) 221–228. doi:10.14257/ijhit.2015.8.2.20.
[29] H. Chaban, O. Kukhtiak, Zastosuvannya aparata teoriyi shtuchnyx nejronnyx merezh u zadachax prykladnoyi pedagogiky zakladiv vyshhoyi osvity [Application of the artificial neural networks theory in problems of applied pedagogy of higher education institutions], Ukrainian Educational Journal 1 (2020) 51–56. doi:10.32405/2411-1317-2020-1-51-56.
[30] D. O. Bukreyev, I. M. Serdyuk, Metod vykorystannya nejronnoyi merezhi dlya prognozuvannya efektyvnosti roboty studentiv [A method for using a neural network to predict student performance], in: Informacijni texnologiyi v osviti ta nauci, volume 11, 2019, pp. 61–64. URL: http://eprints.mdpu.org.ua/id/eprint/8136/.
[31] C. Liu, Y. Feng, Y. Wang, An innovative evaluation method for undergraduate education: an approach based on bp neural network and stress testing, Studies in Higher Education 47 (2022) 212–228. doi:10.1080/03075079.2020.1739013.
[32] V. V. Pererva, O. O. Lavrentieva, O. I. Lakomova, O. S. Zavalniuk, S. T. Tolmachev, The technique of the use of Virtual Learning Environment in the process of organizing the future teachers' terminological work by specialty, CEUR Workshop Proceedings 2643 (2020) 321–346.
[33] A. Rivas, A. González-Briones, G. Hernández, J. Prieto, P. Chamoso, Artificial neural network analysis of the academic performance of students in virtual learning environments, Neurocomputing 423 (2021) 713–720. doi:https://doi.org/10.1016/j.neucom.2020.02.125.
[34] H. Waheed, S.-U. Hassan, N. R. Aljohani, J. Hardman, S. Alelyani, R. Nawaz, Predicting academic performance of students from vle big data using deep learning models, Computers in Human Behavior 104 (2020) 106189. doi:10.1016/j.chb.2019.106189.
[35] A. Cader, The potential for the use of deep neural networks in e-learning student evaluation with new data augmentation method, in: I. I. Bittencourt, M. Cukurova, K. Muldner, R. Luckin, E. Millán (Eds.), Artificial Intelligence in Education, Springer International Publishing, Cham, 2020, pp. 37–42. doi:10.1007/978-3-030-52240-7_7.
[36] Q. H. Do, J.-F. Chen, A neuro-fuzzy approach in the classification of students' academic performance, Computational intelligence and neuroscience 2013 (2013) 179097. doi:10.1155/2013/179097.
[37] H. Fazlollahtabar, I. Mahdavi, User/tutor optimal learning path in e-learning using

comprehensive neuro-fuzzy approach, Educational Research Review 4 (2009) 142–155. doi:10.1016/j.edurev.2009.02.001.

[38] O. Taylan, B. Karagözoğlu, An adaptive neuro-fuzzy model for prediction of student's academic performance, Computers & Industrial Engineering 57 (2009) 732–741. doi:10.1016/j.cie.2009.01.019.

[39] Regulations on the accreditation of educational programs, which provide training for higher education, 2019. URL: https://zakon.rada.gov.ua/laws/show/z0880-19#Text.

Cloud technologies for basics of artificial intelligence study in school

Nataliia V. Valko[1], Tatiana L. Goncharenko[1], Nataliya O. Kushnir[1] and Viacheslav V. Osadchyi[2]

[1]Kherson State University, 27 Universytetska St., Kherson, 73000, Ukraine
[2]Bogdan Khmelnitsky Melitopol State Pedagogical University, 20 Hetmanska Str., Melitopol, 72300, Ukraine

Abstract

Changes in society related to the development of science, technology, computing power, cloud services, artificial intelligence, increasing general access to huge amounts of open data, lead to increased global investment in technology and services. Appropriate training is required by specialists to create a workforce to work with artificial intelligence. On the one hand, it puts forward new requirements for the training of young people, and educational content, on the other hand, provides opportunities for the use of cloud technologies during the educational process. Widespread use of AI in various fields and everyday life poses the task of understanding the basic terms related to Artificial intelligence (AI), such as Machine learning (ML), Neural network (NN), Artificial neural networks (ANN), Deep Learning, Data Science, Big Data, mastering the basic skills of using and understanding the AI principles, which is possible during the study in the school course of computer science. Cloud technologies allow you to use the power of a remote server (open information systems, digital resources, software, etc.) regardless of the location of the consumer and provide ample opportunities for the study of artificial intelligence. In this article we reveal the possibilities of cloud technologies as a means of studying artificial intelligence at school, consider the need for three stages of training and provide development of tasks and own experience of using cloud technologies to study artificial intelligence on the example of DALL-E, Google QuickDraw, cloud technologies Makeblock, PictoBlox, Teachable Machine at different stages of AI study.

Keywords

artificial intelligence, cloud technologies, school, education, education applications, informational computer technologies

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valko@ksu.ks.ua (N. V. Valko); goncharenkokspu@gmail.com (T. L. Goncharenko); kushnir@ksu.ks.ua (N. O. Kushnir); osadchyi@mdpu.org.ua (V. V. Osadchyi)
https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/NValko.aspx (N. V. Valko);
https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairPhysics/Staff/tgoncharenko.aspx (T. L. Goncharenko);
https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Kushnir.aspx (N. O. Kushnir); http://osadchyi.mdpu.org.ua (V. V. Osadchyi)
0000-0003-0720-3217 (N. V. Valko); 0000-0002-2021-9320 (T. L. Goncharenko); 0000-0001-7934-5308 (N. O. Kushnir); 0000-0001-5659-4774 (V. V. Osadchyi)
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1. Problem statement

The Stanford Institute for Human-Centered Artificial Intelligence (HAI) published its Artificial Intelligence Index (AI) in 2021 [1]. According to their findings, the demand for labor with artificial intelligence has increased significantly. During the pandemic, which has been going on for two years, global investments in the development of the artificial intelligence industry have increased by 40%. The world leaders are the United States and China, whose investments are more than 80% of investments in AI and blockchain development [2]. This attention is due to the automation of processes, the use of artificial intelligence in business can increase its efficiency, save time and human resources. Over the past 10 years, the number of AI-related research has increased from 14.2% to about 23% as of 2019. Among the research, there are publications with keywords about the ethics of artificial intelligence.

Such growth is facilitated by: powerful computing solutions, the development of cloud services and access to a huge amount of open data. Despite fears, frustrations, misunderstandings and "winter" in AI research, the level of acceptance of artificial intelligence is increasing rapidly. Canada published the world's first national AI strategy in 2017. More than 30 other countries and regions have published similar documents as of December 2020. At the same time, humanity has come to understand the risks posed by the AI introduction. Therefore, countries are beginning to introduce regulatory documents that will help limit its use. For example, China and Shat California have introduced a law to punish people for misleading people with Deep Fake technology: any videos or photos that carry manipulation or misinformation must be labeled accordingly. In mid-April 2021, the European Commission published a Regulation draft governing the use of artificial intelligence [3]. The Regulation applies a risk-based approach, distinguishing between the AI use which creates:

- *Unacceptable risk* – includes all those AI systems that have significant potential for manipulating people through subconscious techniques beyond their consciousness, or exploiting the vulnerabilities of certain vulnerable groups, such as children or people with disabilities, in order to significantly distort their behavior in such a way that may cause them or other psychological or physical harm to the person. It also includes AI-based scores for general purposes, real-time biometric identification systems in public places, etc.
- *High risk* – systems that pose a high potential risk to the health and safety or fundamental rights of individuals. In particular, these are technologies used in medicine, justice, employment.
- *Low or minimal risk* – about tools such as chat bots, spam filters, music recommendations, etc.

The main issue is users' understanding they are interacting with the machine, not the person.

It is not entirely clear to what extent this will affect the scope of AI. It will allow to form the rules on which AI further development will be based. It will also help to adequately assess not only the benefits but the risks of such systems using.

Ukraine is moving in this direction. The Association for the Development of Artificial Intelligence has developed and submitted to the government for approval the concept of the

development of artificial intelligence in Ukraine until 2030. In December 2020, the government approved the concept [4]. The main directions of the Concept include:

- improvement of secondary, higher education and advanced training in order to train qualified professionals in the artificial intelligence;
- stimulating research in the field, in particular through grants;
- stimulation of entrepreneurship in the AI, as well as the development of personnel retraining method who may lose their jobs due to automation in 5–10 years;
- work to increase the cyber security level, improve legislation in the cyber security;
- application of artificial intelligence technologies in the defense and public administration;
- solving problems of state registers;
- use of AI in justice, in particular to prevent dangerous phenomena through analysis of available data.

It is also about developing of a legal framework for the AI use in accordance with international standards. The concept covers nine areas of artificial intelligence application, one of which is education.

Digital literacy, improvement of educational and methodical base and preparation of qualified personnel for work with AI are the main tasks facing education. Digital literacy primarily refers to the use of digital tools for solving applied problems, searching for information on the Internet, protection of personal data, media literacy, etc.

2. Research questions

People use artificial intelligence without even realizing it. Every industry already has tools that use artificial intelligence technology. Examples include Google Intelligent Search, contextual advertising, mobile applications such as Reface, smart assistants (such as Siri and Alexa), disease prediction tools, drone production, optimized, personalized treatment recommendations, talk bots for marketing and service of customers, stock trading advisors, e-mail spam filters, social media monitoring tools for dangerous content or false news, song or TV show recommendations from Spotify and Netflix, and more.

Therefore, there is a need to consciously use this tool and expand its scope. One way is to learn the basics of AI in the curricula of schools, universities for future teachers, as well as in informal education. It raises the question of using available tools to learn the AI basics. Most of the current developments are in the form of cloud resources. Therefore, the purpose of this article is to review of existing AI basics training programs and identify available cloud tools for studying AI performance.

3. Related work

Such areas as data science, artificial intelligence, machine learning, deep learning, distributed and quantum computing have been considered only as hobbies by some interested educators, or as a specific area of research of algorithms, mathematical statements. However, most countries

are already preparing to introduce the study of such topics in school education. In 2019, the Association for the Promotion of Artificial Intelligence (AAAI) and the Association of Computer Science Teachers (CSTA) created recommendations for study of artificial intelligence in schools [5]. It emphasizes the reasons underlying the introduction of artificial intelligence study in schools. Among them: the growing role of intellectual assistants and autonomous mechanisms in society. AI technologies are supported by government strategies. AI causes a decrease in demand in some professions and increase in others, the need for skilled workers knowledgeable in artificial intelligence. The document defines what students should know and do studying artificial intelligence throughout their education from primary school to senior age. Researchers have also developed an online catalog of resources that teachers can use. The authors identify five problematic issues that may underlie the study of artificial intelligence: perception (speech recognition, computer vision), presentation and reasoning (path planning, web search, and strategy in games), machine learning (recognition, preferences, and translation), natural interaction with intellectual agents (Alexa and Siri assistants, adaptive education), social impact of AI (positive and negative impact, value of compromises, ethical issues). For each of the topics, examples of tasks are given and the knowledge and skills that students of a certain age should master are described.

At one of the AAAI conferences, the development of curricula for study of AI at school was presented. In particular, in 2020, Personal Robots Group at the MIT Media Lab, MIT STEP Lab, and Boston College presented the DAILy Workshop [6]. The program also included pilot partners, STEAM Ahead and BC College Bound. The course consists of four sections: AI Introduction, Supervised Machine Learning, GANs, AI and My Future. Each section contains explanations of basic concepts and exercises to better understand the work of artificial intelligence, neural networks and more.

Lin and Van Brummelen [7] describe the experience of conducting seminars in which teachers and researchers created lesson plans and AI concepts were embedded in various core subjects. They identified entry points in various subjects (not computer science) for AI teaching.

The first step of curricula development to study the basics of artificial intelligence by students in Ukraine was the course "10-11 grade. Computer Science. Artificial Intelligence", developed within the UNICEF program by Oksana Pasichnyk, Oleksiy Molchanovsky, Vyacheslav Osaulenko, Veronica Tamayo Flores [8]. It contains the adapted versions of the AI course and test materials.

The analysis of scientific publications on education in the artificial intelligence showed there is the majority of curricula are presented by universities in Ukraine in the form of textbooks and articles. In part, these curricula are presented in schools and lyceums that actively cooperate with universities or their teachers [9, 10, 11, 12, 13, 14]. It should be noted, in Ukraine study of artificial intelligence as an object was based on the use of expert systems as teaching aids. However, the current level of knowledge allows us to consider the tasks of direct training of artificial intelligence and expert systems: teaching, management, planning, monitoring, diagnostics, data interpretation, forecasting, designing [15].

Mokin [16] presents examples of solving real problems by machine learning methods for forecasting water quality in the Southern Bug River, forecasting the number of COVID-19 diseases, etc. These models are designed to be studied by graduate students and scientists involved in mathematical modeling and computational methods. In particular, master's students

of specialty 126 – Information Systems and Technologies of Vinnytsia National Technical University are working on it. In the author's works there are many solutions to real problems by machine learning and artificial intelligence based on Kaggle's own public laptops [17]. Also, these developments are successfully used by the author to teach high school students (10–11 grades of specialized schools).

4. Results

Widespread use of AI in various fields and everyday life poses the task of mastering the basic skills of its use and understanding the principles of work in the school study. Therefore, the question of defining basic terms is relevant. Transferring the simplest task into terms and analogies available to a particular age group is a separate task. Usually using the terms "artificial intelligence", "machine learning", "deep learning", "neural networks" is often a substitution of concepts. Let's define these concepts.

Artificial intelligence (AI) is a technological and scientific solution that helps to develop programs similar to the human mind that can think, recognize and self-learn. Machine learning (ML) are methods in the artificial intelligence, algorithms used to teach classification and clustering. It is due to the processing of large data sets and finding patterns in them. Neural networks (NN), Artificial neural networks (ANN) and deep learning works with complex data and fuzzy logic. Deep learning is one of the methods of machine learning. Data science are methods of data analysis for their further processing, sorting, sampling and search. It sets the correlation between data. Big Data – technologies of working with large data sets.

To begin the introduction of the study of artificial intelligence basics, it is necessary to meet the following conditions:

- setting tasks in terms and analogies that will be clear to a certain age group;
- selection of tools. It will ensure the task performance and the appropriate level of skills;
- development of learning course, content and determination of expected learning outcomes.

Among the tasks that can be set and solved with the help of AI is the development of smart systems that will help not only in business or office, but also at home. Smart systems can perform many tasks, from setting the alarm to turning the light on/off. Another task for AI is to collect data from different portals. With machine learning, you can apply different algorithms to the data to get it in the right shape. The task of obtaining recommendations based on what customers view or buy in the online store is also performed on the basis of AI machine learning. It will also help to make more profit for the business. When it comes to buying a product or service, visiting a website and using a helpline through an online chat or chat window is the norm in today's online stores. This 24/7 help is only possible thanks to AI (Chat bot). Modern electronic dictionaries and search engines also use AI to translate text or issue search queries based on text or images. Some of these tasks can be considered in lessons in the form of simplified tasks. Examples:

1. Image recognizer. Using the platform, images of any object, such as a toy, are added to the database, and then, by expanding the detection of the human body and objects. It is raised to the camera, and the program detects the toy and names it.

2. Language recognizer. Design own intelligent chat bot with artificial intelligence. It is possible to create a chat bot that recognizes the language and converts it into text using the language recognition extension, and then accordingly this chat bot answers the questions.
3. Recognizer of the face or body parts. For example, developing of a visitation system based on face recognition. It can be, for example, a system of automatic door unlocking using face recognition.
4. Home automation based on artificial intelligence. Control devices with voice commands using artificial intelligence speech recognition technology.

To fulfill the first condition, we have established three stages of studying artificial intelligence in the school:

1. *Familiarity with the AI capabilities.* It is designed to create an idea of the AI functions, its importance in human life and in life or professional processes. The purpose is to get acquainted with the tasks that AI can solve, which it cannot, to establish the causes and consequences of errors in the work of AI. It will also be appropriate to consider the ethical issues that arise when using AI, such as data security and privacy.
2. *Construction of own machine learning programs in designers.* The aim is to get acquainted with the stages of building a recognition program, and the AI basic concepts: neural network, set date, data sampling, sample size, etc. At the same time, students acquire skills of creating a dataset, training the network, using the network.
3. *The transition to programming.* This stage involves the study of the mathematical foundations of neural networks and programming. In the previous stages, this mechanism was "hidden" from students by the functions of services. At this stage there is a detailed study of the neural network, the principles of its training, data set and their markup.

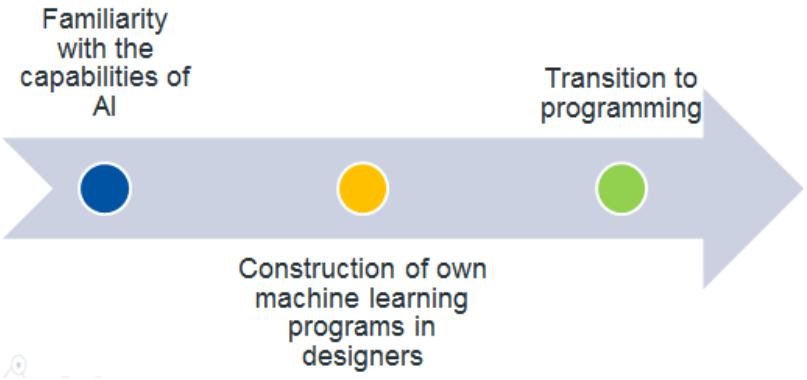

Figure 1: Stages of AI learning.

At the first stage there is an acquaintance with AI technology on examples of its use and basic terms mastering on this subject. There are a number of cloud services that help build the necessary knowledge and build interdisciplinary and integrated research. Such services are:

- DALL-E – a neural network called DALL-E that creates images from text captions for a wide range of concepts expressible in natural language [18]. It allows combining a variety

Figure 2: DALL-E combines the shape of the chair with the lotus root.

of things that combine real and imaginary things. Students can be asked to choose text captions and discuss: Is this possible? How can this be created? How do others perceive it? What does it take to put this into practice, etc. (figure 2)

- Recognition of emotions is a separate topic of AI training. Scientists have launched a game to show how artificial intelligence recognizes emotions. They want to draw attention to the problem of tracking a person [19, 20]. The game is available in the cloud and involves various tasks related to the recognition of emotions by artificial intelligence through a computer webcam. It has two stages. In the first you need to guess – in the picture a person squints at the rays of light or winks. In the second, you need to capture on camera each of the six emotions (Happiness, Sadness, Fear, Surprise, Disgust, Anger) so that the AI recognizes it. The first game shows how difficult it is for a person to determine the condition of another person by a static photo. The second is to train children's acting skills, whether AI will be able to determine your emotions. In class, it will be appropriate to discuss the ability to understand emotions. Even recognizing their own is not so easy. And to teach artificial intelligence to recognize our emotions is a task of the highest level (figure 3).
- The topic of images recognition can be considered on the example of Google QuickDraw [21, 22]. The software gives task to draw a particular object, and AI must guess what the user drew. It will be useful for learning to discuss the stages of creating and solving pictures. The system accompanies each stage of image construction by a voice. It is possible to track the dynamics of the AI approach to the correct answer. It is interesting

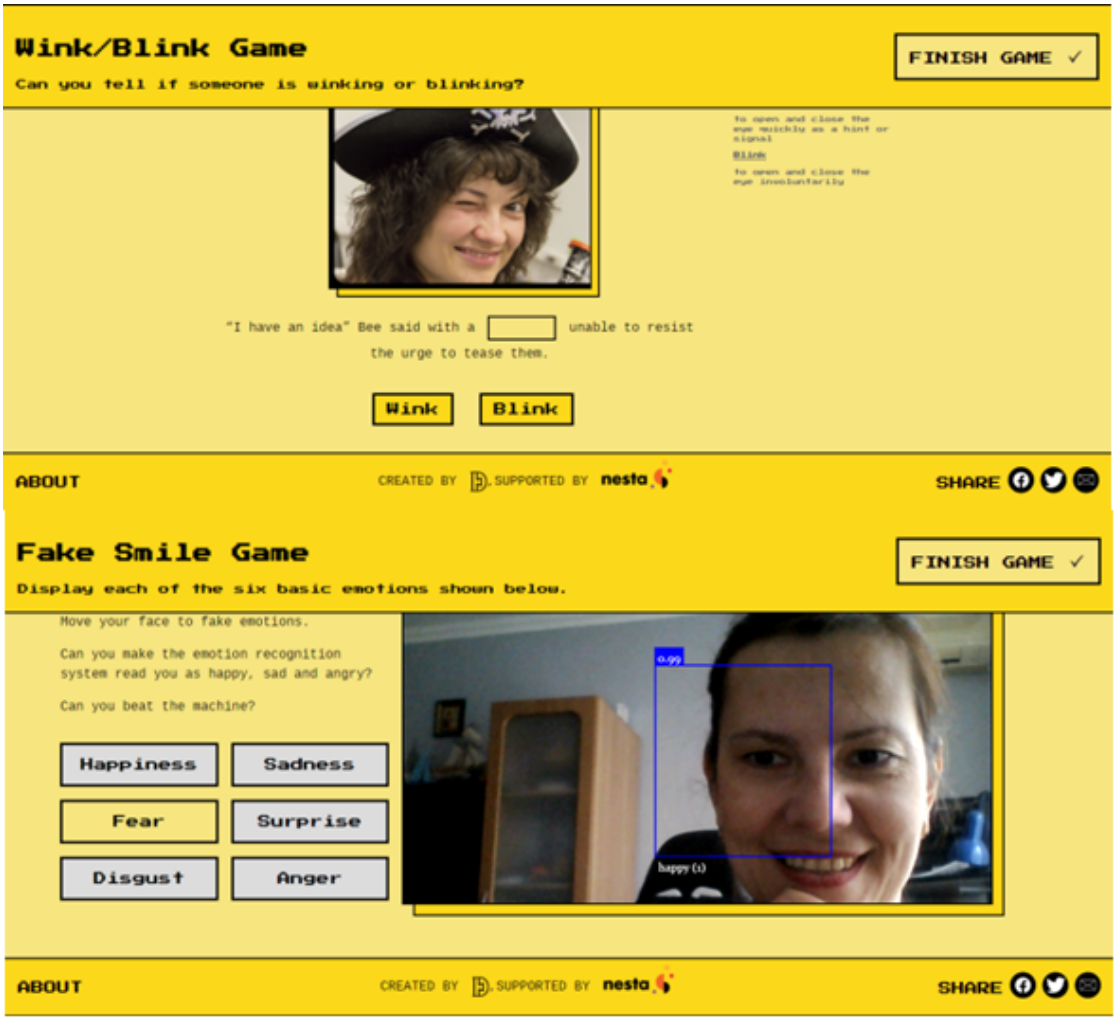

Figure 3: Software Emojifying.

to gradually analyze the image elements, which are clearly defined by the system for its identification. How many traits did it take to identify? How fast did the image system recognize? What and how many features are needed to recognize a cat, a dog, a person? Will the image be recognized from a non-standard point of view (top view, side view)? Why are there problems with the identification of people, animals, objects by intelligent systems, how to prevent it? What are the good/bad consequences of identification? (figure 4)

When the AI functionality is studied, it is possible to move on to the second stage – building your own machine learning programs in designers. You can use the following cloud technologies:

- Makeblock has five AI tools: mental services, machine learning, text-to-speech conversion, and translation (figure 5).

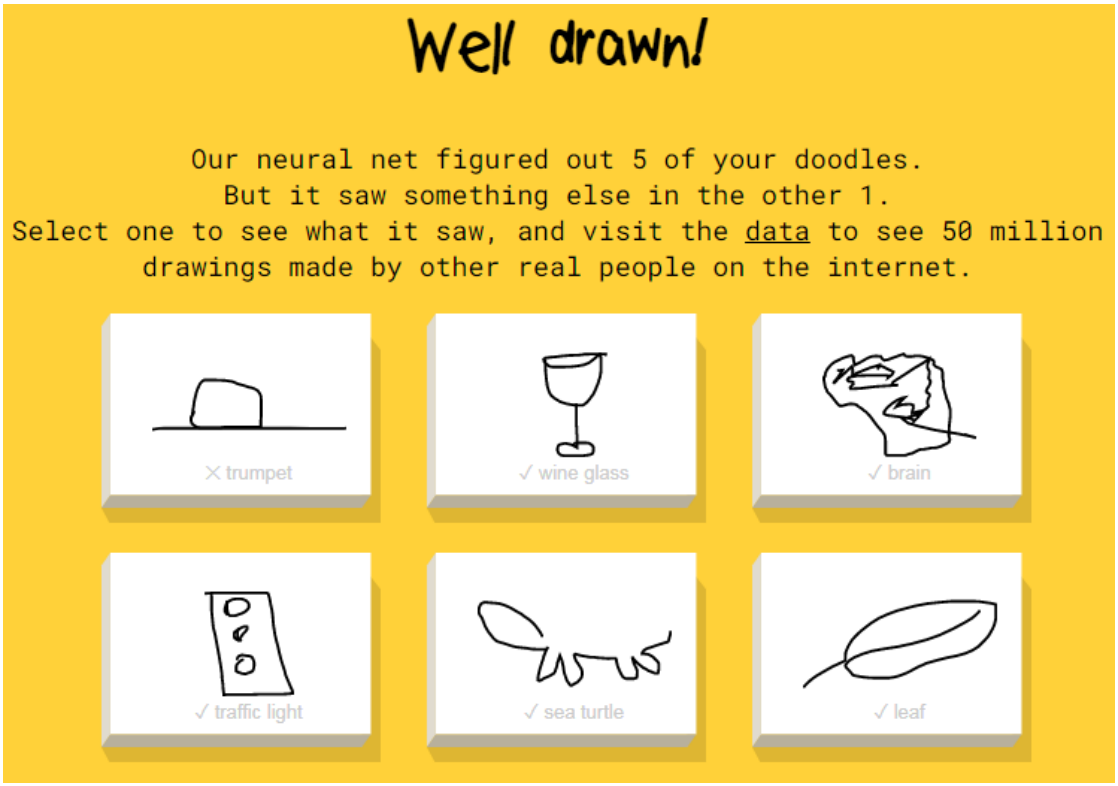

Figure 4: Results of QuickDraw.

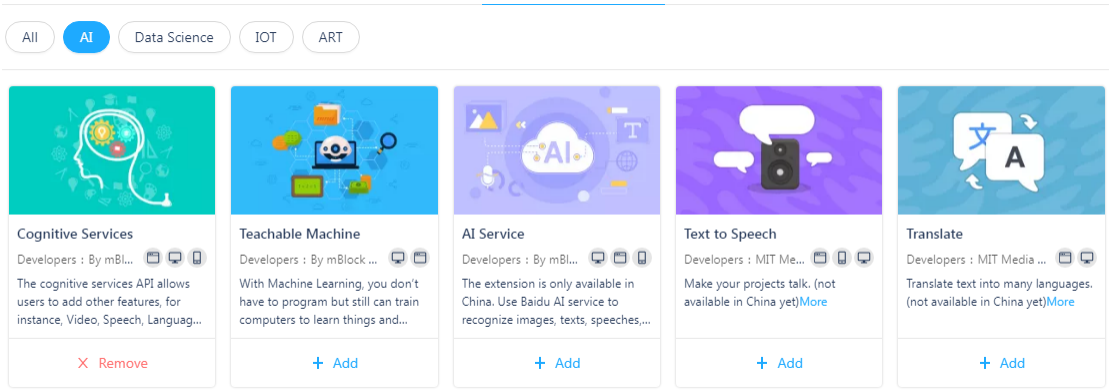

Figure 5: AI tools.

- PictoBlox [23] has tools for Computer Vision, Face Recognition, Optical Character Recognition, Language Recognition, Machine Learning, Ethics in AI, Internet of Things (figure 6).
- Teachable Machine – a service from Google [24]. It can recognize images, voice commands, human movements (figure 7).

Figure 6: PictoBlox screens.

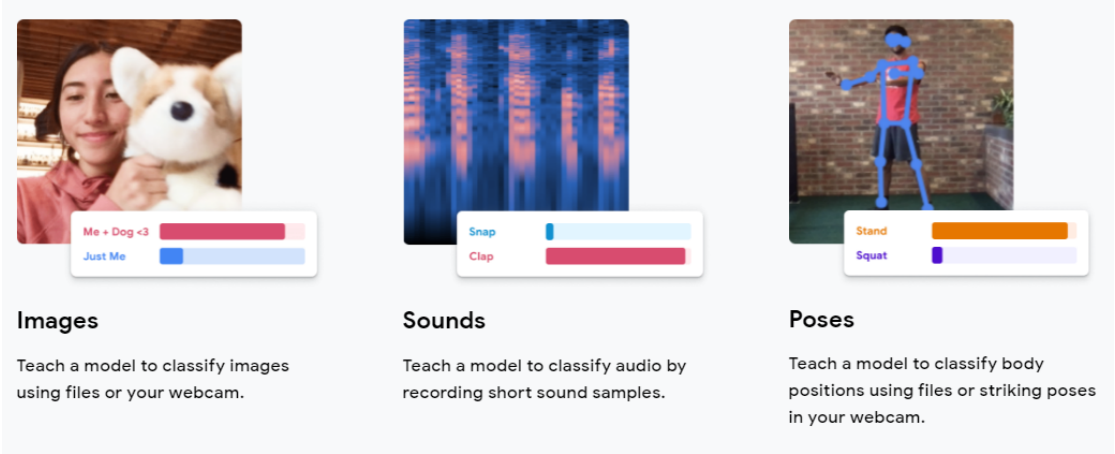

Figure 7: Teachable Machine capabilities.

All these services are free and can be used during the lesson. The only requirement is sufficient power of the device to stream video. Also, these resources work in the same way: first you need to collect a dataset of images, then teach, then use for recognition (figure 8).

These services are suitable for the second stage of training. They allow creating a full-featured program without a deep knowledge of the mathematical foundations of AI and programming. At this stage, students gain an understanding of the network training process, understand the importance of the dataset and the size of the data sample.

The third training stage is the transition to programming. It is aimed at mastering the fundamentals of algorithmization and programming [11, 13]. Kaggle is a platform for analytics and predictive modeling competitions [25, 26, 27] can be used to support this stage (figure 9). On the platform you can create your own laptops with algorithms and participate in competitions

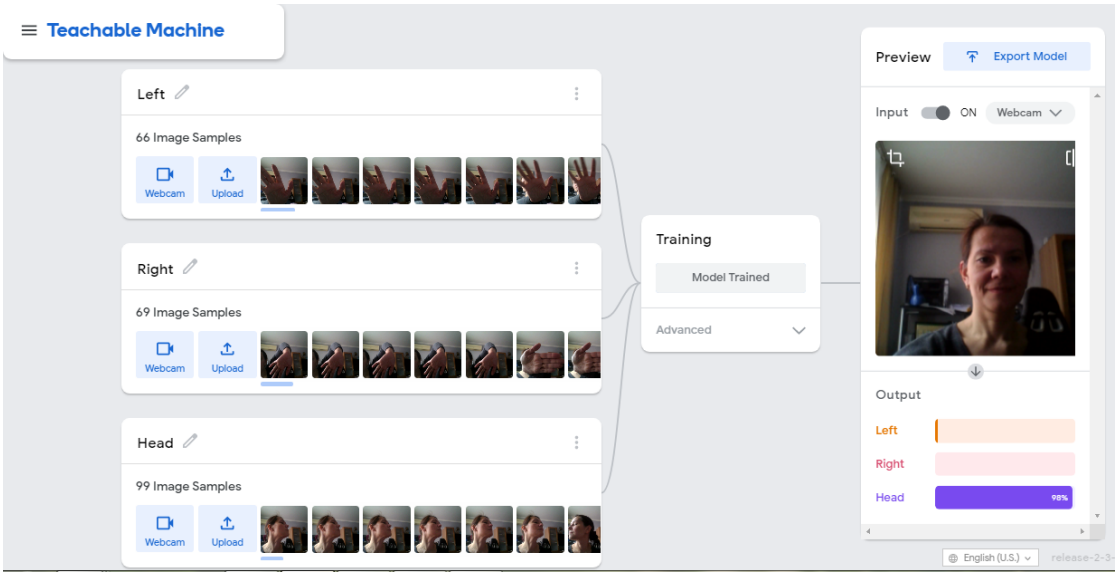

Figure 8: The example of the image recognition system learning.

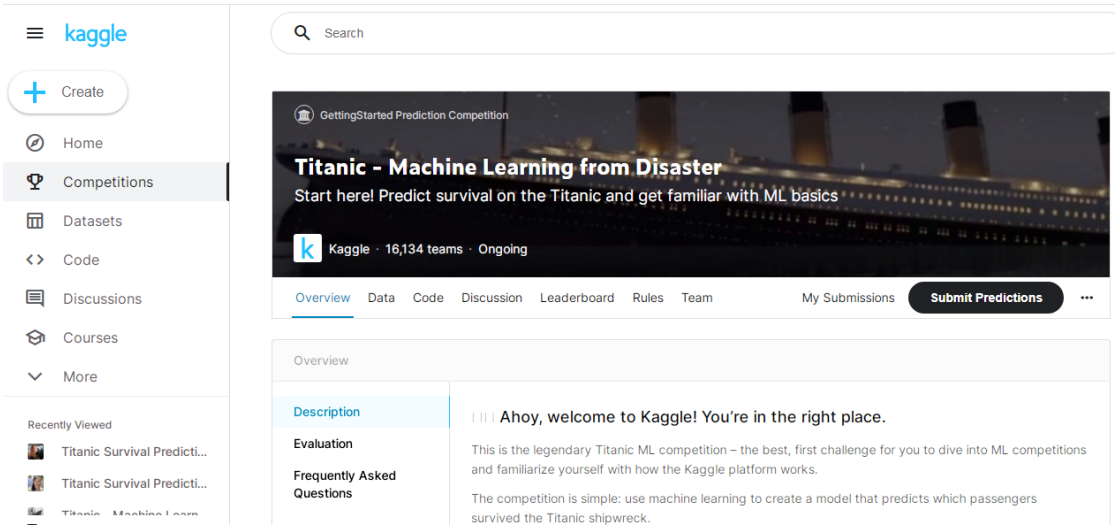

Figure 9: The start page of the competition "Titanic - Machine Learning from Disaster".

on big data.

5. Conclusions and prospects for further research

Technologies are changing and countries are trying to anticipate their development and regulate them by standards. It also forces the economy to move in the extensional direction of development and to look for workers who are knowledgeable in technology and technologically

literate. It does not mean the ability to “program”. It means understanding the principles of operation and using technology as effectively as possible. In examples of daily activities, we see manifestations of chatbots, neural networks, machine learning. So far, these technologies are in a disparate state. But in the future we expect their integration and interaction – the development of so-called “strong intelligence” [8]. Being able to recognize their work, know the principles of their operation, predict the consequences of use, consciously use – this is a non-exhaustive list of what should be able to a person familiar with the technologies of artificial intelligence. Our task was to consider the available cloud resources that allow classes for students of different ages and for different classes, not only computer science. We also found that some of these tools are fairly easy to use and can be used as a means of generating tasks in classes in art, ethics, literature and other school subjects that are not related to the natural sciences. So, cloud technologies allow to form technological literacy in children of an early school age. The knowledge formation in fundamental subjects requires a more formalized approach and performance of tasks on large data sets. There are resources allowed to consider the construction and operation of artificial intelligence algorithms. Their analysis and development of a course for the study of artificial intelligence for adolescents, the purpose of our next research.

References

[1] D. Zhang, S. Mishra, E. Brynjolfsson, J. Etchemendy, D. Ganguli, B. Grosz, T. Lyons, J. Manyika, J. C. Niebles, M. Sellitto, Y. Shoham, J. Clark, R. Perrault, The AI Index 2021 Annual Report, 2021. arXiv:2103.06312.

[2] G. Ricart, J. Gonzalez, V. Papanikolaou, H. Santer, F. Clari, N. Sarris, P. V. Daele, W. Tavernier, The next generation internet initiative, in: S. Klessova, S. Engell, M. Botterman, J. Cave (Eds.), ICT Policy, Research, and Innovation: Perspectives and Prospects for EU-US Collaboration, Wiley, 2020, pp. 217–253.

[3] Opinion of the European Economic and Social Committee on Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain union legislative acts (COM(2021) 206 final — 2021/106 (COD)), Official Journal of the European Union 517 (2021) 61–66. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021AE2482.

[4] The concept of artificial intelligence development in Ukraine, 2020. URL: https://zakon.rada.gov.ua/laws/show/1556-2020-%D1%80#Text.

[5] D. S. Touretzky, C. Gardner-McCune, F. Martin, D. Seehorn, K-12 guidelines for artificial intelligence: what students should know, in: 2019 International Society for Technology in Education, 2019. URL: https://exploreaiethics.com/curriculum/k-12-guidelines-for-artificial-intelligence-what-students-should-know/.

[6] DAILy Workshop, 2021. URL: https://raise.mit.edu/daily/ethicalMatrix.html.

[7] P. Lin, J. Van Brummelen, Engaging teachers to co-design integrated ai curriculum for k-12 classrooms, in: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, CHI ’21, Association for Computing Machinery, New York, NY, USA, 2021. doi:10.1145/3411764.3445377.

[8] 10–11 grade. Informatics. Artificial Intelligence, 2021. URL: https://ukraine.learningpassport.unicef.org/#/course/58/item/513.
[9] N. Valko, V. Osadchyi, Education individualization by means of artificial neural networks, E3S Web of Conferences 166 (2020) 10021. doi:10.1051/e3sconf/202016610021.
[10] S. Semerikov, I. Teplytskyi, Y. Yechkalo, O. Markova, V. Soloviev, A. Kiv, Using spreadsheets as learning tools for computer simulation of neural networks, SHS Web of Conferences 75 (2020) 04018. doi:10.1051/shsconf/20207504018.
[11] S. O. Semerikov, I. O. Teplytskyi, I. S. Mintii, Functional programming in the fundamental training of future teachers, New Computer Technology 6 (2008) 54–55. URL: https://ccjournals.eu/ojs/index.php/nocote/issue/view/3/3.
[12] O. M. Spirin, Multilevel program requirements for studying the basics of artificial intelligence in a pedagogical university, Problemy osvity (2000) 31–43.
[13] N. O. Kushnir, V. V. Shakotko, Forming algorithmic competencies of future teachers of informatics at the new stage of educational development, Naukovyi chasopys NPU imeni M.P. Drahomanova. Seriia 2. Kompiuterno-oriientovani systemy navchannia (2019) 83–92. URL: https://sj.npu.edu.ua/index.php/kosn/article/view/210. doi:10.31392/NPU-nc.series2.2019.21(28).14.
[14] O. Markova, S. Semerikov, M. Popel, CoCalc as a learning tool for neural network simulation in the special course "Foundations of mathematic informatics", CEUR Workshop Proceedings 2104 (2018) 388–403.
[15] D. V. Lubko, S. V. Sharov, Methods and systems of artificial intelligence, FOP Odnorog T. V., Melitopol, 2019.
[16] V. Mokin, Pryklad realnoi zadachi - modeliuvannia yakosti vody - Kurs AI-ML-DS Training, 2021. URL: https://youtu.be/Tmx17mINvNY.
[17] V. Mokin, River Water Quality EDA and Forecasting The Southern Bug (Pivdennyi Booh) River Basin, 2021. URL: https://www.kaggle.com/vbmokin/wq-southern-bug-river-01052021.
[18] A. Ramesh, M. Pavlov, G. Goh, S. Gray, M. Chen, R. Child, V. Misra, P. Mishkin, G. Krueger, S. Agarwal, I. Sutskever, DALL-E: Creating Images from Text, 2021. URL: https://openai.com/blog/dall-e/.
[19] Is emotion recognition technology "emojifying" you?, 2021. URL: https://emojify.info.
[20] J. A. Siqueira de Cerqueira, H. Acco Tives, E. Dias Canedo, Ethical guidelines and principles in the context of artificial intelligence, in: XVII Brazilian Symposium on Information Systems, SBSI 2021, Association for Computing Machinery, New York, NY, USA, 2021. doi:10.1145/3466933.3466969.
[21] A. Hagerty, I. Rubinov, Global AI Ethics: A Review of the Social Impacts and Ethical Implications of Artificial Intelligence, 2019. arXiv:1907.07892.
[22] Quick, Draw!, 2021. URL: https://quickdraw.withgoogle.com/.
[23] Agilo Research Pvt. Ltd., PictoBlox - Scratch-Based AI Programming Software for Kids, 2020. URL: https://thestempedia.com/product/pictoblox.
[24] Teachable machine, 2021. URL: https://teachablemachine.withgoogle.com/.
[25] Kaggle: Your Machine Learning and Data Science Community, 2022. URL: https://www.kaggle.com.
[26] W. Chow, A pedagogy that uses a Kaggle competition for teaching machine learning: an

experience sharing, in: 2019 IEEE International Conference on Engineering, Technology and Education (TALE), 2019, pp. 1–5. doi:10.1109/TALE48000.2019.9226005.

[27] J. Polak, D. Cook, A Study on Student Performance, Engagement, and Experience With Kaggle InClass data Challenges, Journal of Statistics and Data Science Education 29 (2021) 63–70. doi:10.1080/10691898.2021.1892554.

UI/UX design of educational on-line courses

Kateryna V. Vlasenko[1,2], Iryna V. Lovianova[3], Sergii V. Volkov[4], Iryna V. Sitak[4], Olena O. Chumak[5], Andrii V. Krasnoshchok[6], Nataliia G. Bohdanova[7] and Serhiy O. Semerikov[3,8,9,10]

[1]*National University of "Kyiv Mohyla Academy", 2 Hryhoriya Skovorody Str., Kyiv, 04070, Ukraine*

[2]*Technical University "Metinvest Polytechnic" LLC, 71A Sechenov Str., Mariupol, 87524, Ukraine*

[3]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

[4]*Volodymyr Dahl East Ukrainian National University, 59A Tsentralnyi Ave., Severodonetsk, 93400, Ukraine*

[5]*Donbas National Academy of Civil Engineering and Architecture, 14 Heroes of the Heavenly Hundred Str., Kramatorsk, 84333, Ukraine*

[6]*Donetsk State University of Internal Affairs, Kryvyi Rih Research Education Institute, 21 Stepana Tilhy Str., Kryvyi Rih, 50065, Ukraine*

[7]*Educational Scientific Professional Pedagogical Institute of Ukrainian Engineering Pedagogical Academy, 9a Nosakova Str., Bakhmut, 84511, Ukraine*

[8]*Kryvyi Rih National University, 11 Vitalii Matusevych Str., Kryvyi Rih, 50027, Ukraine*

[9]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[10]*University of Educational Management, 52A Sichovykh Striltsiv Str., Kyiv, 04053, Ukraine*

Abstract

This paper considers the problem of an interface for educational platform, which is fully effective for achieving the outcomes of educational activity. The current research is a theoretical analysis of existing recommendations on UI/UX design, applied when creating educational systems, as well as of research papers that study user interface (UI) usability and evaluate user experience (UX) in designing on-line platforms. This article describes a mechanism for evaluating usability with the help of baseline and final evaluation tool. It also studies UX components, that ensure its high quality. A list of standard components of web-design is being discussed in the present paper; modern trends in web-design of educational platforms are identified. The paper provides the description of an on-line course model, which is built on the basis of analysis of the prerequisites for existing and functioning of educational on-line systems and which is aimed at achieving outcomes of educational activity. There is ground to believe that the design of educational on-line courses will contribute to achieving the outcomes of educational activity, if user interface components comply with a list of criteria, such as easy-to-perceive content, no extra information, easy and simple navigation on the pages of the course, following the principles of usability.

Keywords

educational platform interface, user interface components, UI/UX design, principles of usability, achieving educational activity outcomes, designing on-line platforms, educational on-line course model.

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1. Introduction

The process of designing interface for educational platforms is a complex task, but crucial for achieving educational activity outcomes. Every time, when course users interact with an educational platform, they become smarter and closer to their goal, which is to get a real sense of achievement. This incremental progress is attained owing to both, the developers, who designed the educational resource and teaching staff, who filled it with educational materials.

The main goal of the systems for electronic learning (SEL) is to deliver knowledge, to share information and to help students in their educational activity effectively, using the cutting-edge information technologies. Usability of SEL is of importance, as its success depends on applying the key principles of usability. The evaluation criteria for success can be defined by the level of user satisfaction after their interaction with the SEL interface [1].

Users see in the software system not the coding languages, but the interface, which contributes to the success or failures of this system. Students are willing to see the system interface in accordance with their needs and requirements. If the interface is rigid, difficult and boring, it will not allow users to use the system. So, the user interface plays a vital role in any software system.

According to ISO 9241-210:2019 [2] *user interface* (UI) specifies all the components of the interactive system (software or hardware), which provide information and ways to manage it, which allow users to perform certain tasks with the help of an interactive system. In other words, a user interface is an intermediary between a human and a computer, fostering interaction; usability is a tool which provides activities for effective interaction for achieving definite goals.

Standard ISO 9241-210:2019 [2] also defines system *usability* as a degree, to which a system, a product or a service can be used by certain users for achieving certain goals with effectiveness, efficiency, and satisfaction in a certain context of its usage. Effectiveness in this case shows accuracy and the extent, to which users achieve their goals. Effectiveness measures resources, which are consumed to achieve precision and comprehensiveness of the achieved goals; satisfaction is convenience and accessibility of the work of the system for users [3]. Usability is a basis for the success of any system and a prerequisite for the success of on-line learning, but design is also critical in evaluating quality thereof [4]. Thus, **the purpose of this article** is

CTE 2021: 9th Workshop on Cloud Technologies in Education, December 17, 2021, Kryvyi Rih, Ukraine
vlasenkokv@ukr.net (K. V. Vlasenko); lirihka22@gmail.com (I. V. Lovianova); sergei.volkov@ukr.net (S. V. Volkov); sitakirina@gmail.com (I. V. Sitak); chumakelena17@gmail.com (O. O. Chumak); krasnoshchok2017@gmail.com (A. V. Krasnoshchok); bogdanovang@ukr.net (N. G. Bohdanova); semerikov@gmail.com (S. O. Semerikov)
http://irbis-nbuv.gov.ua/ASUA/0005870 (K. V. Vlasenko); https://kdpu.edu.ua/personal/ilovianova.html (I. V. Lovianova); http://formathematics.com/tutors/sergii-volkov/ (S. V. Volkov); http://formathematics.com/tutors/iryna-sitak/ (I. V. Sitak); http://formathematics.com/tutors/olena-chumak/ (O. O. Chumak); https://scholar.google.com.ua/citations?user=yYUXmc4AAAAJ (A. V. Krasnoshchok); http://nnppi.in.ua/index.php/kafedri-nnppi/kafedra-okhoroni-pratsi/2-uncategorised/343-bohdanova-nataliya-hryhorivna (N. G. Bohdanova); https://kdpu.edu.ua/semerikov (S. O. Semerikov)
0000-0002-8920-5680 (K. V. Vlasenko); 0000-0003-3186-2837 (I. V. Lovianova); 0000-0001-7938-3080 (S. V. Volkov); 0000-0003-2593-1293 (I. V. Sitak); 0000-0002-3722-6826 (O. O. Chumak); 0000-0002-4437-7593 (A. V. Krasnoshchok); 0000-0002-7956-5818 (N. G. Bohdanova); 0000-0003-0789-0272 (S. O. Semerikov)
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conducting a theoretical analysis of user interface (UI) features and user experience (UX) in designing educational on-line platforms. Within the framework of the overall objective, the following research objectives were set:

1. To analyse the definition of usability of user interface (UI).
2. To describe user experience (UX) in designing on-line platforms.
3. To analyse features of UI/UX design when developing educational systems, as well as to develop an educational on-line course model.

2. Method

Theoretical analysis of research papers and resources, that introduce guidelines on UI/UX design when developing an educational system; analysis of the research into UI usability and user experience (UX) in designing on-line platforms contributed to developing an educational on-line course model.

2.1. Usability of user interface (UI)

An important task for developers who foster interaction between a computer and a human in educational sphere is creating useful software for supporting students and their distance learning, as well as ensuring adaptation of a student to the system. Usability and usefulness are closely connected but not identical notions. According to Nielsen [5], who differentiates between usability and usefulness, the former includes not only usefulness, but also effectiveness, efficiency and satisfaction. A number of experts in this sphere [6, 7] believe that usability is often the most ignored aspect of web-sites, but in many respects it is one of the most critical. If the designed environment for on-line education is difficult to use and to understand, it starts loosing users. Moreover, users are not going to spend much time on trying to understand how the interface functions, so as a rule educational software is developed for assisting convenient education. Also, usability provides users with an opportunity to effectively manipulate interactive software that are selected for performing the definite educational task. The above mentioned is proved by Squires and Preece [8], who emphasise that system developers do not pay enough attention to the consequences of usability features of educational software system for achieving educational outcomes.

One more important question, raised by the developers of educational systems is evaluation of their effectiveness, which is defined by a user's interaction with the interface of this system. Research into the evaluation of SEL usability was done by a number of experts [9, 10, 11, 12, 4, 13, 7, 3, 1, 14, 15]. The analysis of these research papers shows that the evaluation of SEL usability is a complex task. The increasing number and variety of learners (sometimes a user interaction with the educational environment is one-time event), technical progress and complexity of educational tasks create both – serious problems and perspectives for using SEL. Additional difficulty is created by the fact that the main goal of a user is learning, which can be implicit or abstract by nature [14]. Hence, Notess [16] believes that evaluation of electronic education can push the usability practitioners beyond their comfort zone.

The authors of this paper take into consideration the idea by Squires [17], who highlighted the necessity to integrate usability and learning, as well as pointed out waiver of communication by staff working in sphere of a human-computer interaction and educational environments. In fact, usability of electronic learning design is directly connected to their educational value. Systems of electronic learning can be convenient, but not educational, and vice versa [8]. Usability evaluation can be used with the help of baseline and final evaluation tool [9]. Evaluation can be done when designing systems for detecting potential usability problems. Final evaluation can be done after introducing the system in order to define actual usability problems. There are two different evaluation methods for supporting the above mentioned types. Methods of analytical evaluation are as a rule used during evaluation, but empirical ones – during the final evaluation.

Methods of analytical evaluation are usually used by design experts in order to define usability problems when designing a system [9]. These methods include heuristic evaluation, cognitive evaluation and evaluation of the analysis on the level of pressing the keys [18, 19]. Heuristic evaluation covers using a list of design heuristics or principles for design evaluation and detecting any possible system usability problems. There are several such lists of project heuristics, but the most frequently used is a list of ten principles of design (table 1), suggested by Nielsen [12].

These are general principles of design, but some authors (e.g., Jordan [20], Rubin and Chisnell [10], Zaharias [14], Giannakos [15]) adapted them to usage in different contexts, for instance, in e-commerce [20]. The result of heuristic evaluation consists of a list of design problems, seriousness of these problems and suggestions on improving design.

Cognitive evaluation is an analytical method, used to evaluate simplicity of learning and using the system. A detailed analysis of the key tasks, which are supported by the system, is done. For each task there are four questions, asked to forecast the system usability. The questions are: Is the goal clear in this stage? Is the corresponding action obvious? Is it clear, that certain actions lead to the goal? What problems appear when taking the action? [9]

Analysis of the level of pressing the keys can be used to define the effectiveness of interaction with the user and compare various designer solutions. Quantitative measures of the time can be related to every user's action, for instance, clicking a mouse or entering the text, and are used to determine the time for performing each task. They can be used to choose the menu structure, the mode of interaction and usage of concrete objects of interaction.

Empirical methods of evaluation are used to identify factual indicators of effectiveness, efficiency and satisfaction [9]. These methods are field tests, observations, interviews, questionnaires and system usability testing. Empirical methods mean work with real users and collecting data which must be analysed. Empirical methods can consume much more time and funds, than analytical methods, but they can give quantitative data on the factual viability of the system.

Formal usability testing includes development of controlled experiment, which is usually done in a special usability laboratory [10, 11]. Formal usability testing requires certain important components: the experiment must be carefully designed; the hypothesis of the research must be identified; representative users must be selected; a list of relevant tasks must be prepared; evaluation must be done; data must be collected; the analysis findings be done. To identify the user profiles and the level of user satisfaction with the interaction, special questionnaires can be used before and after testing. Official usability testing can give factual indicators of effectiveness from the point of view of the level of the task performance and effectiveness from

Table 1
Ten principles of design by Nielsen [12].

Title	Description
1. Visibility of system status	The design should always keep users informed form users on what is happening through a proper feedback within reasonable amount of time.
2. Match between the system and the real world	The design should speak the users' language. Use only words, phrases and concepts, familiar to the users rather than internal jargon. Follow real world conventions, making information appear in a natural and logical order.
3. User control and freedom	Users often perform actions by mistake. They need a clearly marked "emergency exit" to quit the unwanted action without necessity to go through an extended process.
4. Consistency and standards	Users should not have to wonder whether different words, situations or actions mean the same. It is necessary to follow the platform and industry conventions.
5. Error prevention	Good error messages are important, but the best designs carefully prevent any problems from occurring. It is necessary either to eliminate error-prone conditions or to check them and give users a confirmation option before they commit to action.
6. Recognition rather than recall	Minimise the user's memory load, making elements, actions and options visible. The user should not have to remember the information from one part of the interface to another one. Information, required to use the design (for instance, field labels or menu items), should be visible or easily retrievable, when needed.
7. Flexibility and efficiency of use	Short-cuts hidden from novice users can speed up interaction for an experienced user, so that the design can satisfy both user groups. Allow users to tailor frequent actions.
8. Aesthetic and minimalist design	Interfaces should not contain information which is irrelevant or rarely needed. Each extra unit of information in the interface competes with the relevant units of information and diminishes their relative visibility.
9. Help users recognise, diagnose and recover from errors	Error messages should be expressed in plain language(no error codes), accurately indicate the problem and constructively suggest a solution.
10. Help and documentation	In the perfect scenario the system does not need any additional explanations. However, it can be necessary to provide documentation, to help users understand how to complete their tasks.

the point of view of the tasks performed.

2.2. User experience (UX) in designing the on-line platform

The notion "user experience" (UX), according to the standard [2] means human perception and responses which result from usage or expected usage of a product, a system or a service. Users' perceptions include emotions, preferences, comfort, behaviour and achievements, that happen before, during and after the usage. Interaction with the user is a result of a brand image, presentation, functionality, productivity of a system, interactive behaviour and additional

capacity of a system, a product or a service. It is also the result of internal and physical condition of the user, which springs from the previous experience, attitude, skills of a person, from the context of usage.

This notion can have a wider meaning, which is researched in the special literature [21, 22, 23]. Despite the increasing interest to the experience in using systems, it is difficult to achieve joint agreement on the nature and sphere of usage of UX [21]. Most respondents in the research [21] agree, that UX is dynamic, dependent on the context and subjective, including such factors as time, place and goal. As regards more disputable questions, the authors suggest defining UX as something individual (rather than social), which appears as the result of interaction with a product, a system, a service or an object. But the terms used require additional explanations to list all the possible objects that impact the user experience. UX selects emotional factors and is aimed at positive experience and strengthening the trust in the object [20]. UX is a result of a user's internal condition (preferences, expectations, needs, motivation, mood, etc.), features of the designed system (for instance, complexity, purpose, usability, functionality, etc.) and context (or environment), in which interaction takes place (for instance, organisational/ social environment, content of the activity, free will to use, etc.) [24].

The first requirement of a perfect user experience (UX) is meeting precise needs of the user, without fuss and problems. Then follow simplicity and elegance, creating products, which are pleasant to possess and to use. Real user experience goes beyond the reach of what users want, what they aspire for or just presenting functions from the check-list. To ensure high quality of UX in the company's offers, it is necessary to have seamless consolidation of services in different spheres, design, marketing, graphic and industrial design, interface design included [25].

It is critical to differentiate general interaction with user interface (UI) and UX, though UI, obviously, is an essential part of design. Let's take Ukrainian educational platform Prometheus as an example [26]. The catalogue of on-line courses has an attractive interface design (figure 1), but a user who wants to get information about a specific on-line course will face a difficulty when searching it, as the catalogue has only general topics and does not have such an option as search using key words.

UX is a central component, especially in successful web-sites and digital products. Moreover, overall effectiveness of a system increases owing to UX. In course of researching into UX, such tool as framework of conception and optimisation gained momentum. Dixon et al. [27] raise the issue of negative perception of complicated and confusing user service implementation. As researchers believe, in order to improve the quality of a service, it is necessary to minimise the number of days, which spend by users to achieve the desired outcome.

When developing a service which is aimed at triggering pleasant emotions in a user or override competitors in terms of complexity of presenting information, it leads to users outflow. Users can be overwhelmed by the number of self-service channels – interactive voice service, web-sites, e-mail, chats, communities for on-line support, social networks, etc. They often have no opportunity to take move in order to solve the problem.

Obviously, the simplicity of the service contributes to solving the users' problems. This approach is applied not only to the commercial services, but also to educational services. Designing an easy-to-understand and simple interface for on-line learning can increase effectiveness of its usage for both – learners and university teaching staff.

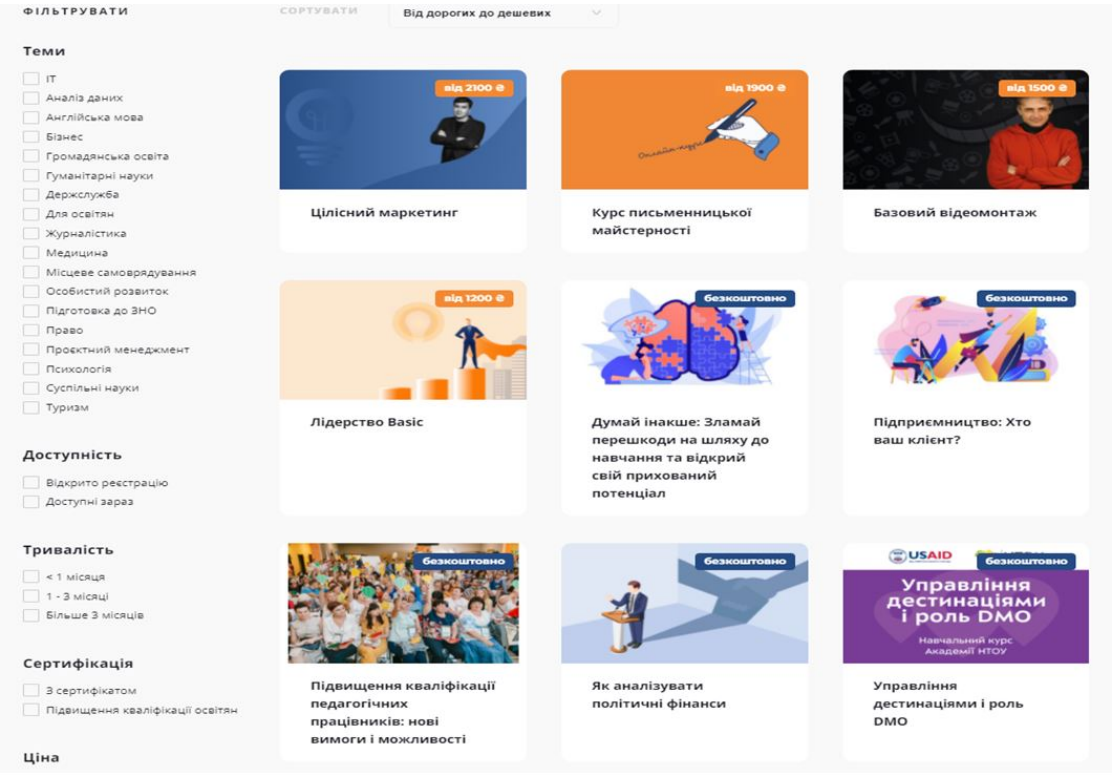

Figure 1: Catalogue of on-line courses on educational platform Prometheus.

Optimally developed program user interface from the point of view of UX, is an inseparable part of success or failure of any educational product. When developing an on-line course, the teachers must have competencies which help them impact the quality of UX and as a result – the platform itself.

2.3. UI/UX design in designing educational systems

User interface (UI) usability and effectiveness of user experience (UX) depend on the quality of the system design, which consolidates both these tasks into one single process of creating an educational system.

As a rule, people associate the notion “design” with various things, depending on the sphere of human activity, but Dervojeda et al. [28] defines design as an engine for innovations. Design is a creative method of developing and creating a new or a significantly improved product, service or system, which means a comprehensive approach to creating various objects, considering various factors and conditions of economic, ecological, technological, cultural environment, opportunities, social priorities and preferences.

Modern educational on-line systems are developed using the Internet and web-technologies, so when considering these systems, a separate type of design is referred to – web-design. Web-design is a part of web-development and includes the process of designing a user web-

interface for web-sites or web-applications. As Borodayev [29] states, web-design is a kind of graphic design, aimed at developing and arranging objects of informational environment on the Internet, which adds high consumer attributes and aesthetic qualities. Such interpretation separates web-design from web-programming, emphasises the specifics of the subject matter of a web-designer, positions web-design as a kind of graphic design.

Web-design, as defined by Indeed Editorial Team [30], is the process of creating web-sites and web-pages for fostering effective and pleasant usage. Web-design determines the goals of a web-site or a web-page and contributes to its accessibility by all the prospective users. This process involves arranging content and visuals on a series of pages, program integration and other interactive elements, choice of attractive style and colours.

Specialists, who do this job are called web-designers, their main tasks are:

- the choice of readable fonts;
- the choice of attractive colour schemes that allow to easily read the fonts;
- introduction of a brand identity into colours, fonts and a mock-up;
- designing the web-site structure map for ensuring intuitive navigation;
- placement of icons, logos, texts, videos, programs and other elements;
- using such coding languages as HTML and CSS for creating layouts and presentation of pages;
- creating optimised versions of web-sites and pages for viewing them on both PCs and mobile devices.

There is a list of standard components for creating an optimal design of a web-site (table 2).

Among the latest trends in web-design, which attracts experts' attention, is its minimalism, which is applied when designing the structure and content of on-line courses. Moreover, studying the strategies that impact user interface, studios Acodez [31], Nielsen Norman Group [32], WebsiteBuildErexpert [33], TheNextWeb [34] claim that minimalism is something users prefer in particular. Experts warn that using too much technology decreases the chance to attract clients by the web-product.

The findings of the research by Baharin et al. [35] prove that the design of the on-line courses interface is no less important than their content or the choice of the learning method. Analysing the directions in UI design, scientists grounded, that its quality impacts not only the success of a separate course, but of the educational platform as a whole.

Scientists also discuss the above mentioned trend in their research papers. Wolverton and Guidry Hollier [36] describe the survey of the teaching staff in universities concerning the usage of minimalistic approach when designing courses. The authors of the article believe that it is necessary to use less technology, to simplify learning, an on-line learning course should not be sophisticated. Sani and Shokooh [37] point out that minimalism without unnecessary aspects and arrangement of visual elements decreases confusion in the audience and increases effective interaction with the web-site. In order to identify and prove the factors that influence satisfaction of teaching staff with learning on the Internet, Bolliger and Wasilik [38] drafted a web-questionnaire, which was used to measure teachers' satisfaction in the context of on-line educational environment. Describing the respondents' answers, scientists noticed that using the principles of minimalism allowed to make an on-line course graphically simple. In turn,

Table 2
A list of standard components of web-design

Component	Description
Layout	Determines a way to show material on the page. The choice of a layout is a principal task for a designer. It must be simple, intuitively understandable and accessible. Web-designers can use blank spaces, called gaps, to arrange the web-site elements with the help of mesh design to keep them in order.
Images	Illustrations, graphic images, photos, icons and others are used to add information to the text. To create the desired effect, designers can choose images that complement each other, and the brand, which the web-site represents.
Visual hierarchy	The order in which a user will get the information on the web-site is identified. A designer creates it, using a visual pattern to the web-site. A visual pattern is a method in which a designer directs the look and the behaviour of a user. For instance, F-Patterns or Z-Patterns emphasise the upper horizontal part of the web-site, where mostly navigation menu and a logo, sometimes a search-box are placed. Those are elements, that inspire for interaction with users.
Colour scheme	Defines the combination of colours, that must be in harmony with the brand and the industry, which it presents. To achieve this goal, a dominant colour is chosen along with several others to create a proper palette. Colour palette can be solid (different shades of one colour), similar (colours, close to each other) or complementary. Designers also take into account what colours attract users more.
Typesetting	Defines the style and font of the text. Web-designers choose one or a combination of them, which is attractive and easy to read. To make the best choice, it is necessary to choose the font which meets the expectations of the target audience. Some web-sites can have notched fonts, while others can use non-serif fonts, depending on the sphere, goal and a regular user.
Readability	Representation of the content, which is easy to see and to read on the web-page. The text on the web-page must be readable, as users usually spend little time on that and have to find the information quickly. Designers can achieve it, choosing the relevant size and font for the text. Contrast between the text and colours of the web-site background also enhances legibility.
Navigation	Navigation elements are tools that allow users to choose, where they want to get on the web-site. They can be present in the upper or lower header of the web-site, depending on its layout and structure. These elements are important as they direct visitors to the necessary information as fast as possible. Designers can choose various navigation designs and layouts, for instance with the help of a button that folds and unfolds the navigation menu. Elements of navigation can contain arrows that direct users back to the upper part of the page, to a certain part of the page or to another page.
Content	Content is all the information, present on the web-site. It is a key element, as visitors want to get information quickly. When a web-site is clearly structured and attracts users' attention, they are more likely to turn into clients.
Adaptability	Adaptability is a function of the web-site that allows to show it on a mobile device and to adapt its layout and proportions so that it is readable. Web-design ensures convenience in surfing the web-sites and their navigation on mobile devices. If a web-site is well-developed and adapted to mobile devices, users can easily achieve the goal.

teaching staff in universities, working with the course, claimed that purely efficient design allows them not to get distracted by the course presentation when doing the course itself. Studying minimalistic documentation strategies and their successful application for creating short videos, Pflugfelder [39] offered instructions, taking into consideration minimalism in Web-applications. Lazonder [40] also emphasises the importance of developing such instructions and claims that in order to create a truly minimalistic interface, a web-designer has to arrange the elements showing only the ones which are of the highest importance and do not distract users from the necessary elements. Evaluating positive and negative impact of interface on the process of learning, del Campo et al. [41] did the research into User eXperience (UX) with the help of a quality analysis of the students' survey, studying their level of satisfaction by the use of web-pages. Bender et al. [42], Betts [43], Bolliger [44], Bolliger and Wasilik [38], Boettcher [45] also did research into the factors of students' satisfaction with on-line products. Among the factors that explain students' satisfaction with on-line courses, scientists outline the following: intuitively understandable navigation system and blank space on the page of on-line courses, speed of a web-page downloading on the platform, simplicity of orientation and easy access to the necessary content, usage of as few interactive elements of web-design as possible.

In a research paper by Vlasenko et al. [46] the analysis of web-design minimalism was conducted, using as examples a few elements of presenting content. Dynamic web-elements, such as accordion, slider and tabs were singled out. The findings of the research show that the optimal variant, from the point of view of minimalism is tabs. In course of the research, a list of criteria was offered. These criteria foster perception of the course materials, do not overload users with extra information, make navigation on the course pages easy and accessible. Thus, the analysis of certain prerequisites of existence and functioning educational on-line systems allowed us to make a decision on the model developing on-line course (figure 2).

When constructing the model, we took into account that the user interface, which does not contain enough components, or they are used inappropriately or poorly, affects the components of usability of the online course. This can affect each convenience component individually or all at once. For example, the non-availability or an insufficient number of navigation elements reduces the effectiveness of the principles of "Recognition, not remembrance" and "Flexibility and efficiency of use". And inadequate use of color scheme or printing will reduce the effectiveness of all the principles of usability. Therefore, the UI / UX design online course model should reflect the relationship between the UI components and the overall usability of the online course.

3. Discussion

Now that modes of learning are blended and remote, usage of systems of e-learning is becoming more topical and popular. Interest in developing cognitive on-line environments is on increase; it fosters comprehensive preparation of a learner in combination of conventional and on-line learning. The authors of this paper, together with Ardito et al. [1], Alomari et al. [4], who deal with the problem of using cutting-edge e-technologies with educational goals, share the opinion that the main prerequisite for the success of on-line learning is usability of SEL for users and the level of their satisfaction with the interface. An opinion by Squires [17] on usability of systems of electronic learning is of importance. Hence, the research by the scientists proved the

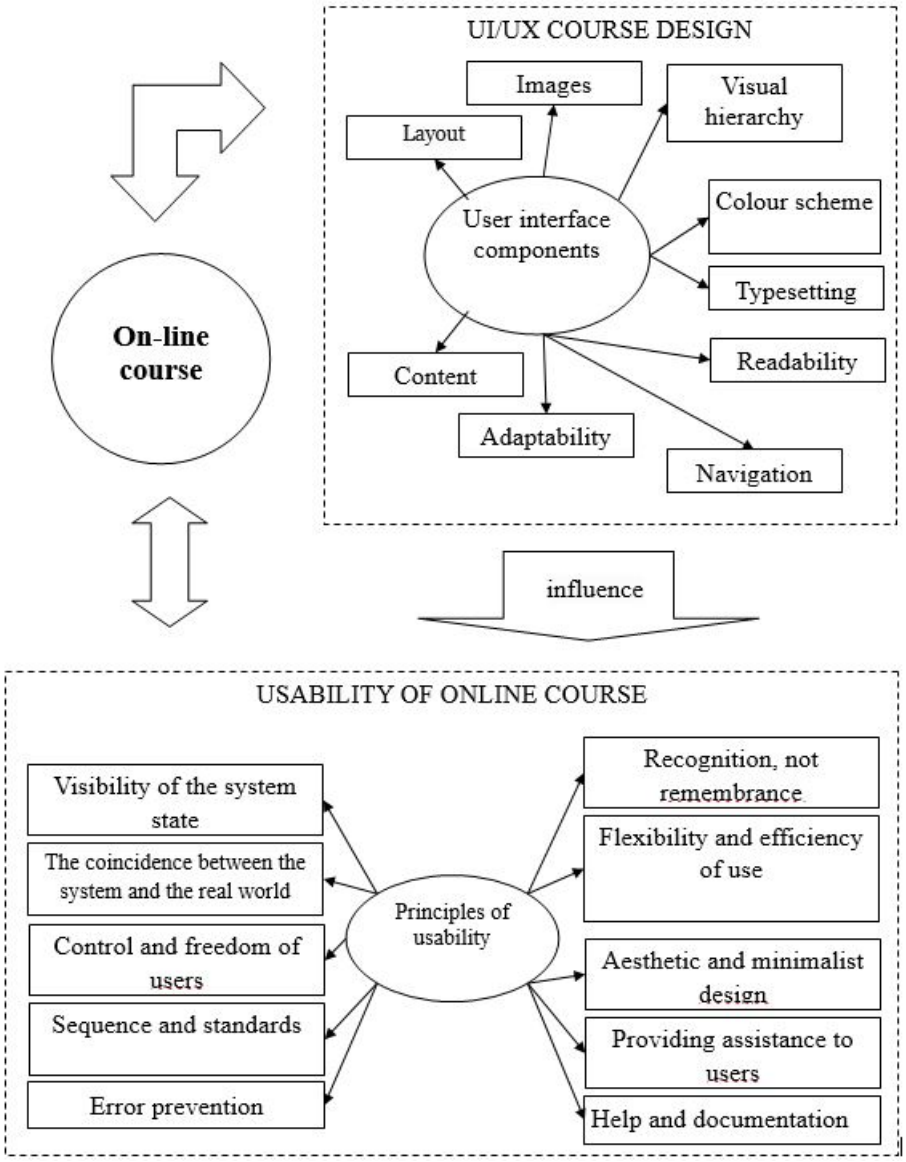

Figure 2: The model developing on-line course.

assumption of the authors of this paper on topicality of the research into features of the user interface (UI) and user experience (UX) in designing educational on-line platforms.

We also agree with the opinion by Squires [17] about the direct connection between the usability of the e-learning design and its educational value. The course interface on the educational platform was singled out by Hasan [47] as one of the factors that impacts the on-line learning. Applying analytical and empirical methods of assessment of the usability problems and indicators of effectiveness efficiency and satisfaction by the educational platform was proved

by the research, where it is stated that principles of instructional design, principles of usability implementation [48, 49, 50, 51, 52] and suggestions concerning design and development of an on-line course [53] must be considered.

Based on the conducted research, the authors of this article developed a model of on-line courses. The first structural element of the model was defined as user interface components, among which are: a layout, an image, visual hierarchy, colour scheme, typesetting, readability, adaptability, navigation, content. The authors assumed that functionality of the model is ensured by the impact of interface design on usability of the on-line course. This, in turn, allowed to decide on such structural element of the on-line course model as principles of usability. The research presents the developed model of usability principles, such as following: visibility of the system status; match between the system and the reality; control and freedom of users; consistency and standards; preventing errors; recognition, rather than recall; flexibility and effectiveness of usage; aesthetic and minimalistic design; assisting users; information and documentation.

4. Conclusions

The authors of this paper based their research on the analysis of the resources and scientific papers on introducing guidelines on UI/UX design when developing educational systems; usability of user interface (UI); evaluation of user experience (UX) in designing on-line platforms.

The notion of usability of user interface (UI) was analysed and it was determined, that for different types of evaluation different evaluation methods are available. This research paper presents the methods of analytical assessment, among which are heuristic evaluation, cognitive evaluation and analysis evaluation on the level of pressing the keys. It is also defined, that methods of analytical evaluation, as a rule, are used by experts on design for detecting usability problems when designing a system. As far as empirical methods are concerned, such methods of evaluation are used for determining factual indicators of effectiveness, efficiency and user satisfaction by the on-line courses.

Research into user experience (UX) in designing on-line platforms allowed to make the following conclusions: UX is a core component of successful web-sites and digital products; optimally developed program user interface from the point of view of UX is an inseparable part of any educational product; in order to enhance the quality of service, it is necessary to minimise the number of actions, which are taken by users for achieving the desired outcome.

The analysis of features of UI/UX design when developing educational systems allowed the authors of this paper to identify, that along with a list of standard components of an optimal web-site design, cutting-edge trends in web-design are also taken into consideration. Among such trends are minimalism of web-design, which is used both – during the design of the structure and content of on-line courses, and during the influence on the user interface. The conducted analysis also allowed to develop an educational on-line course model. The authors outlined two constituents in the structure of the model, namely user interface components and usability principles. The model functions owing to the impact of the interface design on usability of the on-line course. There is space for further research into the effectiveness of the impact of the developed model on achieving the outcomes of educational activity of Master

students, majoring in “014 Secondary Education. Mathematics”.

References

[1] C. Ardito, M. F. Costabile, M. De Marsico, R. Lanzilotti, S. Levialdi, T. Roselli, V. Rossano, An approach to usability evaluation of e-learning applications, Universal Access in the Information Society 4 (2006) 270–283. URL: http://www.di.uniba.it/~ivu/papers/2006/UAIS2006_Arditoetal.pdf.

[2] International Organization for Standardization, ISO 9241-210:2019 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems, 2019. URL: https://www.iso.org/standard/77520.html.

[3] D. Van Greunen, J. Wesson, Formal usability testing of interactive educational software: A case study, in: J. Hammond, T. Gross, J. Wesson (Eds.), Usability: Gaining a Competitive Edge, Springer US, Boston, MA, 2002, pp. 161–176. doi:10.1007/978-0-387-35610-5_11.

[4] H. W. Alomari, V. Ramasamy, J. D. Kiper, G. Potvin, A User Interface (UI) and User eXperience (UX) evaluation framework for cyberlearning environments in computer science and software engineering education, Heliyon 6 (2020) e03917. doi:10.1016/j.heliyon.2020.e03917.

[5] J. Nielsen, Usability 101: Introduction to Usability, 2012. URL: https://www.nngroup.com/articles/usability-101-introduction-to-usability/.

[6] J. Nielsen, R. Molich, Heuristic evaluation of user interfaces, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI ’90, Association for Computing Machinery, New York, NY, USA, 1990, p. 249–256. doi:10.1145/97243.97281.

[7] J. Wesson, Usability evaluation of web-based learning, in: D. Passey, M. Kendall (Eds.), TelE-Learning: The Challenge for the Third Millennium, Springer US, Boston, MA, 2002, pp. 357–363. doi:10.1007/978-0-387-35615-0_50.

[8] D. Squires, J. Preece, Usability and learning: Evaluating the potential of educational software, Computers & Education 27 (1996) 15–22. doi:10.1016/0360-1315(96)00010-3.

[9] X. Faulkner, Usability Engineering, Macmillan Press Ltd, Basingstoke, Hants, 2000.

[10] J. Rubin, D. Chisnell, Handbook of usability testing: how to plan, design, and conduct effective tests, 2nd ed., Wiley Publishing Inc., Indianapolis, IN, 2008.

[11] D. Mayhew, The Usability Engineering Lifecycle: A Practitioner’s Handbook for User Interface Design, Morgan Kaufmann Publishers Inc, San Francisco, CA, 1999.

[12] J. Nielsen, Ten usability heuristics for user interface design, 2020. URL: https://www.nngroup.com/articles/ten-usability-heuristics/.

[13] S. Ssemugabi, R. de Villiers, A comparative study of two usability evaluation methods using a web-based e-learning application, in: Proceedings of the 2007 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on IT Research in Developing Countries, SAICSIT ’07, Association for Computing Machinery, New York, NY, USA, 2007, p. 132–142. doi:10.1145/1292491.1292507.

[14] P. Zaharias, A usability evaluation method for e-learning: Focus on motivation to learn, in: CHI ’06 Extended Abstracts on Human Factors in Computing Systems, CHI EA ’06,

Association for Computing Machinery, New York, NY, USA, 2006, p. 1571–1576. doi:10.1145/1125451.1125738.
[15] M. N. Giannakos, The evaluation of an e-learning web-based platform, in: Proceedings of the 2nd International Conference on Computer Supported Education - Volume 1: CSEDU, INSTICC, SciTePress, 2010, pp. 433–438. doi:10.5220/0002799504330438.
[16] M. Notess, Usability, user experience, and learner experience, 2001. URL: https://elearnmag.acm.org/archive.cfm?aid=566938.
[17] D. Squires, Usability and educational software design: Special issue of interacting with computers, Interacting with Computers 11 (1999) 463–466. doi:10.1016/S0953-5438(98)00062-9.
[18] B. Shneiderman, C. Plaisant, M. Cohen, S. Jacobs, N. Elmqvist, N. Diakopoulos, Designing the User Interface: Strategies for Effective Human-Computer Interaction, 6th ed., Pearson, New York, 2016.
[19] A. Dix, J. Finlay, G. B. Abowd, R. Beale, Human-Computer Interaction, 3rd ed., Pearson, 2004. URL: https://hcibook.com/e3/.
[20] P. W. Jordan, Designing Pleasurable Products: An Introduction to the New Human Factors, CRC Press, London, 2000. doi:10.1201/9780203305683.
[21] E. L.-C. Law, V. Roto, M. Hassenzahl, A. P. Vermeeren, J. Kort, Understanding, scoping and defining user experience: A survey approach, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '09, Association for Computing Machinery, New York, NY, USA, 2009, p. 719–728. doi:10.1145/1518701.1518813.
[22] M. S. Alharbi, User experience dimensions, aspects and measures: systematic literature review, Master thesis, Prince Sultan University, 2016.
[23] L. Luther, V. Tiberius, A. Brem, User experience (ux) in business, management, and psychology: A bibliometric mapping of the current state of research, Multimodal Technologies and Interaction 4 (2020) 18. URL: https://www.mdpi.com/2414-4088/4/2/18. doi:10.3390/mti4020018.
[24] M. Castillo-Vergara, A. Alvarez-Marin, D. Placencio-Hidalgo, A bibliometric analysis of creativity in the field of business economics, Journal of Business Research 85 (2018) 1–9. doi:10.1016/j.jbusres.2017.12.011.
[25] D. Norman, J. Nielsen, The Definition of User Experience (UX), 2018. URL: https://www.nngroup.com/articles/definition-user-experience/.
[26] Prometheus, 2022. URL: https://prometheus.org.ua.
[27] M. Dixon, K. Freeman, N. Toman, Stop trying to delight your customers, Harvard Business Review 88 (2010) 116–122. URL: https://hbr.org/2010/07/stop-trying-to-delight-your-customers.
[28] K. Dervojeda, D. Verzijl, F. Nagtegaal, M. Lengton, E. Rouwmaat, Design for innovation: Service design as a means to advance business models, 2014. URL: https://ec.europa.eu/docsroom/documents/13406/attachments/2/translations/en/renditions/native.
[29] D. V. Borodayev, Web-site as an object of graphic design, Septima, Kharkiv, 2006.
[30] Indeed Editorial Team, What is web designing? definition, elements and uses, 2021. URL: https://www.indeed.com/career-advice/finding-a-job/what-is-web-designing/.
[31] R. PK, 10 top tips to achieve minimalism in your web design, 2016. URL: https://acodez.in/minimalism-in-web-design/.

[32] K. Moran, The characteristics of minimalism in web design, 2015. URL: https://www.nngroup.com/articles/characteristics-minimalism/.
[33] L. Carney, Web design trends and statistics 2022 – putting users first, 2022. URL: https://www.websitebuilderexpert.com/designing-websites/web-design-trends-2020/.
[34] J. Cao, 7 pillars of minimalist web design, 2015. URL: https://thenextweb.com/dd/2015/06/09/7-pillars-of-minimalist-web-design/.
[35] A. T. Baharin, H. Lateh, H. mohd Nawawi, S. S. Nathan, Evaluation of satisfaction using online learning with interactivity, Procedia - Social and Behavioral Sciences 171 (2015) 905–911. doi:https://doi.org/10.1016/j.sbspro.2015.01.208.
[36] C. C. Wolverton, B. N. Guidry Hollier, A minimalist design for distance learning, International Journal of Educational Management 33 (2019) 1457–1465. doi:10.1108/IJEM-09-2017-0237.
[37] S. M. Sani, Y. K. Shokooh, Minimalism in designing user interface of commercial websites based on gestalt visual perception laws (case study of three top brands in technology scope), in: 2016 Second International Conference on Web Research (ICWR), 2016, pp. 115–124. doi:10.1109/ICWR.2016.7498455.
[38] D. U. Bolliger, O. Wasilik, Factors influencing faculty satisfaction with online teaching and learning in higher education, Distance Education 30 (2009) 103–116. doi:10.1080/01587910902845949.
[39] E. H. Pflugfelder, The minimalist approach to online instructional videos, Technical Communication 60 (2013) 131–146. URL: https://www.ingentaconnect.com/contentone/stc/tc/2013/00000060/00000002/art00004.
[40] A. W. Lazonder, Minimalist instruction for learning to search the World Wide Web, Education and Information Technologies 6 (2001) 161–176. doi:10.1023/A:1012756223618.
[41] J. M. del Campo, V. Negro, M. Núñez, Use and abuse of audiovisual media in the college classroom. Slides show and web pages, Procedia - Social and Behavioral Sciences 93 (2013) 190–194. doi:10.1016/j.sbspro.2013.09.176.
[42] D. M. Bender, B. J. Wood, J. D. Vredevoogd, Teaching time: Distance education versus classroom instruction, American Journal of Distance Education 18 (2004) 103–114. doi:10.1207/s15389286ajde1802_4.
[43] K. S. Betts, Factors influencing faculty participation in distance education in postsecondary education in the United States: An institutional study, Ph.D. thesis, The George Washington University, 1998. URL: https://www.learntechlib.org/p/129168.
[44] D. U. Bolliger, Key factors for determining student satisfaction in online courses, International Journal on E-Learning 3 (2004) 61–67. URL: https://www.learntechlib.org/p/2226.
[45] J. V. Boettcher, Online course development: What does it cost?, 2004. URL: https://campustechnology.com/Articles/2004/06/Online-Course-Development-What-Does-It-Cost.aspx.
[46] K. Vlasenko, D. Kovalenko, O. Chumak, I. Lovianova, S. Volkov, Minimalism in designing user interface of the online platform "Higher school mathematics teacher", CEUR Workshop Proceedings 2732 (2020) 1028–1043. URL: http://ceur-ws.org/Vol-2732/20201044.pdf.
[47] L. Hasan, Evaluating the usability of educational websites based on students' preferences of design characteristics, International Arab Journal of e-Technology 3 (2014) 179–193. URL: https://www.researchgate.net/publication/281904323_Evaluating_the_Usability_of_

Educational_Websites_Based_on_Students%27_Preferences_of_Design_Characteristics.
[48] K. Vlasenko, S. Volkov, I. Sitak, I. Lovianova, D. Bobyliev, Usability analysis of on-line educational courses on the platform "Higher school mathematics teacher", E3S Web of Conferences 166 (2020) 10012. doi:10.1051/e3sconf/202016610012.
[49] K. V. Vlasenko, S. V. Volkov, I. V. Lovianova, O. O. Chumak, I. V. Sitak, D. Y. Bobyliev, Management of online platform development and support process, CEUR Workshop Proceedings 2879 (2020) 333–345.
[50] K. V. Vlasenko, S. V. Volkov, I. V. Lovianova, I. V. Sitak, O. O. Chumak, S. O. Semerikov, N. H. Bohdanova, The criteria of usability design for educational online courses, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[51] K. V. Vlasenko, I. V. Sitak, D. A. Kovalenko, S. V. Volkov, I. V. Lovianova, S. O. Semerikov, S. L. Zahrebelnyi, Methodical recommendations for the development of online course structure and content, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[52] V. V. Achkan, K. V. Vlasenko, I. V. Lovianova, O. H. Rovenska, I. V. Sitak, O. O. Chumak, S. O. Semerikov, Web-based support of a higher school teacher, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[53] M. Moore, A. Sheffield, H. Robinson, A. Phillips, Designing a course for teachers: Introduction to teaching online, in: M. Searson, M. N. Ochoa (Eds.), Proceedings of Society for Information Technology & Teacher Education International Conference 2014, Association for the Advancement of Computing in Education (AACE), Jacksonville, Florida, United States, 2014, pp. 583–588. URL: https://www.learntechlib.org/p/130815.

The optimum assessment of the information systems of shipboard hardware reliability in cloud services

Lyudmyla V. Kravtsova[1], Tatyana V. Zaytseva[1], Oleh M. Bezbakh[1], Hennadiy M. Kravtsov[2] and Nataliia H. Kaminska[1]

[1]*Kherson State Maritime Academy, 20 Ushakova Str., Kherson, 73009, Ukraine*

[2]*Kherson State University, 27 University Str., Kherson, 73003, Ukraine*

Abstract

The world wide pandemic situation revealed the problems in all spheres of human life which haven't been faced before. Recently the world has changed greatly as well as the relationship between people and their professional activity. The great bunch of the workload, if basically acceptable, is done with the use of modern innovative technologies. Such problems have not trampled down the sphere of higher education as well. Distance learning, which was previously addressed to only as accompanying possibility of lessons conduct, nowadays is considered to be the only practicable form of conducting lectures, practical lessons, tests, i.e. it has become a usual daily practice for both teachers and students. Among the basic functional requirements to the electronic educational resources in the system of distance learning there are the visualization and interaction principles both when getting familiar with the theoretical material and when completing virtual laboratory and practical tasks. The Microsoft Office documents have become the most widespread elements among the electronic educational resources. That is why there is a pressing need in presenting the electronic MS Excel spreadsheets on the resource web-pages. The simple and convenient way to solve the problem of Excel documents introduction into the electronic resources of the distance learning systems is the use of cloud services. The services help to acquire the access to the information resources of any level and of any capacity with the possibility to allocate the rights of the users belonging to different groups in relation to the resources. For that purpose the availability of the Internet network access and web-browser would be enough [1]. The cloud calculation technologies introduction allows for the use of the programs that do not require special licensing, update versions monitoring and eliminates the need of software technical support as the provider himself exercises control over the functioning, data saving, antivirus protection and possible cyberassaults. The peculiarities of professional training of navigators require the students to acquire the knowledge of professionally-oriented tasks algorithms as well as the knowledge of technologies that can help to implements them. One of the main routines the officer needs to deal with on the navigational bridge is the use of the information systems of shipboard hardware. But before usage he needs to assure of the systems reliability. That is why it is extremely important to gain during the course of professional training the necessary skills of navigation equipment exploitation reliability assessment by means of Microsoft Office documents and cloud services. So the subject matter of the suggested research is the procedure development for the navigation equipment exploitation reliability assessment by means of modern services use in the course of professional training of future seafarers. The aim of the paper is the solution of the problems of optimum assessment of the information systems of shipboard hardware reliability by means of cloud technologies usage. The following tasks are completed in the course of the research: the peculiarities and characteristics of navigational information processed by the shipboard navigation and information system have been analyzed; the results of the information systems of shipboard hardware usage have been studied; the technological diagram of the basic components structuring of the "Information systems of shipboard hardware" complex for the Master's degree training course has been created; the effective technology of the program Excel documents processing has been chosen; the system of access and usage of web-services for calculation tables processing in the system of distance learning has been designed;the process of competency formation which will enable students to use cloud services has been suggested.

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Keywords
cloud services, electronic learning, shipboard navigation and information system, probability of navigation equipment failure, service reliability

1. Introduction

Kherson State Maritime Academy (KSMA) is the unique educational establishment which unites the profound technical preparation of students with the professional character of the knowledge received by students by the graduation. For example, the integral components of the curricula for the future navigators training are such subjects as the Technology of the materials, Physics, Theoretical and practical engineering, Information technologies and others without which it is impossible to comprehend such professionally-oriented subjects as Theory and ship construction, Navigation and Pilotage, Cyber security aboard, Information systems of shipboard hardware, Global Maritime Distress and Safety System. It is worth while mentioning that the syllabuses of the technical subjects are developed in compliance with the International Maritime Organization (IMO) standards for the preparation of future seafarers.

The course "Information systems of shipboard hardware" is of high importance for the educational and professional training of future specialists to carry out the professional activity aboard ships, for the formation of students' knowledge as for the current state and problems of the modern ship automatization in accordance with the valid regulatory documentation to enable them to perform their professional duties related to ship navigation at the managerial level. The amount of the information that any student has to acquire while mastering this subject course encompasses the wide range of factors which as a whole comprise the theoretical and practical bundle of knowledge a competitive navigator must possess to withstand the competition at the international employment market. The required pack of knowledge encompasses such elements as the understanding of the unique peculiarities and characteristics of the navigational information which is processed by the shipboard navigation and information system (NIS), the ability to effectively use the communication channels of the automated information systems while keeping the watch on the bridge and communicating with shore services, to assess the probability of shipboard navigation and information system elements failure and their operational reliability. All of the above mentioned is considered to be the basis for the provision of the navigational safety in general, for the protection of the environment and the efficient

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limonova@ukr.net (L. V. Kravtsova); sunny@liveworld.biz (T. V. Zaytseva); ombezb@gmail.com (O. M. Bezbakh); kgm@ksu.ks.ua (H. M. Kravtsov); natalikamkam@gmail.com (N. H. Kaminska)
https://ksma.ks.ua/?p=3374 (L. V. Kravtsova); https://ksma.ks.ua/?p=3374 (T. V. Zaytseva); https://ksma.ks.ua/?p=3363 (O. M. Bezbakh); https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Kravtsov.aspx (H. M. Kravtsov); https://ksma.ks.ua/?p=3380 (N. H. Kaminska)
0000-0002-0152-635X (L. V. Kravtsova); 0000-0001-6780-719X (T. V. Zaytseva); 0000-0003-1030-7586 (O. M. Bezbakh); 0000-0003-3680-2286 (H. M. Kravtsov); 0000-0002-9975-7403 (N. H. Kaminska)
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usage of vessel traffic management system.

The effective work of the shipboard navigation equipment is the guarantee of safe navigation both for the given vessel where it is installed and for the ships in vicinity which must compulsory have information connection with it. Though even the most modern equipment will not be used at the optimum level if the person working with it is not ready for the operational performance. The course "Information systems of shipboard hardware" is taught during the Master course so it is considered to be one of the closing subjects in the curriculum for the navigational training.

For the maritime industry specialist the process of education for the Master degree is the compulsory step in the career advancement if he wants to obtain the rank of senior officer in navigation to operate a ship at the managerial level. Considering the theoretical and practical bunch of knowledge and training students acquired at the previous levels of education a teacher should at maximum practicable level provide the appropriate level of knowledge on such an important for the maritime industry specialist field as the information systems of shipboard hardware.

The professional training of future seafarers must guarantee the fulfillment of the requirements of the competency standards stipulated by the rules of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. One of the structural elements of the professional competency is the acquisition of navigation information assessment skills. The information is obtained from all practicable sources including radar, automatic radar plotting aids (ARPA) and electronic complexes of navigation and information systems. The information obtainment and assessment is aimed at decision making for collision avoidance and safe navigation provision.

One of the issues discussed in the suggested course is the assessment of the navigation equipment failure probability and of the operational reliability of the shipboard navigation and information systems components. The reliable operation of the systems provides for the safe vessel operation, full identification of its parameters in comparison with the real condition of a vessel at a specific period of time.

2. Related work

The information provision of vessel traffic control systems and the problems of their reliability have been researched by Vilsky [2], Vilskiy [3], Vilskyi and Nadych [4], Vagushchenko [5]. The subject matter experts stress out that the risks of shipboard emergencies arise from the inaccurate or untimely information and they believe that to solve this problem it is necessary to use the scientific approach which will provide for the well-reasoned technology for the information provision research in the vessel traffic control systems. The complex use of modern information technologies on ships is described in the publications of Zaytseva et al. [6], Voloshynov et al. [7].

The state probability assessment of any technical system in one way or another is connected to the necessity of mathematical grounds comprehension relevant to such research, knowledge of basic provisions of probability theory, the ability to design an adequate mathematical model, which will be relevant to the physical content of the problem. The objects' and systems' reliability research has always been an urgent matter as there are no systems that can function

during the unlimited period of time. That is why the issues of basics of the reliability theory, mathematical methods of systems reliability assessment, the usage of probabilistic criterion are discussed by Vasilevskyi and Ignatenko [8]. The basic methods of systems reliability assessment during the sudden or gradual failures, the means of increasing the criterion of objects trouble-free operation are discussed by Shklyar [9]. The reliability theory determines the principles of troubleshooting appearance, system and its elements performance restoration, it also accounts for the influence of both external and internal factors onto the processes inside the system, enables the determination of the ways to increase system's reliability.

But nowadays it is not enough to be a professional in highly specialized sphere of the professional activity, which is in particular true about seagoing fleet officers who bear the responsibility for the ship, the cargo and the crew. The availability of the expertise knowledge in the world wide trends of digitalization is granted during the period of professional training of future navigator in higher educational establishment. One of such tendencies is the use of cloud technologies in education and, correspondingly, in future professional activity at workplace. Currently this problem is in focus of attention. For example, the publication [10] is aimed at conceptual definitions grounding, determining the principles and methods of cloud-oriented educational and scientific environment formation, electronic resources classification provision, guidelines provision for different types of services usage.

The problems of cloud-based learning tools and especially information subjects teaching are discussed by Balyk et al. [11], Bilousova et al. [12], Fedorenko et al. [13], Glazunova et al. [14], Khmil et al. [15], Kolgatin et al. [16], Korotun et al. [17], Markova et al. [18, 19], Lytvynova and Burov [20], Oleksiuk and Oleksiuk [21], Osadcha and Osadchyi [22], Spirin et al. [23], Striuk and Rassovytska [24], Symonenko et al. [25], Valko et al. [26], Vakaliuk and Marienko [27], Vakaliuk et al. [28], Velychko et al. [29], the principles of individual work organization by means of cloud services Yandex are described by Aleksanyan [30]. Cloud services provided by the companies Google, Microsoft are described in the works by Bondarenko et al. [31], Bondarchuk et al. [32], Korobeinikova et al. [33], Lytvynova et al. [34], Sultanova et al. [35].

Though the issue of the professional training of a specialist able to adapt to the changing requirements of today in the context of information society globalization, who can freely and effectively use the latest advancements in the sphere of digital technologies, still remains a matter of acute interest.

3. Solving basic problems

The most complicated issue is considered to be the introduction of the described theoretical methods for the practical research conduct in the professionally-oriented direction specific for navigators as compared to the global approach of the analyzed information sources usage there is a very specific peculiarity in the course of the professional maritime training. It is explained by the fact that during the education in higher maritime educational establishment the process of general cycle subjects teaching is organized on the basis of the competency-based approach though anyway it cannot encompass all challenges of such a fundamental science as the theory of information systems reliability.

The result which can prove students' comprehension of the described topic is the creation of

data base which is able to optimize the process of operational reliability assessment of shipboard navigation and information system components. It is presupposed that the work with the base is possible in typical office MS Excel program as well as with the use of cloud services. This will enable higher level of convenience and availability to the data base of the users who are granted the access as well as the increase of the mobility level of the user himself.

A Master degree student completes the tasks in electronic MS Excel spreadsheets or in cloud services Google Apps or Microsoft OneDrive. The created data base can be used even during the voyage being aboard ship as the cloud services are available at any place worldwide under the only condition of Internet access.

The task of a teacher here is to develop such subject content and the relevant technology of its realization which will be capable of achieving the main task – future navigator professional training in the sphere of the comprehension of the peculiar features in the course of the information systems of shipboard hardware usage and as a result practical implementation of innovations in the course of professional activity.

A navigator receives the information about ship's position, technical condition of equipment, and its technological characteristics at every specified moment of time exceptionally by means of computers which are installed aboard, i.e. all required data is supplied by the information systems of shipboard hardware. It is clear that a senior deck officer, who is getting a professional training at the Master degree course, must be completely aware of the intended purposes, main functions and operational principle of automated identification system.

The information systems of shipboard hardware in their logical structure use the achievements of modern innovative information technologies such as: microprocessors, logic controllers, which can be programmed, optical electronics and the like. The very use of modern innovative information technologies for the purposes of navigation enables:

- the improvement of shipboard hardware in general;
- the creation of new navigational devices and systems which in turn provided for the increase in accuracy and safety of navigation;
- the development of more effective data sensors showing the information about shipboard technological processes particulars;
- the processing of the navigational information in the real timescale factor;
- the improvement of the quality of ship maneuvering due to the use of more precise information about the navigational process and also due to the fact that the deck officers become less overloaded with the routine operations on information search and processing;
- the improvement of the control over the work of the shipboard hardware and hence increasing the safety of the ship;
- the use in complicated situations of the distant assistance of the qualified shore-based personnel by means of creating the possibility of fast transmissions of large amounts of information which will be displayed ashore and will be used to characterize the development of the situation in the process of ship passage;
- the departure from the traditional rigid organization of ship control systems due to the fact that they now become open because of their integration by means of information channels;

- the fulfillment of automatic completion of a series of "intellectual" tasks connected to ship maneuvering, ship safety provision, technical aids of navigation control and others.

If one gets familiar with the syllabus content of the mentioned course which encompasses such important topics for navigation as "The fundamental concepts of information transmission by means of AIS", or "The effective use of AIS in the "ship-to-ship" and "ship-to-shore" modes, he/she will at once notice that to study the topic "The possibility of failure and operational reliability of shipboard information and navigation systems components assessment" it is especially crucial to have the profound knowledge both in high mathematics in general and specifically in one of its subdisciplines "The probability theory", on the one hand, and the knowledge of vessel traffic control systems information provision structure, fundamental concepts of reliability theory, on the other hand.

A navigator must be able to classify and cluster maritime data and notices; to research the process of information formation and circulation inside the vessel traffic control systems; to understand cluster – probabilistic methodologies of informational ship movement danger research and the principles of data formation and circulation on the water routes; to perform formalization of navigational field data flows which provide the process of navigation.

Considering all of the above mentioned and own experience, a teacher forms the optimum path of information provision to students and chooses the methods of knowledge reinforcement, using at maximum the potential of modern technologies. In this regard, it is necessary to pay attention to some peculiar features of the education process during the Master degree course, namely the fact that students can enter the course not only after the graduation from Kherson State Maritime Academy but also from any other higher maritime educational establishment in Ukraine as well as abroad. It means that the previous level of professional training (Bachelor degree) can be different but still the curriculum of the Master degree course is the same for everyone.

So, let's move immediately to the failure probability and operational reliability of shipboard information and navigation system components assessment and calculations performance in accordance with the assigned task in electronic MS Excel spreadsheets, in Google Sheets or on OneDrive service.

The overall assessment of shipboard navigation and information system components is based, first of all, on the database creation of the mentioned components with the account of their optimum allocation in the base, all necessary parameters input, which characterize this or that research object; second of all, the creation of calculation framework, which allows for the process of the reliability indices determination to be carried out automatically. Here the crucial for a Master degree student is the ability to use the mathematical apparatus when performing the professionally-oriented calculations; the knowledge of the fundamental principles of the probability theory; the skills of the practical use of vessel traffic control systems. On the other hand, they must learn how to freely use the modern communication means, how to complete common project in collaboration, how to safely use the information space. This is, first of all, the case of the use of cloud technologies, which not only broadens the student's insight of the distant form of education but also makes modern digital technologies an integral part of life-long learning.

A navigator must be able to structure the data received as the readings of devices into the

electronic spreadsheets, to create a convenient algorithm of the input data processing, to make a series of calculations according to the formulas given, to obtain and analyze the final result. For example, according to the data about the ship's position (latitude and longitude of the departure) and the port of destination (latitude and longitude of arrival), he must be able to calculate the route the vessel will proceed, the distance between the port of departure and arrival, the best heading of the vessel, under the condition of complications in the form of stormy weather on the way, supply for stormy weather and many other indices which enable the movement of a ship and the fulfillment of all charter conditions. The knowledge and skills of their practical application provide for the ability of students to comprehend the essence of the problem, to percept any calculation formula as the guideline for actions to be taken, to be able to structure the calculations and to assess the validity of the result obtained. In this respect it is clear that all the calculations are done in electronic spreadsheets because the created beforehand and edited and well-structured calculation framework allows for the substitution of the input data and immediate correct results obtaining.

According to the topic of the research special attention has to be paid to the knowledge from the basic course of the probability theory and especially to the laws of continuous random variables distribution. For example, the probability of trouble-free operation of shipboard automated control systems elements such as magnetic compasses, gyrocompasses, speed logs, echo sounders and the like and the probability of their operational reliability is calculated by means of the exponential distribution law. It must be stated that the reliability theory considers more than ten distribution laws but the demonstrative (exponential) law is used when it is necessary to carry out the general reliability assessment because it complies with the exploitation analysis of complex technical systems in case of sudden serious failures. This distribution law is characterized by the simplicity and allows for the easy calculations of reliability indices which can appear as the result of mistakes while designing, manufacturing and exploitation of elements.

Peculiar features of work on seagoing vessels such as distance from shore require from deck officers the knowledge and skills of system reliability assessment and how to maintain it in operational condition under any circumstances. The reasons for system failure can be storms, magnetic storms, and any other emergency situation which can lead to the failure of the information system of shipboard hardware. That is why it is especially crucial to have the experience in system reliability assessment, in the probability of its failure assessment, in timely recognition of possible damage. For example, if $\lambda(t)dt$ characterizes the probability of the whole system failure or any of its elements in a period of time $(t, t + dt)$ inside the group of elements which remain operational by a specific moment of time t, then it is possible to determine the connection between the probability of trouble-free operation and the intensity of failures:

$$\int_0^t \lambda(x)dx = lnP(t) \tag{1}$$

or

$$P(t) = \exp\left[-\int_0^1 \lambda(x)dx\right] \tag{2}$$

The above mentioned connection in in a general way displays the basic reliability law. If $\lambda(t) = const$, then $P(t) = e^{(-\lambda t)}$ and $a(t) = \lambda e^{(-\lambda t)}$, where $P(t)$ – is the probability of

trouble-free operation of the object; $a(t)$ – is the frequency of failures or the frequency time distribution of trouble-free operation, i.e.

$$a(t) = -\frac{dP(t)}{dt} \tag{3}$$

This interpretation is quite often met specifically in practice of information systems of shipboard hardware research and the formula (3) characterizes the exponential time distribution of trouble-free operation. If to construct a function graph $\lambda(t)$, which is called λ – technical systems' characteristics, it will be possible to notice that there is a distribution into three separate areas where the first area located at the interval $(0, t_1)$ – is the great intensity of system's failure provoked by the manufacturing defects; the second area located at the interval (t_1, t_2) – is the interval of stable exploitation, and the last interval (t_2, ∞) – is the area of the fast growth of the failure possibility, i.e. the period which requires great caution (figure 1).

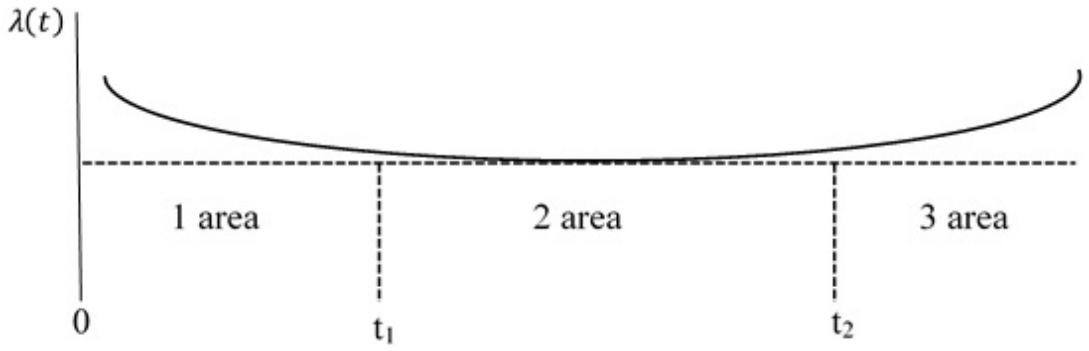


Figure 1: λ-technical system's characteristic.

To effectively assess the systems' reliability it is necessary to clearly comprehend its structural diagram. In that case, first of all, it becomes possible to develop the full value data base with the regard of all associated systems, and, second of all, it enables better understanding of the correlation between its elements, and as a result more effective assessment of system's operational capability in case of one or several elements' failure. The following diagram displays the general appearance of the shipboard automated system which serves as the basis for database structuring (figure 2).

To assess the probability of failures and the operational reliability of shipboard navigation and information system's components in the data base the following calculation formulas will be used:

$$T_{av} = \frac{1}{\lambda}, \tag{4}$$

where T_{av} – the average time of trouble-free operation (according to the documentation); λ – the intensity of failures;

$$P_c(t) = e^{\lambda t}, \tag{5}$$

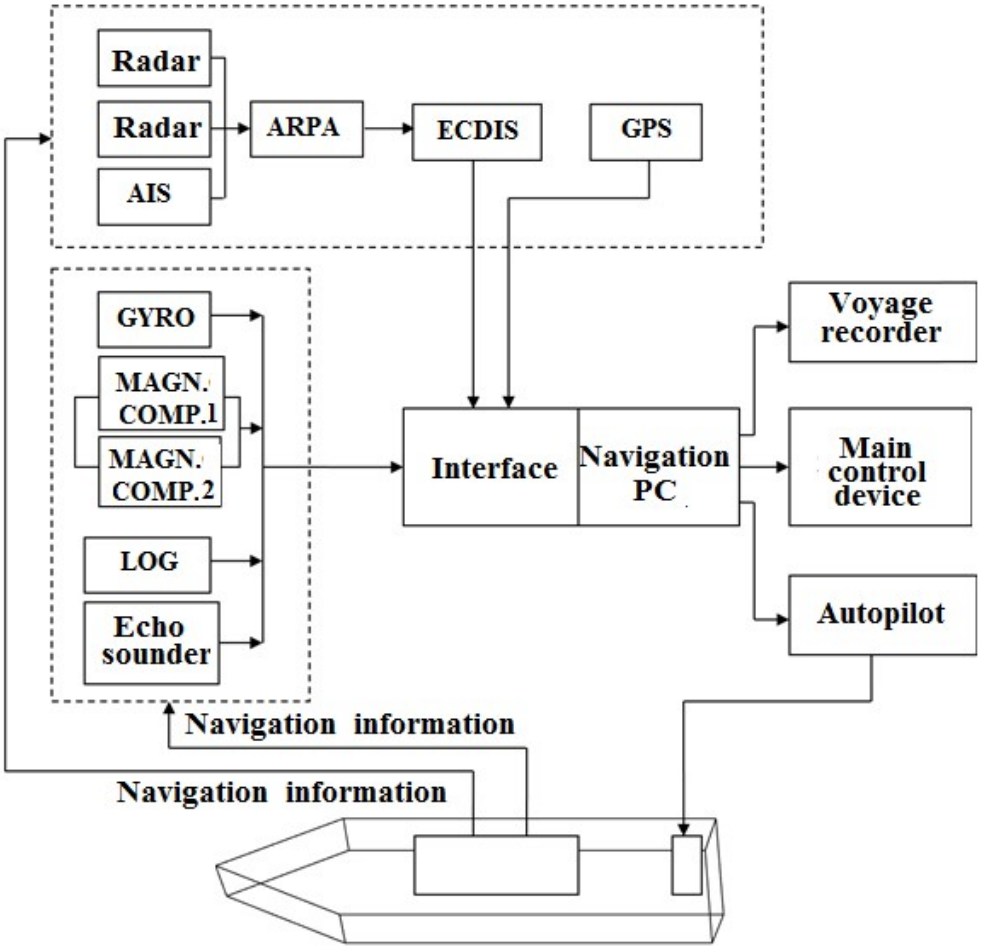


Figure 2: Shipboard automated system structural diagram.

where $P_c(t)$ – is the possibility of trouble-free operation, t – is the time of exploitation;

$$F_{av} = \frac{T_{av}}{T_{av} + T_r}, \tag{6}$$

where T_r – is the time of repairs.

Besides, it is necessary to calculate the preventive-maintenance ratio F_{pr} using the formula:

$$F_{pr} = \frac{T_r}{T_{pr} + T_r} \tag{7}$$

Operational reliability is calculated by means of the formula:

$$P_e(t) = F_r \cdot (1 - F_{pr}) \cdot P_c(t) \tag{8}$$

The maintenance of the shipboard navigation and information system operational capability is referred to the competencies of the deck officers. The criteria which helps to assess the

competency according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers is the professional's profound comprehension of navigation systems operational aspects. But if to consider the professional competency of navigational officer he must not only comply with all of the stipulated requirements and competencies of his professionally-oriented area solely but also he must be able to freely use modern digital technologies, have adequate skills of standard software use, such as Microsoft Office, and also be familiar and know how to use some specialized programs installed on ship-board computers. Additionally, nowadays the compulsory elements of knowledge, skills and abilities include also the ability to use cloud technologies. This service was created at the end of the last century but the major breakthrough became possible with the development of mobile devices and Internet in general, so now it has occupied an important place in our lives.

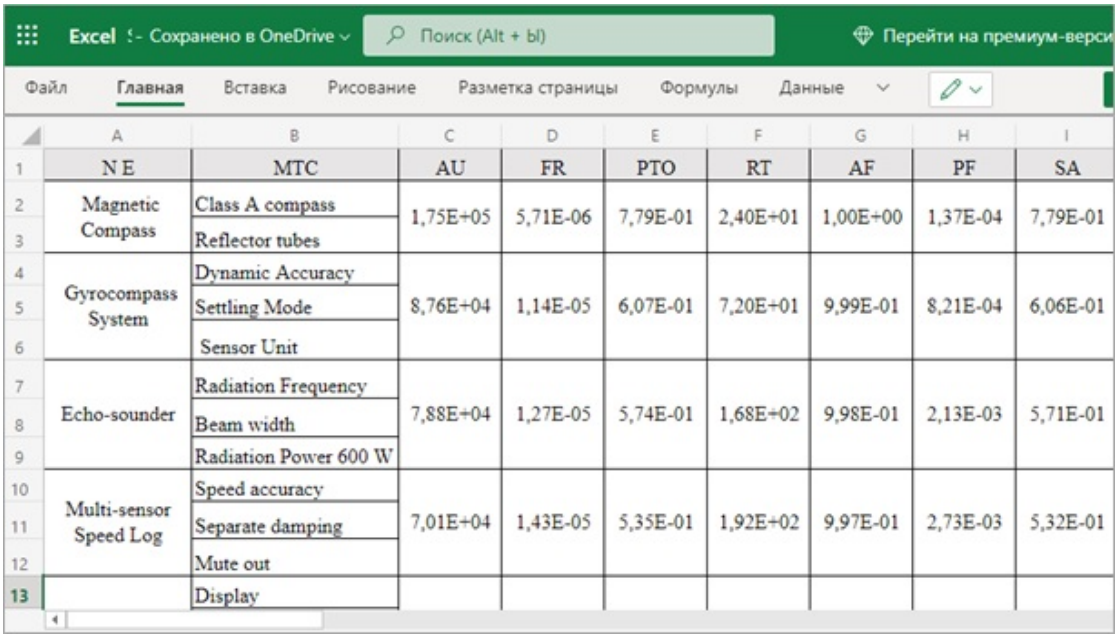
Experienced professionals use cloud technologies in the routine operations with the information flows as it economizes the time significantly under the condition of the Internet access. The dynamics of digital technologies is characterized by the high level of interactivity and allows for the collaboration when working upon common projects even if the people engaged in them are at any distance from one another. The specific features of work aboard, i.e. its being away from the standard means of communication, requires from the deck officers, who work with the information systems of shipboard hardware, the availability of the whole new level of competency. So, taking into account all of the above mentioned, it is necessary to design the whole complex of competencies while teaching the topic "The possibility of failure and operational reliability of shipboard information and navigation systems components assessment".

Let's illustrate by means of the example the fulfillment of the computational part of the practical assignment during which the Master degree students of the navigation department so the tasks using standard office programs as well as possibilities of cloud services. This is a useful practical experience for future navigators because it will be in their responsibility to perform the calculations but it is necessary to account for the fact that office programs are not always installed on shipboard computers and cloud technologies allow to work with any kind of documents but only under the condition of the Internet access.

Because the provision of trouble-free operation of shipboard navigation and information systems components and the control over their reliability are the parts of a navigator's professional duties it is suggested to create such a data base which will allow to structure the process the necessary parameters determination in compliance with the chosen navigational technical aid, to add to the program all calculation formulas, to foresee the methods of data and calculation results cross-check, to make graphical display of the trouble-free system operation possibility $P_c(t)$ and the system operational reliability connection $P_e(t)$ to the time automatic.

The following figure (figure 3) displays the fragment of the data base for the parameters determination of the navigation equipment reliability assessment according to the formulas given above. By changing the input data it is possible to receive all the necessary indices of its reliability and the assessment of its trouble-free operation possibility.

As it was stated above the course "Information systems of shipboard hardware" is taught to the Master degree students of specialization 271.01 – Navigation and ship handling. According to the curricular of the Master degree course students must complete their final shipboard practice. But the real period of practice doesn't always coincide with what is planned. This is explained by the great level of competition at the international employment market for seafarers.



	A	B	C	D	E	F	G	H	I
1	N E	MTC	AU	FR	PTO	RT	AF	PF	SA
2	Magnetic Compass	Class A compass	1,75E+05	5,71E-06	7,79E-01	2,40E+01	1,00E+00	1,37E-04	7,79E-01
3		Reflector tubes							
4	Gyrocompass System	Dynamic Accuracy	8,76E+04	1,14E-05	6,07E-01	7,20E+01	9,99E-01	8,21E-04	6,06E-01
5		Settling Mode							
6		Sensor Unit							
7	Echo-sounder	Radiation Frequency	7,88E+04	1,27E-05	5,74E-01	1,68E+02	9,98E-01	2,13E-03	5,71E-01
8		Beam width							
9		Radiation Power 600 W							
10	Multi-sensor Speed Log	Speed accuracy	7,01E+04	1,43E-05	5,35E-01	1,92E+02	9,97E-01	2,73E-03	5,32E-01
11		Separate damping							
12		Mute out							
13		Display							

Figure 3: The fragment of the data base for the parameters determination of the navigation equipment reliability assessment by means of Google Tables: NE – Navigation Equipment, MTC – Main Technical Characteristics, AU – Average Uptime – According to Documentation, FR – Failure Rate, PTO – Probability of Trouble-free Operation, RT – Repair Time – Appropriate to Maritime Practice, AF – Availability Factor, PF – Prevention Factor, SA – Serviceability.

That is why there is pressing need in creating of such conditions that would enable a Master degree student to have his practice on a seagoing vessel and at the same time to complete successfully the curricular.

For that purpose when teaching the mentioned course it was suggested to use the technology of the simultaneous usage of standard software and cloud services. It would provide for the continuous education process of Master degree students and would eliminate the need to master all the specific peculiarities of such complicated subject in a short period of time when they return from their voyages and must get ready to pass credits and exams in a limited period of time. It is worth while mentioning here that before leaving for the voyage a Master degree student consults the teacher on the conditions of cloud services usage aboard.

Modern computerized technologies enable students and teachers to use several devices for communication and cooperative activities: laptops, computers, smartphones, tablets, etc. Cloud services Microsoft, Google Apps are available at different devices so they are considered to be a widely-accessible and universal information technology for the work in the educational environment. To obtain the skills of work with cloud services a cadet, at his discretion, chooses between cloud services Microsoft or Google to fulfill practical tasks assigned (figure 3).

4. Research results

The developed technology was implemented into the education process in 2018–2019 academic year. At that time there was no COVID-19 pandemic situation, but anyway the first results have proved the necessity of such a course introduction. Though starting from the middle of 2019–2020 academic year the technology became an urgent necessity as the states were closed and, as a results, our students were deprived of the chance to come back home in time according to the terms stated in their employment contracts. The majority of students had to stay aboard and carry out their professional duties until there was a possibility to be repatriated. Thanks to the introduction of cloud services the Master degree students had an opportunity to study the material, fulfill the assignments, to defend the laboratory tasks without leaving their workplaces. The marks they received can be used as the evidence of the fact that hypothesis as for the practicability of the new education technology introduction.

So, the results of the research has proved the following.

The course "Information systems of shipboard hardware" is taught at the Master degree course. Only some part of Master degree students, namely 30%, have the possibility to complete the course off-line visiting the lessons. The other part, approximately 25%, combines the off-line classroom learning with the individual mastering of the information by means of LMS Moodle. The platform allows for the possibility to gain access to all theoretical materials, teachers' instructions to laboratory works and individual assignments, to consult teachers on-line. But the other 45% of Master degree students spend most of the academic year onboard, thus having a possibility only from time to time the address the cloud services. Nevertheless, it appeared to be enough to receive the frameworks and instructions to the assignments, to complete assignments in their free time and send them back to teachers for checking. The researchers, i.e. the authors of the article, collected the data of the statistic monitoring of the academic performance results in three groups of the Master degree courses full time department in a period of 2018–2019, 2019–2020 and 2020–2021 academic years. The average academic performance results are given in table 1.

Table 1
The summary table of academic performance results assessment of Master degree students in different technologies.

	Average score					
Academic Years	First group		Second group		Third group	
	Progress	Knowledge quality	Progress	Knowledge quality	Progress	Knowledge quality
2018–2019	100%	63%	92%	47%	83%	54%
2019–2020	100%	67%	87%	52%	88%	58%
2020–2021	100%	67%	95%	55%	92%	65%
Average	100%	66%	91%	51%	88%	58%

As can be seen from the graph (figure 4), not all of the Master degree students have used the possibility to obtain knowledge by means of standard or cloud technologies though the results of the research prove the fact that the interest of Master degree students towards the

new forms of education is growing, especially with the account for the peculiar features of maritime education.

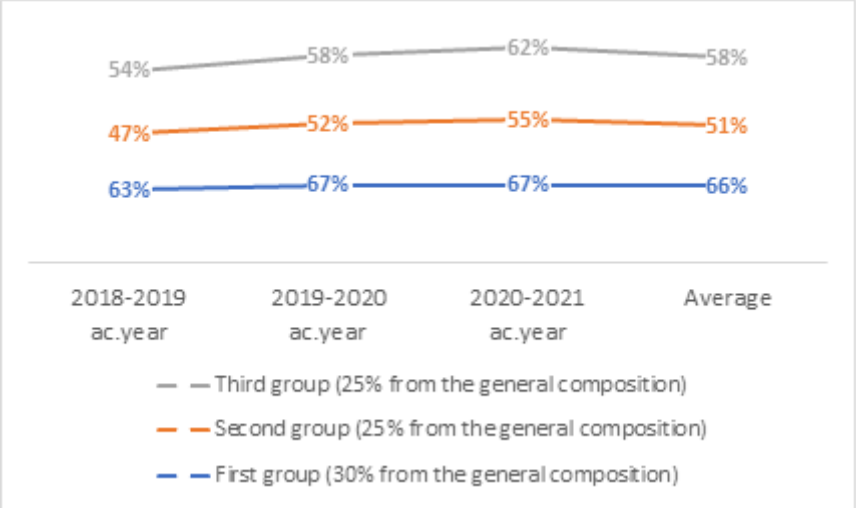


Figure 4: Graphic representation of the academic performance results assessment of Master degree students in different technologies.

5. Conclusions and directions for further research

Every navigational device is provided with the special manufacturer's blank sheet where it is stated how often should a check up of the navigation device should be conducted by the authorized company. As a rule, the check up, conducted once in five years, provides for the reliable operation of the navigation device for the next five years. Many navigators and superintendants cannot understand why the check up should be conducted namely in 5 years. There are different reasons for that. For example, 5 year exploitation of such device as a magnetic compass it is quite long time because the accuracy of the magnetic compass readings are getting much worse with the time.

Any classification society issues "Type Approval Certificate for Product" for every shipboard device and instrument which is valid for five years, so in five years it is necessary to check and confirm the operable condition and capacity of the device for the next five years by means of check up conducted by the authorized organization. By using the information on the average time of the trouble-free operation of any navigation device, which is calculated based on the maritime practice, a future navigator obtains practical skills of planning the schedule of the most commonly used technical aids to navigation check ups, based on the data as for the trouble-free operation possibility and operational reliability of this navigation equipment, received from the research described in the article.

On the other hand, the requirements to competency formation connected to the use of digital technologies are getting more and more stringent every year. At the same time the funding of the educational sphere doesn't get any better, on the contrary the expenses for the information

infrastructure development are becoming less and less. So, one of the effective means to solve the problem is the use of cloud services in the process of education.

Recently the scale rates of cloud technologies implementation are growing rapidly. The single educational information space is being developed with the use of cloud technologies which are predominantly provided by the Microsoft and Google companies. The organization of the education process with the use of cloud technologies had the following advantages:

- the services work effectively with all types of hardware and software systems;
- there is possibility to apply modern achievements in the sphere of digital technologies;
- there is no need to buy licensed software;
- the access to program apps is granted in any situation (irrespective of students' location, if they visit off-line lessons in the classroom or study individually on-line);
- possibility of cloud services application by students in their future professional activity.

Due to the cloud technologies implementation a Master degree student, while being aboard, can use the created data base for the shipboard information systems reliability assessment by changing the input data in accordance to the shipboard hardware systems parameters of his vessel. The authors of the research believe that the further engagement of Master degree students into the use of modern services can greatly increase the level of their professional training which, for sure, will enable to increase of their competitive abilities at the international employment market for seafarers.

References

[1] L. Kravtsova, N. Kaminska, H. Kravtsov, Cloud services in the distance learning system for future sailors, CEUR Workshop Proceedings 2732 (2020) 1187–1202. URL: http://ceur-ws.org/Vol-2732/20201187.pdf.

[2] G. B. Vilsky, Information the risks of navigation in the diagram of Ishikawa, Scientific bulletin of the KSMA 1 (2016) 19–25. URL: http://journals.ksma.ks.ua/nvksma/article/view/731.

[3] G. B. Vilskiy, Research of information support for traffic management system of marine vessels, Ukrainian Scientific Journal of Information Security 3 (2013) 198–203. doi:10.18372/2225-5036.19.5626.

[4] H. Vilskyi, M. Nadych, Methodology for Probabilistic Assessment of the Safe Parameters of a Vessel in Conditions of Restricted Navigation, VydavInform, Odessa, 2012.

[5] L. Vagushchenko, Ship navigation information systems, Phoenix, Odessa, 2004.

[6] T. Zaytseva, L. Kravtsova, O. Tereshchenkova, A. Yurzhenko, Simulation modeling as a means of solving professionally-oriented problems in maritime industry, in: S. Babichev, V. Lytvynenko (Eds.), Lecture Notes in Computational Intelligence and Decision Making, Springer International Publishing, Cham, 2022, pp. 94–106. doi:10.1007/978-3-030-82014-5_7.

[7] S. A. Voloshynov, F. M. Zhuravlev, I. M. Riabukha, V. V. Smolets, H. V. Popova, Application of VR technologies in building future maritime specialists' professional competences, CEUR Workshop Proceedings 2898 (2021) 68–81. URL: http://ceur-ws.org/Vol-2898/paper03.pdf.

[8] O. Vasilevskyi, O. Ignatenko, Standardization of indicators of reliability technical means, VSTU, Vinnitsa, 2013.
[9] V. Shklyar, Reliability of control systems, Tomsk Polytechnic University Publishing House, Tomsk, 2009.
[10] V. M. Demyanenko, V. V. Kovalenko, A. O. Kravchenko, Y. G. Nosenko, M. V. Popel, M. V. Rassovytska, A. M. Striuk, M. P. Shishkina, A. V. Yatsishin, Methodology of formation of cloud-oriented educational and scientific environment of pedagogical educational institution, Pedahohichna dumka, Kyiv, 2017.
[11] N. Balyk, V. Oleksiuk, Y. Vasylenko, G. Shmyger, Designing of virtual cloud labs for the learning CISCO cybersecurity operations course, CEUR Workshop Proceedings 2393 (2019) 960–967.
[12] L. I. Bilousova, L. E. Gryzun, D. H. Sherstiuk, E. O. Shmeltser, Cloud-based complex of computer transdisciplinary models in the context of holistic educational approach, CEUR Workshop Proceedings 2433 (2019) 336–351.
[13] E. H. Fedorenko, V. Y. Velychko, S. O. Omelchenko, V. I. Zaselskiy, Learning free software using cloud services, CEUR Workshop Proceedings 2643 (2020) 487–499.
[14] O. Glazunova, T. Voloshyna, V. Korolchuk, O. Parhomenko, Cloud-oriented environment for flipped learning of the future IT specialists, E3S Web of Conferences 166 (2020) 10014. doi:10.1051/e3sconf/202016610014.
[15] N. Khmil, I. Morkvian, O. Kyselova, Creation the site-quest by using the cloud services: From the experience of teaching future teachers, CEUR Workshop Proceedings 2732 (2020) 1164–1171.
[16] O. H. Kolgatin, L. S. Kolgatina, N. S. Ponomareva, E. O. Shmeltser, Systematicity of students' independent work in cloud learning environment, CEUR Workshop Proceedings 2433 (2019) 184–196.
[17] O. V. Korotun, T. A. Vakaliuk, V. N. Soloviev, Model of using cloud-based environment in training databases of future IT specialists, CEUR Workshop Proceedings 2643 (2020) 281–292. URL: http://ceur-ws.org/Vol-2643/paper16.pdf.
[18] O. M. Markova, S. O. Semerikov, A. M. Striuk, The cloud technologies of learning: Origin, Information Technologies and Learning Tools 46 (2015) 29–44. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1234. doi:10.33407/itlt.v46i2.1234.
[19] O. M. Markova, S. O. Semerikov, A. M. Striuk, H. M. Shalatska, P. P. Nechypurenko, V. V. Tron, Implementation of cloud service models in training of future information technology specialists, CEUR Workshop Proceedings 2433 (2019) 499–515. URL: http://ceur-ws.org/Vol-2433/paper34.pdf.
[20] S. Lytvynova, O. Burov, Methods, forms and safety of learning in corporate social networks, CEUR Workshop Proceedings 1844 (2017) 406–413. URL: http://ceur-ws.org/Vol-1844/10000406.pdf.
[21] V. P. Oleksiuk, O. R. Oleksiuk, Methodology of teaching cloud technologies to future computer science teachers, CEUR Workshop Proceedings 2643 (2020) 592–608.
[22] K. P. Osadcha, V. V. Osadchyi, The use of cloud computing technology in professional training of future programmers, CEUR Workshop Proceedings 2879 (2020) 155–164.
[23] O. Spirin, V. Oleksiuk, N. Balyk, S. Lytvynova, S. Sydorenko, The blended methodology of learning computer networks: Cloud-based approach, CEUR Workshop Proceedings 2393

(2019) 68–80.
[24] A. M. Striuk, M. V. Rassovytska, The system of cloud oriented learning tools as an element of educational and scientific environment of high school, Information Technologies and Learning Tools 42 (2014) 150–158. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1087. doi:10.33407/itlt.v42i4.1087.
[25] S. V. Symonenko, V. V. Osadchyi, S. O. Sysoieva, K. P. Osadcha, A. A. Azaryan, Cloud technologies for enhancing communication of IT-professionals, CEUR Workshop Proceedings 2643 (2020) 225–236. URL: http://ceur-ws.org/Vol-2643/paper12.pdf.
[26] N. V. Valko, N. O. Kushnir, V. V. Osadchyi, Cloud technologies for STEM education, CEUR Workshop Proceedings 2643 (2020) 435–447. URL: http://ceur-ws.org/Vol-2643/paper25.pdf.
[27] T. A. Vakaliuk, M. V. Marienko, Experience of using cloud-oriented open science systems in the process of teaching and professional development of natural and mathematical teachers, Information Technologies and Learning Tools 81 (2021) 340–355. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/4225. doi:10.33407/itlt.v81i1.4225.
[28] T. A. Vakaliuk, O. V. Korotun, S. O. Semerikov, The selection of cloud services for ER-diagrams construction in IT specialists databases teaching, CEUR Workshop Proceedings 2879 (2020) 384–397. URL: http://ceur-ws.org/Vol-2879/paper21.pdf.
[29] V. Y. Velychko, E. H. Fedorenko, N. V. Kaidan, V. N. Soloviev, O. V. Bondarenko, The support of the process of training pre-service mathematics teachers by means of cloud services, CEUR Workshop Proceedings 2879 (2020) 318–332.
[30] G. Aleksanyan, The use of yandex cloud services in the organization of independent activities of SSE students, in: Pedagogy: traditions and innovation, volume 2, 2012, pp. 150–153. URL: https://moluch.ru/conf/ped/archive/63/2605/.
[31] O. V. Bondarenko, S. V. Mantulenko, A. V. Pikilnyak, Google Classroom as a tool of support of blended learning for geography students, CEUR Workshop Proceedings 2257 (2018) 182–191.
[32] O. Bondarchuk, V. Balakhtar, K. Balakhtar, Monitoring of the quality of the psychological component of teachers' activity of higher education institutions based on Google Forms, E3S Web of Conferences 166 (2020) 10024. doi:10.1051/e3sconf/202016610024.
[33] T. I. Korobeinikova, N. P. Volkova, S. P. Kozhushko, D. O. Holub, N. V. Zinukova, T. L. Kozhushkina, S. B. Vakarchuk, Google cloud services as a way to enhance learning and teaching at university, CEUR Workshop Proceedings 2643 (2020) 106–118.
[34] S. H. Lytvynova, O. M. Spirin, L. P. Anikina, Cloud services Office 365: Tutorial, Komprint, Kyiv, 2015.
[35] L. Y. Sultanova, O. P. Tsiuniak, L. O. Milto, M. O. Zheludenko, L. M. Lyktei, L. M. Petrenko, A. D. Uchitel, The potential of Google Classroom web service for lecturers of higher educational establishments under pandemic conditions, CEUR Workshop Proceedings 2879 (2020) 346–365.

Selecting cloud computing software for a virtual online laboratory supporting the Operating Systems course

Olena S. Holovnia[1], Vasyl P. Oleksiuk[2,3]

[1]Zhytomyr Polytechnic State University, 103 Chudnivska Str., Zhytomyr, 10005, Ukraine
[2]Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 M. Kryvonosa Str., Ternopil, 46027, Ukraine
[3]Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine

Abstract

The article provides a survey on cloud platforms suitable for a virtual online laboratory, which contains Linux online environments and is intended to support the Operating Systems course. The study justifies the choice of utilizing private cloud as a deployment model and IaaS as a service model and substantiates the decision to create specially tailored cloud environments adapted for educational needs in contrast to applying ready-made IaaS (Infrastructure as a Service) cloud services given by providers. The related works on cloud platforms for teaching operating systems are analyzed. The study also makes a review of the authors' previous research on virtualization tools and environments for the Operating Systems course and Cisco CyberSecurity Operations course. The basic and additional requirements for cloud computing software for virtual online laboratory supporting Operating Systems course have been elaborated. Finally, the work makes the comparison of Eucalyptus, OpenStack, CloudStack and OpenNebula cloud platforms and substantiates the selection among these cloud computing software the platforms of the first and the second choice.

Keywords

Linux, operating systems, virtual online laboratory, private cloud, IaaS

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1. Introduction

Most of the Operating Systems (OS) courses include practical assignments on real OSs. In many cases, these assignments require giving students administrative access to their isolated instance of the OS. Also, OS courses usually consider Linux OS, although the majority of computers in university labs, as well as students' laptops more often come with Windows installation. For this reason, different virtualization technologies may be used.

Virtual online laboratories became popular for teaching various courses [1] including courses in OS. However, OS course belongs to the courses with needs that are considerably harder to

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olenaholovnia@gmail.com (O. S. Holovnia); oleksyuk@fizmat.tnpu.edu.ua (V. P. Oleksiuk)
http://irbis-nbuv.gov.ua/ASUA/1460426 (O. S. Holovnia);
http://tnpu.edu.ua/faculty/fizmat/oleksyuk-vasil-petrovich.php (V. P. Oleksiuk)
0000-0003-0095-7585 (O. S. Holovnia); 0000-0003-2206-8447 (V. P. Oleksiuk)
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meet than the needs of most of the courses, which usually could be taught using cloud services of Software as a Service (SaaS) model.

The purpose of the article is to make a survey on cloud platforms applicable for a virtual online laboratory containing Linux online environments in the Operating Systems course, to compare these platforms and to select the most suitable platforms.

2. Related work

The available works on cloud platforms for teaching operating systems describe the experience of using a wide range of tools, including cloud services given by provider and specially tailored cloud environments adapted for educational needs.

Rajaei and Aldakheel [2] are convinced that the Operating Systems course is among the courses that benefit from using cloud-based environments the most. The authors suggest applying Amazon AWS instances to give students the ability to learn how different scheduling algorithms behave, how virtual memory is managed etc. Gaffar and Hajjdiab [3] describe the experience of working with processes, threads, pipes and sockets using cloud-based laboratories (Ubuntu Linux instances on Amazon AWS). Bhatia et al. [4] focuses on the design of cloud for higher education institution, its proof-of-concept implementation methodology (private cloud, based on OpenStack platform). The authors also formulate the resource requirement model, which estimates the amount of resources needed for a specific number of virtual machines (VMs). Malan [5] describes the experience of moving Harvard College's introductory computer science course (CS50) into Amazon Elastic Compute Cloud (Amazon EC2). Markova et al. [6] shows and analyses the ways of implementation of cloud services, based on SaaS, PaaS (Platform as a Service) and IaaS models, for teaching courses in mathematics, natural science and information technologies. The authors also define the most important advantages of those implementations including the possibility of using modern parallel programming tools as the foundation of cloud technologies.

3. The survey of cloud computing software for virtual online laboratory supporting the Operating Systems course

3.1. Previous research

While teaching different university courses in operating systems and computer networking we have accumulated the experience of using diverse virtualization tools. More details on the Operating Systems course experience are given in the study [7]. The experience of teaching Cisco CyberSecurity Operations course is presented in the work [8].

The study [8] describes using a virtual cloud laboratory based on Apache CloudStack and EVE-NG Community for teaching the CCNA Cyber Operations course at Cisco Networking Academy. The work shows the design and implementation of the virtual cloud laboratory. The laboratory provides the opportunity to create the sufficient number of virtual machines, to change the computing power, to simulate real computer systems, networks and network topology, to save the virtual machines state between reboots, to combine students' subnets into

one virtual network, to work remotely trough a virtual private network, as well as to support students' learning and to control their learning outcomes.

As regards courses in operating systems, we have been utilizing different tools over the years, including Oracle VirtualBox hypervisor, Amazon EC2 t2.micro instances, Cloud 9 IDE, virtual machine from NDG Linux Essentials [9] course and Webminal online environment as well as bare-metal Linux installation without virtualization on some of the students' laptops. To meet the needs of the course and individual students' needs several virtualization tools could be combined according to the methodology for using Unix-like OS virtualization technologies in training bachelors of Informatics and the varied approach to applying these technologies [10, 11].

In 2021 we are supporting a two-semester Operating Systems course for students of Computer Engineering, Cybersecurity, Software Engineering, Computer Science specializations at Zhytomyr Polytechnic State University (Ukraine). We currently use VirtualBox and a Docker-based virtual machine from NDG Linux Essentials online course with intermittently utilizing Amazon EC2 and various free online environments in cases when the main virtualization tools are not available.

In the work [7] we analyzed Linux ready-made online virtual environments and made the comparison of standalone online Unix/Linux terminals in terms of their use for the Operating Systems course. As a result, list of major features of Linux online environment include the support of most Linux command (including administrative ones), administrative privileges for students inside virtual environments, basic networking operations support, the ability to upload/download files to/from virtual environments (and/or saving virtual environment state between reboots), guest OS updating and bash-scripting support.

The requirements for Linux online virtual environments for teaching the operating systems course have been also formulated and include realism, relevancy, availability, stability, scalability and security [7].

We anticipated facing several challenges when working on Linux online virtual environments designing and implementation, namely the challenge of a wide choice, the challenge of implementing, the challenge of network isolation, the challenge of a "playground" and the challenge of a transition [7].

The next stage of the research is to investigate virtualization technologies suitable for Linux online environments, including private open-source cloud platforms, and to select applicable tools. At this stage of the study, we are dealing with the challenge of a wide choice. Different virtualization tools and platforms are available, so selecting the best suitable set of tools is a complex task.

3.2. Elaborating the requirements for cloud computing software for virtual online laboratory in the Operating Systems course

Previously analyzed ready-made Linux online environments included standalone online Unix/Linux terminals (JSLinux, Copy.sh, Virtual x86, Webminal, Linuxzoo, JS/UIX, Weblinux, Browsix, CB.VU), online IDEs which include Unix/Linux terminals (Codio, Cloud 9, Codeanywhere, Paiza.io) and full-function Unix/Linux virtual environments in the cloud (Amazon EC2, Google Cloud Platform, Microsoft Azure) [7].

Later at least one of the mentioned standalone online Unix/Linux terminals (Webminal) changed the terms of its availability, so we had to move to other environments as alternative virtualization tools. This case illustrates the need to select more stable solutions for teaching OS course. Besides, free utilization of standalone online terminals has serious functional limitation (i.e., sudo access, networking).

Online IDEs with Unix/Linux terminals are better suited for programming courses while we need the environment for practising administrating commands.

Full-function Unix/Linux virtual environments in the cloud are given by cloud service providers according to Infrastructure as a Service (IaaS). They are ready-made and need comparatively small resources for setting up and further administrating. These services also give sudo access in guest OSs, keep virtual environments state between reboots, support virtual networking and guest OSs updates.

But the usage of these services is usually non-free, need students' credit card number for registration and have other limitation.

The other disadvantage of all cloud services given by the provider is that the terms of use may be changed for both free and paid services. Changes could affect the price, availability, maximum amount of allocated resources. In the case of Cloud9 IDE the service was initially offering a free Ubuntu VM, a full-function terminal with sudo access and an IDE for collaborative programming for all the registered users. But later because of numerous security violations from these VMs, the provider changed the terms. After the changes, users are able to connect VMs from other services only.

So, individually designed virtual Linux environments for the Operating Systems course should provide the students with opportunities close to those given by providers of IaaS cloud services, but the solution must be more provider independent. Although we still appreciate compatibility between analyzed cloud computing software and providers' cloud service platforms.

Eligible virtualization software includes cloud computing software as well as environments that are not necessarily intended to run in the cloud. An example of the latter is Proxmox VE, the application of which for teaching the OS administrating is described in the study [12].

However, in the work [7] we marked the need for scalability. With a scalable system, it is possible to start with a comparatively simple solution and gradually enhance it, adding new features, larger hardware capacities and meeting the needs of the course, which change over time. Although some degree of scalability can be reached with a wide range of tools, cloud platforms were initially designed with scalability in mind. Therefore, in further research, we will concentrate on cloud platforms.

According to the NIST Definition of Cloud Computing [13] the major *cloud deployment models* are the following:

- *private cloud* (exclusively used by a single organization, but not necessarily owned by this organization);
- *community cloud* (exclusively used by a specific community of customers, who belong to organizations that have shared concerns);
- *public cloud* (available for the general public, although its using is not necessarily free of charge);
- *hybrid cloud* (a composition of two or more different cloud infrastructures).

As a virtual online laboratory for the Operating Systems course would be used exclusively by the university, the most suitable cloud deployment model is a private cloud.

Also, understanding that studying product description, documentation analysis and test installation may not show all the important aspects of the product usage in each particular case, we decided to select two pieces of cloud computing software, which would be the platform of the first choice and the platform of the second choice. The platform of the second choice may be used if any serious and unexpected obstacles will be discovered with the platform of the first choice.

Taking into account all the above-mentioned factors the requirements for cloud computing software for virtual online laboratory in the Operating Systems course should be as follows.

The basic requirements for cloud computing software for virtual online laboratory in the Operating Systems course:

- private cloud deployment model support;
- Linux guest support;
- distribution under free and open-source software licenses;
- virtual networking support;
- web interface for students with ability to create, administrate, delete virtual instances, and also to establish and configure network connections between these instances;
- detailed documentation;
- integration with authentication protocols (LDAP).

The additional requirements for cloud computing software for virtual online laboratory in the Operating Systems course:

- simple basic installation for beginners;
- Windows guests support.

3.3. The comparison of free and open-source cloud computing software for virtual online laboratory in the Operating Systems course

We analyzed four popular cloud computing software available under free and open-source licenses – Eucalyptus, OpenStack, CloudStack and OpenNebula. The major characteristics of Eucalyptus, OpenStack, CloudStack and OpenNebula important to this study are given in table 1.

Eucalyptus. Eucalyptus [14] is an open-source IaaS cloud computing software for building private and hybrid clouds. The product is developed by Eucalyptus Systems and distributed under GNU GPL v3 license with community support and an option of paid support. A distinctive feature of Eucalyptus is its compatibility with Amazon AWS. Eucalyptus uses similar instances types, tools, virtualization technologies, terminology and supports AWS APIs. Eucalyptus also has a FastStart solution for beginners. FastStart is intended to be run from CentOS 7.9 minimal installation and requires few unused IP addresses in the subnet. Eucalyptus supports easy download of ready-made Linux images (CentOS, CentOS Atomic Host, Fedora, Fedora Core OS, Ubuntu) from a command line.

Table 1
The comparison of free and open-source cloud computing software for virtual online laboratory in the Operating Systems course.

Characteristics	Eucalyptus	OpenStack	CloudStack	OpenNebula
Cloud service model	IaaS	IaaS	IaaS	IaaS
License	GNU GPL v3	Apache License 2.0	Apache License 2.0	Apache License 2.0
Cloud deployment model	private and hybrid cloud	private, public and hybrid cloud	private, public and hybrid cloud	private, public and hybrid cloud
Based on virtualization technology	virtual machines (KVM, Xen, Vmware hypervisors)	bare-metal virtualization, virtual machines, virtual containers (various virtualization platforms)	virtual machines (KVM, Vmware vSphere, XenServer/XCP, VirtualBox), virtual containers (LXC)	virtual machines (Vmware vCenter, KVM, VirtualBox), virtual containers (LXD), microVMs (AWS Firecrackers)
Host OS	Cent OS 7.9, Red Hat Enterprise Linux 7.9 (both 64-bit)	Windows, Solaris, Linux OSs and Vmware ESXi hypervisor	Linux, Windows	Linux (including Cent OS and Ubuntu)
Guest OS	all guests supported by the basic virtualization software	all guests supported by the basic virtualization software	Linux, Windows	all guests supported by the basic virtualization software
Name of guest OS environment	instances, virtual machines	instances, virtual machines, virtual containers (depending on basic virtualization software)	instances, virtual machines, virtual containers (depending on basic virtualization software)	instances, virtual machines, virtual containers, microVMs (depending on basic virtualization software)
Interface for administrator	web-based console and administration CLI	web-based UI (Horizon)	wed-based UI (CloudStack UI)	Sunstone GUI, FireEdge GUI, CLI
Interface for guest OS access	web-based console, Euca2ools, AWS CLI	Horizon, OpenStackClient	wed-based UI (CloudStack UI)	Sunstone GUI, CLI
Virtual networking	AWS VPC	neutron	AWS-style networking, Nicira NVP	Linux bridge networks, 802.1Q networks, VXLAN networks, OpenvSwitch networks
Integration with LDAP	yes	yes	yes	yes

Eucalyptus contains an administration CLI, a web-based console for instances management (figure 1), and supports command line tools for connection to instances, which currently are Euca2ools (Cent OS, RHEL, Mac OS X hosts) [15] and AWS CLI (Linux, Windows, macOS hosts and Docker) [16].

System requirements for Eucalyptus include Intel / AMD CPU with 4 cores 2 GHz each, minimum 16 RAM for each virtual machine, minimum 100 Gb of storage on each host, but recommends 200 Gb on Node Controller host running Linux virtual machines, 500 Gb on Storage Controller hosts and 500 Gb on Walrus object storage gateway as well (if used). Machines that host components (except Cloud Controller and Node Controller) must support UDP multicast

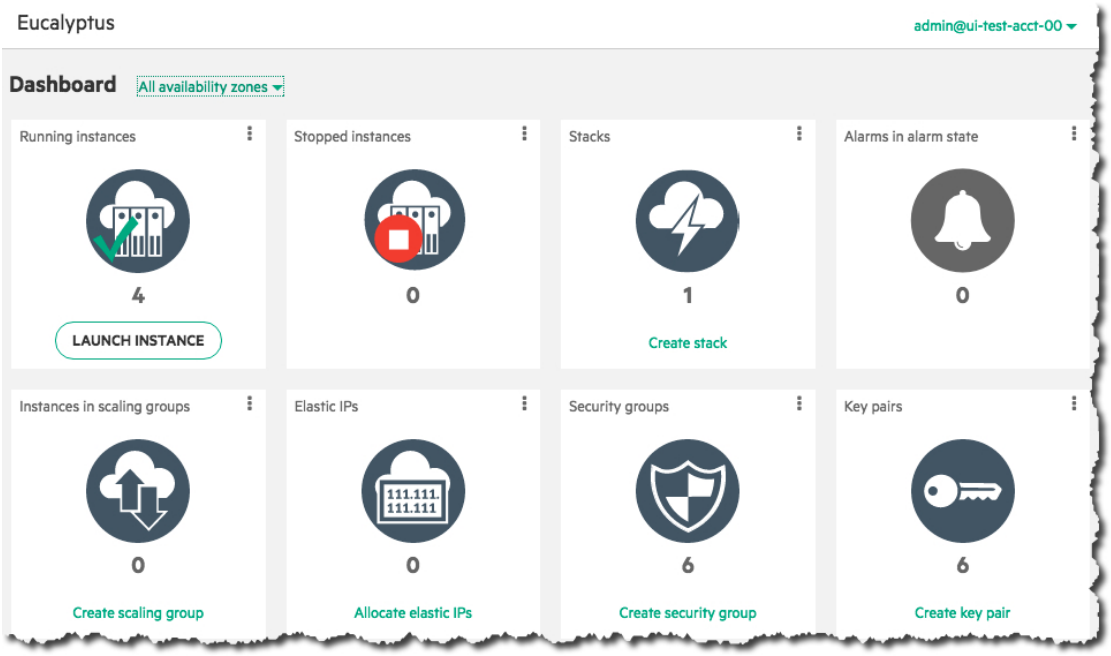

Figure 1: Eucalyptus dashboard [17].

for IP address 239.193.7.3. All services must be installed on physical machines, not virtual [14].

OpenStack. OpenStack is a free and open-source cloud computing platform with a focus on open standards. OpenStack was founded and initially developed by Rackspace Hosting and NASA (the influence of the latter is particularly notable in the names of components). Currently, the platform is managed by OpenStack Foundation, which is a non-profit organization.

The developers of OpenStack call it a cloud operating system [18]. The platform is compliant with many tools, operating systems and technologies. OpenStack uses Apache License 2.0.

OpenStack comes with Horizon Web UI (figure 2), OpenStack SDK, and also supports third-party tools like Kubernetes, CloudFoundry, Terraform.

It works with a wide range of hosts, including Windows, Solaris, Linux OSs and Vmware ESXi hypervisor. Supported Linux hosts include Cent OS, Debian, Fedora, openSUSE, RHEL, Ubuntu and other distributions [20].

For new users the Training Labs scripts are available, providing an automated deployment of the cluster using VirtualBox or KVM VMs, hosted on a desktop PC or a laptop with Linux, MacOS or Windows OS, minimum 8 Gb RAM and 20 GB of free storage [21].

System requirements for OpenStack vary greatly because of the high flexibility of the platform and depend on the objective of building the cloud, the components selected and other factors.

For example, Ubuntu OpenStack installation could be deployed according to three main scenarios: single-node deployment, multi-node deployment and data-centre cluster deployment. Depending on the scenario, OpenStack minimally requires 1 physical host with 16 GB RAM, multi-core CPU and 50 GB of free disk space (for single-node deployment); 2 physical hosts each with 16 GB RAM, multi-core CPUs and 50 Gb of free disk space (for multi-node deployment);

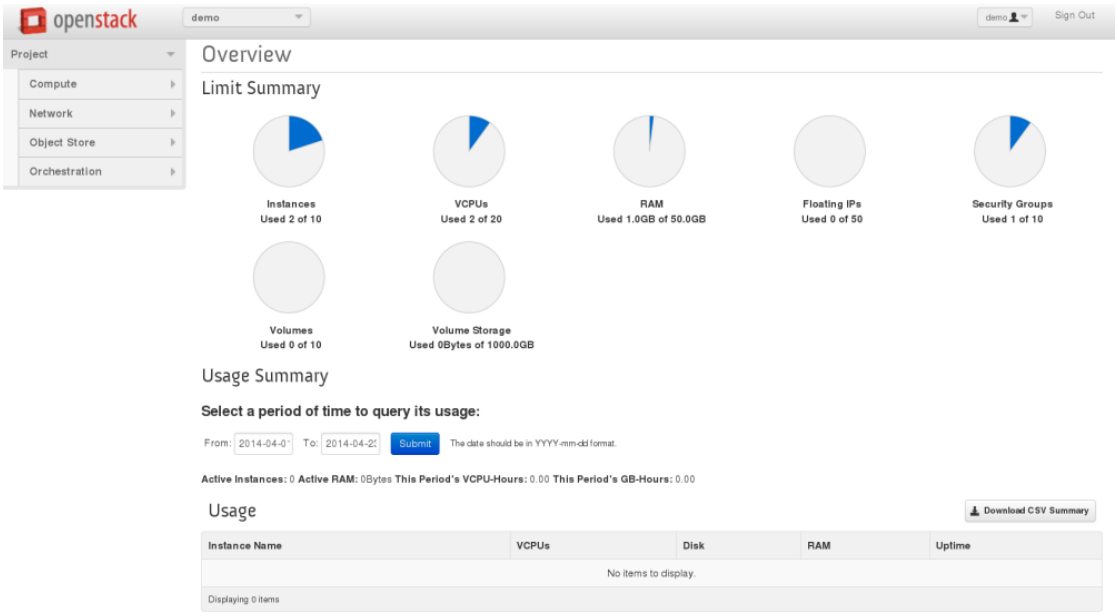

Figure 2: OpenStack dashboard [19].

6 physical servers each with 8 Gb RAM, IPMI BMCs, dual NICs, support of HA architectures, network switch and Internet gateway (for data centre cluster deployment) [22].

It also should be noted that minimal deployment for the Wallaby series (released in June 2021) consists of Keystone identity service, Glance image service, Placement service, Nova compute service, Neutron networking service and will be most likely also include Horizon dashboard and Cinder block storage service [23].

CloudStack. CloudStack [24] has been initially developed by Cloud.com (purchased by Citrix). Further development is currently being implemented by the Apache Foundation.

CloudStack is an open-source IaaS cloud software designed for large networks, but applicable to smaller networks as well. It is distributed under Apache License 2.0.

CloudStack supports Amazon AWS APIs and Open Cloud Computing Interface [25]. A web-based UI (CloudStack UI) is available (figure 3).

Minimal system requirements for CloudStack management server, database and storage include 64-bit x86 CPU, 4 GB RAM, 250 GB of free storage (500 GB recommended), 1 NIC, static IP address and fully qualified domain name at each physical host. The management server may be installed on a virtual machine. Hosts, where hypervisors and virtual machines would run, must support Intel-VT or AMD-V hardware-assisted virtualization, have 64-bit x86 CPU, 4 GB RAM, 36 GB of free storage, 1 NIC [26].

OpenNebula. OpenNebula [27] is an open-source IaaS platform to build and manage enterprise clouds. Is developed by OpenNebula Systems and OpenNebula community, distributed under Apache License version 2.

OpenNebula is supported by its community, although a paid subscription for enterprise usage is also available (OpenNebula EE).

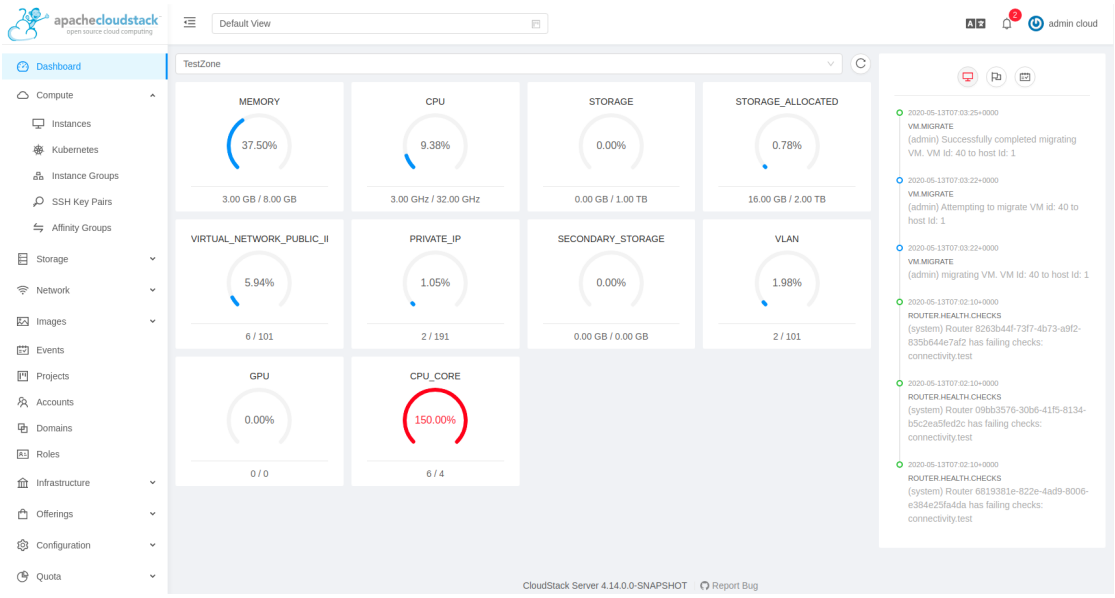

Figure 3: Apache CloudStack dashboard [25].

OpenNebula supports integration with Amazon AWS and Microsoft Azure. The product contains built-in UIs (Sunstone GUI, FireEdge GUI) and also works with third-party tools, including Terraform, Kubernetes, Ansible and Docker [28]. The Sunstone GUI is shown on figure 4.

For new users, the miniONE tool is provided. This tool helps to deploy OpenNebula cloud based on KVM virtual machines, it also installs and configures all necessary components to manage and run the virtual machines. System requirements for OpenNebula miniONE include a physical or virtual server with 4 GiB RAM, 20 GiB of free storage and open ports for SSH (22), Sunstone (80) and FireEDGE (2616) [29].

All the analyzed platforms have detailed online documentation with manuals and step-by-step instructions is available.

Bedi et al. [30] after giving a comparison of Eucalyptus, OpenStack, CloudStack and OpenNebula cloud platforms arrived at the conclusion that despite all the listed systems could be successfully used for cloud deployment, OpenStack and Eucalyptus are more suitable for infrastructure provisioning, while CloudStack and OpenNebula would show better results on datacentre virtualization.

Taking into account all mentioned above, we have come to a conclusion to select the OpenStack cloud platform as the platform of the first choice because of its high flexibility and conformance with open standards. OpenStack also provides Training Labs scripts, which would be particularly useful at the early stage of the virtual laboratory implementation and may be also applied for students' extra-curricular and scientific work.

The other three platforms (Eucalyptus, CloudStack and OpenNebula) also look promising and meet most of the requirements. These platforms have been selected as platforms of second choice.

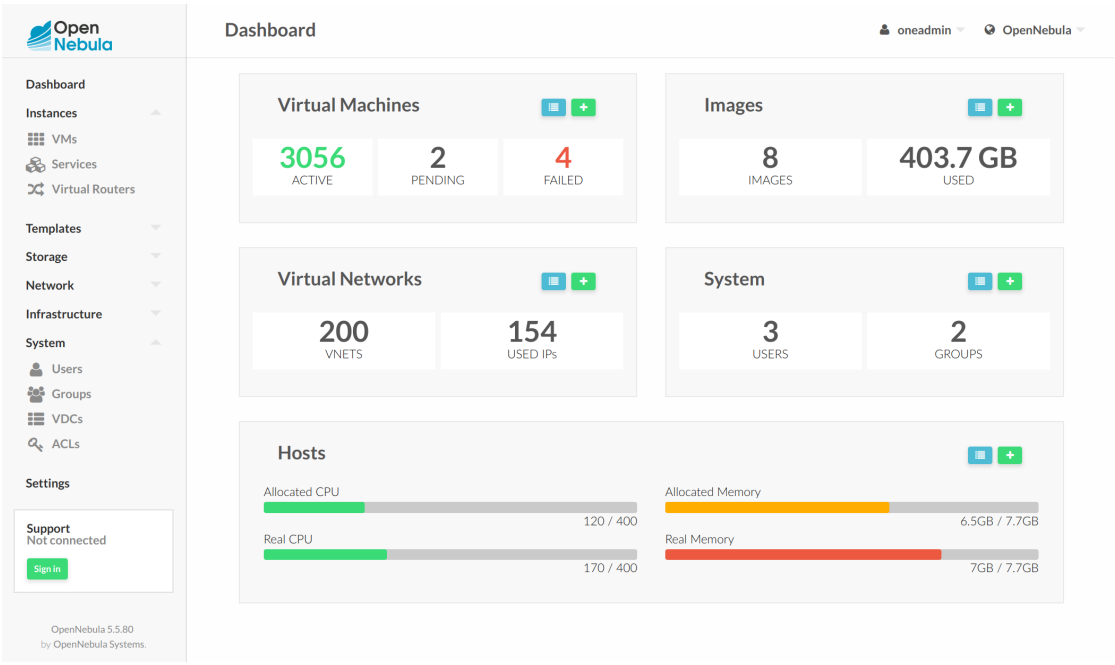

Figure 4: OpenNebula dashboard [27].

4. Conclusions

The work has made the survey on cloud platforms applicable for a virtual online laboratory containing Linux online environments to support the Operating Systems course.

Related works on cloud platforms for teaching operating systems describe the experience of using tools based on different technologies, namely cloud services given by provider (Amazon AWS) and specially tailored cloud environments adapted for educational needs (OpenStack, CloudStack).

The study gives a brief review of the previous research of virtualization tools and environments. The basic requirements for cloud computing software for virtual online laboratory supporting the Operating Systems course have been elaborated and include private cloud deployment model support; Linux guest support; distribution under free and open-source software licenses; virtual networking support; web interface for students with the ability to create, administrate, delete virtual instances, and also to establish and configure network connections between these instances; detailed documentation; integration with authentication protocols (LDAP). The additional requirements include simple basic installation for beginners and Windows guests support.

The work provides a comparison of four popular cloud computing software available under free and open-source licenses (Eucalyptus, OpenStack, CloudStack and OpenNebula).

The study concluded to select OpenStack cloud platform as the platform of the first choice because of flexibility, open standards support and providing Training Labs scripts that could be used for experiments and students' extra-curricular work. Considering that Eucalyptus,

CloudStack and OpenNebula cloud platforms also meet most of the requirements, these platforms have been selected as platforms of the second choice.

Future studies should focus on developing the model of a virtual online laboratory for supporting the Operating Systems course and pilot empirical research of selected cloud platforms.

References

[1] A. Striuk, O. Rybalchenko, S. Bilashenko, Development and using of a virtual laboratory to study the graph algorithms for bachelors of software engineering, CEUR Workshop Proceedings 2732 (2020) 974–983.

[2] H. Rajaei, E. A. Aldakheel, Cloud computing in computer science and engineering education, in: Proceedings of 119th ASEE Annual Conference & Exposition, ASEE Conferences, San Antonio, Texas, 2012, pp. 422–431. doi:10.18260/1-2--21076.

[3] M. A. Gaffar, H. Hajjdiab, Teaching operating systems concepts using the cloud, World Transactions on Engineering and Technology Education 16 (2018) 156–161. URL: http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.16,%20No.2%20(2018)/10-Hajjdiab-H.pdf.

[4] G. Bhatia, I. A. Noutaki, S. A. Ruzeiqi, J. A. Maskari, Design and implementation of private cloud for higher education using openstack, in: 2018 Majan International Conference (MIC), 2018, pp. 1–6. doi:10.1109/MINTC.2018.8363161.

[5] D. J. Malan, Moving CS50 into the Cloud, in: 15th Annual Conference of the Northeast Region of the Consortium for Computing Sciences in Colleges, Hartford, Connecticut, 2010. URL: https://cs.harvard.edu/malan/publications/ccscne10-malan.pdf.

[6] O. M. Markova, S. O. Semerikov, A. M. Striuk, H. M. Shalatska, P. P. Nechypurenko, V. V. Tron, Implementation of cloud service models in training of future information technology specialists, CEUR Workshop Proceedings 2433 (2018) 499–515. URL: http://ceur-ws.org/Vol-2433/paper34.pdf.

[7] O. Holovnia, Linux online virtual environments in teaching operating systems, CEUR Workshop Proceedings 2732 (2020) 964–973. URL: http://ceur-ws.org/Vol-2732/20200964.pdf.

[8] N. Balyk, Y. Vasylenko, V. Oleksiuk, G. Shmyger, Designing of Virtual Cloud Labs for the Learning Cisco CyberSecurity Operations Course, CEUR Workshop Proceedings 2393 (2019) 960–967. URL: http://ceur-ws.org/Vol-2393/paper_338.pdf.

[9] NDG, Linux Essentials – Online Courses & Labs Training, 2022. URL: https://www.netdevgroup.com/online/courses/open-source/linux-essentials.

[10] O. M. Spirin, O. S. Holovnia, Using Unix-like operating systems virtualization technologies in training the bachelors of Computer Science, Information Technologies and Learning Tools 65 (2018) 201–222. doi:https://doi:10.33407/itlt.v65i3.2055.

[11] O. S. Holovnia, Methodology for using Unix-like operating systems virtualization technologies in training bachelors of Informatics, Ph.D. thesis, Institute of Information Technologies and Learning Tools of the NAES of Ukraine, Kyiv, Ukraine, 2019.

[12] A. Batiuk, D. Vankevych, G. Zlobin, Using virtualization technologies in courses “System administration OS Linux”, Electronics and information technologies 3 (2013) 220–225.

[13] P. Mell, T. Grance, The NIST Definition of Cloud Computing, Technical Report 800-145, National Institute of Standards and Technology (NIST), Gaithersburg, MD, 2011. URL: http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf.
[14] Eucalyptus Documentation, 2020. URL: https://docs.eucalyptus.cloud/eucalyptus/5/.
[15] Euca2ools 3.4.1 Reference Guide, 2018. URL: https://docs.eucalyptus.cloud/eucalyptus/4.4.3/euca2ools-guide-3.4.1.pdf.
[16] Amazon Web Services, Installing, updating, and uninstalling the AWS CLI version 2 – AWS Command Line Interface, 2022. URL: https://docs.aws.amazon.com/cli/latest/userguide/install-cliv2.html.
[17] Navigate the dashboard, 2018. URL: https://docs.eucalyptus.cloud/eucalyptus/4.4.5/shared/console_dashboard.html.
[18] Open Source Cloud Computing Platform Software – OpenStack, 2021. URL: https://www.openstack.org/software/.
[19] Openstack dashboard – openstackdocstheme 2.3.1.dev10 documentation, 2021. URL: https://docs.openstack.org/openstackdocstheme/latest/demo/dashboard_demo.html.
[20] TechnologyIntegrationPrinciples – OpenStack, 2021. URL: https://wiki.openstack.org/wiki/TechnologyIntegrationPrinciples.
[21] TechnologyIntegrationPrinciples – OpenStack, 2021. URL: https://wiki.openstack.org/wiki/Documentation/training-labs.
[22] Install OpenStack – Ubuntu, 2022. URL: https://ubuntu.com/openstack/install.
[23] Install OpenStack services – Installation Guide documentation, 2021. URL: https://docs.openstack.org/install-guide/openstack-services.html.
[24] Apache CloudStack – Open Source Cloud Computing, 2020. URL: https://cloudstack.apache.org/.
[25] Welcome to Apache CloudStack's Documentation – Apache CloudStack 4.15.0.0 documentation, 2020. URL: https://docs.cloudstack.apache.org/en/latest/index.html.
[26] Installation overview – Apache CloudStack Installation Documentation 4.6.0 documentation, 2020. URL: http://docs.cloudstack.apache.org/projects/cloudstack-installation/en/4.6/overview/.
[27] OpenNebula – Open Source Cloud & Edge Computing Platform, 2021. URL: https://opennebula.io/.
[28] OpenNebula Overview – Datasheet – OpenNebula Customer Portal, 2019. URL: https://support.opennebula.pro/hc/en-us/articles/360036935791-OpenNebula-Overview-Datasheet.
[29] GitHub – OpenNebula_minione – Easy to use deployment tool for an OpenNebula evaluation environment, 2021. URL: https://github.com/OpenNebula/minione.
[30] P. Bedi, B. Deep, P. Kumar, P. Sarna, Comparative study of OpenNebula, CloudStack, Eucalyptus and OpenStack, International Journal of Distributed and Cloud Computing 6 (2018) 37–42. URL: http://www.publishingindia.com/ijdcc/68/comparative-study-of-opennebula-cloudstack-eucalyptus-and-openstack/703/4909/.

Hardware and software tools for teaching the basics of quantum informatics to students of specialized (high) schools

Liudmyla V. Lehka[1], Svitlana V. Shokaliuk[1] and Viacheslav V. Osadchyi[2]

[1]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*
[2]*Bogdan Khmelnitsky Melitopol State Pedagogical University, 20 Hetmanska Str., Melitopol, 72300, Ukraine*

Abstract

The article defines the criteria for choosing a cloud-based platform for mastering the basics of quantum informatics by students of a specialized (high) schools: cross-browser; intuitive interface; the possibility of free access; access without registration and simplified registration; the presence of a systematized reference system with examples; support for the development of the environment by the developer; support for working in a personal educational environment; support for working with quantum algorithms in graphical mode; automatic conversion of quantum algorithms from graphic format to program code text; support for the Ukrainian-language localization; availability of a mobile application; responsive design. The possibilities of platforms for implementing quantum algorithms from the following companies are analyzed: Microsoft, QuTech, Amazon Braket, IBM. The choice of the IBM Quantum cloud-based platform is justified. Work at IBM Quantum Composer and IBM Quantum Lab is described. Information about quantum operations and gates is presented: their designation in IBM Quantum Composer and IBM Quantum Lab, the gate matrix, and the purpose of the gate. An example of implementing quantum teleportation in the form of a circuit and program is given.

Keywords

quantum calculations, quantum computer, quantum circuit, quantum algorithm, IBM Quantum Lab, IBM Quantum Composer, Python, Jupyter Notebook

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1. Introduction

The study of the subject content lines of the school computer science course, namely, "Information Technologies for creating and processing information objects", "Modeling, algorithmization and programming", "Telecommunication technologies", is carried out with the support of appropriate hardware and software (in particular, Internet services).

With the experimental introduction of quantum informatics issues into the school course [1, 2] we can say about the problem of appropriate and pedagogically balanced expert selection of hardware and software tools to support studying, taking into account many criteria.

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asp-18-lehka@kdpu.edu.ua (L. V. Lehka); shokalyuk@kdpu.edu.ua (S. V. Shokaliuk); osadchyi@mdpu.org.ua (V. V. Osadchyi)
https://kdpu.edu.ua/personal/svshokaliuk.html (S. V. Shokaliuk); http://osadchyi.mdpu.org.ua (V. V. Osadchyi)
0000-0001-5768-5475 (L. V. Lehka); 0000-0003-3774-1729 (S. V. Shokaliuk); 0000-0001-5659-4774 (V. V. Osadchyi)
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2. Criteria for selecting hardware and software tools to support the study of informatics and telecommunication technologies in secondary education schools

The teacher's use of various types of hardware and software in the informatics curriculum [3] is not limited, provided that it complies with the requirements of current legislation [4, 5, 6, 7]. Also, the program does not specify universal criteria for their selection. Nevertheless, there are the author's systems of criteria for selecting hardware and software tools to support the study of informatics.

Yatsenko and Yatsenko [8, p. 107] propose the following criteria for selecting software:

- criteria related to the capabilities of the programming language:
  - support for writing mathematical expressions in mathematical form;
  - calculation model used (data flow / control flow);
  - support for algorithmic constructs;
- criteria related to the possibility of using the environment at the initial stage of learning programming languages:
  - simplicity, modernity and visual appeal of the interface;
  - availability of methodological manuals;
  - Ukrainian-language interface;
  - cost (free / paid);
- criteria related to technological aspects of the environment:
  - cross-platform;
  - supporting popular robotic constructors;
  - license (proprietary or open);
  - supporting and developing the environment.

Shevchuk [9, p. 31] considers the programming environment as a learning tool to be important characteristics: prevalence, availability, interface features, implementation method, system requirements, methodological support, and user-friendly and intuitive interface.

Bazurin [10, p. 15] notes that the choice of a programming environment for use in the process of learning a programming language is influenced by the following conditions:

- computer specifications and system requirements of the programming environment;
- availability of operating systems and additional software required for the operation of the software environment;
- software environment functionality;
- software environment interface;
- availability of documentation for the software environment;
- availability of educational and methodological support;
- level of competence of an informatics teacher.

Vakaliuk [11, p. 156] outlines the following characteristics that should meet the cloud-based environment: accessibility and mobility; openness; integrity and continuity; efficiency; regularity; consistency and structure; innovation; integration with cloud-based resources; clarity; functionality; collectivity; ensuring project activities; scientificity; reliability; communication; flexibility and adaptability; individualization; fullness; convenience; expediency.

Vorozhbyt [12, p. 29] identifies the following criteria for the use of web-based technologies to create learning content:

- the cost of developing;
- flexibility of use;
- feedback from students;
- clarity of presentation of educational material;
- pedagogical control of knowledge, motivation to study;
- the ability to use multimedia dynamic content;
- educational activities of students;
- cooperation of teachers and students, students with each other.

When choosing a cloud-based platform for mastering the basics of quantum informatics by students of a specialized (high) schools, we took into account the following criteria:

- cross-browser capability;
- intuitive interface;
- possibility of free (unpaid) access;
- simplified registration;
- availability of a systematic help system with examples;
- support for the development of the environment by the developer;
- support for working in a personal educational environment;
- support for working with quantum algorithms in graphical mode;
- automatic conversion of quantum algorithms from graphic format to program code text;
- support for Ukrainian localization;
- availability of the mobile application;
- responsive design.

3. Cloud-based platforms for implementing quantum algorithms

The choice of a cloud-based platform to support the study of the basics of quantum informatics by students of specialized (high) schools was preceded by an analysis of possible platforms for implementing quantum algorithms from Microsoft, QuTech, Amazon Braket, IBM, and other (Alibaba, Google, Intel, D-Wave Systems, Quantum Circuits, IonQ, Honeywell, Xanadu, and Rigetti).

Microsoft via the Azure Quantum cloud-based platform for quantum computing (figure 1) allows visitors to learn how to use the Quantum Development Kit to create applications for

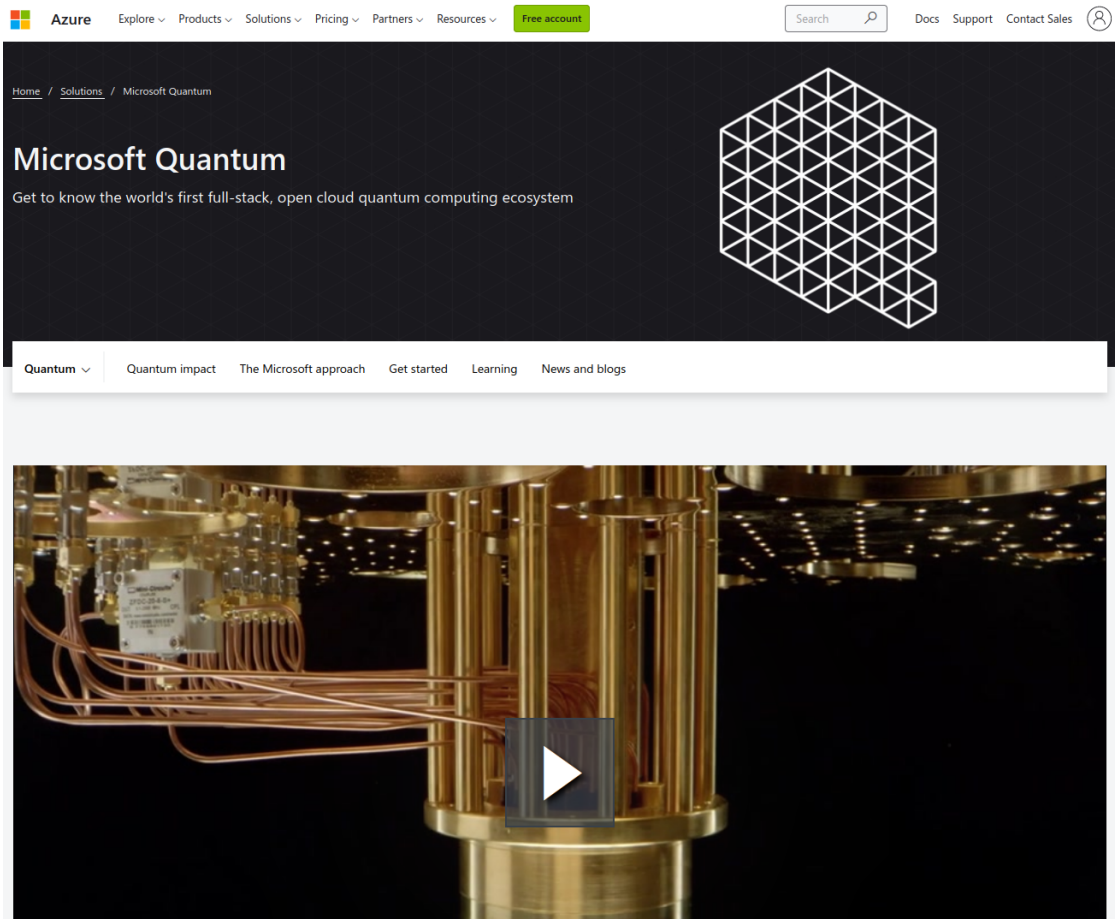

Figure 1: Home page of a cloud-based platform for Azure Quantum computing [13].

quantum equipment in the Q# language. Microsoft does not have its own quantum computer but provides access to Honeywell Quantum Solutions, IonQ, and 1QBit quantum equipment.

The Dutch company QuTech, through a cloud-based platform for Quantum Computing Quantum Inspire, provides free access without registration to educational materials and a quantum simulator, and for registered users – to quantum chips (figure 2).

Online quantum computing service Amazon Braket (figure 3) provides access to quantum equipment for companies D-Wave, IonQ and Rigetti.

IBM was the first to provide cloud access to its own quantum equipment (2016), and now, in our opinion, Quantum Composer and Quantum Lab from IBM provide the greatest opportunities for free use of quantum computers [16].

IIBM quantum simulators run on computers of classical architecture and allow you to simulate the execution of quantum algorithms and calculations. Quantum simulators work faster, so it is recommended that you first test your quantum algorithm on the simulator [18]. At the time of accessing the IBM quantum simulator resource, available for research were simulators from 32 to 5000 qubits (see Table 1).

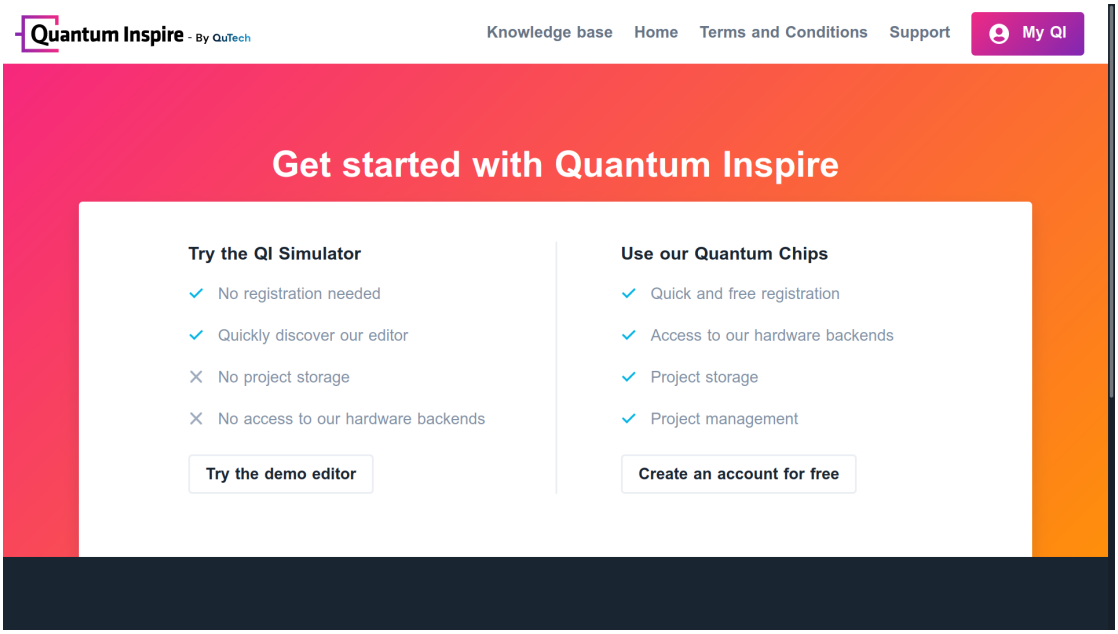

Figure 2: Fragment of the page of a cloud-based platform for quantum computing Quantum Inspire [14].

IBM provides open (free) access to real quantum computers from 1 to 32 qubits (see Table 2). IBM quantum computers with more qubits are available to users on additional terms. The larger the "quantum volume", the larger the circuit can be implemented on its qubits.

4. IBM Quantum as a leading cloud-based platform for quantum computing

IBM Quantum provides the ability to create quantum circuits in the IBM Quantum Composer and to write quantum computer programs in QASM and Python in the IBM Quantum Lab.

4.1. IBM Quantum Composer

IBM Quantum Composer is the simplest set of IBM Quantum tools for creating and graphically visualizing quantum algorithms and then running them on quantum simulators or real IBM quantum computers. In figure 5 shows:

1 – sidebar provides access to your own files, tasks, or documentation. You can open or close the sidebar by clicking the icon on the tab;
2 – menu bar is used to create a new circuit, manage and save circuits, customize the workspace, get help, and more;
3 – account login area and parameter settings for running the quantum circuit;

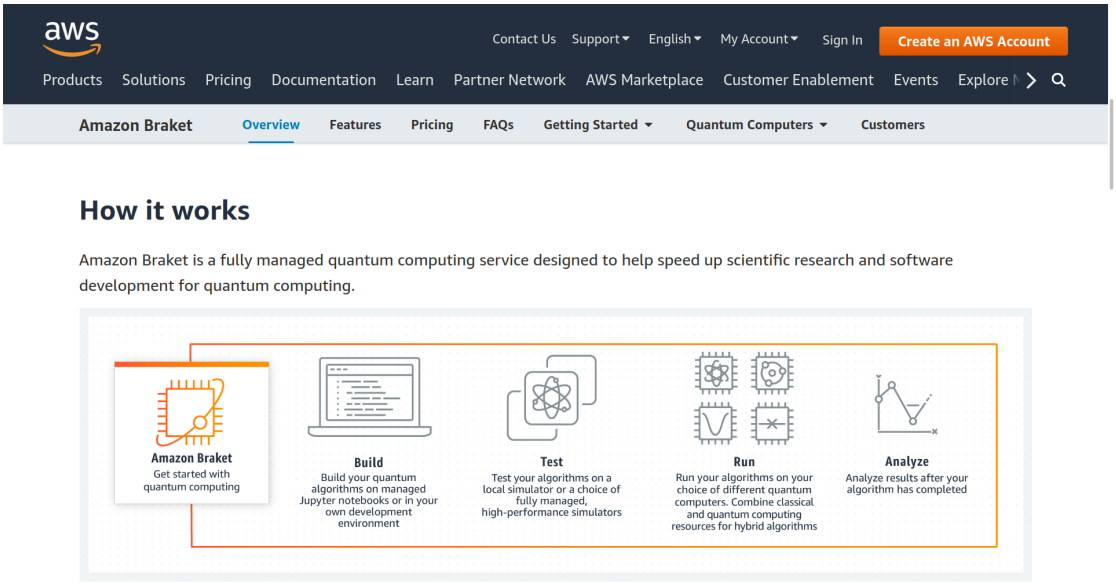

Figure 3: Fragment of the page of a cloud-based platform for quantum computing Amazon Braket [15].

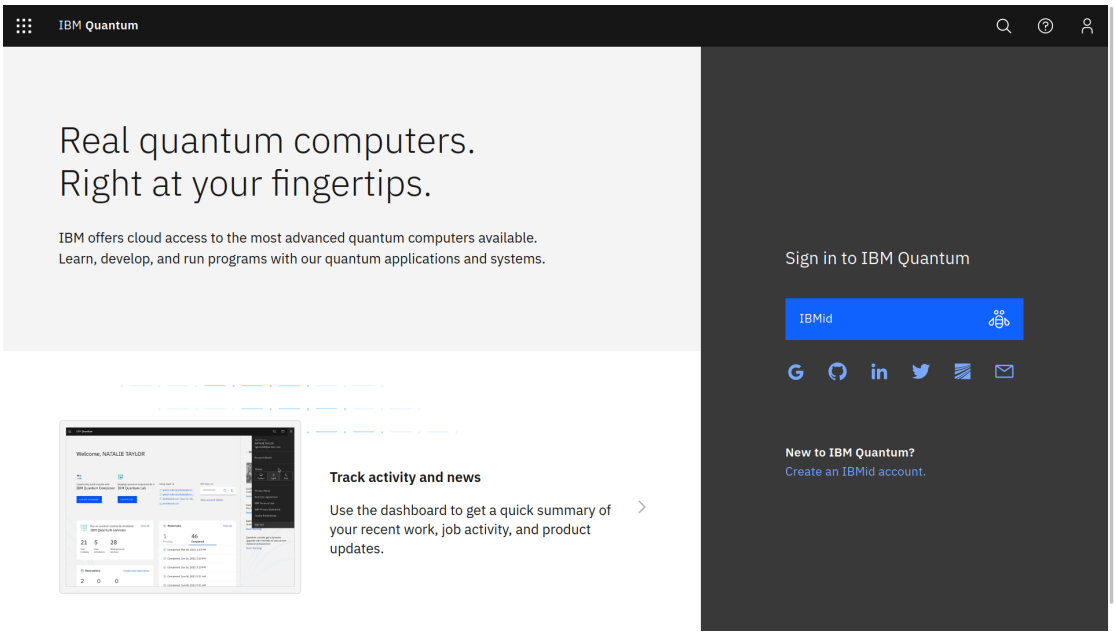

Figure 4: The main page of cloud-based platform for quantum calculation IBM Quantum [17].

4 – quantum gates and the operation panel are the building blocks of quantum circuits. Different types of gates are grouped by color: classic gates are dark blue, phase gates are light blue,

Table 1
Key features of IBM quantum simulators.

Name of the IBM quantum simulator	Qubits	Basis gates
simulator_stabilizer	5000	ID, X, Y, Z, H, S, SDG, SX, SWAP, CX, CY, CZ, DELAY
simulator_mps	100	U1, U2, U3, U, P, CP, CX, CZ, ID, X, Y, Z, H, S, SDG, SX, T, TDG, SWAP, CCX, UNITARY, ROERROR, DELAY
simulator_extended_stabilizer	63	ID, X, Y, Z, H, S, SDG, SX, SWAP, CX, CZ,DELAY, P, CCX, U1, CCZ, T, TDG
simulator_statevector	32	U1, U2, U3, U, P, R, RX, RY, RZ, ID, X, Y, Z, H, S, SDG, SX, T, TDG, SWAP, CX, CY, CZ, CSX, CP, CU1, CU2, CU3, RXX, RYY, RZZ, RZX, CCX, CSWAP, MCX, MCY, MCZ, MCSX, MCP, MCU1, MCU2, MCU3, MCRX, MCRY, MCRZ, MCR, MCSWAP, UNITARY, DIAGOAL, MULTIPLEXER, INITIALIZE, KRAUS, ROERROR, DELAY
ibmq_qasm_simulator	32	U1, U2, U3, U, P, R, RX, RY, RZ, ID, X, Y, Z, H, S, SDG, SX, T, TDG, SWAP, CX, CY, CZ, CSX, CP, CU1, CU2, CU3, RXX, RYY, RZZ, RZX, CCX, CSWAP, MCX, MCY, MCZ, MCSX, MCP, MCU1, MCU2, MCU3, MCRX, MCRY, MCRZ, MCR, MCSWAP, UNITARY, DIAGONAL, MULTIPLEXER, INITIALIZE, KRAUS, ROERROR, DELAY

and non-unitary operations are gray. The button with three dots allows you to open the directory of quantum operations and gates, get help with the use of hotkeys, minimize the panel of quantum operations to one row, save the created quantum circuit as a file in different formats (pdf, svg, png);

5 – graphical circuit editor. Adding operations to be performed on cubes is performed by simply dragging the gate to the area of the graphical quantum circuit editor;

6 – code editor allows you to view and copy automatically generated OpenQASM or Qiskit code for use in other applications;

7 – phase disks represent the phase vector of the qubit state on the complex plane defined by a radial line that rotates counter clockwise;

8 – visualizations of the state of qubits modelling the created circuit in the process of construction.

Elements are presented in Table 3:

- gate H, or Hadamard gate, required to transfer the qubit to the state of superposition;
- Pauli X gate is equivalent to a bitwise negation;
- CNOT gate, also known as the controlled negation gate (CX), acts on a pair of qubits, one of which acts as a control and the other as a target. It executes an negation on the target

Table 2
The main characteristics of IBM quantum computers.

IBM quantum computer	Qubits	Quantum volume	Basis gates	Free access
ibmq_16_melbourne	15	8	CX, ID, RZ, SX, X	Yes
ibmq_5_yorktown	5	8	CX, ID, RZ, SX, X	Yes
ibmq_armonk	1	1	ID, RZ, SX, X	Yes
ibmq_athens	5	32	CX, ID, RZ, SX, X	Yes
ibmq_belem	5	16	CX, ID, RZ, SX, X	Yes
ibmq_bogota	5	32	CX, ID, RZ, SX, X	Yes
ibmq_brooklyn	65	32	CX, ID, RZ, SX, X	No
ibmq_cairo	27	64	CX, ID, RZ, SX, X	No
ibmq_casablanca	7	32	CX, ID, RZ, SX, X	No
ibmq_dublin	27	64	CX, ID, RZ, SX, X	No
ibmq_guadalupe	16	32	CX, ID, RZ, SX, X	No
ibmq_hanoi	27	64	CX, ID, RZ, SX, X	No
ibmq_jakarta	7	16	CX, ID, RZ, SX, X	No
ibmq_kolkata	27	128	CX, ID, RZ, SX, X	No
ibmq_lagos	7	32	CX, ID, RZ, SX, X	No
ibmq_lima	5	8	CX, ID, RZ, SX, X	Yes
ibmq_manhattan	65	32	CX, ID, RZ, SX, X	No
ibmq_manila	5	32	CX, ID, RZ, SX, X	Yes
ibmq_montreal	27	128	CX, ID, RZ, SX, X	No
ibmq_mumbai	27	128	CX, ID, RZ, SX, X	No
ibmq_nairobi	7	32	CX, ID, RZ, SX, X	No
ibmq_paris	27	32	CX, ID, RZ, SX, X	No
ibmq_peekskill	27	–	CX, ID, RZ, SX, X	No
ibmq_quito	5	16	CX, ID, RZ, SX, X	Yes
ibmq_rome	5	32	CX, ID, RZ, SX, X	No
ibmq_santiago	5	32	CX, ID, RZ, SX, X	Yes
ibmq_sydney	27	32	CX, ID, RZ, SX, X	No
ibmq_toronto	27	32	CX, ID, RZ, SX, X	No

qubit each time the control is in a state $|1\rangle$. If the control qubit is in superposition, this gate creates entanglement;

- gate Z changes the sign of the qubit;
- qubit measurement is an irreversible operation that changes the state of the qubit. The measurement result is a traditional bit;
- barrier is useful for visualizing quantum circuits.

IBM Quantum Composer allows you to visualize the circuit of quantum operations and the result in the form of probabilities, the output statevector, graphically on Q-sphere, as well as view the description of the created circuit on the QASM 2.0 or Qiskit quantum assembler with the ability to open the code of the IBM Quantum Lab. Viewing the created circuit in inspector mode allows simultaneous step-by-step viewing of the state of changes in qubits both on the graphical diagram and in the QASM quantum assembler window. IBM Quantum Composer allows you to choose a cloud-based quantum device on which the constructed quantum circuit

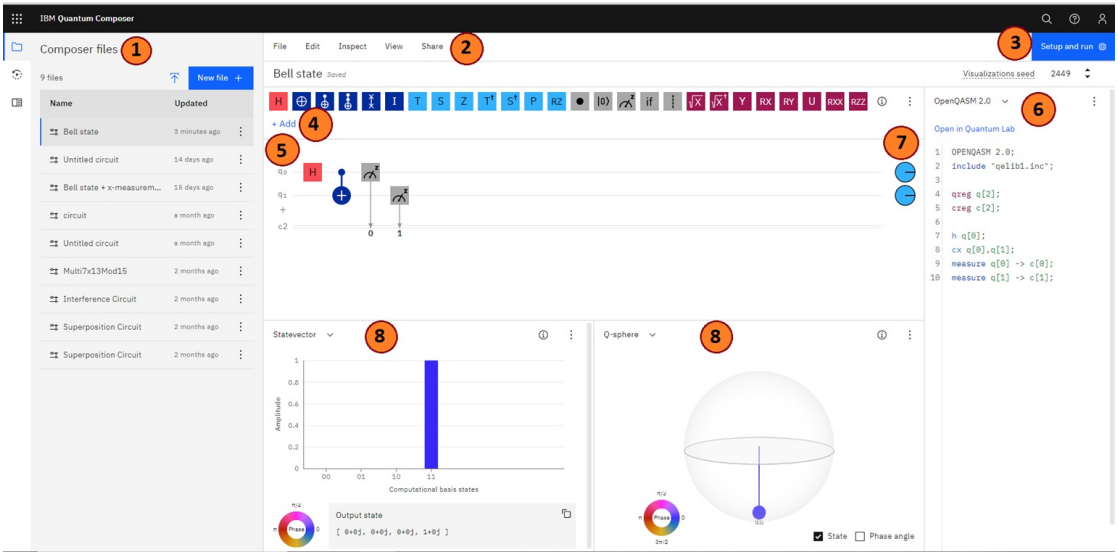

Figure 5: IBM Quantum Composer.

Table 3
Some notations used in IBM Quantum Composer.

Circuit element	Notation in Quantum Composer	Example of use in IBM Quantum Lab	Matrix representation
H gate		circuit.h(qreg)	$H = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$
X gate		circuit.x(qreg)	$X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$
CNOT gate		circuit.cx(qreg)	$CX = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$
Z gate		circuit.z(qreg)	$Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$
Measurement		circuit.measure(qreg, creg)	
Barrier operation		circuit.barrier	

will be calculated. The quantum circuit is read from left to right.

Working with IBM Quantum Composer with access without registration requires using only the simulator.

To take advantage of the great features of IBM Quantum Composer, to be able to choose a simulator, run the circuit on a real quantum hardware, you need to log in with one of your

accounts (Google, GitHub, Twitter, LinkedIn, Fraunhofer or email) or get an IBM account to access trial versions, demos, starter kits, services and APIs. Organizations within the IBM Quantum Network can access the latest quantum computing systems and development tools after submitting and reviewing an electronic application [19].

4.2. IBM Quantum Lab

IBM Quantum Lab is available in any standard browser for viewing quantum circuits, textual explanations to them, and visualizing them, provided that they are authorized (for example, via a Google account). In IBM Quantum Lab, you can create a new program for quantum hardware or open a circuit that was previously built in IBM Quantum Composer through the code editor. The IBM Quantum Lab interface will be familiar to those users who have experience with Python Notebook or Jupyter Notebook (figure 6).

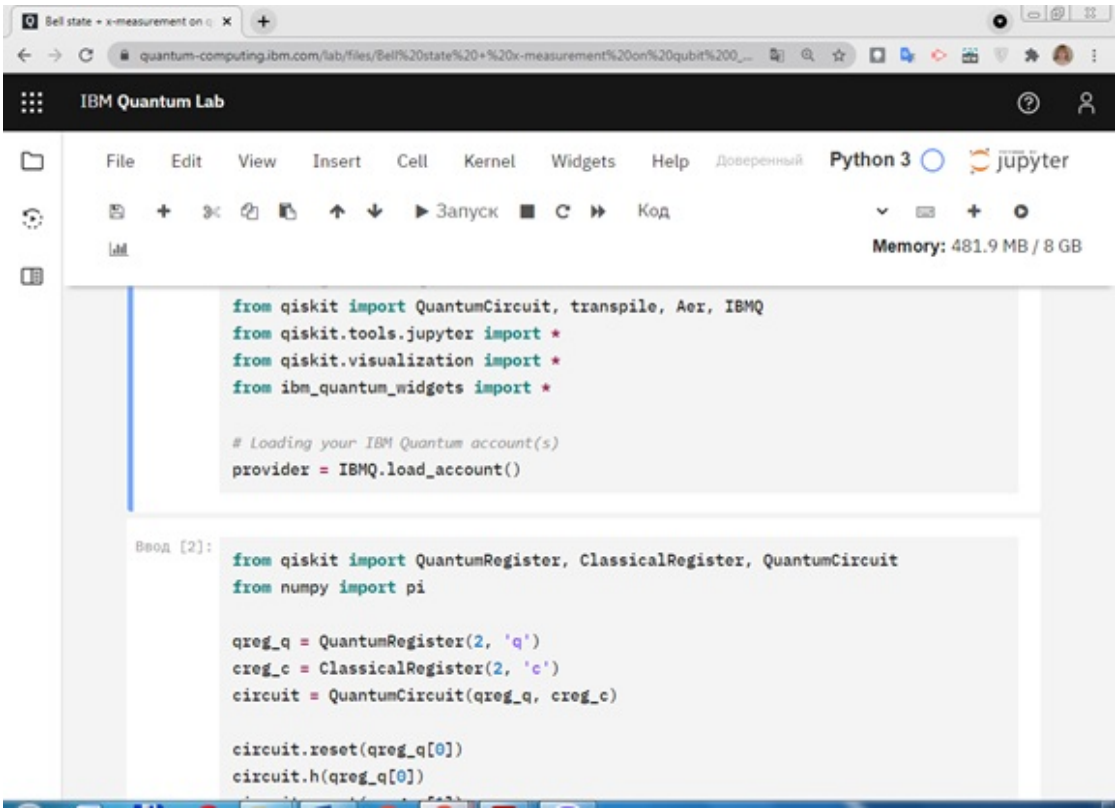

Figure 6: IBM Quantum Lab interface.

A command line is launched using the usual Jupyter Notebook keys: the button “Run” or the key combination Shift + Enter. While constructing a program for quantum equipment, you have to specify the required number of qubits and classical bits (by default, each qubit is set to zero initial state). Then you should add gates (operations) to manipulate them and output the result, or add any way to visualize the constructed quantum circuit.

We will demonstrate the possibilities of implementing quantum algorithms on the platform using the example of the quantum teleportation algorithm. Quantum teleportation is the transfer of quantum states from one qubit to another. Quantum teleportation is not the transport or any physical movement of a qubit from one location to another. In quantum mechanics, the clone (copy) negation theorem applies [20, p. 89]. When copying while working on quantum equipment, an implicit measurement occurs that destroys the current quantum state. To solve this problem, we use quantum entanglement. For qubits to be entangled, they have to interact with each other. Measuring the state of one entangled qubit results in an instantaneous transition to the corresponding state of another entangled qubit.

Here is a verbal description of the quantum teleportation algorithm, the graphical description of which is carried out using the IBM Quantum Composer service and is shown in figure 7:

1) using the Not operation, we will convert the zero qubit to state 1, and leave the first and second qubits in the primary zero states. (Note. This action should be in the example so that we don't pass a NULL value, in fact, the null qubit will contain the value that needs to be teleported);
2) let's convert the first qubit to a superposition by H gate;
3) let's entanglement the first and second qubits with a CNOT gate (where the first is the control one, and the second is the target one. If the control (first) qubit is in state 1, then the target (second) is inverted by the CNOT gate);
4) similarly we entanglement the zero and first qubits;
5) convert a zero qubit to a superposition (using H gate);
6) we measure the states of the zero and first qubits (Measurement operation). The measurement results are stored in two classical bits transmitted by a classical connection;
7) on the side where the state of the zero qubit is passed, there is a second qubit, to which we apply the gates X and Z (in the sequence X or Z, it does not matter what will be the first), as a result, we get the value of the zero qubit in the second qubit;
8) we measure the value of the second qubit.

For step-by-step tracking of the execution of the compiled circuit, you can use the Inspect command (figure 8).

The teleportation result can be seen on the phase disks and the lower part of the Quantum Composer window in state vector, probabilities and Q-sphere.

Let's analyze the appearance of Phase disks after constructing and running a quantum circuit (figure 7):

- for a zero qubit, the phase disk is unpainted, so it is in the state $|0\rangle$;
- for the first and second qubits, the phase disk is completely painted over, so it is in the $|1\rangle$ state.

Consider visualizing the result in Statevector and Q-sphere modes, reading from right to left – 011. Three positions of the resulting binary number indicate that the last qubit has a value of 1. Q-sphere, which can be rotated, relates the calculated value of each qubit of the quantum circuit to a point on the surface of the sphere.

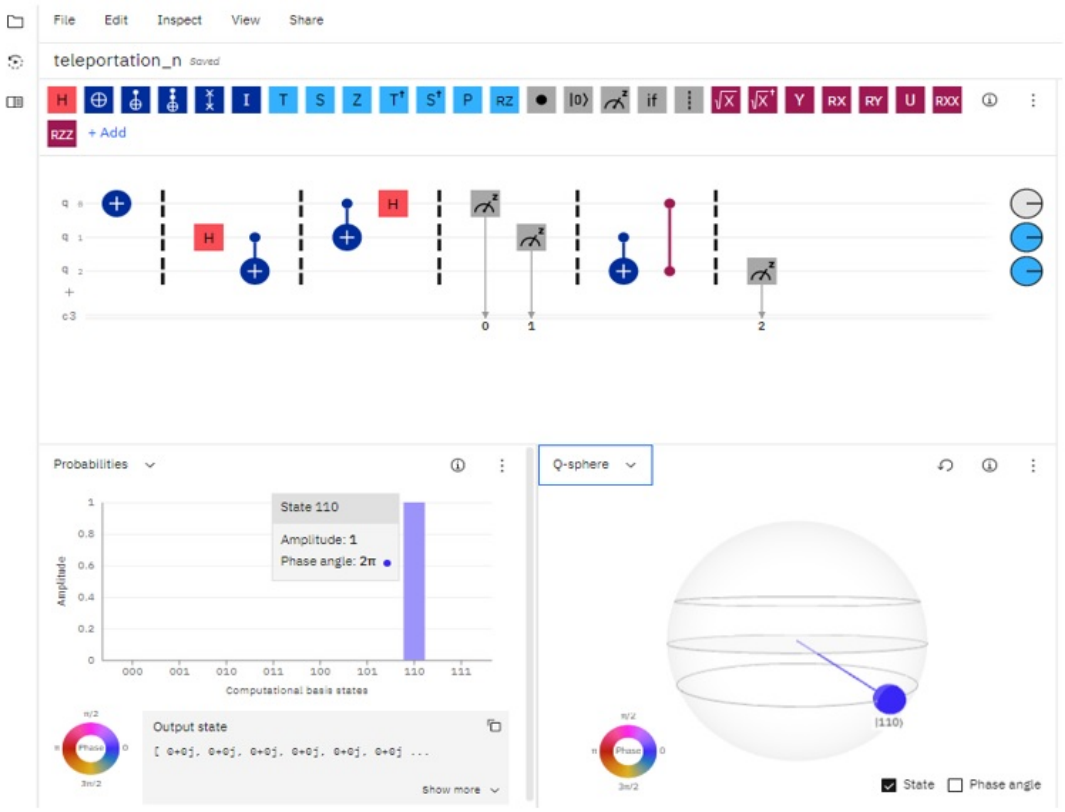

Figure 7: The circuit of the quantum teleportation algorithm for IBM Quantum Composer.

To visualize completed qubit operations in Qiskit Jupyter Notebook, you can use code `%matplotlib inline` and use draw – `QantumCircuite.draw()` – and as a circuit `QantumCircuite.draw(output='mpl')`.

To complete the circuit, configure the simulator. `Qasm_simulator` is an element of Aer in Qiskit – `simulator = Aer.get_backend('qasm_simulator')`.

The results of the circuit performed on the simulator are stored in the corresponding variable. Then they can be displayed as a histogram:

```
from qiskit.visualization import plot_histogram
plot_histogram(result.get_counts(circuit))
```

Executing the circuit on a quantum computer requires using IBM account. To do this run the following commands:

```
IBMQ.load_account();
provider = IBM.get_provider(hub=$'ibm-q'$)
```

Next, you need to choose a quantum computer from those that are available at this time, for example, `qcomp = provider.get_backend('ibmq_16_melbourn')`.

Using IBM Quantum Composer we will open a description of the created circuit in Python:

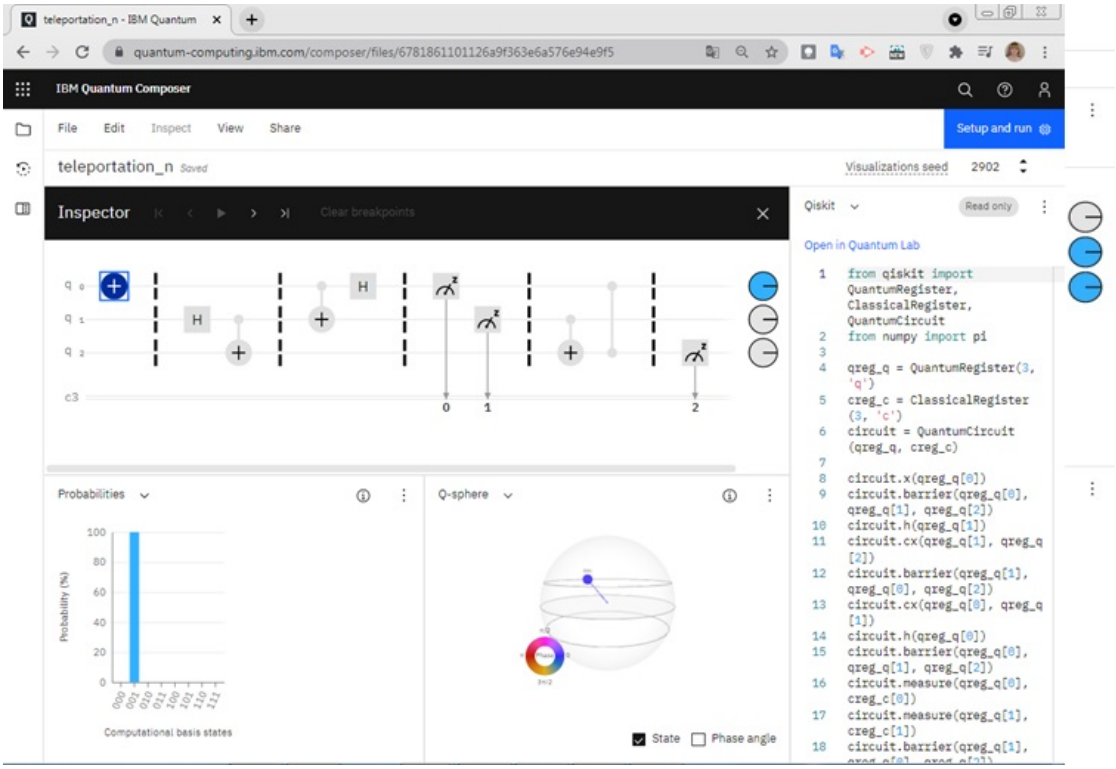

Figure 8: Illustration of step-by-step execution of the diagram via Inspect.

```
import numpy as np
# Importing standard Qiskit libraries
from qiskit import QuantumCircuit, transpile, Aer, IBMQ
from qiskit.tools.jupyter import *
from qiskit.visualization import *
from ibm_quantum_widgets import *

# Loading your IBM Quantum account(s)
provider = IBMQ.load_account()
from qiskit import QuantumRegister, ClassicalRegister, QuantumCircuit
from numpy import pi

qreg_q = QuantumRegister(3, 'q')
creg_c = ClassicalRegister(3, 'c')
circuit = QuantumCircuit(qreg_q, creg_c)

circuit.x(qreg_q[0])
circuit.barrier(qreg_q[0], qreg_q[1], qreg_q[2])
circuit.h(qreg_q[1])
```

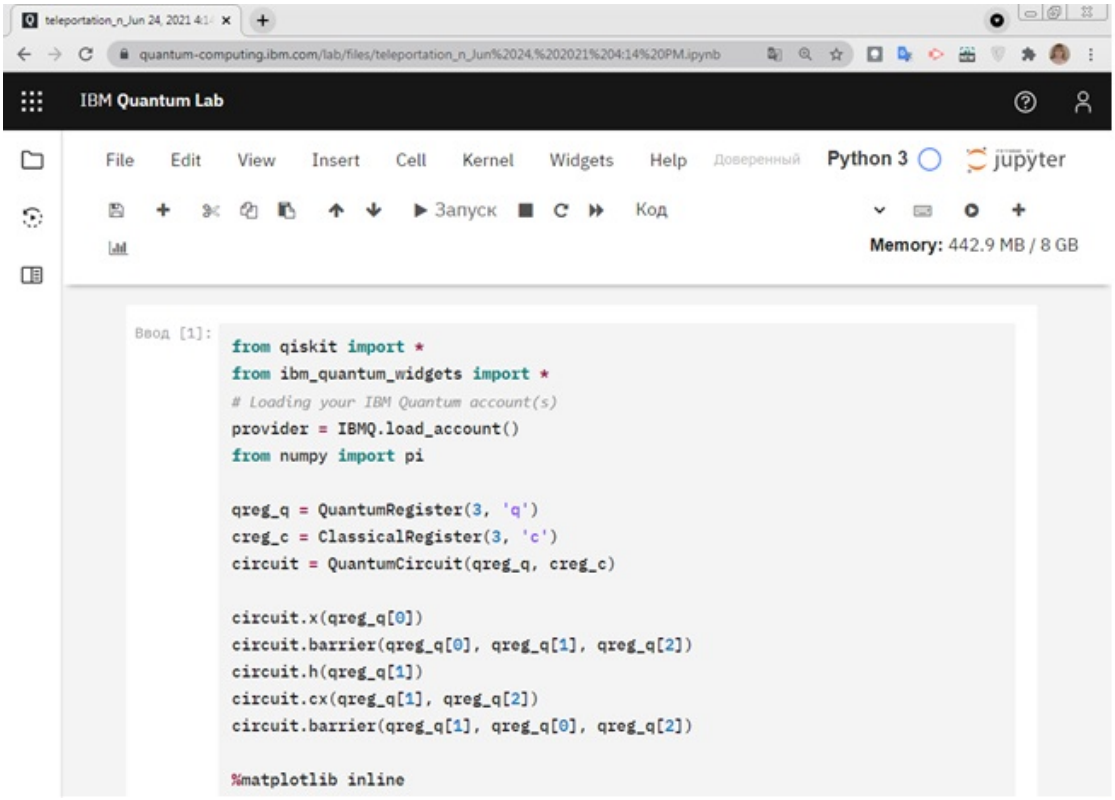

Figure 9: Illustration of performing completed operations with qubits in Qiskit Jupyter Notebook.

```
circuit.cx(qreg_q[1], qreg_q[2])
circuit.barrier(qreg_q[1], qreg_q[0], qreg_q[2])
circuit.cx(qreg_q[0], qreg_q[1])
circuit.h(qreg_q[0])
circuit.barrier(qreg_q[0], qreg_q[1], qreg_q[2])
circuit.measure(qreg_q[0], creg_c[0])
circuit.measure(qreg_q[1], creg_c[1])
circuit.barrier(qreg_q[1], qreg_q[0], qreg_q[2])
circuit.cx(qreg_q[1], qreg_q[2])
circuit.cz(qreg_q[0], qreg_q[2])
circuit.barrier(qreg_q[1], qreg_q[0], qreg_q[2])
circuit.measure(qreg_q[2], creg_c[2])

editor = CircuitComposer(circuit=circuit)
editor
```

Changes can be made to the above code, and a diagram can be added at intermediate stages, for example, after each gate barrier:

```
editor = CircuitComposer(circuit=circuit)
editor
```

Taking into account the formulated and illustrated capabilities of the IBM Quantum cloud-based quantum computing platform, in particular, the IBM Quantum Composer and IBM Quantum Lab services, as well as the results of comparing the capabilities of analog platforms according to the constructed system of criteria (Table 4), it was found that this platform is the most acceptable in support of mastering the basics of quantum informatics by students of specialized (high) schools. First of all, because this platform has free access, is constantly being improved by the developer, and provides the ability to implement quantum algorithms graphically with synchronous conversion to program code (in QASM mode – quantum assembler or Qiskit with support for Python 3.6 and higher).

Table 4
Compliance with the criteria for the main characteristics of cloud-based platforms for the implementation of quantum computing.

Criterion (characteristic)	Microsoft	QuTech	Amazon Braket	IBM
cross-browser capability	+	+	+	+
intuitive interface	+	+	+	+
access without registration and simplified registration	identification by phone number or bank card	+	identification by phone number, address	+
possibility of free access	+	+	+	+
availability of a systematic help system with examples	-	+	-	+
support for the development of the environmen t by the developer	+	+	+	+
support for working in a personal educational environment	?	+	?	+
support for working with quantum algorithms in graphical mode	?	-	?	+
automatic conversion of quantum algorithms from graphic format to program code text	?	-	?	+
support for Ukrainian-language localization	-	-	-	-
availability of the mobile app	-	-	-	-
responsive design	+	+	+	-

Currently, the lack of Ukrainian localization of the IBM Quantum interface is not a significant problem for students in grades 10-11. With such an organization of training, it is natural to develop their key multilingual competence. Due to the rapid development of the IBM Quantum platform, we can hope for the emergence of responsive design and a mobile application.

5. Conclusions

So, based on the outlined criteria for selecting a cloud-based platform for mastering the basics of quantum informatics in general secondary education institutions, analysing the possibility of platforms for implementing quantum algorithms of leading companies, a cloud-based platform IBM Quantum that meets certain criteria in the best way for studying the basics of quantum informatics have been determined.

At the moment, the experimental implementation of educational and methodological materials on the basics of quantum programming in the educational process of a specialized (high) schools has been completed, and the results obtained are being processed.

References

[1] L. V. Lehka, S. V. Shokaliuk, E. Y. Bogunenko, Propaedeutics of studying quantum computer science in a specialized (high) school, Physical and Mathematical Education 28 (2021) 51–56. doi:10.31110/2413-1571-2021-028-2-009.

[2] L. V. Lehka, A. O. Bielinskyi, S. V. Shokaliuk, V. N. Soloviev, P. V. Merzlykin, Y. Y. Bohunenko, Prospects of quantum informatics and the study of its basics in the school course, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[3] Curricula for grades 10-11, 2021. URL: https://mon.gov.ua/ua/osvita/zagalna-serednya-osvita/navchalni-programi/navchalni-programi-dlya-10-11-klasiv.

[4] President of Ukraine, On the decision of the national security and Defense Council of Ukraine of April 28, 2017 "On the application of personal special economic and other restrictive measures (sanctions)", 2017. URL: https://zakon.rada.gov.ua/go/133/2017v.

[5] President of Ukraine, On the decision of the National Security and Defense Council of Ukraine of May 2, 2018 "On the application and cancellation of personal special economic and other restrictive measures (sanctions)", 2018. URL: https://zakon.rada.gov.ua/go/126/2018.

[6] Law of Ukraine "On copyright and related rights", 1993. URL: https://zakon.rada.gov.ua/go/3792-12.

[7] Cabinet of Ministers of Ukraine, On approval of regulations on the distribution of copies of audiovisual works, volumes, videograms, computer programs, databases, 2000. URL: https://zakon.rada.gov.ua/go/1555-2000-%D0%BF.

[8] O. I. Yatsenko, O. S. Yatsenko, Criteria and indicators for selecting the playing environment for the development of information and communication competence of future primary

school teachers, Actual issues of modern computer science 12 (2019) 105–108. URL: http://eprints.zu.edu.ua/31178/1/Zbirnuk_Zhytomyr_IKT_2019-2.pdf.
[9] P. Shevchuk, The problem of choosing a programming language and environment as a learning tool, 2010, pp. 30–31. URL: http://eprints.zu.edu.ua/id/eprint/13592.
[10] V. M. Bazurin, Programming environments as a means of teaching pupils to programming basics, Information Technologies and Learning Tools 59 (2017) 13–27. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1601. doi:10.33407/itlt.v59i3.1601.
[11] T. A. Vakaliuk, Features cloud oriented learning environment for training bachelors information, Naukovyi chasopys NPU imeni M.P. Drahomanova. Seriia 2. Kompiuterno-oriientovani systemy navchannia (2019) 154–157. URL: https://sj.npu.edu.ua/index.php/kosn/article/view/28.
[12] A. V. Vorozhbyt, Using web-based technologies in learning Informatics in the establishments of general secondary education, Thesis for a candidate degree in pedagogical sciences, specialty 13.00.02 – theory and methods of teaching (computer science), National Pedagogical Dragomanov University, Kyiv, Ukraine, 2019. URL: https://old.npu.edu.ua/images/file/vidil_aspirant/dicer/%D0%94_26.053.03/Vorozhbyt.pdf.
[13] Microsoft, Microsoft Quantum, 2022. URL: https://azure.microsoft.com/solutions/quantum-computing/.
[14] QuTech, Quantum Inspire, 2022. URL: https://www.quantum-inspire.com/features/.
[15] Amazon Web Services, Amazon Braket: Accelerate quantum computing research, 2022. URL: https://aws.amazon.com/braket/?nc1=h_ls.
[16] Five years ago today, we put the first quantum computer on the cloud. Here's how we did it, 2021. URL: https://research.ibm.com/blog/quantum-five-years.
[17] IBM Quantum, 2021. URL: https://quantum-computing.ibm.com/.
[18] IBM Quantum Services – Simulators, 2021. URL: https://quantum-computing.ibm.com/services?services=simulators.
[19] Contact IBM Quantum, 2021. URL: https://www.ibm.com/it-infrastructure/us-en/resources/campaignmail/quantum-computing/contact/.
[20] V. Silva, Practical Quantum Computing for Developers: Programming Quantum Rigs in the Cloud using Python, Quantum Assembly Language and IBM QExperience, Apress, 2018.

Using the Yammer cloud service to organize project-based learning methods

Dmytro M. Bodnenko[1], Halyna A. Kuchakovska[1], Oleksandra V. Lokaziuk[1,2], Volodymyr V. Proshkin[1], Svitlana H. Lytvynova[3] and Olha H. Naboka[4]

[1]*Borys Grinchenko Kyiv University, 18/2 Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine*

[2]*Institute of Mathematics NAS of Ukraine, 3 Tereschenkivska Str., Kyiv, 01024, Ukraine*

[3]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[4]*Donbas State Pedagogical University, 19 Henerala Batyuka Str., Sloviansk, 84116, Ukraine*

Abstract

The article reveals and interprets the key features of project-based learning based on cloud-based services: social activity; convenient communication in a team during the project implementation and at the resulting stage; open educational space; self-learning and self-improvement; use of interdisciplinary links to combine students of different years of study (1–4 degrees of the first (bachelor's) level and students of the second master's level) to joint research teams to study through research; purposeful motivation of cognitive and research activity of students within the discipline with the use of interdisciplinary connections; formation of digital literacy of students. The advantages and disadvantages of the Yammer cloud service are presented and a comparative analysis of this service with similar cloud services is performed. Examples of using Yammer in professional project activity are given. The stages of using project methods using the small group method are analyzed and detailed: initiation; planning; conducting/implementation; presentation; assessment/defense.

Keywords

cloud service, Yammer, corporate social network, project teaching methods

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1. Introduction

One of the important tasks of modern university education is to improve the quality of professional student's training. This encourages teachers to update the content, forms, and methods of

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d.bodnenko@kubg.edu.ua (D. M. Bodnenko); h.kuchakovska@kubg.edu.ua (H. A. Kuchakovska); o.lokaziuk@kubg.edu.ua (O. V. Lokaziuk); v.proshkin@kubg.edu.ua (V. V. Proshkin); s.h.lytvynova@gmail.com (S. H. Lytvynova); olganaboka911@gmail.com (O. H. Naboka)

https://fitu.kubg.edu.ua/pro-fakultet/kafedry/2016-06-16-07-27-24/sklad/513-no-name.html (D. M. Bodnenko); https://fitu.kubg.edu.ua/pro-fakultet/kafedry/2016-06-16-07-27-24/sklad/555-no-name.html (H. A. Kuchakovska); https://www.imath.kiev.ua/people/profile.php?pid=468 (O. V. Lokaziuk); https://fitu.kubg.edu.ua/pro-fakultet/kafedry/2016-06-16-07-27-24/sklad/508-no-name.html (V. V. Proshkin); https://iitlt.gov.ua/structure/departments/technology/detail.php?ID=49 (S. H. Lytvynova); https://esu.com.ua/search_articles.php?id=71391 (O. H. Naboka)

0000-0001-9303-6587 (D. M. Bodnenko); 0000-0002-4555-896X (H. A. Kuchakovska); 0000-0001-9663-251X (O. V. Lokaziuk); 0000-0002-9785-0612 (V. V. Proshkin); 0000-0002-5450-6635 (S. H. Lytvynova); 0000-0003-4635-0009 (O. H. Naboka)

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teaching to increase student motivation, ensuring the implementation of the principle of practice orientation. Project-based learning or project-based learning technologies are becoming increasingly popular among modern teaching methods [1, 2]. These are educational technologies aimed at acquiring knowledge in close connection with real-life practice, the formation of relevant skills and abilities through the systematic organization of problem-oriented learning. A characteristic feature of project-based learning is that problems must be meaningful to students, in fact, become their own problems. In addition, as noted by Barron and Darling-Hammond [3], students not only work in groups to solve real-life problems but also learn to feel responsible for the work done. Teachers play the role of coaches and facilitators. In today's conditions, characterized by the dynamic introduction of distance education, there is a significant question of organization and implementation of project-based learning methods. Therefore, the study of the possibilities of digital tools and services to address this issue is relevant.

2. The objective of research

In the works of Berezhna et al. [4], Glazunova et al. [5], Gryshchenko et al. [6], Horbatiuk et al. [7, 8], Iatsyshyn et al. [9], Pavlenko and Pavlenko [10], Podlasyi [11], Valko et al. [12], Vlasenko et al. [13], the advantages of using project method in the educational process, historical aspects of the formation of project-based teaching methods are highlighted. Thus, Dzyabenko et al. [14] notes that the project method is a way to achieve a didactic goal through the detailed elaboration of the problem (technology), which should end with a real practical result, designed in one way or another; a set of techniques, actions in a certain sequence to achieve the task - solving a problem that is personally significant for students and designed as a certain final product. The scientific developments of foreign scientists deserve attention. So, Blumenfeld et al. [15] found that the project method has the potential for learning, analyzed how it affects student motivation, identified difficulties that students and teachers may face in the process of working on projects. Tseng et al. [16] proved that combining project-based learning methods with STEM can increase effectiveness, generate meaningful learning, and influence student attitudes in future career pursuit. Kokotsaki et al. [17] proved that modern digital technology, group processes of high quality, teachers' ability to effectively scaffold students' learning and provide guidance and support, the balance between didactic instruction with in-depth inquiry methods and well-aligned assessment have been identified in the literature as facilitating factors in the implementation of PBL. In addition, it is worth noting results of researches in which theoretical and methodical bases of project teaching methods realization are revealed, among them Ayas and Zeniuk [18], Macias-Guarasa et al. [19], DeFillippi [20].

Theoretical and methodological principles of education informatization are presented in the works of Bykov [21], Fedorenko et al. [22], Holiver et al. [23], Pochtovyuk et al. [24], Smyrnova-Trybulska et al. [25], Velychko et al. [26]. Of particular interest in the issues of our article are studies on the use of social networking service in the educational process.

Thus, in the previous work of the authors of this article, the ways of organization of control and analysis of students of higher education institutions success by means of social services and social networks are considered; the advantages and disadvantages of using existing means of social services and social networks in conducting various types of control are analyzed;

examples of social services use of Instagram, Google Forms, Kahoot and English-language services Quizalize and Nearpod [27]. In works [28, 29, 30, 31, 32, 33] examples of the use of social networks for implementing the educational process, including social network Yammer [34] are given. The negative consequences of excessive use of social networks are given [35].

The purpose of the article is to reveal the possibilities of the cloud service Yammer for implementing project teaching methods in the process of professional training of students.

This purpose is specified in the following *tasks*:

- to find out the attitude of lecturers to the use of project-based teaching methods, in particular with the help of cloud services;
- to outline the specifics of the corporate social network Yammer as a cloud service;
- to give a comparative description of the Yammer social network on the example of the online service Keepteam and messengers;
- to reveal practical and methodical aspects of using the Yammer network for implementing project-based learning methods.

3. Research methodology

The following methods were used in the research process: analysis of scientific and pedagogical literature on the selection of features, stages of project teaching methods implementation in the educational process; analysis of online resources, methodological literature on generalizing the possibilities of social networks for the realization of project-based learning methods at different stages of implementation; study and generalization of pedagogical experience in the use of social networks in education; survey of university teachers in order to identify the problem area of the study. The survey of teachers of Borys Grinchenko Kyiv University was conducted during May 2021, the experimental project activity of students was carried out during March–June 2021.

4. Results and discussion

In May 2021, we conducted a survey of 25 experts — teachers of Borys Grinchenko Kyiv University, who have experience in using project-based teaching methods. The survey was conducted to find out the attitude of lecturers to the use of project-based teaching methods, in particular through cloud services. We did not aim to reconcile the respondents' opinions. It was more important to outline the main areas that make up the problem ares of research. Respondents were asked to answer the following questions:

1. Indicate the main advantages of project-based learning methods.
2. Do you have the necessary knowledge to implement project-based learning methods in distance education?
3. Do you have experience in implementing project-based learning methods using cloud services? If so, what problems do you face?

As a result, we have identified the main features of project-based learning:

- social activity that takes place within groups of students;
- the opportunity to use not only knowledge of academic disciplines, but also to learn to negotiate, make joint decisions, be responsible in accordance with the role in the training team, interpret the results of their activities;
- open educational space in which students move at their own pace;
- students' need for self-study and self-improvement;
- the possibility of attracting students of different courses; for junior students, it is better to use creative, game and practice-oriented types of projects; for senior students, it is more expedient to use research types of projects that are more complex and close to the real scientific research of the master;
- increasing the level of students' interest in a particular discipline (research area);
- improving students' skills to navigate in the information space;
- the need to get out of narrow specialization and integrate knowledge from different disciplines, etc.

In addition, our own experience of using project methods, using the method of small groups, made it possible to highlight their stages of implementation:

1) initiation (choice of topic and selection of ideas);
2) planning (modeling of realization algorithm of the future project);
3) conducting/implementation (practical implementation of the project plan: search and processing of materials on the selected topic, analysis, and synthesis of selected information, adaptation of the material to the project format, research, step-by-step control of tasks, formation of further goals and clarification of mechanisms);
4) presentation (demonstration of results);
5) evaluation/defense (control of tasks under the plan/protection of completed projects), etc.

As a result of conversations with experts, problematic issues were identified. Thus, the vast majority of teachers (65%) do not have the knowledge to implement project-based learning methods in distance education, in particular through social services (figure 1).

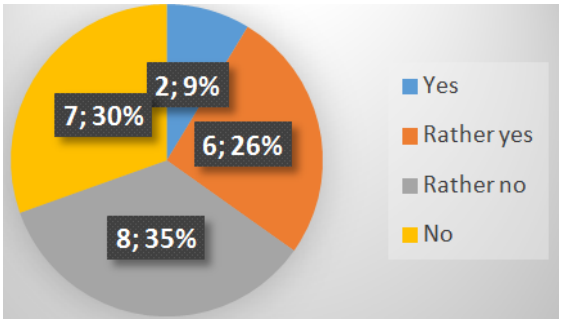


Figure 1: The results of a survey on implementing project-based learning methods using cloud services.

Some teachers (32%) note the effectiveness of implementing project teaching methods using cloud services (figure 2). Moreover, this is associated with the imperfection of the development

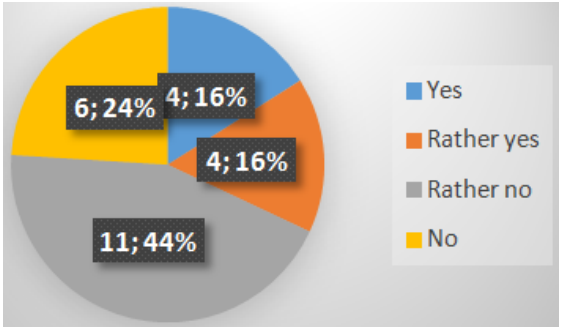


Figure 2: The results of a survey on implementing project-based learning methods using cloud services.

of methods for using digital tools and services for the implementation of distance learning in general and project-based learning methods in particular.

The disappointing results of the teacher survey motivate us to search for new digital tools for the implementation of project-based teaching methods. As such tools, consider social networks, given their popularity among participants in the educational process (students and teachers). As you know, there are currently quite a lot of social networks, but their methodological and didactic potential has not been sufficiently revealed. This is especially true of social networks within the corporate network. One such social network is Yammer. This is a private social network from Microsoft, which is integrated into the Microsoft Office 365 (corporate) software package. Yammer helps you stay in touch with the people you need, share information with workgroups, and organize projects. Only employees of a certain company can join, so communication in Yammer will be safe and visible only to people from a certain organization.

In the updated version of Yammer from 2016, all Microsoft Office 365 plans are integrated with Yammer Corporate, all Office 365 subscribers receive the appropriate licenses. In addition, Microsoft has introduced the Yammer Partner Enablement program, in which students (future specialists of the corporation) can share their experience in the field of promotion and realization of successful corporate social projects.

Why was the social network chosen to implement project-based learning methods?

Yammer can create teams to work together in teams and organizations, exchange files and collect feedback. As part of the service, you can configure the profile of the project team with photos, basic information about the group, and its members. It is clear that Yammer is not the only social service that can implement project-based learning methods. It can be compared, for example, with other cloud services and messengers (table 1).

Highlight Yammer features for the organization of project activity:

- *Joining a group.* Groups are an opportunity to work in a team or to stay up to date on a particular issue. The general group of the company is the group in which everyone can publish; each automatically becomes a member of this group. It is possible to join any public group, but you will need an invitation to join a private group.
- *Track user actions.* Following a user on the Yammer network means viewing his message on the news feed. Yammer allows you to search for people by name using the search box,

Table 1
Comparison Yammer capabilities and other services (✓- function available, x - the function is absent, $ - the function is available only in the paid version).

	Yammer	Slack	Viber	Telegram	Skype
Text messages	✓	✓	✓	✓	✓
Voice calls	x	x	✓	✓	✓
Video calls	x	x	✓	x	✓
Sending files	✓	✓	✓	✓	✓
Integration with third-party add-ons-file repositories, mail, other messengers, etc.	✓	✓ (30 d. free)	x	x	x
Protection against "information garbage"	x	✓	x	x	x
Access to the full message archive	✓	✓	✓	✓	✓
Ability to save files	✓	✓	✓	✓	x
Minimum price per user per month	$\approx 5\$$	$\approx 7\$$	–	–	–
Supported platforms	Mac, Win, Linux, iOS, Android, Windows Phone, Web	Mac, Win, Unix, iOS, Android, Web	Mac, Win, Unix, iOS, Android, Web, Phone	Mac, Win, Unix, iOS, Android, Windows Phone, Web	Mac, Win, Unix, iOS, Android, Windows Phone, Web

or to view the general information channel of the company, and to track the user whose message was interesting to you.

- *The answer is in the conversation.* The convenience of keeping the conversation makes the Yammer network especially useful. When an employee responds to a message, Yammer begins the chain. This simplifies the tracking of the entire conversation. To reply to a message, click the Reply button below the message, where the reply field will be displayed.
- *Notification of the message by pressing the "Like" button.* Yammer lets you say that you like the message.
- *Joining the conversation.* A web channel is a source of information. A web channel is a source of information.

Considering the selected features of Yammer, we indicate its capabilities for the implementation of project-based learning methods.

The work on the project consists of five stages. At the first stage, students are offered a topic. The teacher pays attention to the relevance of the chosen topic, awakens students' interest in the project, outlines the problem area of educational research, emphasizes significance, offers different perspectives on the topic. At this stage, the purpose and objectives of the study are formulated. Here are some examples of projects:

1. Overview of business models and types of analytics.

2. Familiarity with Google-tables in the implementation's context of information-analytical activities, including elements of descriptive and mathematical statistics.
3. Use of analytical activities in e-commerce using Google Analytics, Amplitude.
4. Databases and SQL — a declarative programming language for user interaction with databases, used to generate queries, update and manage relational databases, create a database schema and modify it, control system for access to the database.
5. Comprehensive business intelligence software from Microsoft Power BI.
6. Python review for data analysis.
7. Model on request On-Demand. We are one click away.

Let's highlight the Yammer functions for implementing the **first stage**: maintaining connections within the team. The Yammer network is a fast and convenient way to keep in touch with the team, discuss ideas, share news, communicate and share the experiences of other team members. Data exchange. The Yammer network is communication, file sharing, collaboration in teams on projects and specific topics. If necessary, partners from external educational institutions and organizations can be involved with the help of secure communication channels.

At the **second stage**, the organization of activity is carried out. The research project is implemented in groups created by the teacher. For each group the purpose, tasks are defined, the role of each participant of the research is outlined. Thus, one group investigates general scientific methods (analysis, synthesis, abstraction, generalization, etc.); another – methods of empirical research (survey, observation, experiment), the next – information and forecasting techniques (cognitive mapping, modeling, analysis of the decision-making process, expert evaluation, etc.), another group – methods of presenting information in information documents (extraction, paraphrasing, interpretation), etc. Use the Yammer function – a combination of leadership and command. Leaders and team members in terms of distance education are scattered territorially. It is important to know what the team members are doing and that the plans of the different people have been agreed upon.

In the **third stage**, the teacher announces certain problem situations. The groups decide whether the techniques they are considering can solve real professional problems. In the process of discussing the project, an action plan is developed, a bank of ideas and proposals is created. Systematization and generalization of work results is carried out. To implement the second and third stages, in addition to the above functions, Yammer uses the following: Connecting and engaging all colleagues. The Yammer network is a powerful and secure mobile application that takes collaboration to the next level by keeping team members anywhere, anytime.

At the **fourth stage** there is a presentation of research products. This stage is necessary for further analysis of the study, self-assessment, evaluation by experts (individual students or visiting graduate students, teachers). At the stage of presentation, students are required to concisely and logically coherently build a message, use clarity, adhere to the structure of the report. Let's select Yammer functions for the realization of the specified stage:

1. *Work in Office programs without any problems.* The Yammer network is a social network integrated with Office programs, which allows you to work productively with the help of the usual interface and file-sharing functions.

2. *Interaction with colleagues.* The Yammer network is an exchange and retrieval of information between management and team members; it is an encouragement and a reaction to the feedback; this is a recognition of merit and encouragement of diligence of team members.
3. *Dissemination and receipt of information.* The Yammer network is an announcement for the whole company, exchange of notes with additional details after important meetings, exchange of key news.

The research project is evaluated/defended at the **fifth stage** according to the following criteria: research nature of the work; reliability of collected facts; literacy and logic of presentation; presentation skills (speech culture, clarity, and illustration). They use the Yammer function – providing feedback because it is important to give team members the right to vote and show that you hear them. The Yammer network is a live chat with the entire company with questions and answers, a call of employees to answer your questions with questions or answers.

So, the outlined Yammer possibilities are a convincing argument for purposeful teaching of students in the context of the use of project teaching methods using the method of small groups. At the same time, the experience of implementing project teaching methods and conversations with students highlighted the problems of students' low awareness of the possibility of using cloud technologies. In order to solve the problem related to the weak knowledge of students about the implementation of project teaching methods with cloud technologies, we developed an e-learning course module in the LMS Moodle system on the topic "Creating educational content through corporate social service Yammer".

This module contains tasks related to the use of the project method aimed at the implementation of cooperative students' learning. Note that cooperative learning is not so much a form of learning as a special method of organizing educational activities in the group, which is based on positive interdependence between individuals in the process of learning, and the result of such educational activities is created by joint efforts final product [36, 37, 38].

A content module was created to study "Using Yamer in professional activities". The module takes into account the authors' research on the use of social services for teaching students [37] and the role of informatization in changing the competencies of high school teachers [38]. The created module is added to computer science disciplines with the help of LMS Moodle for students of the following specialties: "Applied Technologies: ICT in research and teaching", "Communicative Strategies of Oriental Language: Module ICT in Professional Activity" (discipline "Information and Analytical Studies: Modern Information Systems and Technologies"), "International Information" (discipline "International Information: ICT in International Information"), "English Philology" (discipline "Information Technology in Foreign Languages: Modern Information Technology in Foreign Languages"), etc.

In addition, the participants got acquainted with the module "Use of ICT in education" created by the scientific student group of Borys Grinchenko Kyiv University. Note also that the module "Creating educational content through corporate social service Yammer" was created for information technology disciplines taught to undergraduate and graduate students. "Module Creation of educational content by means of corporate social service Yammer" contains the following components: lectures (1. History of development and general characteristics of cloud service; 2. Online analogue of the wall for notes – Yammer service; 3. Advantages and disad-

vantages; 4. Using Yammer in professional activities) and presentation of the submitted topic; practical work (15 detailed tasks for mastering the skills of work in the service); video manual (step-by-step instructions for performing most tasks of practical work); glossary (dictionary of terms); test to test knowledge.

On figure 3 a screenshot element of the training course "Creation of educational content by means of corporate social service Yammer" in the LMS Moodle system.

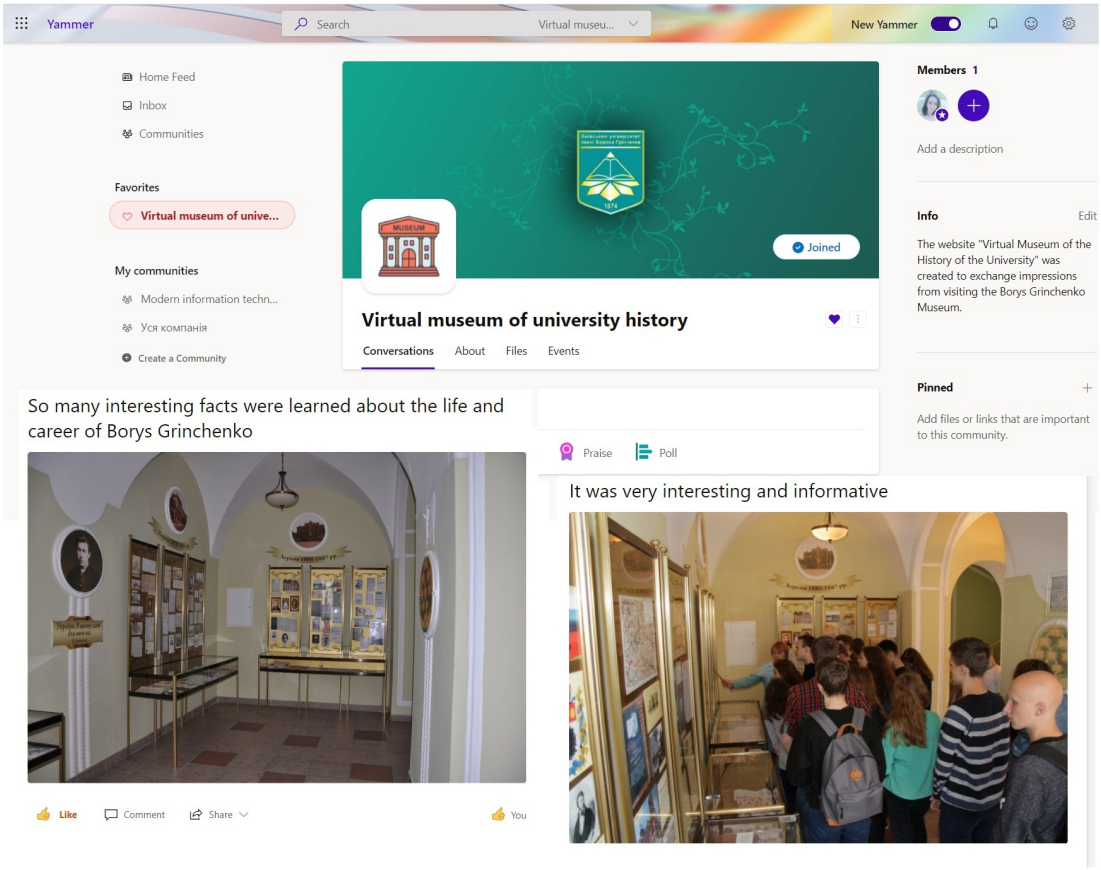
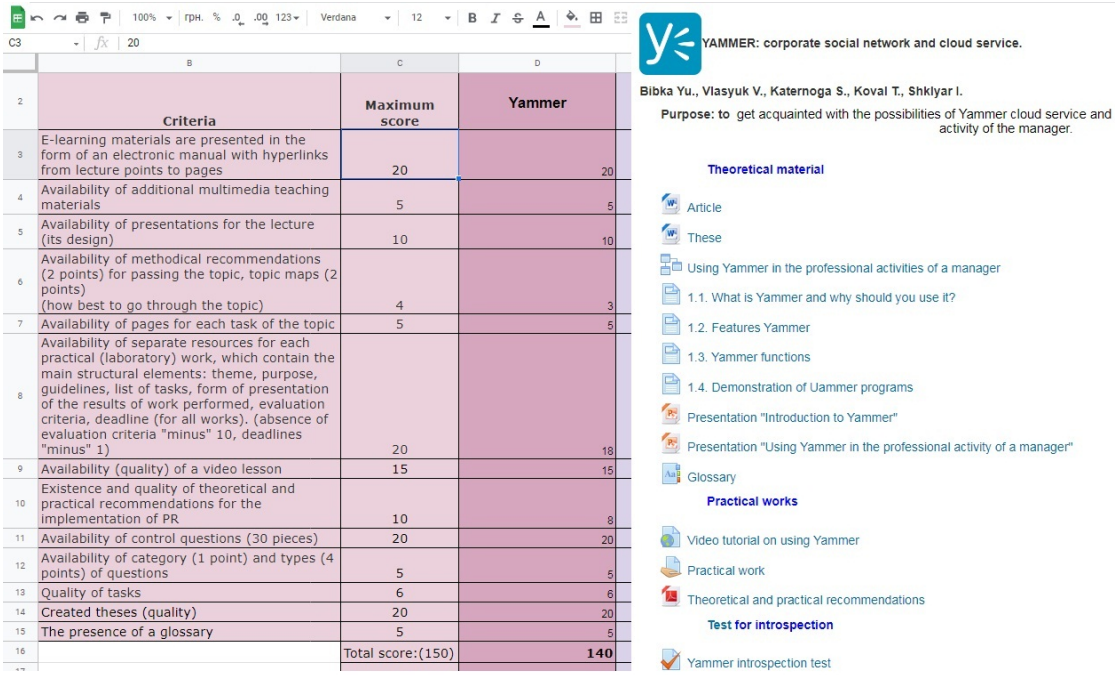


Figure 3: Creation of educational content by means of corporate social service Yammer.

As part of the scientific student group "The use of ICT in education" of Borys Grinchenko Kyiv University, we invited students to take part in the project's implementation method. During March 2021, 8 teams were formed, each with 4 students of the same level under academic achievements. In each group, there were two students majoring in "Computer Science", the other students – humanities. The teams were offered the implementation of an interdisciplinary project – the development of a website "Virtual Museum of University History". The project was implemented during March–June 2021 in a distance format. Four teams (K1–K4) used the Yammer network in the process of working on the project, other teams (K5–K8) communicated with the help of various digital resources. Projects were evaluated on a 10-point scale according to the criteria: the work is practical, contains a well-presented theoretical basis, is characterized

by a logical, consistent presentation of material with appropriate conclusions and sound proposals; has positive feedback from experts, students, teachers; In defending the work, students demonstrate in-depth knowledge of the topic, freely operate with research data, make sound suggestions, use clarity (tables, diagrams, graphs, etc. or handouts), easily answer questions. The evaluation was carried out based on expert assessments of participants in the educational process (through the use of cloud services Google Forms and Google Sheets) (figure 4).



Criteria	Maximum score	Yammer
E-learning materials are presented in the form of an electronic manual with hyperlinks from lecture points to pages	20	20
Availability of additional multimedia teaching materials	5	5
Availability of presentations for the lecture (its design)	10	10
Availability of methodical recommendations (2 points) for passing the topic, topic maps (2 points) (how best to go through the topic)	4	3
Availability of pages for each task of the topic	5	5
Availability of separate resources for each practical (laboratory) work, which contain the main structural elements: theme, purpose, guidelines, list of tasks, form of presentation of the results of work performed, evaluation criteria, deadline (for all works). (absence of evaluation criteria "minus" 10, deadlines "minus" 1)	20	18
Availability (quality) of a video lesson	15	15
Existence and quality of theoretical and practical recommendations for the implementation of PR	10	8
Availability of control questions (30 pieces)	20	20
Availability of category (1 point) and types (4 points) of questions	5	5
Quality of tasks	6	6
Created theses (quality)	20	20
The presence of a glossary	5	5
	Total score:(150)	**140**

Figure 4: The results of a survey on implementing project-based learning methods using cloud services (table of criteria for evaluating completed projects, and an example of the implemented project).

The following results were obtained during the projects: K3 – 10 points, K2 – 10 points, K1 – 9 points, K8 – 9 points, K4 – 8 points, K6 – 6 points, K5 – 6 points, K7 – 4 points. This shows the effectiveness of the use of Yammer in the educational process, in particular, in implementing project-based learning methods.

5. Conclusions

By analyzing the experience of project activities among teachers of higher education, the main features of project-based learning on cloud-based services were identified: social activity; convenient communication in a team during the project implementation and at the resulting stage; open educational space; self-learning and self-improvement; use of interdisciplinary links to combine students of different years of study (1–4 degrees of the first (bachelor's) level and students of the second master's level) to joint research teams to study through research; purposeful motivation of cognitive and research activity of students within the discipline with the use of interdisciplinary connections; formation of digital literacy of students.

Over 10 years of experience of the scientific circle “ICT in the educational process” and 20 years of teaching experience of the co-authors of the study gives grounds to distinguish the following stages of using project methods using the method of small groups: initiation; planning; conducting/implementation; presentation; assessment/defense.

Conducted an analysis of the advantages and disadvantages of using well-known social services and messengers to ensure project activities. The key (within the work of small groups) functions of the Yammer cloud service have been identified and disclosed.

Prospects for further research include step-by-step detailing and methodological support for the use of cloud-based learning technologies for students majoring in the field of “human–human” using project methodology.

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References

[1] N. Balyk, I. Grod, Y. Vasylenko, V. Oleksiuk, Y. Rogovchenko, Project-based learning in a computer modelling course, Journal of Physics: Conference Series 1840 (2021) 012032. doi:10.1088/1742-6596/1840/1/012032.

[2] Y. V. Shuhailo, T. M. Derkach, Project-based learning for undergraduate engineering students minoring in textile technology and design, Journal of Physics: Conference Series 1840 (2021) 012042. doi:10.1088/1742-6596/1840/1/012042.

[3] B. Barron, L. Darling-Hammond, Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning, 2008. URL: https://eric.ed.gov/?id=ED539399.

[4] G. V. Berezhna, O. V. Aleinikova, O. A. Kovtun, H. B. Danylchuk, V. O. Babenko, P. P. Nechypurenko, Training on gender mainstreaming in project management: case of international donor programs and projects for Ukrainian local communities’ development, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[5] O. G. Glazunova, O. V. Parhomenko, V. I. Korolchuk, T. V. Voloshyna, The effectiveness of GitHub cloud services for implementing a programming training project: students’ point of view, Journal of Physics: Conference Series 1840 (2021) 012030. doi:10.1088/1742-6596/1840/1/012030.

[6] I. M. Gryshchenko, L. Jin, T. M. Derkach, S. Tang, Experience in teaching analytical chemistry in a joint English-language educational project of Chinese and Ukrainian universities, Journal of Physics: Conference Series 1946 (2021) 012008. doi:10.1088/1742-6596/1946/1/012008.

[7] R. Horbatiuk, O. Voitovych, I. Voitovych, Formation of project competence of future

environmentalists, E3S Web of Conferences 166 (2020) 10026. doi:10.1051/e3sconf/202016610026.

[8] R. M. Horbatiuk, N. M. Bilan, O. A. Sitkar, O. S. Tymoshchuk, The formation of educational environment in foreign language training of energy engineering students by means of project technology, Journal of Physics: Conference Series 1840 (2021) 012047. doi:10.1088/1742-6596/1840/1/012047.

[9] A. V. Iatsyshyn, V. O. Kovach, V. O. Lyubchak, Y. O. Zuban, A. G. Piven, O. M. Sokolyuk, A. V. Iatsyshyn, O. O. Popov, V. O. Artemchuk, M. P. Shyshkina, Application of augmented reality technologies for education projects preparation, CEUR Workshop Proceedings 2643 (2020) 134–160.

[10] M. Pavlenko, L. Pavlenko, Formation of communication and teamwork skills of future IT-specialists using project technology, Journal of Physics: Conference Series 1840 (2021) 012031. doi:10.1088/1742-6596/1840/1/012031.

[11] I. Podlasyi, Training of a specialist: Optimal models and pragmatic solutions, Higher Education in Europe 7 (1982) 39–42. doi:10.1080/0379772820070207.

[12] N. V. Valko, V. V. Osadchyi, V. S. Kruhlyk, Cloud resources use for students' project activities, CEUR Workshop Proceedings 2879 (2020) 304–317.

[13] K. Vlasenko, O. Kondratyeva, I. Khyzhniak, O. Chumak, S. Volkov, Developing training materials for the on-line course "Project method in teaching higher mathematics", CEUR Workshop Proceedings 2732 (2020) 756–769.

[14] O. Dzyabenko, N. Morse, S. Vasylenko, L. Varchenko-Trotsenko, V. Wember, M. Boyko, E. Smirnova-Trybulska, Innovative pedagogical methods in the digital age, 2020. URL: https://elibrary.kubg.edu.ua/id/eprint/32856/.

[15] P. C. Blumenfeld, E. Soloway, R. W. Marx, J. S. Krajcik, M. Guzdial, A. Palincsar, Motivating project-based learning: Sustaining the doing, supporting the learning, Educational Psychologist 26 (1991) 369–398. doi:10.1080/00461520.1991.9653139.

[16] K.-H. Tseng, C.-C. Chang, S.-J. Lou, W.-P. Chen, Attitudes towards science, technology, engineering and mathematics (stem) in a project-based learning (pjbl) environment, International Journal of Technology and Design Education 23 (2013) 87–102. doi:10.1007/s10798-011-9160-x.

[17] D. Kokotsaki, V. Menzies, A. Wiggins, Project-based learning: A review of the literature, Improving Schools 19 (2016) 267–277. doi:10.1177/1365480216659733.

[18] K. Ayas, N. Zeniuk, Project-based learning: Building communities of reflective practitioners, Management Learning 32 (2001) 61–76. doi:10.1177/1350507601321005.

[19] J. Macias-Guarasa, J. Montero, R. San-Segundo, A. Araujo, O. Nieto-Taladriz, A project-based learning approach to design electronic systems curricula, IEEE Transactions on Education 49 (2006) 389–397. doi:10.1109/TE.2006.879784.

[20] R. J. DeFillippi, Introduction: Project-based learning, reflective practices and learning, Management Learning 32 (2001) 5–10. doi:10.1177/1350507601321001.

[21] V. Bykov, Developing the educational process participants' competencies on the basis of cloud-oriented information and educational systems: Scientific report at the meeting of the presidium of the national academy of educational sciences of ukraine, march 18, 2021, Herald of the National Academy of Educational Sciences of Ukraine 3 (2021). URL: https://visnyk.naps.gov.ua/index.php/journal/article/view/129. doi:10.

37472/2707-305X-2021-3-1-2-3.
[22] E. H. Fedorenko, V. Y. Velychko, A. V. Stopkin, A. V. Chorna, V. N. Soloviev, Informatization of education as a pledge of the existence and development of a modern higher education, CEUR Workshop Proceedings 2433 (2019) 20–32.
[23] N. Holiver, T. Kurbatova, I. Bondar, Blended learning for sustainable education: Moodle-based English for Specific Purposes teaching at Kryvyi Rih National University, E3S Web of Conferences 166 (2020) 10006. doi:10.1051/e3sconf/202016610006.
[24] S. I. Pochtovyuk, V. P. Chernenko, T. A. Vakaliuk, Information and communication technologies in the study of mathematical methods in psychology, CEUR Workshop Proceedings 2732 (2020) 1249–1259.
[25] E. Smyrnova-Trybulska, T. Noskova, T. Pavlova, O. Yakovleva, N. Morze, New educational strategies in contemporary digital environment, International Journal of Continuing Engineering Education and Life Long Learning 26 (2016) 6–24. doi:10.1504/IJCEELL.2016.075036.
[26] V. Y. Velychko, E. H. Fedorenko, D. A. Kassim, Conceptual bases of use of free software in the professional training of pre-service teacher of mathematics, physics and computer science, CEUR Workshop Proceedings 2257 (2018) 93–102.
[27] D. M. Kuchakovska, H Aand Bodnenko, V. V. Proshkin, Organization of control and analysis of students' achievements in higher educational institutions by means of social services, Information Technologies and Learning Tools 73 (2019) 135–148. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/2802. doi:10.33407/itlt.v73i5.2802.
[28] O. V. Shcherbakov, G. A. Shcherbyna, Social network for learning support at the university, Systemy obrobky informatsii 8(106) (2012) 159–162. URL: http://www.repository.hneu.edu.ua/jspui/handle/123456789/1545.
[29] A. Iatsyshyn, Application of virtual social networks for purposes of general secondary education, Journal of Information Technologies in Education (ITE) (2015) 119–126. URL: http://ite.kspu.edu/index.php/ite/article/view/221. doi:10.14308/ite000491.
[30] O. P. Pinchuk, Perspective analysis of use of social networks as learning tools in learning environment, Information Technologies and Learning Tools 54 (2016) 83–98. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1482. doi:10.33407/itlt.v54i4.1482.
[31] P. M. Leonardi, Social media, knowledge sharing, and innovation: Toward a theory of communication visibility, Information Systems Research 25 (2014) 796–816. doi:10.1287/isre.2014.0536.
[32] J. Kim, M. Hastak, Social network analysis: Characteristics of online social networks after a disaster, International Journal of Information Management 38 (2018) 86–96. doi:10.1016/j.ijinfomgt.2017.08.003.
[33] T. A. Vakaliuk, O. V. Korotun, S. O. Semerikov, The selection of cloud services for ER-diagrams construction in IT specialists databases teaching, CEUR Workshop Proceedings 2879 (2020) 384–397. URL: http://ceur-ws.org/Vol-2879/paper21.pdf.
[34] S. Munusamy, A. Osman, S. Riaz, S. Ali, F. Mraiche, The use of socrative and yammer online tools to promote interactive learning in pharmacy education, Currents in Pharmacy Teaching and Learning 11 (2019) 76–80. doi:10.1016/j.cptl.2018.09.021.
[35] A. Dhir, Y. Yossatorn, P. Kaur, S. Chen, Online social media fatigue and psychological wellbeing — A study of compulsive use, fear of missing out, fatigue, anxiety and depression,

International Journal of Information Management 40 (2018) 141–152. doi:10.1016/j.ijinfomgt.2018.01.012.

[36] D. M. Bodnenko, H. A. Kuchakovska, V. V. Proshkin, O. S. Lytvyn, Using a virtual digital board to organize student's cooperative learning, CEUR Workshop Proceedings 2731 (2020) 357–368. URL: http://ceur-ws.org/Vol-2731/paper21.pdf.

[37] H. Kuchakovska, The organization of students' joint activity by means of popular network services, CEUR Workshop Proceedings 1844 (2017) 155–165. URL: http://ceur-ws.org/Vol-1844/10000155.pdf.

[38] D. Bodnenko, The role of informatization in the change of higher school tasks: the impact on the professional teacher competences, CEUR Workshop Proceedings 1000 (2013) 281–287. URL: http://ceur-ws.org/Vol-1000/ICTERI-2013-p-281-287.pdf.

The didactic potential of cloud technologies in professional training of future teachers of Ukrainian language and literature

Olha B. Petrovych[1], Alla P. Vinnichuk[1], Oksana A. Poida[1], Viktoriia I. Tkachenko[1], Tetiana A. Vakaliuk[3,2,4] and Olena H. Kuzminska[5]

[1]*Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, 32 Ostrozhskogo Str., Vinnytsia, 21100, Ukraine*

[2]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[3]*Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine*

[4]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

[5]*National University of Life and Environmental Sciences of Ukraine, 15 Heroyiv Oborony Str., Kyiv, 03041, Ukraine*

Abstract

The article deals with the peculiarities of the usage cloud technologies for the organization of students-philologists' individual and group work in studying the discipline "Scientific Research Basics". The relevance of the introduction of cloud technologies for formation the readiness of the future teachers of Ukrainian language and literature to the professional activity is substantiated. Analysis of the scientific sources suggested that the quality of professional training process of future teachers-philologists has reached a new level by the means of cloud technologies. The domestic and foreign experience of cloud technologies implementation into current educational practices is generalized. The features of blended learning organization for professional training students-philologists at the Mykhailo Stelmakh Faculty of Philology and Journalism of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University during the studying the discipline "Scientific Research Basics" by using cloud technologies are described. The practical aspects and experience of preparation the future teachers of Ukrainian language and literature to a fluent usage of innovative cloud-based means are detailed. It is specified that the educational process is based on the communication by Gmail, Viber and Telegram messengers, store on Google Drive resource, work with educational video on YouTube, conducting online classes in Google Meet, creation publication in any of the social networks (Facebook, Instagram, TikTok), formation the different styles of references design on The Cite This for Me resource, conducting literature search on various search engines, namely Google Scholar, ScienceDirect, Web of Science, creating multimedia presentation at Prezi or Canva, making MindMaps on Mindomo, infographics on interactive board Google Jamboard or Padlet, on services for graphic design Canva and Visme, etc. Prospects for experimental studying the effectiveness of using cloud technologies in learning discipline "Scientific Research Basics" are determined.

Keywords

cloud technologies, professional training, scientific research basics, cloud-based learning environment, the future teachers-philologists, visualization, didactic potential.

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1. Introduction

The high-speed development of information and communication technologies is significantly ahead of the process of adaptation of these technologies to the pedagogical process. Significant changes in the education system are needed for adequate interaction of the tutor with the students of the new generation, for their training and development. This requires the tutor to take into account the peculiarities of the perception of educational information by modern students, the transition from mostly verbal teaching methods to the use of interesting for young people forms and methods of organizing educational activities. After all, now it is not enough to transfer only knowledge in the process of professional training, but it is important to involve the students into active learning and research activities in the media space, and to form the students' ability to critically interpret information in a cloud-based learning environment. Therefore, the problem of using cloud technologies in the educational process and finding effective tools for productive educational interaction becomes especially relevant.

Thus, it should be noted that there is still no comprehensive justification for the introduction of cloud learning technologies in the training of future teachers of Ukrainian language and literature, that would reveal the potential of cloud-based learning environment in forming of the students' key competencies, increasing their personal and creative potential.

The theory of the use of cloud technologies in the educational process was studied by Al-Sharafi et al. [1], Alshref et al. [2], Attaran et al. [3], Bykov and Shyshkina [4], Kiv et al. [5], Kobysia [6], Lytvynova [7], Marienko [8], Markova et al. [9, 10], Morze and Kusminska [11], Munk et al. [12], Nechypurenko et al. [13], Okai et al. [14], Oleksiuk et al. [15], Peras and Mekovec [16], Popel and Shyshkina [17, 18], Qasem et al. [19], Striuk and Rassovytska [20], Vakaliuk et al. [21, 22], Velychko et al. [23], Volikova et al. [24], Yadav [25], Yeh and Hsu [26], Zhaldak and Franchuk [27].

Popel and Shyshkina [17] determined the relationship between such concepts as "cloud-based systems" and "cloud-based environments".

Yadav [25] attracted the attention to a cloud education system and described how it is beneficial for students, faculty and the educational institutes for providing quality education. Attaran et al. [3] discussed potential strategic benefits of cloud technology in education, and highlighted its evolving trends.

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olha.petrovych@vspu.edu.ua (O. B. Petrovych); alla.vinnichuk@vspu.edu.ua (A. P. Vinnichuk); oksana.poida@vspu.edu.ua (O. A. Poida); viktoriia.tkachenko@vspu.edu.ua (V. I. Tkachenko); tetianavakaliuk@gmail.com (T. A. Vakaliuk); o.kuzminska@nubip.edu.ua (O. H. Kuzminska)
https://library.vspu.edu.ua/inform/nauk_profil.htm#petrovich_olga (O. B. Petrovych); https://library.vspu.edu.ua/inform/nauk_profil.htm#vinnichuk_alla (A. P. Vinnichuk); https://library.vspu.edu.ua/inform/nauk_profil.htm#pojda_oksana (O. A. Poida); https://library.vspu.edu.ua/inform/nauk_profil.htm#tkachenko_viktoria (V. I. Tkachenko); https://sites.google.com/view/neota/profile-vakaliuk-t (T. A. Vakaliuk); https://nubip.edu.ua/node/3983 (O. H. Kuzminska)
0000-0002-7185-3823 (O. B. Petrovych); 0000-0003-0359-4169 (A. P. Vinnichuk); 0000-0001-8249-1357 (O. A. Poida); 0000-0003-0492-3817 (V. I. Tkachenko); 0000-0001-6825-4697 (T. A. Vakaliuk); 0000-0002-8849-9648 (O. H. Kuzminska)
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Lytvynova [7] convinces that implementation of a cloud-oriented learning environment at secondary schools provides endless opportunities both teacher and student, because it helps to create the conditions for innovation in learning.

A considerable amount of research papers has been investigating the peculiarities of use the cloud technologies in higher educational institutions. Okai et al. [14] discovered that the higher education is skeptical in committing to cloud technology. They identified the reasons for the slow rate of adoption of cloud computing at university level, discussed the challenges faced and proposes a cloud computing adoption model that contains strategic guidelines to overcome the major challenges identified and a roadmap for the successful adoption of cloud computing by universities. According to Fedorenko et al. [28], the practice of implementing such technologies in the educational process of higher educational institutions are expanding every day and gives only positive results.

Al-Sharafi et al. [1] developed a theoretical model to explore the factors affecting cloud computing adoption at higher education institutions. Their model is based on the integration of four well-established models, including the technology-organizational-environmental framework, the fit viability model, the diffusion of innovations, and the institutional theory. Peras and Mekovec [16] identified the factors of the use cloud service in education institutions, and developed a conceptual model for the continuance intention to use cloud service in education institutions.

Qasem et al. [19] gave the systematic literature review and analyzed the existing research on adopting and using cloud computing in higher education institutions, reviewed background research to develop a coherent taxonomy and provide a landscape for future research on cloud computing in higher education institutions. One more systematic literature review was conducted by Alshref et al. [2]. It was focused on the e-learning technology acceptance theories and models and opened issues and challenges facing the Libyan higher education institutions.

Shakor and Surameery [29] analyzed the researchers' views in Iraqi universities on cloud computing and presented the impacts of the COVID-19 pandemic on cloud computing environment in higher education institutions in Iraq.

Yaroshenko et al. [30] pointed out that the main purpose of information and digital training in the pedagogical higher educational institutions is to ensure the formation of digital competence of future primary school teachers, to prepare them for developing primary students' digital literacy in classes on various academic subjects, for active use of ICT in primary school teachers' professional activities.

Moiseienko et al. [31] defined didactic conditions of digital formation competences of students of pedagogical universities: actualization of motivational value training of students of pedagogical universities; organization of interaction between students and teachers of pedagogical universities on the Internet through the creation of digital information educational environment; creation of individual educational trajectories of students.

Some aspects of the use of e-learning tools, cloud technologies for teaching the Ukrainian language and literature were considered in the works of Biychuk [32], Palamar and Nazarenko [33], Petrovych et al. [34], Skrynnik [35], Ulishchenko [36]. Skrynnik [35] created, scientific and theoretical grounded and experimental tested the methods of teaching Ukrainian literature with the use of cloud technologies and described it in her PhD thesis "Techniques of teaching Ukrainian literature in the 5th-6th grades using cloud technologies". The researcher defined

a cloud-based learning environment in the system of literature education as an artificially modeled environment of pedagogical interaction, which involves the use of cloud technologies, has a clearly defined didactic purpose, promotes the formation of key and subject competencies, development of readers' personal potential, promotes the creative self-expression of each of the subjects of educational interaction [35].

Palamar and Nazarenko [33] analyzed the content aspects of the competence approach to teaching literature with the use of booktrailer to increase students' interest in reading. But the usage of cloud technologies in the formation of the readiness of future teachers-philologists to professional activities are poorly explored.

Despite the interest of scientists in cloud technologies, the role of cloud-based learning environment in formation the readiness of future teachers of Ukrainian language and literature for professional activity requires further researches. Therefore, it is important to study methodologically and pedagogically appropriate ways of students' training by the means of cloud technologies.

The aim of the research is to elucidate the didactic capability of the usage of cloud technologies in the format of studying the discipline "Scientific research basics" for effective professional training of students-philologists.

2. Related work

2.1. Cloud technologies in higher education: the didactic potential of usage

Bondarenko et al. [37], Palamar and Nazarenko [33], Petrovych et al. [34], Skrynnik [35], Valko et al. [38] highlight that the professional training of future teachers should take into account the changes in the technological world.

Shakor and Surameery [29] underline that a lot of educational institutions have begun using cloud computing by outsourcing their student email provision and by using data storage. The authors point out the main benefit of using the clouds:

- availability (the ability to access the data from anywhere and by using any portable devices);
- save cost of installing IT infrastructure;
- outsourced development and maintenance;
- minimal training on the personnel;
- super-computing power.

Morze and Kusminska [11] categorize the didactic assignments of using the cloud computing in the higher education institutes: creation and further development of personal training and research environment of student and tutor, organization access it from anywhere at any time; saving large amounts of personal data, etc.; providing centralization and flexible control, minimization the need for maintenance, saving money to purchase new equipment, flexibility in the deployment of new systems etc.

Qasem et al. [19] list the benefits that inspire higher educational institutions to adopt cloud computing. Among them are:

- readily accessible online applications;
- flexible learning environments;
- mobile learning support;
- availability of specialized cloud-based systems;
- scalability of specialized cloud-based systems;
- cost reductions in hardware and operations;
- reduce the costs of software;
- collaborative working;
- virtualization;
- quality of service.

The researchers revealed in their study that cloud computing technology leads to modernize the way of work of teachers, educators in higher educational institutions. But the authors attracted the attention that despite several cloud computing studies in relation to higher educational institutions, other researchers have tended to focus minimally on the organizational aspects and on the individual perspectives of the usage of cloud technologies [19].

Qasem et al. [19] highlight that students are already familiar with the concept of cloud computing to some degree and are probably already used in cloud-based technologies, such as Google Apps and Dropbox, which are free, easy to use, and highly accessible. The authors proclaim that cloud-based systems are attractive to the education sector because they are readily available, quick to respond, and easy to roll out to numerous audiences.

At the same time, Valko et al. [38] notify that cloud technologies usage has several disadvantages that are to be considered at educational process supported with such a technology is being organized. For instance:

- depending on electricity availability;
- the cloud service provider is empowered with absolute access to and control on data;
- resource is being worked and supported until the cloud service provider does it;
- resources may change monetary policy and limit the functional or they are no longer available;
- the data typing and standards lacking limit the cross-platform transition between resources.

Yeh and Hsu [26] affirm that cloud technologies have much greater potential than other network infrastructures because they can overcome other computing limitations by offering great processing capability and data storage capacity given the servers where they are stored.

Varina et al. [39] draw our attention to the use of cloud computing, particularly Google Workspace for Education, in the educational process not only for formation of a competitive and successful personality in the electronic information society, but also for significantly improve and diversity the activity of a teacher, activization creativity of students, creation appropriate conditions for the formation and development of their relevant skills and abilities, improve the assimilation and reproduction of information obtained by them, promotion the development of students' adaptive potential.

According to Bondarenko et al. [37], modern students are "digitally born", because they live in a media environment. So, the use of computers, Internet resources and mobile devices is the part of students' everyday life. The researchers draw our attention to such "key properties" of this educational environment:

- immersion, the ability to be an active doer instead of a passive viewer;
- interactivity, the active interaction of education process participants among each other and with an artificial environment;
- dynamism, variability, transience of events;
- sense of presence;
- continuity, the ability for continuous interaction of participants in the educational process (offline, online, etc.);
- causality, the ability to identify the causal relationships among educational phenomena and processes, and to visualize them with multimedia.

The above mentioned should be taken into account in professional training of the students-philologists because of its didactic potential. Meaningful choice of educational tasks, the possibility of constant feedback and creating an atmosphere of cooperation allows developing of the comfortable learning environment.

Thus, future teachers of Ukrainian language and literature must be able to appropriately select and effectively apply cloud technologies in the educational process. It allows to personalize the learning process, bring it closer to the needs of modern students. Constant updating of such technologies requires a modern teacher to be reflective, able to critically assess their own abilities, to focus on self-development and self-improvement.

2.2. Peculiarities of application the cloud-based services in higher education

Falfushynska et al. [40] summed up the students' and faculty members' attitude towards e-learning and the most complicated challenges regarding distance education. According to their survey the online learning using Zoom, Moodle, Google Meet, BigBlueButton and Cisco has become quite popular among the students and faculty members' in Ukraine in time of COVID-19 pandemic.

According to Symonenko et al. [41], both students and teachers can use the following basic tools on Google Workspace for Education cloud platform: Gmail with support for text, voice (Google Talk) and video chat; Google Drive for saving files and providing access rights to them; Google Docs for creating documents, spreadsheets and presentations of any complexity with the ability to use templates. Varina et al. [39] state that future teachers use information technology in almost any activity, and propose to take into account huge popularity and versatility of Google, because this cloud service allows to organize the learning process in such a way that students actively and enthusiastically master the educational materials. A group of researchers point out the advantages of such learning management system as Google Classroom. These benefits are such as:

- access to materials from any place;

- creation of a task and distribution of its individual copy for each student;
- joint work on tasks, implementation of project activities;
- real-time communication;
- possibility of conducting interactive classes online;
- tasks assessment.

One more important statement is that Google Classroom e-learning environment also allows future teachers to import elements from other services, for example LearningApps.org modules, which can be used directly as educational or training resources and allow students to learn the most important categories of the course in a form of a game. A group of researchers sums up the advantages of cloud computing in the educational environment that provide an opportunity to consider them as a deterministic component of the impact on professionally important and personality-oriented competencies development [38].

Nazarenko and Palamar [42] draw our attention to the importance of blended learning and the possibilities of introducing new types of ICTs into educational process. The authors outline that in the process of study the most popular in using become such on-line resources as LearningApps, Prezi, Emaze, PoowToon, Kizoa, Padlet, Thinglink, Piktochart, Tagul, Canva, Realtimeboard, Mindmeister, Mindomo, Ilovefreesoftware, Zaption etc. The researchers emphasize that it is also crucial for students to use Google as a searching tool in the process of their educational activity.

Aliagas-Marín and Margallo [43], Basaraba [44], Brössel [45], Dimova et al. [46], Ehret et al. [47], Ibarra-Rius and Ballester-Roca [48], Romero Oliva et al. [49], Rosa [50], Rius and Roca [51], Simões and Costa [52], Virani [53], Vollans [54] examine the problem of the usage of book trailers as a new form of media communication and involvement the students in reading. Therefore, future teachers-philologists need to master this method, which belongs to cloud technologies [33]. Besides Borys Grinchenko Kyiv University initiated the All-Ukrainian Festival "Bookfashion" and the students of Mykhailo Stelmakh Faculty of Philology and Journalism constantly take part in and regularly win prizes in various categories. Samples of book trailers can be found on the university website or in YouTube.

Tosheva [55] underlines the didactic and technological aspects of cloud-based services for creating MindMaps. The researcher assures that they are seen as an adaptive tool for planning, organizing, creating, presenting, solving problems, such as communication and a method of memorizing information, making them a powerful tool for visualizing processes and occurrence studied in higher education. Ivanova et al. [56] gives the list of the most common MindMaps servises, such as iMindMap Cloud, MindMeister, Mind42 and Goggle which have an easy and intuitive interface and can be used in blended learning.

Santiana and Fatimah [57] trace the improving of the effectiveness of training by the means of Prezi cloud-based presentation rather than Power points. In the article such advantages of using Prezi for educational purposes, were identified: increasing teacher's confidence, decreasing his/her teaching anxiety, helping the students to visualize the studying material, giving motivation to study and producing better learning experience. Besides, it encourages the future teachers-philologists to have high quolity Internet and be creative on making Prezi presentation.

Kravtsov and Gnedkova [58] attract the attention to cloud technologies which provide opportunities to integrate various methods of interactive learning into the cloud based learning

environment. The authors consider the most popular and user-friendly Internet services, among them are:

- Google Docs is an online office where you can create different documents, and also allows you to conduct the joined work with documents [59];
- OneDrive is Microsoft service, similar to Google Docs service;
- Scribd is an online cloud storage service that allows you to publish documents prepared in popular formats: Microsoft Office, Open Office, Adobe Acrobat etc.;
- Slideshare is online repository of presentations;
- Google Scholar is search engine for educational and scientific publications;
- YouTube is a service that allows you to download and watch videos in the browser [60];
- Skype is a service that provides audio and video communication of users, in particular in video conferencing format;
- Wikipedia is an online encyclopedia based on wiki technologies;
- Blogger is Internet service in the form of an online diary (or blog) [61];
- Facebook, Viber are social networks that allow you to create study groups, communities, etc [62].

On the basic of the considered services Kravtsov and Gnedkova [58] define didactic possibilities of cloud technologies which confirm expediency of their application in the higher education:

- simplicity and convenience of joint work of tutors and students;
- quick inclusion of the created products into the educational process;
- organization of interactive learning and students' group work;
- access to documents anywhere and anytime;
- organization of various forms of control;
- moving the learning management system in the cloud (for example, LMS Moodle, etc.).

Thus, according to the results of analyzed scientific works about cloud services, we chose to use Gmail, Viber and Telegram messengers for communication, Google Drive resource as online cloud storage service, YouTube for work with educational video, Google Meet for conducting online classes, social networks (Facebook, Instagram, TikTok) for creation publication, Google Scholar, ScienceDirect, Web of Science for literature search, Prezi or Canva for creating multimedia presentation, Mindomo for making MindMaps, Google Jamboard or Padlet as interactive board, Canva and Visme for graphic design etc. In our opinion, the didactic possibilities of chosen cloud services help in formation the professional readiness of future teachers-philologists, in particular their information and communication competency.

3. Features of using cloud technologies in the professional training of students-philologists

Today, a blended learning is gaining wide development in the field of education and it provides an opportunity to individualize the process of acquiring knowledge, skills, abilities and ways of

students' cognitive activity [63, 64, 65, 66, 67]. This type of learning occurs mainly through indirect interaction of distant participants in the educational environment, which is based on modern information and communication technologies. As practice and a number of researches show, blended learning is aimed at creating a comfortable informational educational environment, communication systems, which provide all the necessary educational information. Following Kobysia [6], we state that in blended learning a significant part of traditional learning time is replaced by online learning activities and may include providing links to resources, downloading texts and materials, facilitating the submission of tasks for independent work. Thus, a blended learning is a model of using distributed information and educational resources in educational process with the usage of asynchronous and synchronous distance learning elements. It is practiced as an element of stationary training during classes and in independent students' work. Based on this, blended learning inherits elements of distance learning, but eliminates its shortcomings. This is the educational model which is used in our professional activities at the Mykhailo Stelmakh Faculty of Philology and Journalism of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University during the studying the discipline "Scientific Research Basics".

The development of cloud technologies provides the tutors with new opportunities for effective organization of the educational process. Let's try to detail the use of didactic possibilities of cloud technologies during the study of the discipline "Scientific Research Basics". First of all, it is worth noting the benefits of these technologies for establishing educational communication, in particular through Gmail, Viber and Telegram messengers. So, these resources help in the full exchange of messages, sending images, text documents and even videos, providing feedback between teacher and student. Learning content is often stored as files on Google Drive resources, which are linked via a hyperlink system, and the level of access can be changed by the owner. YouTube features are used to work with the educational videos. Google Meet features are widely used for online classes, group consultations, collaboration, discussions, presentations of mini-projects.

While studying the discipline "Scientific Research Basics", students-philologists do creative tasks using social services of Internet, Web 2.0 technologies, distributed computing technologies (cloud technologies). Each student does tasks both individually and in groups, creates a significant amount of visual didactic materials (crossword puzzles, multimedia presentations, booklets, MindMaps, booktrailers, instructions etc.).

Here are some examples of educational tasks of the discipline "Scientific Research Basics" and samples of student work which they have done with the usage of cloud technologies. Thus, before the practical class "Science as a productive force in the development of society" students-philologists were asked to do the following creative tasks (optional):

1. Watch the video "Scientific Research - Part 1: Introduction" at https://www.youtube.com/watch?v=OeBvL2zuaKs. Make a MindMap based on video information. An example of one of the created MindMap on Mindomo resource can be seen in figure 1.
2. Choose the person of one outstanding scientist. Prepare a publication for any of the social networks (Facebook, Instagram, TikTok) with brief information about this researcher. Examples of created publications can be seen in figure 2.

Future teachers of Ukrainian language and literature worked out the theoretical issues of the next practical class "Psychology and technology of scientific creativity" in the format of group

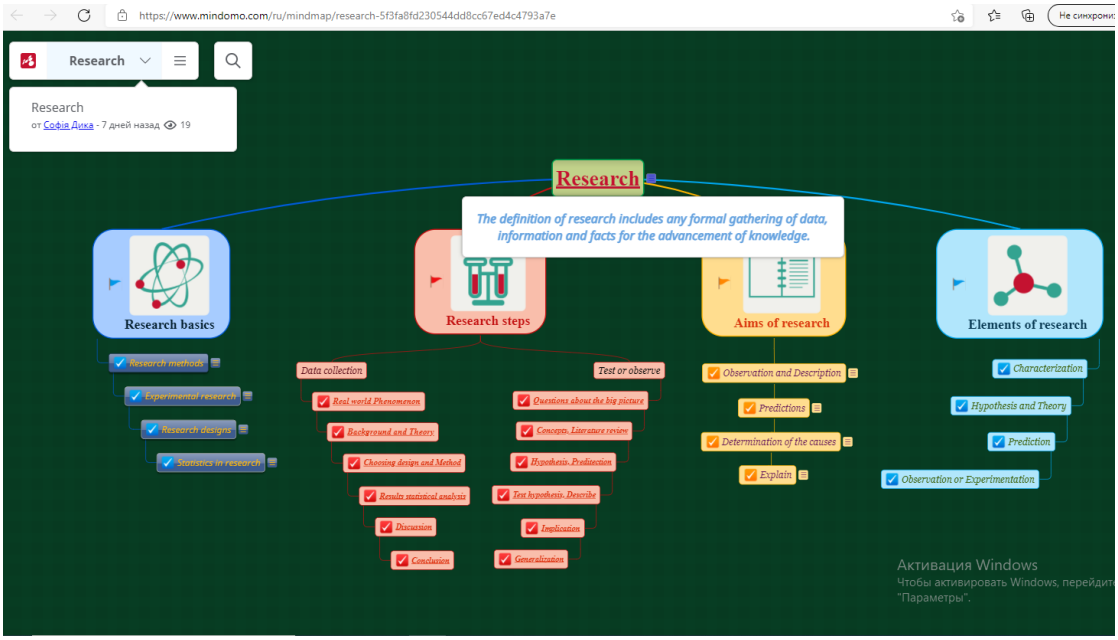

Figure 1: MindMap made by a student.

work. A separate question was proposed to each group. As a result of their teamwork, the students created a MindMap on Mindomo or any other resource and made a video presentation of this issue and uploaded it to YouTube. One of the presentations of "Organization of creative activity" can be viewed on YouTube at https://youtu.be/w3JcjYiaN2k.

Working out the tasks for the practical class "Scientific research on the methodology of philological disciplines. Modeling and its role in research" students-philologists were asked to get acquainted with different styles of references design (MLA style, APA style, Harvard style, IEEE style etc.). In such a way they highlighted the differences between different styles. The Cite This for Me resource (https://www.citethisforme.com/) helped to master the students' practical skills. Besides students searched for literature by keywords in various search engines that index scientific publications of all formats and disciplines, namely Google Scholar (https://scholar.google.com.ua/), ScienceDirect (https://www.sciencedirect.com/), Web of Science (https://www.webofscience.com/wos/woscc/basic-search), and they practiced in setting the necessary filters during the search, learned lifehacks on copying different styles citation etc.

Another task was to watch 2 educational videos about Scientific Models on YouTube (https://www.youtube.com/watch?v=BSU4_k_5pGE, https://www.youtube.com/watch?v=nGauq57P5Bg) and prepare a multimedia presentation or infographics with information about modeling learned from the video. For example, one of the multimedia presentations was prepared by a student at Prezi (https://prezi.com/). Several images from this presentation can be seen in figure 3.

Future teachers of Ukrainian language and literature also prepared infographics with information about modeling using various Internet resources, such as the online board Padlet (https://padlet.com/dashboard) and cross-platform service for graphic design Canva (https:

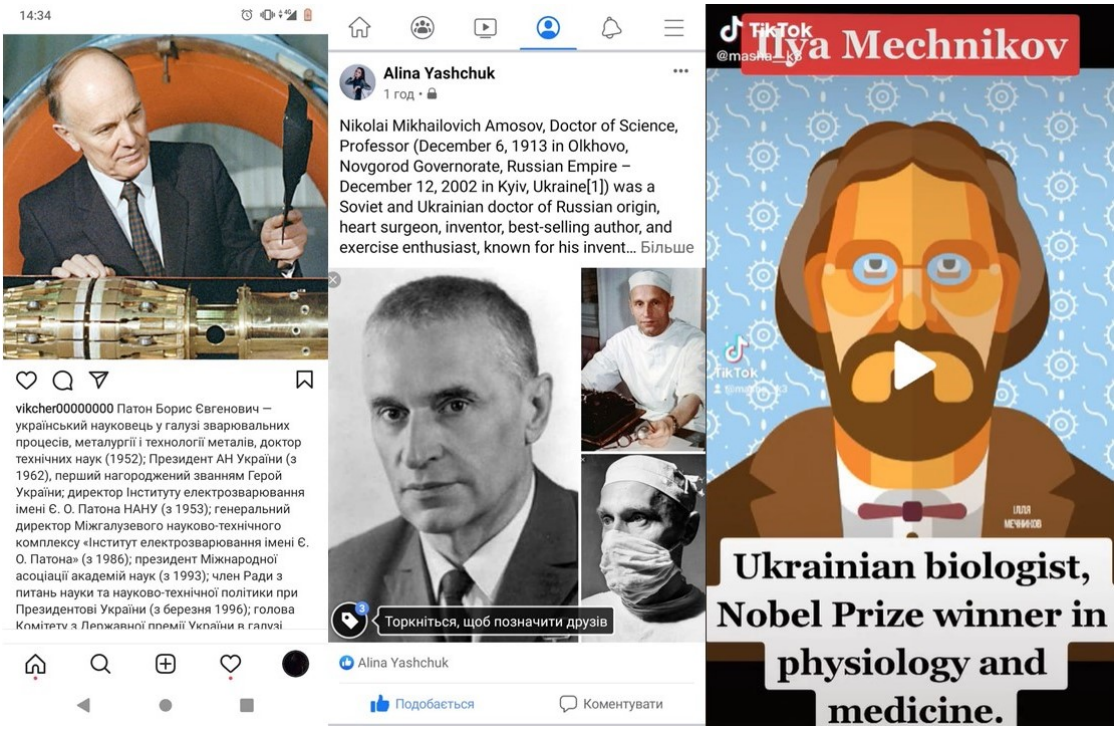

Figure 2: Publication in social networks.

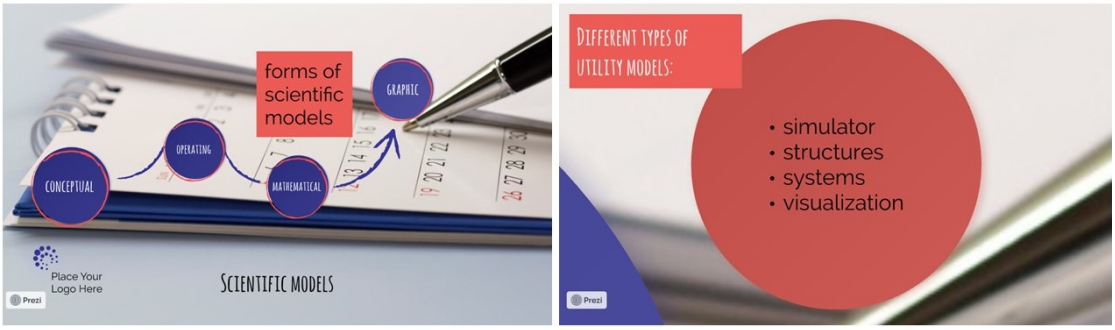

Figure 3: Images from the student's multimedia presentation.

//www.canva.com/uk_ua/). Samples of student work you can see in figure 4.

The creative tasks of the next practical class also included watching the educational video and further work with it, ie creating a visual graphic information image using various cloud technologies. So, after watching the video "How to Write a Research Methodology in 4 Steps" at the link https://www.youtube.com/watch?v=yplWZs3dqNQ&list=PLbaAPLFGKWYbobxJt0MS601d_hPKlz1wx&index=12 students-philologists prepared an instruction for the researcher about the research methodology with the usage of online board Padlet (https://padlet.com/dashboard) and graphic design service Visme (https://www.visme.co)

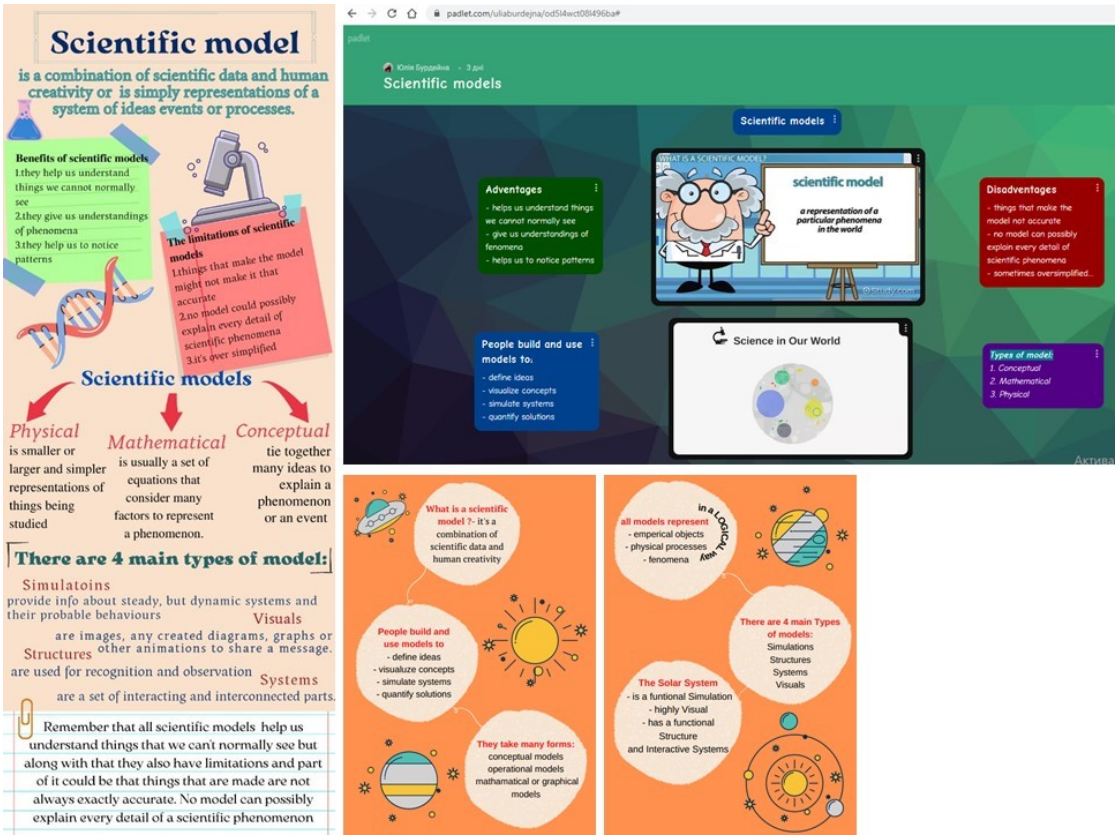

Figure 4: Examples of infographics created by students using cloud technologies.

(figure 5).

After watching the video "A Level Psychology - Experimental Designs" at the link https://www.youtube.com/watch?v=9eZYufPP2-o students-philologists created a comparative table with the advantages and disadvantages of each of the 3 experiment designs (figure 6). Resources such as the interactive board Google Jamboard (https://jamboard.google.com/) and the graphic design service Canva (https://www.canva.com/uk_ua/) helped to do this task.

These examples demonstrate the steady interest of students in innovative technologies in educational process. The cloud-based learning environment is familiar and usual for them, so involving students in doing learning tasks in this environment does not cause their resistance, but on the contrary serves as an incentive for creativity, solving cognitive problems, research activities.

4. Conclusions and prospects for further research

Based on the analysis of scientific research and our own practical experience, we can formulate the following didactic possibilities of cloud technologies in the professional training of future teachers of Ukrainian language and literature:

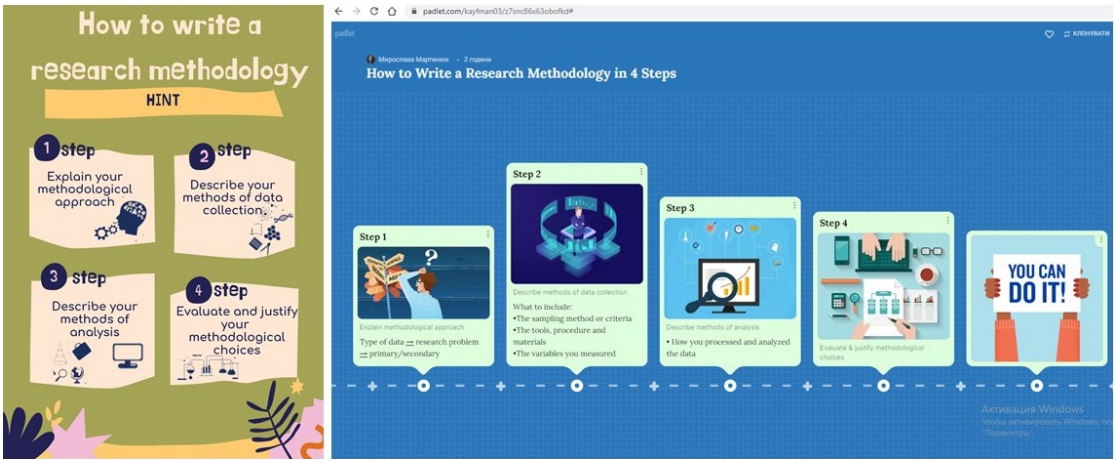

Figure 5: Samples of students' works.

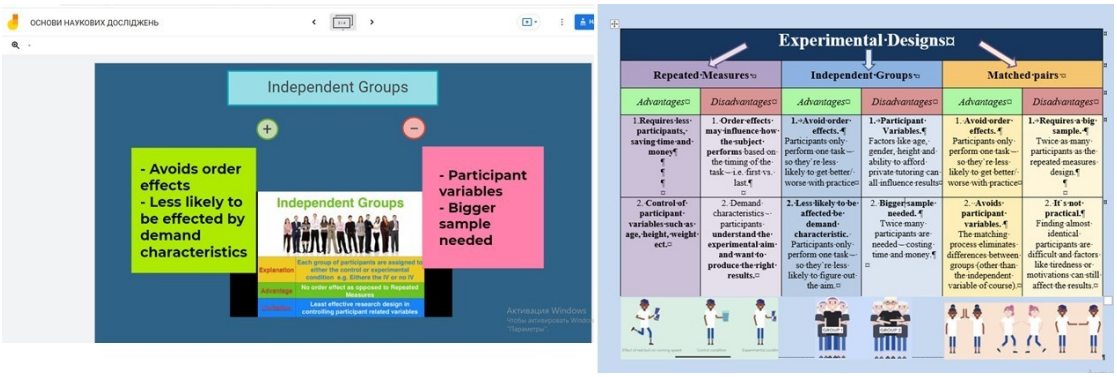

Figure 6: Samples of students' works.

- activation of students' cognitive activity and motivation, productivity of educational activity;
- mobility, which gives opportunities for research, project activities and adaptation of educational material to real life;
- formation of new ways of knowledge transfer for the implementation of blended learning;
- the ability to store large amounts of data in various formats (audio, video, graphics, text, databases) and simplify the publication of materials, uploading them online for quick access to it by both students and tutor;
- interactivity and continuity of the educational process even in the conditions of temporary and geographical separation of subjects of study;
- the ability to organize the group work;
- the possibility of organizing collective work of tutor and students;
- innovation and the possibility of modifications - expanding the limits of applicability of existing forms and methods of learning, fast presentation of created products in

educational process, stimulation of independent activity and obtaining a specific visual result;
- the possibility of integration of academic disciplines;
- organization of student-oriented learning;
- improving the skills of finding the necessary information, its evaluation;
- formation and increase of the level of media literacy.

The usage of cloud technologies in educational process during studying the discipline "Scientific Research Basics" helps in the practice-oriented and competence-oriented professional development of students-philologists at the Mykhailo Stelmakh Faculty of Philology and Journalism of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University. Thus, with the help of cloud technologies the future teachers of Ukrainian language and literature master the skills needed for a teacher of the 21st century, improve their knowledge and abilities both in professional subjects and in English, organize their self-development and self-education.

A prospects areas for further research are the experimental study of the effectiveness of using cloud technologies in studying discipline "Scientific Research Basics" and investigation of the psychological aspects of the problem of the using the cloud technologies in competence-oriented professional development of students-philologists.

References

[1] M. A. Al-Sharafi, Q. AlAjmi, M. Al-Emran, Y. A. M. Qasem, Y. M. Aldheleai, Cloud computing adoption in higher education: An integrated theoretical model, in: M. Al-Emran, K. Shaalan (Eds.), Recent Advances in Technology Acceptance Models and Theories, Springer International Publishing, Cham, 2021, pp. 191–209. doi:10.1007/978-3-030-64987-6_12.

[2] H. H. M. Alshref, H. Abas, N. A. A. Bakar, The adoption of ICT in Libyan higher education institutions (LHEIs): Theoretical models and challenges, Journal of Physics: Conference Series 1897 (2021) 012003. URL: https://doi.org/10.1088/1742-6596/1897/1/012003. doi:10.1088/1742-6596/1897/1/012003.

[3] M. Attaran, S. Attaran, B. G. Celik, Promises and challenges of cloud computing in higher education: A practical guide for implementation, Journal of Higher Education Theory and Practice 17 (2017). URL: https://www.articlegateway.com/index.php/JHETP/article/view/1523.

[4] V. Bykov, M. Shyshkina, Emerging technologies for personnel training for it industry in ukraine, in: 2014 International Conference on Interactive Collaborative Learning (ICL), 2014, pp. 945–949. doi:10.1109/ICL.2014.7017903.

[5] A. E. Kiv, V. N. Soloviev, S. O. Semerikov, CTE 2018 – How cloud technologies continues to transform education, CEUR Workshop Proceedings 2433 (2019) 1–19. URL: http://ceur-ws.org/Vol-2433/paper00.pdf.

[6] A. P. Kobysia, The use cloud technology of the design work of students, New computer technology 17 (2019) 46–51. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/943.

[7] S. H. Lytvynova, Cloud-oriented learning environment of secondary school, CEUR Workshop Proceedings 2168 (2017) 7–12. URL: http://ceur-ws.org/Vol-2168/paper2.pdf.
[8] M. V. Marienko, The current state of using the cloud-based systems of open science by teachers of general secondary education, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[9] O. M. Markova, S. O. Semerikov, A. M. Striuk, H. M. Shalatska, P. P. Nechypurenko, V. V. Tron, Implementation of cloud service models in training of future information technology specialists, CEUR Workshop Proceedings 2433 (2019) 499–515. URL: http://ceur-ws.org/Vol-2433/paper34.pdf.
[10] O. M. Markova, S. O. Semerikov, A. M. Striuk, The cloud technologies of learning: Origin, Information Technologies and Learning Tools 46 (2015) 29–44. URL: https://journal.iitta.gov.ua/index.php/itlt/article/view/1234. doi:10.33407/itlt.v46i2.1234.
[11] N. Morze, O. Kusminska, Pedagogical aspects of cloud computing, Journal of Information Technologies in Education (ITE) (2011) 020–029. URL: http://ite.kspu.edu/index.php/ite/article/view/445. doi:10.14308/ite000238.
[12] R. Munk, D. Marchant, B. Vinter, Cloud enabling educational platforms with corc, CEUR Workshop Proceedings 2879 (2020) 438–457.
[13] P. Nechypurenko, T. Selivanova, M. Chernova, Using the cloud-oriented virtual chemical laboratory VLab in teaching the solution of experimental problems in chemistry of 9th grade students, CEUR Workshop Proceedings 2393 (2019) 968–983.
[14] S. Okai, M. Uddin, A. Arshad, R. Alsaqour, A. Shah, Cloud computing adoption model for universities to increase ict proficiency, SAGE Open 4 (2014) 2158244014546461. doi:10.1177/2158244014546461.
[15] V. P. Oleksiuk, O. R. Oleksiuk, T. A. Vakaliuk, An experiment on the implementation the methodology of teaching cloud technologies to future Computer Science teachers, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[16] D. Peras, R. Mekovec, Continuance intention to use cloud services in educational institutions, in: C. Stephanidis, M. Antona, S. Ntoa (Eds.), HCI International 2021 - Posters, Springer International Publishing, Cham, 2021, pp. 477–484. doi:10.1007/978-3-030-78635-9_62.
[17] M. V. Popel, M. P. Shyshkina, The areas of educational studies of the cloud-based learning systems, CEUR Workshop Proceedings 2433 (2019) 159–172. URL: http://ceur-ws.org/Vol-2433/paper09.pdf.
[18] M. V. Popel, M. P. Shyshkina, The cloud technologies and augmented reality: The prospects of use, CEUR Workshop Proceedings 2257 (2018) 232–236.
[19] Y. A. M. Qasem, R. Abdullah, Y. Y. Jusoh, R. Atan, S. Asadi, Cloud computing adoption in higher education institutions: A systematic review, IEEE Access 7 (2019) 63722–63744. doi:10.1109/ACCESS.2019.2916234.
[20] A. M. Striuk, M. V. Rassovytska, The system of cloud oriented learning tools as an element of educational and scientific environment of high school, Information Technologies and Learning Tools 42 (2014) 150–158. URL: https://journal.iitta.gov.ua/index.php/itlt/article/

view/1087. doi:10.33407/itlt.v42i4.1087.
[21] T. A. Vakaliuk, O. V. Korotun, S. O. Semerikov, The selection of cloud services for ER-diagrams construction in IT specialists databases teaching, CEUR Workshop Proceedings 2879 (2020) 384–397. URL: http://ceur-ws.org/Vol-2879/paper21.pdf.
[22] T. A. Vakaliuk, O. D. Gavryliuk, V. V. Kontsedailo, V. P. Oleksiuk, O. O. Kalinichenko, Selection cloud-oriented learning technologies for the formation of professional competencies of bachelors majoring in statistics and general methodology of their use, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[23] V. Y. Velychko, E. H. Fedorenko, N. V. Kaidan, V. N. Soloviev, O. V. Bondarenko, The support of the process of training pre-service mathematics teachers by means of cloud services, CEUR Workshop Proceedings 2879 (2020) 318–332.
[24] M. M. Volikova, T. S. Armash, Y. V. Yechkalo, V. I. Zaselskiy, Practical use of cloud services for organization of future specialists professional training, CEUR Workshop Proceedings 2433 (2019) 486–498.
[25] K. Yadav, Role of cloud computing in education, International Journal of Innovative Research in Computer and Communication Engineering 2 (2014) 3108–3112. URL: https://www.rroij.com/open-access/role-of-cloud-computing-in-education.pdf.
[26] C.-H. Yeh, C.-C. Hsu, The learning effect of students' cognitive styles in using cloud technology, in: D. K. W. Chiu, M. Wang, E. Popescu, Q. Li, R. Lau, T. K. Shih, C.-S. Yang, D. G. Sampson (Eds.), Advances in Web-Based Learning – ICWL 2013 Workshops, Springer Berlin Heidelberg, Berlin, Heidelberg, 2015, pp. 155–163. doi:10.1007/978-3-662-46315-4_16.
[27] M. I. Zhaldak, N. P. Franchuk, Some applications of the GRAN1 to analyze two-dimensional continuous probability distributions, Journal of Physics: Conference Series 1946 (2021) 012002. doi:10.1088/1742-6596/1946/1/012002.
[28] E. H. Fedorenko, V. Y. Velychko, A. V. Stopkin, A. V. Chorna, V. N. Soloviev, Informatization of education as a pledge of the existence and development of a modern higher education, CEUR Workshop Proceedings 2433 (2019) 20–32.
[29] M. Shakor, N. Surameery, Cloud computing technologies adoption in higher education institutes during COVID-19 pandemic: Case study, Passer Journal of Basic and Applied Sciences 3 (2021) 187–193. doi:10.24271/psr.31.
[30] O. G. Yaroshenko, O. D. Samborska, A. E. Kiv, Experimental verification of efficiency of the formation of information and digital competence of bachelors of primary education based on an integrated approach, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[31] M. V. Moiseienko, N. V. Moiseienko, I. V. Kohut, A. E. Kiv, Digital competence of pedagogical university student: Definition, structure and didactical conditions of ormation, CEUR Workshop Proceedings 2643 (2020) 60–70. URL: http://ceur-ws.org/Vol-2643/paper01.pdf.
[32] H. L. Biychuk, The didactic potential of the usage of a «Ukrainian literature. 5» myltimedia textbook in the primary school, Problemy suchasnoho pidruchnyka 14 (2014) 58–66. URL: http://ipvid.org.ua/upload/iblock/825/825ff4d0acbbb988ae9926441c6ebeeb.pdf.

[33] S. P. Palamar, L. A. Nazarenko, Kompetentnisnyj pidkhid do vykladannja literatury z vykorystannjam khmarnykh tekhnologhij [Competency approach to teaching literature using cloud technologies], Visnyk Lughansjkogho nacionaljnogho universytetu imeni Tarasa Shevchenka: Pedaghoghichni nauky 137 (2018) 102–109. URL: https://repository.moippo.mk.ua/publication/56.

[34] O. B. Petrovych, A. P. Vinnichuk, V. P. Krupka, I. A. Zelenenka, A. V. Voznyak, The usage of augmented reality technologies in professional training of future teachers of Ukrainian language and literature, CEUR Workshop Proceedings 2898 (2021) 315–333. URL: http://ceur-ws.org/Vol-2898/paper17.pdf.

[35] N. V. Skrynnik, Techniques of Teaching Ukrainian Literature in the 5th-6th Classes Using Cloud Technologies, Ph.D. thesis, National Pedagogical Dragomanov University, Kyiv, 2017. URL: http://enpuir.npu.edu.ua/handle/123456789/18380.

[36] V. Ulishchenko, Peculiarities of distant learning organization for philology students, Intercultural Communication (2018) 87–99. URL: http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.desklight-41e18de6-a472-4153-9e46-301480334b8c.

[37] O. V. Bondarenko, O. V. Pakhomova, W. Lewoniewski, The didactic potential of virtual information educational environment as a tool of geography students training, CEUR Workshop Proceedings 2547 (2020) 13–23. URL: http://ceur-ws.org/Vol-2547/paper01.pdf.

[38] N. V. Valko, N. O. Kushnir, V. V. Osadchyi, Cloud technologies for STEM education, CEUR Workshop Proceedings 2643 (2020) 435–447. URL: http://ceur-ws.org/Vol-2643/paper25.pdf.

[39] H. B. Varina, V. V. Osadchyi, K. P. Osadcha, S. V. Shevchenko, S. H. Lytvynova, Peculiarities of cloud computing use in the process of the first-year students' adaptive potential development, CEUR Workshop Proceedings 2879 (2020) 521–538. URL: http://ceur-ws.org/Vol-2879/paper31.pdf.

[40] H. I. Falfushynska, B. B. Buyak, H. V. Tereshchuk, G. M. Torbin, M. M. Kasianchuk, Strengthening of e-learning at the leading Ukrainian pedagogical universities in the time of COVID-19 pandemic, CEUR Workshop Proceedings 2879 (2020) 261–273. URL: http://ceur-ws.org/Vol-2879/paper13.pdf.

[41] S. V. Symonenko, V. V. Osadchyi, S. O. Sysoieva, K. P. Osadcha, A. A. Azaryan, Cloud technologies for enhancing communication of IT-professionals, CEUR Workshop Proceedings 2643 (2020) 225–236. URL: http://ceur-ws.org/Vol-2643/paper12.pdf.

[42] L. Nazarenko, S. Palamar, Didactic potential of new generation ICT in forming information and communication competence of upper secondary school pupils, CEUR Workshop Proceedings 2740 (2020) 248–261. URL: http://ceur-ws.org/Vol-2740/20200248.pdf.

[43] C. Aliagas-Marín, A. Margallo, Digital storytelling, book trailers and literary competence in initial teacher education, in: Storytelling and Education in the Digital Age: Experiences and Criticisms, Verlag Peter Lang AG, 2016, pp. 89–107. doi:10.3726/978-3-653-06976-1.

[44] N. Basaraba, Creating persuasive book trailers as a new media marketing tool, Logos (Netherlands) 27 (2016) 34–51. doi:10.1163/1878-4712-11112110.

[45] S. Brössel, Book trailer: An audiovisual short form at the 'interface' between book and movie [Buchtrailer. Ein audiovisuelles Kleinformat an der 'Schnittstelle' zwischen Buch und Film], Kodikas/ Code 41 (2018) 30–51.

[46] M. Dimova, S. Slavova-Petkova, D. Luchev, Models of digital book trailers and applications

of digital storytelling approach for educational purposes, in: Digital Presentation and Preservation of Cultural and Scientific Heritage, volume 8, Bulgarian Academy of Sciences, Institute of Mathematics and Informatics, 2018, pp. 197–206.
[47] C. Ehret, T. Hollett, R. Jocius, The matter of new media making: An intra-action analysis of adolescents making a digital book trailer, Journal of Literacy Research 48 (2016) 346–377. doi:10.1177/1086296X16665323.
[48] N. Ibarra-Rius, J. Ballester-Roca, Digital storytelling in teacher training: Development of basic competences, creativity and multimodal literacy through book trailers, Springer Singapore, 2018. doi:10.1007/978-981-13-1358-5_13.
[49] M. F. Romero Oliva, H. H. Ponce, M. S. Hernández, The book-trailer as a digital tool in the training literary reading of the future teachers. A case study [El book-trailer como herramienta digital en la formaciÓn lectora de los futuros docentes. Un estudio de caso], Caracteres 8 (2019) 92–128.
[50] T.-S. Rosa, Public online epitexts to children book promotion. Towards a book-Trailer poetic. A model analysis., OCNOS 15 (2016) 21–36. doi:10.18239/ocnos-2016.15.2.1125.
[51] N. I. Rius, J. B. Roca, Book-trailers in Kindergarden and K12 Education: Digital, comunicative and literary competence through digital narratives [Booktrailer en Educación Infantil y Primaria: Adquisición y desarrollo de las competencias comunicativa, digital y literaria a través de narrativas digitales], Digital Education Review (2016) 76–93.
[52] D. Simões, R. Costa, Book trailers and storytelling in the art of persuading the consumer [Book trailers e digital storytelling na arte de persuadir o consumidor], in: Atas da Conferencia da Associacao Portuguesa de Sistemas de Informacao, volume 2020-October, Associacao Portuguesa de Sistemas de Informacao, 2020.
[53] S. N. Virani, Dissemination and the digital: The creation of an academic book trailer, Review of Middle East Studies 45 (2011) 192–198. doi:10.1017/S2151348100002421.
[54] E. Vollans, Think of it as a trailer ... for a book, Publications 4 (2016). doi:10.3390/publications4040032.
[55] E. Tosheva, Cloud solutions for creating mind maps used in technological education, in: International Conference on Information Technology and Development of Education (ITRO), volume 1, 2018, pp. 5–8. URL: https://www.researchgate.net/publication/343237202_Cloud_solutions_for_creating_Mind_Maps_used_in_Technological_Education.
[56] H. I. Ivanova, O. O. Lavrentieva, L. F. Eivas, I. O. Zenkovych, A. D. Uchitel, The students' brainwork intensification via the computer visualization of study materials, CEUR Workshop Proceedings 2643 (2020) 185–209.
[57] S. Santiana, A. S. Fatimah, Prezi, cloud-based presentation, for teaching: How is it interesting?, EduLite: Journal of English Education, Literature and Culture 2 (2017) 445–456. doi:10.30659/e.2.2.445-456.
[58] H. M. Kravtsov, O. O. Gnedkova, Methods of using cloud services in foreign language training, CEUR Workshop Proceedings 2168 (2017) 54–65. URL: http://ceur-ws.org/Vol-2168/paper8.pdf.
[59] I. S. Mintii, Use Google Docs as a condition for optimizing teamwork, Theory and methods of e-learning 1 (2010) 150–154. URL: https://ccjournals.eu/ojs/index.php/e-learn/article/view/220.
[60] O. V. Chorna, V. A. Hamaniuk, O. Y. Markheva, A. V. Voznyak, A. D. Uchitel, Use of

YouTube resources in the process of training German Language Teachers, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[61] D. A. Pokryshen, E. H. Prokofiev, A. A. Azaryan, Blogger and YouTube services at a distant course "Database management system Microsoft Access", CEUR Workshop Proceedings 2433 (2019) 516–528.

[62] O. Gnedkova, V. Lyakutin, Methodological recommendations of internet-services usage in distance learning system "Kherson virtual university", Journal of Information Technologies in Education (ITE) (2011) 183–187. URL: http://ite.kspu.edu/index.php/ite/article/view/435. doi:10.14308/ite000285.

[63] N. Ponomarova, O. Gulich, O. Zhernovnykova, N. Olefirenko, V. Masych, Conditions of blended learning implementation in H. S. Skovoroda Kharkiv National Pedagogical University: experience of Physics and Mathematics Faculty, SHS Web of Conferences 104 (2021) 02017. doi:10.1051/shsconf/202110402017.

[64] S. L. Kucher, R. M. Horbatiuk, O. Y. Serdiuk, M. M. Ozhha, N. M. Hryniaieva, M. M. Fridman, Use of information and communication technologies in the organization of blended learning of future vocational education professionals, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[65] D. O. Bukreiev, A. V. Chorna, I. M. Serdiuk, V. N. Soloviev, Features of the use of software and hardware of the educational process in the conditions of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[66] L. A. Kartashova, A. M. Gurzhii, V. O. Zaichuk, T. M. Sorochan, F. M. Zhuravlev, Digital twin of an educational institution: an innovative concept of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[67] O. V. Bondarenko, S. V. Mantulenko, A. V. Pikilnyak, Google Classroom as a tool of support of blended learning for geography students, CEUR Workshop Proceedings 2257 (2018) 182–191.

Creation of open educational resources during educational practice by means of cloud technologies

Vladyslav Ye. Velychko[1], Elena G. Fedorenko[1], Vladimir N. Soloviev[2] and Ludmila V. Dolins'ka[3]

[1]*Donbas State Pedagogical University, 19 Batyuk Str., Sloviansk, 64122, Ukraine*
[2]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*
[3]*National University "Odesa Law Academy", 23 Fontanska Str., Odesa, 65009, Ukraine*

Abstract

Practical training is an integral part of the professional training of future teachers. During the practical training, trainees not only implement their own theoretical training in practice, but also increase the level of information competence. The rapid use of e-learning resources for distance learning during epidemiological constraints caused by biological threats poses new challenges to education in the availability of e-learning resources. The development of electronic educational resources is a difficult task, one of the ways to solve it is to involve future teachers in this process during the initial practice. The experiment of creating open educational resources by means of cloud technologies during the training practice showed the probability of solving this problem. Restrictions in direct contact between participants in the experiment, both due to epidemiological restrictions and through practical training in various educational institutions, are solved through the use of cloud technologies. The latter provides an opportunity to easily disseminate developed open educational resources and disseminate best practices in creating educational content.

Keywords

educational practice, development of electronic educational resources, open educational resources

1. Introduction

Information and communication technologies are a powerful tool for intensifying the educational process and related organizational processes and activities within the framework of education becoming more open. However, informatization and introduction of the latest tools, materials, and tools into the educational process cannot be considered the ultimate goal of open education and e-learning. Modern educational practice needs tools not only for publishing and storing educational resources. It is necessary to have a developed set of tools for teamwork with a variety of materials according to clearly defined criteria within educational systems that can be used both in educational institutions and outside them. In addition to providing free access, it is

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vladislav.velichko@gmail.com (V. Ye. Velychko); fedorenko.elena1209@gmail.com (E. G. Fedorenko); vnsoloviev2016@gmail.com (V. N. Soloviev); lslvvvas@ukr.net (L. V. Dolins'ka)
http://irbis-nbuv.gov.ua/ASUA/0083385 (V. Ye. Velychko); http://irbis-nbuv.gov.ua/ASUA/1101309 (E. G. Fedorenko); https://kdpu.edu.ua/personal/vmsoloviov.html (V. N. Soloviev)
0000-0001-9752-0907 (V. Ye. Velychko); 0000-0002-1897-874X (E. G. Fedorenko); 0000-0002-4945-202X (V. N. Soloviev); 0000-0002-8763-1977 (L. V. Dolins'ka)
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necessary to provide users with the opportunity to work collectively with materials, modifying them and adapting them to the needs of their own educational activities.

The initiatives of the University of T́ubingen in Germany, the Massachusetts Institute of Technology, and the Hewlett Foundation, launched in the early 2000s, have now evolved into the Open Content Initiative or as Open Educational Resources (OER). We will use a term which, in our opinion, is more successful "Open Educational Resources" or "Open E-Learning Resource". OERs are resources used to teach educational material, teaching materials, or research resources that are in the public domain or have been released under an intellectual property license that allows their free use or reassignment to others.

2. Theoretical foundations of the study

The development of open electronic resources is a complex and multifaceted problem. Specialists of various specialties related to the theory of education, psychology, ergonomics, information and communication technologies, etc. are involved in the creation of electronic educational resources [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]. A number of questions were asked about the process of creating and using open educational resources by Wiley et al. [11]:

- Do students assigned to create, revise, or remix artifacts find these assignments more valuable, interesting, motivating, or rewarding than other forms of assessment? Why or why not?
- Do students who make their assignments publicly available demonstrate greater mastery of learning outcomes or show more enthusiasm for their work than students assigned traditional assessments? Why or why not?
- Do students who openly license their work find additional learning benefits? Does openly licensed student work produce additional benefits to the broader community?
- Are there any drawbacks (real or perceived) that are voiced by students or faculty that participate in OER-enabled pedagogy?

Partial answers to these questions can be found in the works of Velychko et al. [12, 13]. In particular, in the work "Open Access to ICT and Electronic Educational Resources as a Guarantee of Sustainable Development of Society" proposed stages of development of open electronic educational resources during the educational activity (see figure 1 at [13]). Continuing the study of this issue, we explored the possibility of creating open educational resources during the initial practice by means of cloud technologies.

Electronic learning resources are the foundation of e-learning, without such resources the educational process cannot be an educational system. The advantages of open education are its specific features, namely:

- information and communication technologies;
- technologies of interaction of participants of educational process;
- specialized teaching aids;
- network structures of organization and management;

- specific presentation of educational information;
- specialized quality control of education.

Thus, open education is fundamentally different from traditional and more in line with the goals, objectives and content of the information society. The main advantages of open education include:

- mass and accessibility (open education has almost limitless possibilities of wide coverage of the population and territories, organization of free access to information and educational resources);
- adaptability and flexibility (the open education system has a wide range of opportunities to adapt to changing environmental conditions, capable of significant transformations of all important elements of the educational process);
- internationality and globalization (free functioning of the system of open education outside state borders);
- planetary openness and availability of information and educational resources;
- modular structure and asynchrony (modular principle of constructing the content and organization of the educational process allows to form individual curricula and programs that best meet the personal needs of students, as well as to spread over time the various elements of the educational process);
- economic efficiency (educational results are achieved with less, compared to traditional education, time, money, etc.).

Open educational resources according to the definition of "The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO), meeting in Paris from 12 to 27 November 2019, at its 40th session" defines Open Educational Resources (OER) are learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others [14]. Open License is a standard way of granting and restricting the rights to use, transform, reuse or distribute creative results (sound, text, images, multimedia, etc.). Open licenses are designed to protect copyright in environments where content (especially digital) can be easily copied and made available for public access without the author's permission. Open licenses are expected to help guarantee permission to copy and share in a structured legal form, an approach that is more flexible than is available today, when all rights are automatically granted. Licenses in each case provide certain rights, exempting from the restrictions of traditional copyright. OER is an integral part of this process. OERs provide greater flexibility in the use, reuse, and adaptation of materials to local contexts and learning environments, and authors receive well-deserved recognition.

Ukraine has a low culture of digital content consumption, as exemplified by the significant percentage of unlicensed software use. According to The Software Alliance, the estimate of unlicensed use of software in Ukraine in 2017 reached 80%, which is equivalent to $ 108 million, with an average of 57% in Central and Eastern Europe [15]. This culture of digital content consumption also applies to electronic educational resources. Authors often face the

question from colleagues – how to protect the developed educational resources from illegal use. Technological tools to limit digital content transactions exist, but they are unable to address this issue at a fundamental level. The introduction of comprehensive digital content licensing, we believe, will help to address this issue. Compliance with open licenses should help shape the perception of licenses for digital content and the possibility of its use, depending on the license. It is the obligation to license digital content that leads us to legal relations in the field of electronic educational resources and to a civilized process of their creation, distribution and use.

Open educational resources should not only have the appropriate licenses, but also a place where they can be downloaded and downloaded, provide an assessment and describe the experience of use. Like many digital content, open educational resources are stored in appropriate repositories. Examples of open educational resources repositories include Open Discover Space (https://portal.opendiscoveryspace.eu/en), MERLOT (https://www.merlot.org/merlot/) and OER Commons (https://www.oercommons.org/). Unfortunately, there are no repositories in this area in Ukraine. Universities, regional institutes of postgraduate pedagogical education, city and regional departments of education create their own repositories. At the same time, repositories take on a local character and do not have wide publicity in the educational environment. Nevertheless, in Ukraine the pedagogical community is uniting and has opportunities to improve and expand their professional competencies on open educational platforms "EdEra", "Vseosvita", "Na urok", "Prometheus" and others.

Skills in working with open educational resources should be acquired while studying in a higher education institution. Future teachers have a special advantage and responsibility.

Practical training of future teachers is one of the important stages of the educational process. On the one hand, during practical training, future teachers are able to implement the acquired theoretical skills, and on the other hand, gain experience in practical work, which affects the integrity of the existing competencies of future teachers. During practical training, especially during the period of sanitary restrictions caused by biological threats, the role of information and communication technologies increases during communication between students, mentors and trainees, between trainees and supervisors, and between trainees to share experiences and materials. The latter provides an opportunity to create tasks for the joint creation of electronic educational resources and their joint use. Such activities are aimed at increasing the level of formation of information, communication, organizational competencies. Tasks for joint creation of electronic educational resources provide an opportunity to get acquainted with the means of sharing digital content, practical use of cloud technologies, critical analysis of the suitability of certain cloud technology services for the development and creation of electronic educational resources.

Cloud technology services have both advantages and disadvantages, we will single out those that are critical to our tasks. The advantages include: no need for powerful computers (relevant for providing educational institutions with modern computer equipment), losing the meaning of using unlicensed software (relevant in the absence of such an item of expenditure), mobility of use (from any suitable network point), the ability to work together on documents. The disadvantages of cloud services in educational activities include: dependence on Internet connection (stability of broadband access is critical for collaboration on documents), not every cloud application provides the ability to save the results in a user-friendly form on the desired media, there is a risk that the cloud service provider will terminate the service. And if you need

to take full advantage of cloud services, you need to prepare for the disadvantages of having an alternative Internet connection, using open data formats and saving them, even with another cloud service, creating backups.

The concept and phenomenon of joint activities are actively studied by psychology and pedagogy. When considering the concept of "joint activity", attention is paid to two aspects: the subject activity and the processes of forming connections between people who participate in activities and communication. The main "unit" of the analysis of joint activities and its collective subject is the interaction of participants in joint activities. At the heart of the dynamic concept of joint activities is a conceptual "triangle", which combines three areas:

- subject-oriented interaction (interaction aimed at changing the subject of joint activities);
- entity-oriented (interaction aimed at changing the characteristics of the individual subject of joint activities);
- organizational-oriented (interaction, changing ways and style of performing activities).

Considerable attention is paid to the impact of joint activities on intellectual development, the formation of social intelligence and social competence of the subject of education. For all the development of the concept of "joint activities", the organization of such activities is not considered in terms of developing technical means that specifically support and strengthen the joint nature of activities. In this regard, the concept of "joint network activity" develops the concept of "joint activity", including special network tools. Joint network activity requires its design based on the following conditions:

- the availability of new pedagogically sound technical means of joint activities on the Internet, which open opportunities for enriching the activities of programs, objects, data and communications;
- the presence of new organizational forms and scenarios of educational network activities, focused on the formation of participants in the joint activities of the social network.

3. Research results

Pedagogical practical training should be considered as a type of practical activity of students aimed at solving various pedagogical problems. The specificity of this activity is that it identifies with the professional activities of teachers. At the same time, pedagogical practical training is a form of professional training in a higher education institution, the purpose of which is:

- to deepen and consolidate the theoretical knowledge that the student received at the university, and learn to apply this knowledge in practice in educational work with students;
- to equip students with the ability to observe and analyze the educational work carried out at school with students;
- to prepare students for lessons with the use of methods that enhance the cognitive activity of students;

- to develop and consolidate in students a love for the teaching profession, to encourage the desire to study advanced pedagogical experience and improve their pedagogical skills.

Various educational institutions and epidemiological restrictions make their adjustments in the process of practical training. It was a good practice from time to time to gather in a higher education institution and discuss problematic issues with classmates and methodologists, share experiences and more. The present requires communication and common tasks at a distance. To solve this problem it is necessary to use information and communication technologies and means of joint activities. Cloud technologies will be useful for the implementation of the set tasks. Using cloud technologies, we are able to establish communication and common places to work in groups.

Tasks offered to students of educational programs 014 Secondary education (Mathematics), (Physics), (Computer science) of the Faculty of Physics and Mathematics of Donbas State Pedagogical University, who underwent training and production practice in general secondary education institutions of Donetsk, Kharkiv, Luhansk and Dnipropetrovsk regions provided for three areas of activity: the creation of joint electronic educational resources, information visualization, organizational online platforms.

The use of presentations, even made in dynamic systems, do not provide an opportunity to involve students in active learning. Quite different opportunities are provided by whiteboards, thanks to which in the online format of learning the participant of the educational process takes part in discussing problems, solving problems, etc. We selected and offered 10 cloud services to create training material for the training session (table 1). Before the classes, the trainees had to get acquainted with the proposed list, explore the functions and capabilities of each of these cloud facilities and create training material for the class. For comparison, the trainees prepared the teaching material in the form of a presentation and demonstrated it to the students, while the students performed the tasks on paper. After the lesson, students were asked which of the suggested options for the lesson they liked the most. The survey of the class showed that 70.0% of the surveyed students out of 374 who took part in the survey preferred the lesson where the "whiteboard" was used.

To visualize the information and create interactive content, the systems presented in table 2

Table 1
Whiteboard cloud services.

Name	Free usage	Localization	Download object	Embedding in systems
Padlet.com	freemium	Yes/Partly	No	Yes
Linoit.com	free	No	No	Yes
Idroo.com	free	No	Yes	Yes
Miro.com	freemium	No	Yes	Yes
Whiteboardfox.com	freemium	No	No	Yes
Jamboard.google.com	free	Yes	Yes	Yes
NoteBookCast.com	free	No	No	Yes
Conceptboard.com	freemium	No	No	Yes
Groupboard.com	freemium	No	No	Yes
Classroomscreen.com	freemium	No	No	Yes

were studied. Visibility is one of the conditions of electronic educational resources. The development and creation, even of static, e-learning resources is one of the tasks of e-learning. The limited space available for inspection requires the use of presentation technologies in the form of scrolling. Accordingly, the method of their application should change, in contrast to the fact that students see a large paper poster. The constant use of the same patterns, design styles, etc. in educational activities leads to a loss of visual interest in the educational material. The use of various design styles, fonts, icons, etc. increases students' visual activity. Each of the proposed systems has its own unique design style. Even by creating infographics in different systems based on common data, we get fundamentally different digital products.

Table 2
Infographics cloud services.

Name	Free usage	Localization	Download object	Embedding in systems
Easel.ly	Free	No	Yes (wiles)	Yes
Infogram.com	Freemium	No	Yes (wiles)	Yes
Canva.com	Freemium	Yes	Yes	Yes
Crello.com	Free	Yes	Yes	Yes
Genial.ly	Freemium	No	Yes (wiles)	Yes
Chartblocks.com	Free	No	Yes	Yes
Piktochart.com	Freemium	No	Yes (wiles)	Yes
Venngage.com	Freemium	Yes	Yes	Yes
Vizzlo.com	Freemium	No	Yes (wiles)	Yes
Adioma.com	Freemium	No	Yes	Yes

Practitioners faced the problem of downloading created digital objects to their own device. At the same time, their integration into other objects created by cloud technology applications took place without hindrance. The above applications of cloud technologies at the beginning of their founding mostly offered their resources for free, with the growth of their popularity, most of them switched to the financial model "Free – Premium" (Freemium), where some services are provided on a free basis and some on a commercial basis. However, for each of the applications, we were able to obtain a digital object created by us on our own computing device by third-party tricky methods.

The created means of visual presentation of data were used during educational activities. Moreover, students in computer science lessons and outside the classroom were asked to create their own posters, charts, graphs, infographics. The study involved 362 students, of whom 235 students (about 65%) liked to create digital content of this type. The students included the advantages – "beautiful", "visual", "useful". Among the shortcomings were noted – "not clear", "difficult", "I have no artistic flair". Analyzing the answers to the shortcomings, it should be noted that they do not have a meaningful basis, they are answers-justification of their unwillingness to use the proposed applications of cloud services. Regarding the reasons for reluctance, the study was not conducted due to lack of time during the internship.

We also asked the students – "What is the main thing in the application in your opinion?". The obtained answers are presented in figure 1. Most students (32.6%) were inclined to think about "understandable language" used in the application. Despite the availability of cloud online

translation services, the interface in English caused difficulties when using the application. In second place (28.2%) was the ability to work as a mobile application, because today the number of users through mobile systems exceeded the number of users through a stationary computer system. In third place was the design criterion (23.5%). And although the systems that were proposed were directly related to graphic design, the ergonomics of these systems still need to be improved. In last place was the criterion of "available examples of work" (15.7%). In our understanding, this is the "worst" criterion and it is gratifying that the smallest number of students is ready to do tasks on the model, because the capabilities of the systems are sufficient for creativity and creative presentation of information.

Figure 1: The results of a survey of students on the means of creating infographics.

The task of creating shared electronic resources was to analyze existing cloud applications to create presentations and text documents. To do this, the use of office applications for cloud services was proposed, which is presented in Table 3. In contrast to the previous comparison tables, the advantages and disadvantages collected from the subjective judgments of trainees were considered. It was in these applications that they tried to create electronic educational resources, which were then to become open educational resources. It should be noted that while the interns were already familiar with the Google Docs and Office Online systems, the Zoho Office Suite and ONLYOFFICE turned out to be surprisingly interesting and useful. It was in these office applications that interns tried to create electronic educational resources. Tasks were

Table 3
Cloud office applications.

Name	Advantages	Disadvantages
Google Docs (docs.google.com)	Free and no significant restrictions; Convenient, non-distracting design; Well-thought-out collaboration in the cloud; Integration with Google services regular innovations; Templates gallery.	Occasionally there are failures; There is no possibility to personalize the workspace (branding).
Zoho Office Suite (zoho.com)	Extensive list of additional applications; Interesting features in the paid version; Free version available; Convenient work with projects thanks to Workspaces.	Lack of localized documentation and incomplete localization of applications; The mobile version only works in read mode Numerous disadvantages of Zoho Sheet.
Office Online (office.microsoft.com /online/)	Excellent compatibility with MS Office formats; Responsive, stable touch interface and convenient Ribbon tape; Close integration with Office 365 and Microsoft services.	Working with documents needs to be reviewed; A small selection of import and export formats, limited by proprietary licenses; No automatic saving, inconvenient version control; Functional "gaps" in Excel; Fuzzy commenting system.
ONLYOFFICE (onlyoffice.com)	User-friendly interface; Import documents from other services.	No spell check; Quite high rates for individual use of the service; There are no full screen and compact modes; Documentation in English; Weak functionality of Spreadsheet Editor and Presentation Editor.

proposed for groups of three students and the selected topics were similar in content.

After the end of pedagogical practice, a survey of students on the joint creation of open educational resources was conducted. They were asked the following questions:

A. How do you feel about open digital content (Positive / Negative)?
B. Did you have experience of using open educational resources during pedagogical practice (Yes / No)?
C. Have you used digital resources despite not having this action with a license agreement (Yes / No)?
D. Are you ready to create open educational resources (Yes / No)?
E. How do you feel about the joint development of electronic educational resources (Positive / Negative)?
F. Is it appropriate to use unlicensed software to develop open educational resources (Yes / No)?

58 students of the Faculty of Physics and Mathematics of Donbas State Pedagogical University took part in the survey. The results of the survey are presented in figure 2. Questions A–C

were related to the use of open educational resources, and questions D–F were related to their development. We tried to determine whether students would be willing to use open educational resources to develop them. Using the Mann – Whitney U test, we compared the responses in the two groups (A–C) and (D–F). The results of calculations $U_{emp} = 18, U_{0.1} = 3.0, U_{0.05} = 7.0$ indicate the absence of significant differences between groups, and therefore students who are willing to use open educational resources are ready to develop them.

	Yes/Positive	No/Negative
A	40	18
B	45	13
C	35	23
D	30	28
E	52	6
F	31	27

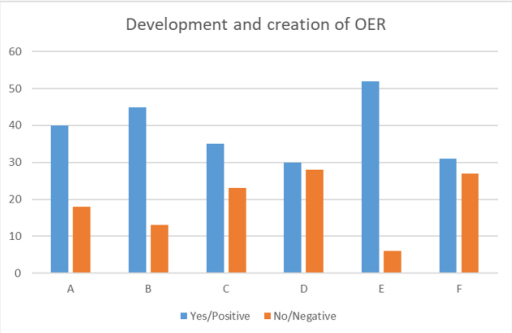

Figure 2: The results of the survey of trainees.

The analysis of the answers tells us about one unpleasant point, which is mentioned in questions C and F. Students do not pay much attention to the issue of licensing a digital product, and it does not matter whether it is an electronic educational resource or software. To justify it, it should be noted that similar surveys conducted three years ago about free software spoke of an even worse attitude to the licensing of software.

4. Conclusions

Open educational resources are a product of the digital world, which has a huge potential for further achievement of UNESCO's goals in the field of education. They help countries, institutions and teachers to share quality education and materials free of charge. They challenge teachers to integrate digital technology into their courses and programs, and enable students to access quality content offline. They are also an incentive for teachers, students and institutions to work together to create original material. It is important that governments use OER opportunities for their socio-economic development purposes. UNESCO can assist in this process by issuing Recommendations that will encourage governments to develop strategic policies to engage OER in the core system of their education systems, encouraging institutions to take full advantage of this development to achieve global development goals.

The result of creating open electronic resources in the interaction of future teachers during the internship was not only the availability of educational content, but also increasing the level of professional competencies in ICT, collective interaction, project activities, creative thinking. The results of the surveys indicate the need to continue this practical activity with the study of the criteria for the effectiveness of the use of open electronic resources and their quality.

References

[1] S. H. Lytvynova, Cloud-oriented learning environment of secondary school, CEUR Workshop Proceedings 2168 (2018) 7–12. URL: http://ceur-ws.org/Vol-2168/paper2.pdf.

[2] S. Day, E. Erturk, e-Learning objects in the cloud: SCORM compliance, creation and deployment options, Knowledge Management & E-Learning 9 (2017) 449–467. URL: https://www.kmel-journal.org/ojs/index.php/online-publication/article/view/392. doi:10.34105/j.kmel.2017.09.028.

[3] T. Vakaliuk, D. Antoniuk, A. Morozov, M. Medvedieva, M. Medvediev, Green IT as a tool for design cloud-oriented sustainable learning environment of a higher education institution, E3S Web of Conferences 166 (2020) 10013. doi:10.1051/e3sconf/202016610013.

[4] N. V. Valko, N. O. Kushnir, V. V. Osadchyi, Cloud technologies for STEM education, CEUR Workshop Proceedings 2643 (2020) 435–447. URL: http://ceur-ws.org/Vol-2643/paper25.pdf.

[5] M. P. Shyshkina, M. V. Marienko, The use of the cloud services to support the math teachers training, CEUR Workshop Proceedings 2643 (2020) 690–704. URL: http://ceur-ws.org/Vol-2643/paper41.pdf.

[6] M. V. Popel, M. P. Shyshkina, The areas of educational studies of the cloud-based learning systems, CEUR Workshop Proceedings 2433 (2019) 159–172. URL: http://ceur-ws.org/Vol-2433/paper09.pdf.

[7] I. V. Kholoshyn, O. V. Bondarenko, O. V. Hanchuk, I. M. Varfolomyeyeva, Cloud technologies as a tool of creating Earth Remote Sensing educational resources, CEUR Workshop Proceedings 2643 (2020) 474–486.

[8] Y. H. Nosenko, M. V. Popel, M. P. Shyshkina, The state of the art and perspectives of using adaptive cloud-based learning systems in higher education pedagogical institutions (the scope of Ukraine), CEUR Workshop Proceedings 2433 (2019) 173–183. URL: http://ceur-ws.org/Vol-2433/paper10.pdf.

[9] P. P. Nechypurenko, V. G. Stoliarenko, T. V. Starova, T. V. Selivanova, O. M. Markova, Y. O. Modlo, E. O. Shmeltser, Development and implementation of educational resources in chemistry with elements of augmented reality, CEUR Workshop Proceedings 2547 (2020) 156–167.

[10] O. M. Markova, S. O. Semerikov, A. M. Striuk, H. M. Shalatska, P. P. Nechypurenko, V. V. Tron, Implementation of cloud service models in training of future information technology specialists, CEUR Workshop Proceedings 2433 (2019) 499–515. URL: http://ceur-ws.org/Vol-2433/paper34.pdf.

[11] D. Wiley, A. Webb, S. Weston, D. Tonks, A preliminary exploration of the relationships between student-created oer, sustainability, and students' success, The International Review of Research in Open and Distributed Learning 18 (2017). URL: http://www.irrodl.org/index.php/irrodl/article/view/3022. doi:10.19173/irrodl.v18i4.3022.

[12] V. Y. Velychko, S. O. Omelchenko, I. A. Khyzhniak, E. G. Fedorenko, Developing and using open electronic educational resources in educational activities, Journal of Physics: Conference Series 1840 (2021) 012063. doi:10.1088/1742-6596/1840/1/012063.

[13] V. Velychko, S. Omelchenko, O. Fedorenko, Open access to ICT and electronic educational resources as a guarantee of sustainable development of society, in: Proceedings of the

2020 3rd International Seminar on Education Research and Social Science (ISERSS 2020), Atlantis Press, 2021, pp. 79–85. URL: 10.2991/assehr.k.210120.017.

[14] UNESCO, Recommendation on open educational resources (OER), 2019. URL: http://portal.unesco.org/en/ev.php-URL_ID=49556&URL_DO=DO_TOPIC&URL_SECTION=201.html.

[15] Software Management: Security Imperative, Business Opportunity, BSA global software survey, BSA, 2018. URL: https://gss.bsa.org/wp-content/uploads/2018/05/2018_BSA_GSS_Report_en.pdf.

Development of an electronic system for remote assessment of students' knowledge in cloud-based learning environment

Mykhailo I. Sherman[1], Yaroslava B. Samchynska[1] and Vitaliy M. Kobets[1]

[1]*Kherson State University, 27 University Str., Kherson, 73003, Ukraine*

Abstract

The system for remote assessment of knowledge automates formation of task (tickets) with questions and tasks for conducting intermediate and final monitoring of knowledge of students is offered. In the process of developing an electronic system for knowledge assessment, the basic requirements for a web application and the modules that the system consists of were determined, the main roles of users in the system and their functionality were identified, access rights were established. The technical, functional, and non-functional features of the software product are described, web technologies for creating an application for knowledge assessment are considered. The diagram of system sequences, the use-case diagram, which schematically describing roles and functions of agents in an information system, the diagram of classes of a database structure are presented with UML description. Based on the defined requirements for the resource in cloud-based learning environment, the following technologies for its development were chosen: the server programming language PHP, JavaScript programming language and its libraries were used, as well as the MySQL database with PhpMyAdmin tool for administration of chosen database management system. OpenServer software complex system was used to develop and test the application functionality. The usage of the proposed electronic assessment system of knowledge contributes to the formation of an open information and cloud-based learning environment of a modern educational institution, enhances the efficiency and more rational distribution of teacher time in preparing tests or exams, activates repetition of educational material and knowledge assimilation, indirectly motivates students to more honest learning.

Keywords

Knowledge Assessment, e-Assessment, Monitoring of Knowledge, Web Application, Distance Learning

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sherman-m@ukr.net (M. I. Sherman); samchynskaya@gmail.com (Y. B. Samchynska); kobetz@ukr.net (V. M. Kobets)

https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Sherman.aspx (M. I. Sherman);

https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Samchinska.aspx (Y. B. Samchynska);

https://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/KobetzVN.aspx (V. M. Kobets)

0000-0001-5120-620X (M. I. Sherman); 0000-0003-1582-8129 (Y. B. Samchynska); 0000-0002-4386-4103 (V. M. Kobets)

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1. Introduction

Control of students' knowledge and skills is an important component of the cloud-based learning environment, which should be conducted throughout the educational period. The assessment of students' level of knowledge depends, for example, on the motivation of students to acquire knowledge, the desire for in-time quality performance of exercises set by the teacher. In 2020, the governments of more than 190 countries closed their educational institutions in order to prevent the rapid spread of COVID-19 [1]. With the changeover of educational institutions to distance learning, the problems of timely, objective and sound assessment and monitoring of student achievements in the digital space is becoming increasingly important and requires such forms and methods of solution, as cloud-oriented learning systems.

2. Related work

The assessment of students' academic achievements is understood as a system of indicators that reflect their objective knowledge and skills, that is this process can be considered as determining the degree of acquisition of knowledge, skills and achievements in accordance with the requirements of the curriculum [2].

The assessment consists of such components as a score, which is an actual fixed value that describes the level of student achievement, his skills, abilities, and may contain the teacher judgments about the characteristics of student achievement while education period, what disadvantages and achievements were formed during this process.

Due to the closure of university campuses and the necessity to maintain social distance, world organizations such as UNESCO [3], the International Association of Universities [4], the OECD Center for Educational Research and Innovation [5], OECD Education and Skills Today [6] began to work actively on the development of solutions for the organization of online examinations of students.

However, even before the COVID-19 pandemic, the benefits and strategic directions of using e-assessment were discussed in the works of Alruwais et al. [7], Arend [8], Crisp [9], Guàrdia et al. [10], Shalatska et al. [11].

Issues of analysis and assessment of student achievement during distance learning and cloud technologies were studied in the works of Bondarchuk et al. [12], Harrison and Hutton [13], Tomaino et al. [14], Kiv et al. [15], Kostikov et al. [16], Proskura et al. [17], Sherman and Samchynska [18], Samchynska and Vinnyk [19, 20], Spivakovskiy et al. [21], Todeush and Sherman [22], Vincent-Lancrin [6], Wang [23], Wijekumar et al. [24], Zaytseva [25].

OES is the complex platform – online examination system, which has been developed in PHP script with MySQL Database [26]. This system is aimed at automated creation of tests for the exam based on questions, which are already entered in the database. The OES platform is capable to identify the strengths and weaknesses of the student after passing the exam tests. The disadvantage of this system is that it supports different types of questions, so it can generate only the tests with one or more answers.

ConductExam platform is an online examination software that includes a large combo of software applications for web-based exam software, offline exam, computer-based test, control-

based exam, online assessment software, and many more [27]. With this system, teachers can add questions or tasks. The student has the opportunity to take the exam on the Internet in accordance with the specified date, time and with the help of a registered login ID and secret key. However, the capabilities of this platform do not include an automatic parsing of questions from training educational materials files.

The system of online education of Kremenchug Mykhailo Ostrohradskyi National University contains a testing system with which teachers can create courses, test tasks, conduct exams and assess the quality of students' knowledge [28]. Applicants for higher education can take exams in the form of tests, communicate with teachers online and receive advice. The system supports only test tasks.

The considered systems of knowledge assessment do not have sufficient flexibility in the formation of questions and tasks of different types, the functionality does not provide information about the results of students' completed tasks, and does not contain an automated selection of questions from different types of documents. Therefore, these features and capabilities need to be considered when developing an advanced online system for knowledge assessment.

3. Research questions

In the circumstances of distance learning there appear certain difficulties and consequently drawbacks in the assessment of educational achievements of higher education students. They are associated with insufficiently objective and non-transparent assessment and recording of the level of knowledge acquired by the student during the education period, insufficient attention to the individual achievements of the student, technical difficulties in creating quality e-tickets, tests and other control tasks.

Concerning the features of electronic assessment of higher education applicants' achievements, ensuring its quality and objectivity require a description of the technical characteristics of the information system, functional and non-functional parameters of the software product to provide an online assessment of the acquired knowledge level.

The development and use of a web application for online assessment of higher education as a part of a sophisticated system of monitoring the levels of higher education applicants' achievements, which is being developed at Kherson State University, will help to improve the process of assessing students' knowledge and skills during distance learning.

The aim of the study is the development of an electronic system for assessing the level of knowledge, which automatically generates tickets, tasks for tests, exams and other control measures in the form of a web application for remote assessment of the level of knowledge acquired by students.

The following *research tasks* were set:

1. To determine the requirements that must be met by an electronic system of remote knowledge assessment.
2. To choose methods of generating control tasks (tickets) using web technologies.
3. To define the architecture and describe the modules of the electronic system.
4. To choose programming technologies for developing the online assessment system.

5. To create a SQL database project based on determined system modules and to develop the system using the PHP programming language.

4. Research results

4.1. Defining requirements for software and e-system modules

The following list of requirements has been formed for the system of online assessment of students' academic achievements:

- Availability of educational courses that contain certain topics and lectures. For each topic, there is a set of control questions, tasks or tests. Tickets for exams are automatically created based on these control materials.
- The teacher can enter questions on the discipline into the database using a special input form, as well as upload lectures, laboratory work, guidelines, etc. The online system uses a parser to receive questions and tasks from these files and enters them into a database.
- Using the task generator, the teacher receives tickets with tasks. To do this, the generator receives information from the system database and in accordance with the configured parameters creates tickets with control questions. A ticket is a form with control tasks, designed for different types of control measures, such as tests, modular control tests, final certification.
- The student can view the content of the disciplines he is studying. For each discipline, which is located in the system, the applicant of higher education sees the scheduled exams, date and time of their holding. When the time to start the exam comes, the student receives a ticket with a specific task and can answer questions.

At the end of the time specified by the exam, the ticket with the student's answers is sent for verification to the online assessment system. If the ticket contains tests, the student and the teacher receive the result of the test immediately. If the ticket contains questions that require a detailed answer, it is sent to the teacher for re-view. After the test, the teacher gives an assessment.

In accordance with the above requirements, the main modules of which the information system should consist were defined. These are presented in figure 1 [22].

The "Catalog of academic disciplines" part of the system includes pages of the site, which displays a list of academic disciplines for the student, defined by his curriculum. Each discipline consists of a number of modules, these modules consist of a number of study topics, which in turn contain questions. The teacher inputs questions into the database himself using the form on the system page. The teacher can upload to the system such educational materials as lectures, practical works or a list of control questions. After this, the system automatically enters questions from these files into the database. In the future, these materials are used to generate tickets with questions or tasks for the test, credit test or exam.

The student can overview the files of lectures or other educational materials in the content of the discipline, as well as see the date when the exam will be held. During the exam, the student

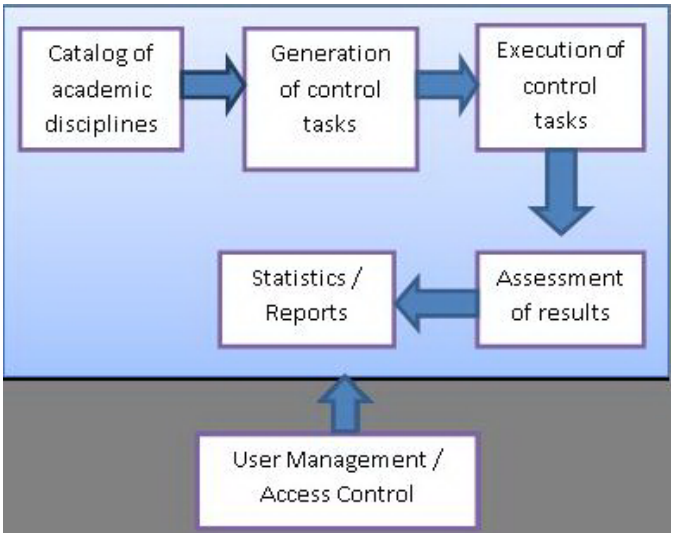

Figure 1: The modules of e-assessment system of students' knowledge.

proceeds to the control tasks which he received in the ticket. A list of control questions for the student is not available until the beginning of the exam.

The "Generation of control tasks" part of the system includes the function of creating tickets with different types of tasks, in particular with questions that require an open answer, as well as tests with the choice of one or more correct answers. On the page with the list of disciplines, the teacher chooses academic discipline and moves to the page of the website containing educational subject topics. The function of creating an exam is available for the teacher. The ticket generator works according to the parameters specified by the teacher in the modal window of presets. The teacher sets the date and time of the test, chooses the type of exam (individual work, modular test, modular test or exam), sets the duration of the exam, specifies the number of test questions and points for the correct answer. After selecting the required parameters, the system generates the appropriate ticket with the task. The teacher can also add any question to the ticket and assess the answer.

The "Execution of control tasks" part of the system provides functionality to the process of passing the exam. The student with access to the exam, provided by the teacher, receives a ticket generated by the system and begins to pass the test. A list of different types of questions reveals. Upon accomplishing the ticket tasks, the completed form with answers is sent to the server, where the answers are processed. If the ticket contains only test questions, the system immediately provides a result on the correctness of the answers. If the ticket contains questions that require a written answer, the system sends a ticket with the answers to the teacher for verification. The sequence of actions for passing the exam within the information system of assessment is presented in figure 2.

The "Assessment of results" part of the system provides functionality to the process of checking the form of control passed by the student and providing results to the teacher and the student in the form of a PDF file. If the higher education applicant does not pass the exam, this

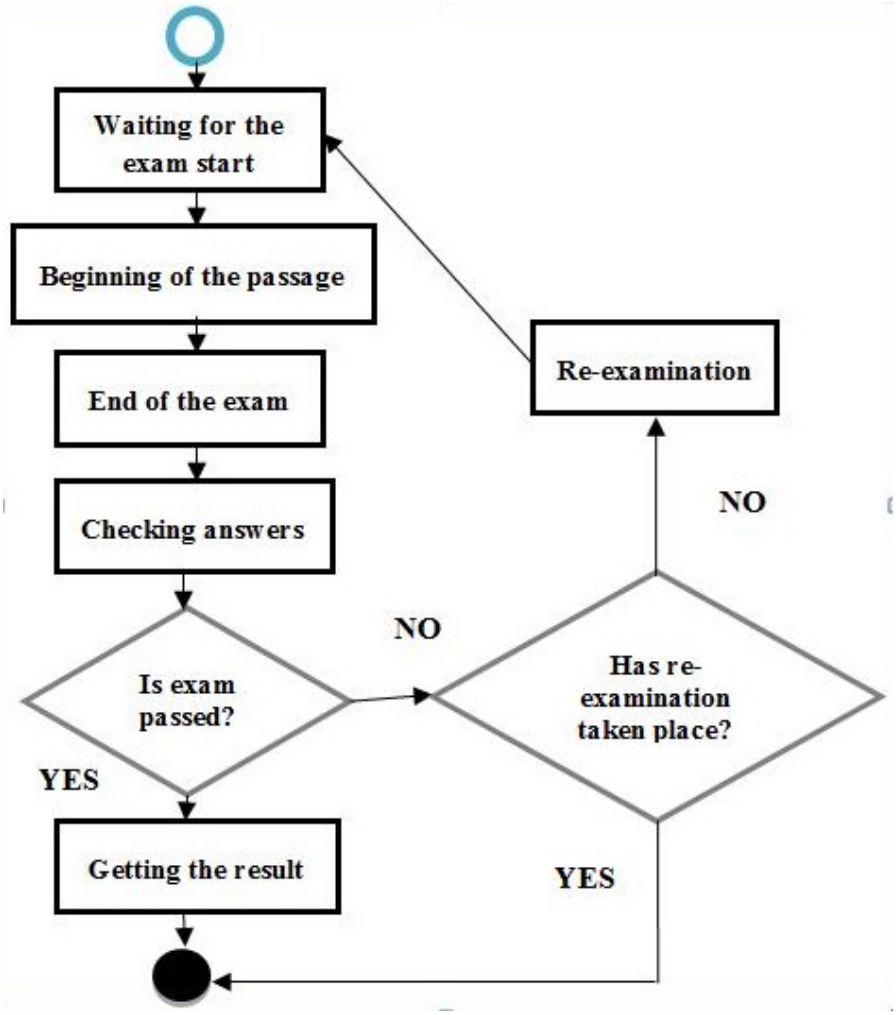

Figure 2: Diagram of actions of passing the exam by the student within the information assessment system.

feature will be unavailable and he will need to take the exam again. The student can review the questions, answers and analyze the result, seeing which questions were answered correctly or incorrectly. The teacher receives the results of the student's control measure in order to analyze the level of student achievement, to determine which topics need to be finalized. According to the results, the teacher assesses the exam.

In the "Statistics / Reports" part of the system, the processing of the general statistical information of educational achievements of the higher education applicant on disciplines takes place and also based on all points for educational disciplines the general rating of success of students is formed. The student has an opportunity to view a list of their subjects, current and final marks in the form of a record book.

The "User Management / Access Control" part of the system provides functionality to manage user rights. The features for each user are defined, as well as the level of access to certain

data. A teacher can review his own academic disciplines, make changes to the uploaded files of educational materials, edit the points which are given to a certain student in discipline but cannot amend the disciplines of other teachers. The student cannot modify the content of their subjects or the results of assessing the levels of their academic achievements. The administrator can edit the roles of system users, make changes to the database, perform general system management.

The sequence of actions in the proposed system is presented in figure 3.

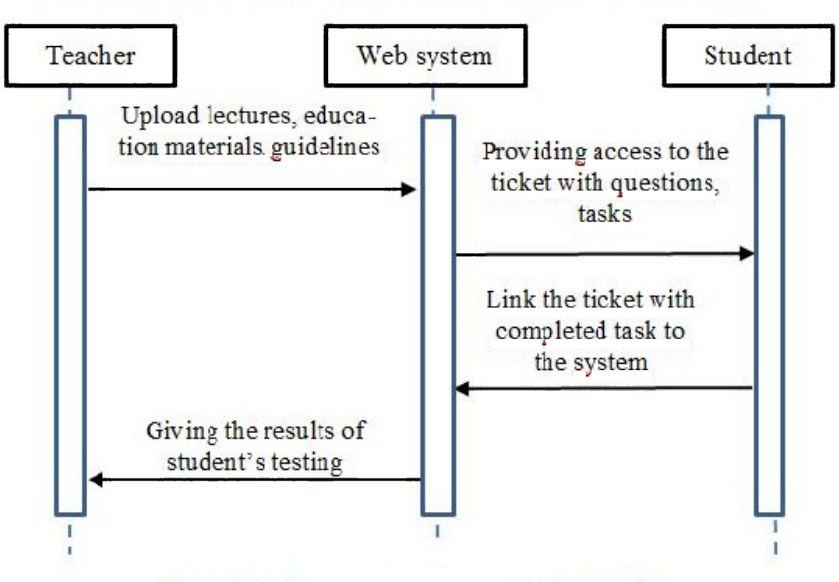

Figure 3: Sequence diagram of the e-assessment system.

4.2. Establishing roles and their functions in the assessment system

An electronic system for remote assessment created in the form of a web application is basically a website with the following functionality:

- registration of students and teachers;
- generation of tickets with control questions or tests from documents prepared by teachers and uploaded to this web resource;
- passing exams or other control measures within the higher education system;
- providing detailed results on passing the exam (test) by the student;
- formation of a students' rating based on assessments of levels of their knowledge on educational disciplines.

Within the developed e-assessment system, three roles were defined: system administrator, teacher and student. The roles of the system and their functions are shown in the form of a use-case UML diagram (figure 4).

The administrator in the electronic assessment system obtains the following functions:

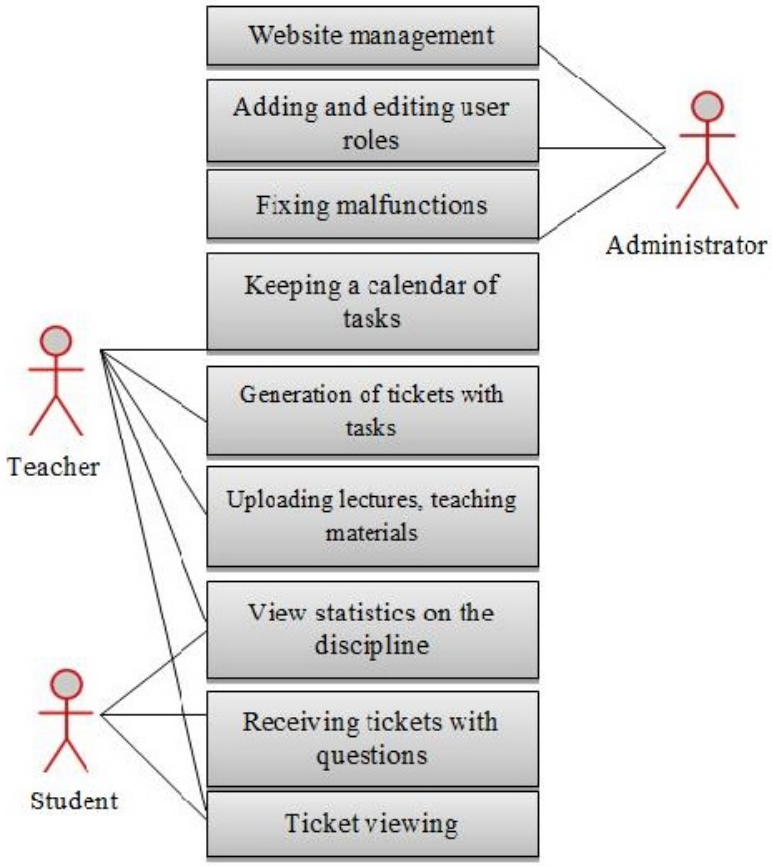

Figure 4: Users roles within e-assessment system and their functions.

- development and maintenance of a web resource, improvement and updating its current structure;
- technical support and security control of the website;
- updating and editing the content of the site, order materials for the site through outsourcing, if necessary;
- feedback from the web resource users;
- control of the correct functioning of the site, tracking its availability for users on the network.

The teacher has the following functions within the e-assessment system:

- organization and support of the learning process;
- monitoring of the success training program completion in accordance with the curriculum;
- providing feedback to students;
- uploading of educational materials and tasks to the web resource in the form of tests or questions with detailed answers.

The student within the system of remote assessment has the opportunity to receive tickets with control tasks, execute the proposed tasks, and review statistical information on the discipline he/she is studying.

4.3. Choice of technologies for a software development

The choice of programming technologies for the developed assessment system was made due to some specialties: it will store information about students, teachers, files with educational materials, as well as user interaction with this information. At this stage of system development, you need to choose the technology for database management, the programming language to execute the logic and functionality of the program, as well as the technology for displaying this data. Also, a platform for testing the web resource is chosen.

The OpenServer software complex was chosen as the platform for developing and testing web applications [29]. The architecture of the location of the catalogs of the software complex implies a clear separation of two different types of data: variable user data (settings, temporary files, logs, etc.) and immutable service data (modules, programs, service files) [29]. In particular, the developed information system uses the following rules: in the modules folder the data never changes, here the standard libraries of the software complex, modules and settings are stored, and in the domains and user data folders, there is information that the software developer can change in accordance with website requirements and configuration.

In the process of developing an electronic assessment system, SQL technology was used for the MySQL database management system in the PhpMyAdmin web application. The Structured Query Language or SQL is a language for executing database queries, which is also used to manage and update databases [30].

The creation of the basic functionality for the e-assessment system was performed using the server-side programming language PHP. The main purpose of this programming language is to create scripts for web pages, as well as programming commands that run on server side. All operating systems, which support the web server maintenance, support PHP.

To build the structure of the website pages, HTML and the JavaScript programming language jQuery library were used, as well as the technology of accessing the server without reloading the page to update Ajax data, which is organized using JavaScript. Using Ajax helps us to avoid page reloading after each request sent to API, i.e. increases the system efficiency and improves overall user impression on interaction with the website [31].

PHPWord is a library written in pure PHP that provides a set of classes to write to and read from different document file formats. Using a software product such as PHPWord is required to read data from Word files.

MySQL technology was used to store system information and data. The language of structured queries is the standard language for executing queries, updating relational databases and managing them. SQL does not determine the sequence, but the result of some operations [30].

4.4. Development of the database structure of the e-assessment system

The structure of the database, designed during the creation of the remote assessment system and developed with the PhpMyAdmin environment using the MySQL data-base management

system, is shown in figure 5.

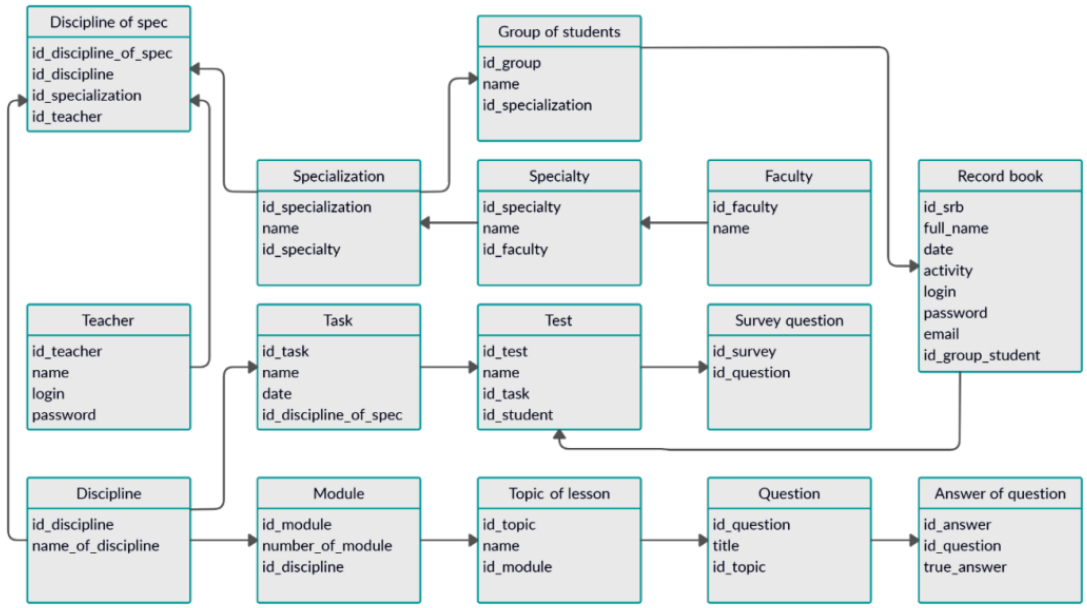

Figure 5: Users roles within e-assessment system and their functions.

Database tables of the developed electronic assessment system:

- Faculty-tb – a table with the names of the faculties of the higher education institution.
- Specialty-tb – a table with the names of the specialties of the faculty.
- Specialization-tb – a table, which contains the names of specializations of the university.
- Group-of-students-tb – a table with numbers of students' academic groups.
- Record-book-tb – a table with basic students' data.
- Teacher-tb – a table with basic teachers' data.
- Discipline-of-spec-tb – a table, which contains academic disciplines of the educational institution.
- Discipline-tb – a table with disciplines related to a particular specialization.
- Task-tb – a table, which contains control questions and tasks.
- Test-tb – a table containing tickets with questions and tasks.
- Survey-question-tb – a table with control tasks or questions related to a specific ticket.
- Module-tb – a table, which contains the ordinal numbers of the constituent educational materials of the disciplines.
- Topic-of-lesson-tb – a table with the topics of lecture materials.
- Question – a table that contains test questions for each lecture, practical work, case study or collection of educational materials.
- Answer-of-question – a table with the answers to the control questions are stored.

Thus, in accordance with the requirements for the application, a database was designed and developed for the electronic assessment system using PHPMyAdmin and the MySQL database management system.

4.5. Implementation of the electronic assessment system functionality

To use the electronic evaluation system and view its web pages, user must register and authorize. Registration is conducted for teachers and students. An email is sent to confirm registration for security purposes. After confirming the registration, a corresponding account is created.

After authorization, the student in the “Personal Profile” tab can see a table that contains information about his faculty, specialty, course, group and email. In the “Disciplines” tab, the student can see the list of disciplines and the average score in these subjects, which calculated of current points.

In the “Catalog of academic disciplines” module, depending on the user role, the teacher can see only his disciplines and the student has access to the disciplines, which are available in accordance with the curriculum.

In the “Generation of control tasks” module in the discipline, the teacher can create a control measure, such as an exam or test, plan the date and time of its conduct, select the training modules, which would be assessed during the control measure. The teacher specifies the required number of questions in the form of tests, points for the correct answers, number of questions which requiring a detailed answer. The created exam (figure 6) is inserted into the Task table.

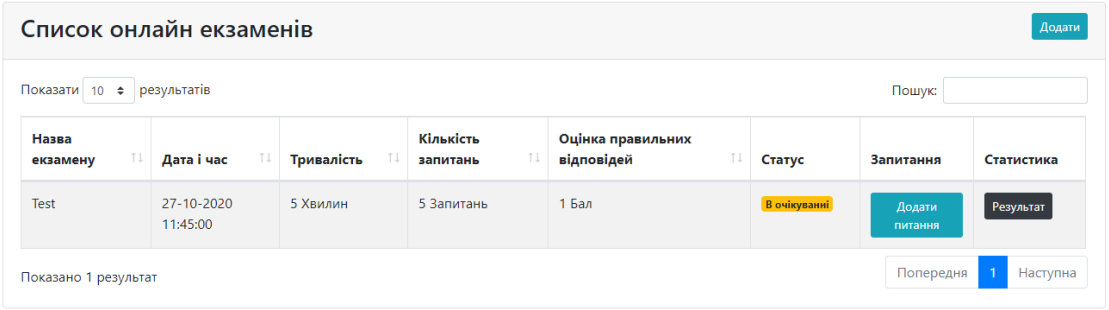

Figure 6: Page of the e-assessment system with the created exam.

The list of questions is retrieved from the Question table, to which the teacher can input questions manually or the system adds them automatically from the files of educational materials (lectures, practical work, etc.). Number of questions and tasks that require a detailed answer is defined in accordance with the parameters set in the settings menu. If there are not enough questions of a particular type in the database, the web system will create a ticket with the possibility for the teacher to add tasks to the ticket later. The ticket generator creates a ticket and inserts it into the Test-tb table, questions are inserted into the Survey-question-tb table.

The teacher can view the generated ticket, add or delete questions. The ticket created in the system is presented in figure 7.

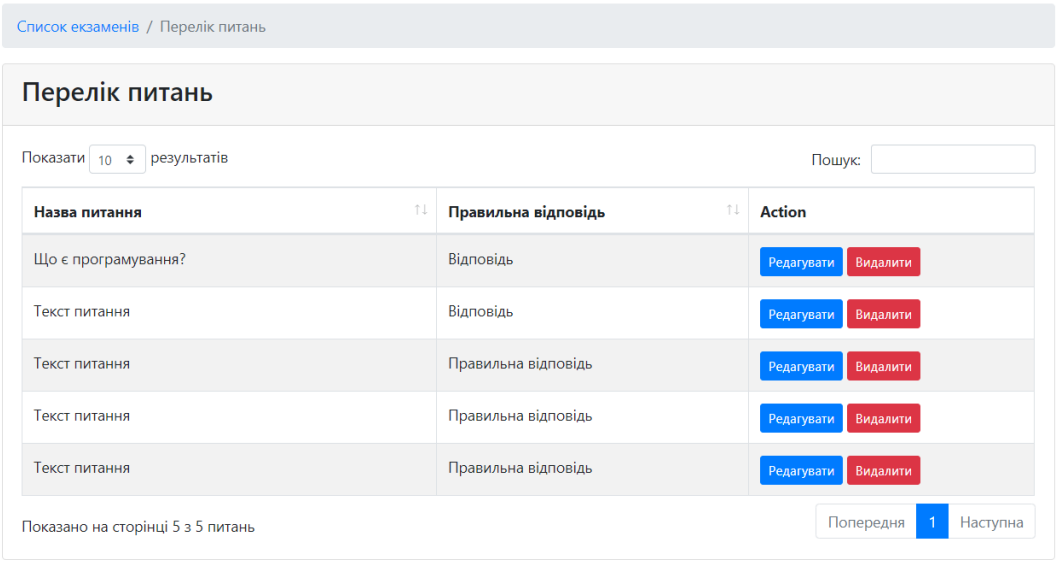

Figure 7: Generated ticket with questions in the e-assessment system.

In the "Task execution" module of the electronic assessment system, the higher education applicant gets access (previously provided by the teacher) to the exam at the time set when creating the exam and gets the opportunity to take a test, answering the ticket questions. The student studying a certain discipline receives a question from the table Survey-question-tb.

After answering the questions and taking the exam (or other tests), the student has the opportunity to download a PDF file that displays statistical information about the exam: question number, the text of the question or task, answer options, the option chosen by the applicant, the number of points for answers, as well as the final assessment for the exam.

The system sends questions that require a detailed answer as a form with answers after the exam to the teacher for verification. The rating of higher education applicants consists of the points they receive while determining the levels of their knowledge within a 100-point scale.

Thus, a system for assessing the levels of acquired knowledge of higher education applicants was developed, the interaction of modules which generate and process the information, with database tables, which contain that information aimed at assessing and monitoring students' academic achievements, was set up.

4.6. Approbation of the developed system for remote assessment of knowledge

The developed system for remote assessment of knowledge was used as part of the system for monitoring the levels of academic achievement of higher education applicants at Kherson State University for Master qualification level of "Software Engineering", " Computer Science", " Information Systems and Technologies" specialties. The electronic assessment system was used to control the level of acquired knowledge of students at full-time and part-time education forms in the total number of 39 people in the "IT Governance" discipline in 2019-2021 academic

year at the Faculty of Computer Science, Physics and Mathematics of Kherson State University. Students were offered a final test in the “IT Governance”, the tasks for which were generated by the proposed electronic assessment system, access to the system is presented on the KSUOnline distance learning platform of Kherson State University as part of the “IT Governance” distance course (figure 8).

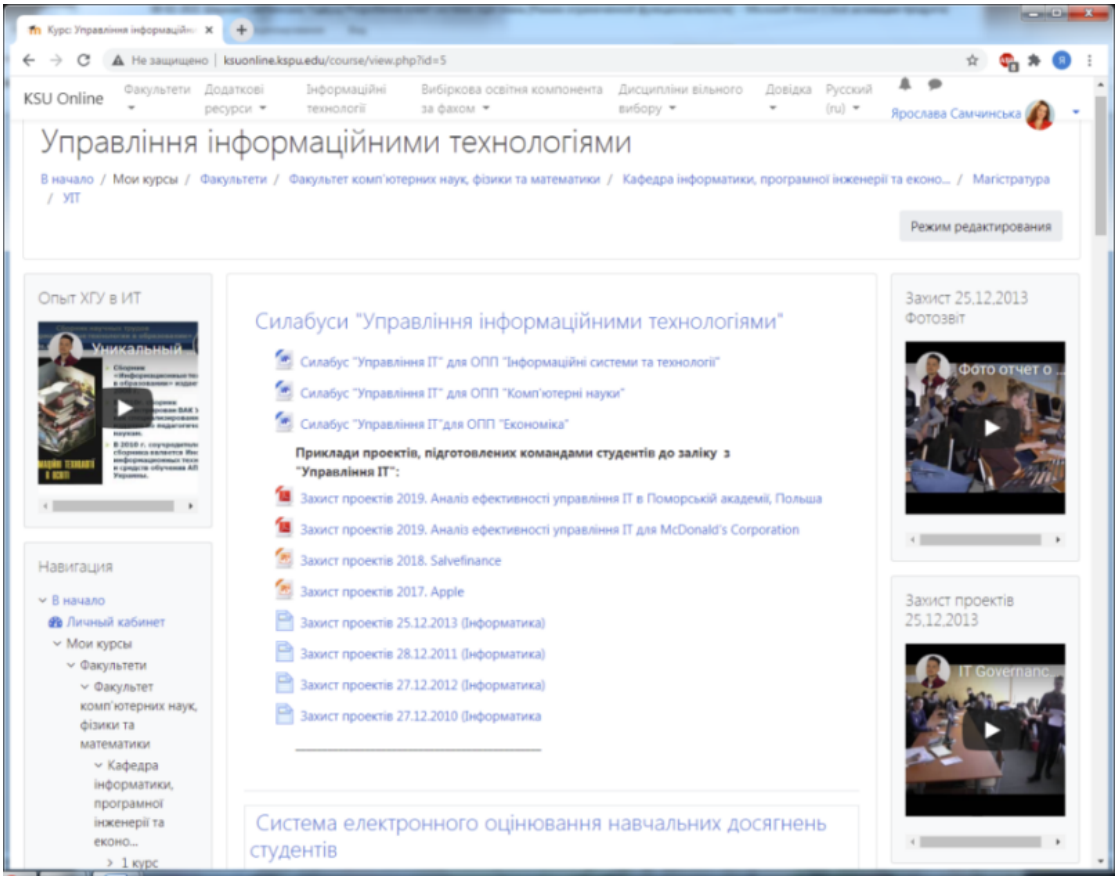

Figure 8: Using the electronic assessment system to control the knowledge of students as part of the “IT Governance” distance learning course in the KSUOnline of Kherson State University.

The usage of the proposed electronic assessment system of knowledge contributes to the formation of an open information and educational environment of a modern educational institution, enhances the efficiency and more rational distribution of teacher time in preparing tests or exams, activates repetition of educational material and knowledge assimilation, indirectly motivates them to more honest learning through the ability to compare their own academic achievements with similar indicators of other applicants for higher education.

5. Concluding remarks and future work

The conducted researches allow us to formulate certain results and to target directions of further developments in the field of higher education in the conditions of modern challenges. In particular, the expediency of development of the electronic system for assessment of students' knowledge was justified to ensure the efficiency and quality of learning, notedly in the context of distance learning.

The system of remote monitoring of knowledge which automates the formation of tickets with questions and tasks for conducting control measures, examinations is offered.

In the process of developing an electronic system for knowledge assessment, the basic requirements for a web application and the modules that the system consists of were determined, the main roles of users in the system and their functionality were identified, access rights were established. The technical, functional, and non-functional features of the software product are described, web technologies for creating an application for knowledge assessment are considered. The diagram of system sequences, the use-case diagram, which schematically describing roles and functions of agents in an information system, the diagram of classes of a database structure are presented with UML description.

Based on the defined requirements for the web resource, the following technologies for its development were chosen: the server programming language PHP, JavaScript programming language and its libraries were used, as well as the MySQL database with PhpMyAdmin tool for administration of chosen database management system. OpenServer software complex system was used to develop and test the application functionality.

The vector of further scientific development should be aimed at the formation of methodology and software for a common database for a group of higher education institutions on control tasks and tickets, which will provide greater objectivity, transparency and diversity of methods for assessing students' knowledge. Also, further research should focus on the integration of the electronic journal into the developed electronic system, which will allow forming a ranking of the success of higher education applicants.

References

[1] S. Giannini, R. Jenkins, J. Saavedra, Reopening schools: When, where and how, 2020. URL: https://blogs.worldbank.org/education/reopening-schools-when-where-and-how.

[2] H. M. Shalatska, O. Y. Zotova-Sadylo, O. Y. Makarenko, L. S. Dzevytska, Implementation of e-assessment in higher education, CEUR Workshop Proceedings 2732 (2020) 1172–1186.

[3] UNESCO, Exams and assessments in COVID-19 crisis: fairness at the centre, 2020. URL: https://en.unesco.org/news/exams-and-assessments-covid-19-crisis-fairness-centre.

[4] G. Marinoni, H. van't Land, T. Jensen, The Impact of COVID-19 on Higher Education around the World, International Association of Universities, Paris, 2020. URL: https://www.iau-aiu.net/IMG/pdf/iau_covid19_and_he_survey_report_final_may_2020.pdf.

[5] OECD, Remote online exams in higher education during the COVID-19 crisis, OECD Education Policy Perspectives (2020). URL: https://www.oecd-ilibrary.org/content/paper/f53e2177-en. doi:10.1787/f53e2177-en.

[6] S. Vincent-Lancrin, Frontiers of smart education technology: Opportunities and challenges, in: OECD Digital Education Outlook 2021 Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots: Pushing the Frontiers with Artificial Intelligence, Blockchain and Robots, OECD Publishing, Paris, 2021, p. 19. URL: https://www.oecd-ilibrary.org/education/oecd-digital-education-outlook-2021_d3153fcd-en. doi:10.1787/d3153fcd-en.

[7] N. Alruwais, G. Wills, M. Wald, Advantages and challenges of using e-assessment, International Journal of Information and Education Technology 8 (2018) 34–37. URL: http://www.ijiet.org/show-96-1158-1.html. doi:10.18178/ijiet.2018.8.1.1008.

[8] B. Arend, Course assessment practices and student learning strategies in online courses, Online Learning 11 (2019). URL: https://olj.onlinelearningconsortium.org/index.php/olj/article/view/1712. doi:10.24059/olj.v11i4.1712.

[9] G. Crisp, Teacher's handbook on e-assessment: A handbook to support teachers in Using e-assessment to improve and evidence student learning and outcomes, Transforming Assessment, 2011. URL: http://transformingassessment.com/sites/default/files/files/Handbook_for_teachers.pdf.

[10] L. Guàrdia, G. Crisp, I. Alsina, Trends and challenges of e-assessment to enhance student learning in higher education, in: E. Cano, G. Ion (Eds.), Innovative practices for higher education assessment and measurement, IGI Global, Hershey, PA, 2017, pp. 36–56. doi:10.4018/978-1-5225-0531-0.ch003.

[11] H. M. Shalatska, O. Y. Zotova-Sadylo, O. Y. Makarenko, L. S. Dzevytska, Implementation of e-assessment in higher education, CEUR Workshop Proceedings 2732 (2020) 1172–1186.

[12] O. I. Bondarchuk, V. V. Balakhtar, Y. O. Ushenko, O. O. Gorova, I. M. Osovska, N. I. Pinchuk, N. O. Yakubovska, K. S. Balakhtar, M. V. Moskalov, 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, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[13] A. Harrison, L. Hutton, Design for the changing educational landscape: Space, place and the future of learning, Routledge, 2013.

[14] M. A. E. Tomaino, A. L. Greenberg, S. A. Kagawa-Purohit, S. A. Doering, E. S. Miguel, An assessment of the feasibility and effectiveness of distance learning for students with severe developmental disabilities and high behavioral needs, Behavior Analysis in Practice (2021). doi:10.1007/s40617-020-00549-1.

[15] A. E. Kiv, M. P. Shyshkina, S. O. Semerikov, A. M. Striuk, M. I. Striuk, H. M. Shalatska, CTE 2019 - When cloud technologies ruled the education, CEUR Workshop Proceedings 2643 (2020) 1–59. URL: http://ceur-ws.org/Vol-2643/paper00.pdf.

[16] A. A. Kostikov, K. V. Vlasenko, I. V. Lovianova, S. V. Volkov, E. O. Avramov, The algorithm for knowledge assessment based on the Rusch model, CEUR Workshop Proceedings (2022).

[17] S. L. Proskura, S. G. Lytvynova, O. P. Kronda, Students academic achievement assessment in higher education institutions, CEUR Workshop Proceedings 2732 (2020) 734–745.

[18] M. I. Sherman, Y. B. Samchynska, The information and reference system on rare and endangered species of animals as a computer tool for the formation of future ecologists digital competency, Information Technologies and Learning Tools 72 (2019) 121–135. URL:

https://journal.iitta.gov.ua/index.php/itlt/article/view/2479. doi:10.33407/itlt.v72i4.2479.
[19] Y. Samchynska, M. Vinnyk, Decision making in information technologies governance of companies, CEUR Workshop Proceedings 1844 (2017) 96–110. URL: http://ceur-ws.org/Vol-1844/10000096.pdf.
[20] Y. B. Samchynska, M. O. Vinnyk, Specific features of educational software promotion at Ukrainian market, Actual problems of economics 157 (2014) 534–540.
[21] O. Spivakovskiy, N. Kushnir, N. Valko, M. Vinnyk, ICT Advanced Training of University Teachers, CEUR Workshop Proceedings 1844 (2017) 176–190. URL: http://ceur-ws.org/Vol-1844/10000176.pdf.
[22] A. Todeush, M. Sherman, Methods of generating tasks for knowledge assessment, Young Scientist (2020) 198–204. doi:10.32839/2304-5809/2020-10-86-42.
[23] T. Wang, What strategies are effective for formative assessment in an e-learning environment?, Journal of Computer Assisted Learning 23 (2007) 171–186. doi:10.1111/j.1365-2729.2006.00211.x.
[24] K. Wijekumar, L. Ferguson, D. Wagoner, Problems with assessment validity and reliability in web-based distance learning environments and solutions, Journal of Educational Multimedia and Hypermedia 15 (2006) 199–215. URL: https://www.learntechlib.org/p/6259.
[25] T. Zaytseva, The introduction of the competence-based approach in educational process of training of skipper, CEUR Workshop Proceedings 1614 (2016) 687–699. URL: http://ceur-ws.org/Vol-1614/paper_25.pdf.
[26] DesignDirect, Custom online examination solution, online exam software, 2022. URL: https://www.designdirectuk.com/online-examination-system.
[27] Conduct Exam Technologies LLP, Online Exam Software, 2022. URL: https://www.conductexam.com/.
[28] KrNU: Pro sait ta onlain systemu, 2018. URL: http://krnu.org/mod/page/view.php?id=1.
[29] Dokumentatsyia Open Server Panel, 2021. URL: https://ospanel.io/docs/.
[30] Bringing MySQL to the web, 2022. URL: https://www.phpmyadmin.net/.
[31] Fetch, 2020. URL: https://learn.javascript.ru/fetch.

The use of specialized software for liquid radioactive material spills simulation to teach students and postgraduate students

Oleksandr O. Popov[1,2,3], Yurii O. Kyrylenko[1,2,4], Iryna P. Kameneva[2], Anna V. Iatsyshyn[1,5], Andrii V. Iatsyshyn[1,2], Valeriia O. Kovach[1,3,6], Volodymyr O. Artemchuk[1,2], Valery N. Bliznyuk[7] and Arnold E. Kiv[8]

[1]*State Institution "The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine", 34a Palladin Ave., Kyiv, 03142, Ukraine*

[2]*G. E. Pukhov Institute for Modelling in Energy Engineering of NAS of Ukraine, 15 General Naumova Str., Kyiv, 03164, Ukraine*

[3]*Interregional Academy of Personnel Management, 2 Frometivska Str., Kyiv, 03039, Ukraine*

[4]*State Scientific and Technical Center for Nuclear and Radiation Safety, 35-37 V. Stusa Str., Kyiv, 03142, Ukraine*

[5]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[6]*National Aviation University, 1 Liubomyra Huzara Ave., Kyiv, 03058, Ukraine*

[7]*Clemson University, 342 Computer Court, Anderson, SC 29625, United States of America*

[8]*Ben-Gurion University of the Negev, P.O.B. 653, Beer Sheva, 8410501, Israel*

Abstract

The study proves relevance of specialized software use to solve problems of emergencies prevention of radioactive liquids spills to teach students and graduate students. Main assessment criteria of accidents at radiation-hazardous objects associated with radioactive liquids spillage is identified. A model of radioactive substances transport in emergency rooms is developed. It takes into account physical features of radioactive liquid spill from the source, air pollution during transition of radioactive liquid from the spill surface into the air and subsequent scattering in the emergency room under influence of local air flows. It is determined that the existing software tools for radiation exposure assessment do not comprehensively cover features of such events and possess number of shortcomings regarding accidents modeling with spillage of radioactive liquids indoors. Computer modeling and forecasting examples for hypothetical event related to liquid radioactive spill in the JRODOS system are presented. The training process of future specialists, specialties 183 "Environmental Protection Technologies", 143 "Nuclear Energy", 103 "Earth Sciences", and 122 "Computer Science" should be based on application of powerful scientific and methodological training base using modern achievements in the field of digital technologies. It is advisable to supplement curricula for students' and postgraduate students' preparation in the mentioned above specialties by studying issues related to: development of mathematical models and software for solving problems of emergencies prevention in case of radioactive liquids spills; usage of features of specialized decision software of emergencies prevention during spills of radioactive liquids.

Keywords

computer simulation, specialized information system, mathematical modelling, emergencies prediction, radioactive liquids, training of students, graduate students

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1. Introduction

Nuclear energy has provided a significant share of Ukraine's total electricity production for many decades. So, stable operation of nuclear energy is a necessary condition for continued economic development of the country. Today in Ukraine there are main directions of theory and practice of safe operation ensuring of nuclear power plants (NPPs) that addresses complex issues of minimizing risk levels. There is a need for more realistic and accurate modeling of hazardous events at NPPs related to normal operation (events, frequency of implementation) which may exceed value of 0.01, 1/year) due to conduct of probabilistic safety analysis for Ukrainian NPP units and introducing of NRBU-97/D-2000 requirements for potential exposure of population in recent decades. Such events included accidents involving spillage of liquid radioactive material (LRM) after a probabilistic safety analysis. One of representative events related to radioactive heavy water spill took place at the Pakistani Karachi NPP (power unit No. 1) in 2017. Four people were irradiated as a result of the spill localization. The effective radiation dose of one of the liquidators reached a value of almost 40 mSv, which is 2 times higher than the set limit dose for personnel in Pakistan. This event was classified as the 2nd level according to the International Nuclear Event Scale (INES) according to the investigation results. Events of this type also took place in Ukraine. Insufficient level of staff skills and lack of readiness to eliminate emergencies of radioactive liquids spillage fast leads to emergencies and huge material costs for energy supply restoration [1].

Nuclear power workers should have skills to use digital technologies which help in modeling and prediction of systemic accidents conditions at radiation-hazardous facilities. Ability to apply these technologies is important for further professional activity. Given that digital technologies are constantly improving and new management systems are developing. It is important to familiarize training staff with the latest developments, systems, software and experience-exchange to apply these tools in further professional activities.

LRM spills are also possible at the Chornobyl Liquid Radioactive Waste Processing Plant, at

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sasha.popov1982@gmail.com (O. O. Popov); uo_kyrylenko@sstc.ua (Y. O. Kyrylenko); kamenevaip@gmail.com (I. P. Kameneva); anna13.00.10@gmail.com (A. V. Iatsyshyn); iatsyshyn.andriy@gmail.com (A. V. Iatsyshyn); valeriiakovach@gmail.com (V. O. Kovach); ak24avo@gmail.com (V. O. Artemchuk); deeescu@gmail.com (V. N. Bliznyuk); kiv.arnold20@gmail.com (A. E. Kiv)
https://www.nas.gov.ua/EN/PersonalSite/Pages/Contacts.aspx?PersonID=0000010803 (O. O. Popov); https://www2.scopus.com/authid/detail.uri?authorId=57208404766 (Y. O. Kyrylenko); https://www.nas.gov.ua/EN/PersonalSite/Pages/default.aspx?PersonID=0000005199 (I. P. Kameneva); https://www.nas.gov.ua/EN/PersonalSite/Pages/default.aspx?PersonID=0000030359 (A. V. Iatsyshyn); https://www.nas.gov.ua/EN/PersonalSite/Pages/default.aspx?PersonID=0000015808 (A. V. Iatsyshyn); https://www.nas.gov.ua/EN/PersonalSite/Pages/default.aspx?PersonID=0000005869 (V. O. Kovach); https://www.nas.gov.ua/EN/PersonalSite/Pages/default.aspx?PersonID=0000000337 (V. O. Artemchuk); https://www.scopus.com/authid/detail.uri?authorId=7006587198 (V. N. Bliznyuk); https://ieeexplore.ieee.org/author/37087598865 (A. E. Kiv)
0000-0002-5065-3822 (O. O. Popov); 0000-0003-3493-201X (Y. O. Kyrylenko); 0000-0003-2659-4487 (I. P. Kameneva); 0000-0001-8011-5956 (A. V. Iatsyshyn); 0000-0001-5508-7017 (A. V. Iatsyshyn); 0000-0002-1014-8979 (V. O. Kovach); 0000-0001-8819-4564 (V. O. Artemchuk); 0000-0002-3883-6941 (V. N. Bliznyuk); 0000-0002-0991-2343 (A. E. Kiv)
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oncology hospitals that use radioisotopes to treat patients, at uranium mining and uranium processing facilities, during transportation of liquid radioactive waste etc.

Thus, the urgent tasks are the following:

1) *for scientists and experts* – to improve the enterprises and organizations safety with risk of LRM spillage by developing mathematical and software solutions to prevent emergencies of this type;
2) *for scientific and pedagogical workers* – to update educational-professional and educational-scientific training programs for future specialists in Earth sciences, computer science, nuclear energy, and environmental protection technologies on development of mathematical and software tools ensuring solution of emergency prevention problems during LRM spills.

Various aspects of digital technologies use to prevent emergencies are discussed in publications [2, 3, 4, 5, 6]. Specialized software for computer modeling of various processes is described in works [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. Analysis of foreign and domestic accidents and incidents with LRM spills [1, 19, 20, 21] shows that problem of radiation emissions impact estimation in such accidents remains relevant and needs further research. Existing mathematical and computer tools for radiation exposure assessment (MELCOR, CONTAIN, MAAP, etc.) do not comprehensively cover features of such dangerous events and possess number of shortcomings in modeling of accidents with LRM spills.

Peculiarities of future specialists training in Earth sciences, computer science, and environmental protection technologies were the subject of research in [22, 23, 24, 25, 26, 18, 27, 28, 29, 30, 31, 32]. However, the problem of specialized software usage for solving problems of emergency prevention (for example, the LRM spill) in training of students and graduate students is not sufficiently considered. Therefore it is relevant and needs further research.

The research aim – to investigate peculiarities of mathematical and software tools development for solving problems of emergency prevention in case of LRM spills and to describe 7 directions of this software application during preparation of students and graduate students majoring in environmental sciences, Earth sciences, computer science, nuclear energy, environmental protection technology.

The research tasks are:

1) analysis of incidents with LRM spills;
2) description of features of development of mathematical and software tools for solving problems of emergency prevention during LRM spills;
3) showing examples of computer modeling of atmospheric dispersion and effective dose by using system JRODOS.

2. Research results

In accordance with the probabilistic safety analysis for Ukrainian NPP units and the radiation safety standard NRBU-97/D-2000 requirements for potential public exposure, there is a need for more realistic and precise modeling of events at NPPs related to abnormal operation the frequency of which may exceed the value of 0.01 1/year). After conducting a probabilistic safety

analysis, such events include accidents involving the spills of radioactive liquids at the area of facilities.

LRM are liquid solutions, which include impurities of radioactive elements (possible bounds in high-molecular complexes). The isotopic composition of LRM is determined primarily by the source of radioactive impurities. The main sources of LRM at nuclear power plants and nuclear complexes are as follows: primary coolant that is discharged for operational reasons; water that is used to backflush filters and ion exchangers; floor drains that collect water that has leaked from the active liquid systems and fluids from the decontamination of the plant and fuel flasks; leaks of secondary coolant; laundries and changing room showers; and chemistry laboratories.

According to INES [33], accidents involving spills of radioactive liquids, depending on the magnitude of the release and the corresponding radiation effects, can be assigned different levels of danger (from level 0 “Event with a deviation below the scale" to 7 “Major accident”). This approach reflects the design features of heat dissipation from the core of reactors operating on liquid coolant. During the severe accident with melting of the reactor core, the products of nuclear fuel fission come into direct contact with the liquid coolant and water of the emergency cooling systems, which will lead to further formation of radioactive liquids. Neutron activation of the coolant during the campaign at the reactor units also makes a significant contribution to the atmospheric release activity. In both, the first and the second case, the activity of the liquids represents a small part of the total release activity. Therefore, when assessing the consequences of severe accidents, the source term associated with evaporation of liquid spills is often neglected. However, if the accident involves the release solely from the evaporation from open surfaces, depending on the concentration of radionuclides in the liquid and the conditions of the accident, the release can pose a significant threat to personnel, public and environment.

2.1. Events related to spill of radioactive liquids

In previous publications, we analysed and systematized accidents with the spills of radioactive liquids. The place and year of the accident or incident, the level on the INES scale are indicated and a brief description of the event is given. It should be noted the low number of official reports on the radiation consequences of accidents and incidents related to the spillage of radioactive liquids.

As an example, in 2010 at the Ignalina NPP [34] there was a spill of about 300 tons of radioactive decontamination solution. Figure 1 shows the pictures of this incident. For this event, no official information on the results of dosimetric monitoring at the NPP site, as well as the classification according to the INES scale, was provided. Figure 2 presents the author’s infographics of incidents with LRM spills at Ukrainian NPPs.

2.2. Mathematical model of radioactive substances transfer in emergency rooms

Figure 3 schematically shows processes that occur after incident with spill of LRM in the rooms of radiation-hazardous object.

Modeling of the LRM Evaporation. To solve the problem of unsteady LRM evaporation, four balance differential equations (1) were written to relate the main parameters of LRM and air

Figure 1: Photos of the accident with the spill of radioactive decontamination solution at the Ignalina NPP (Lithuania, 2010): view of the broken pipeline (a), general view of the spill part (b) [34].

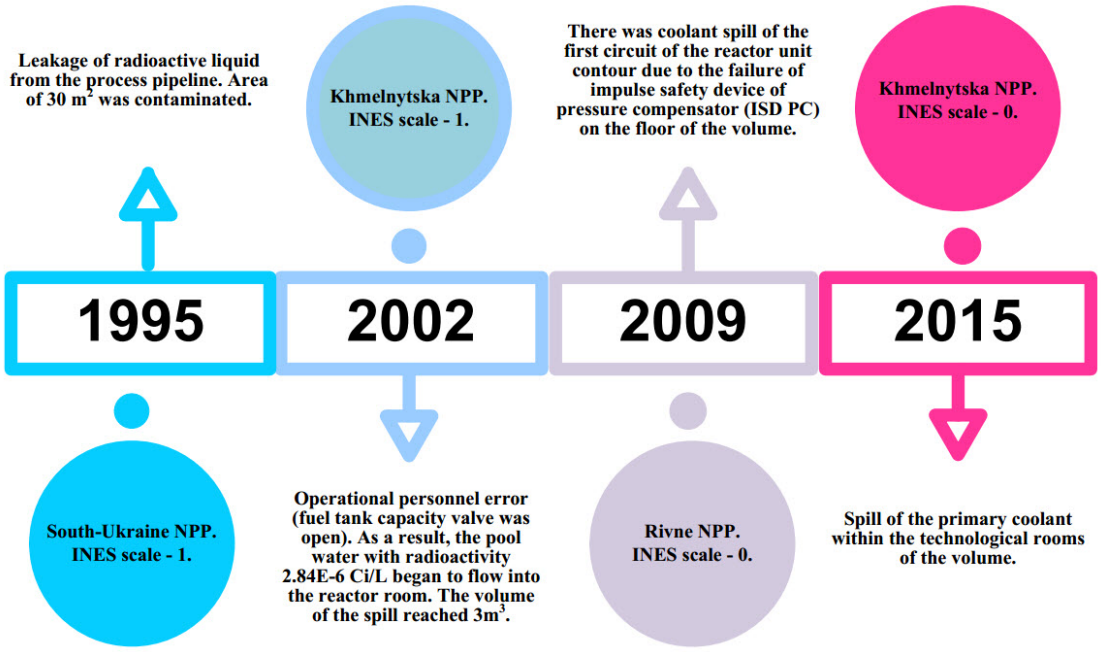

Figure 2: Infographics of LRM spill accidents at Ukrainian NPPs.

space of area over time:

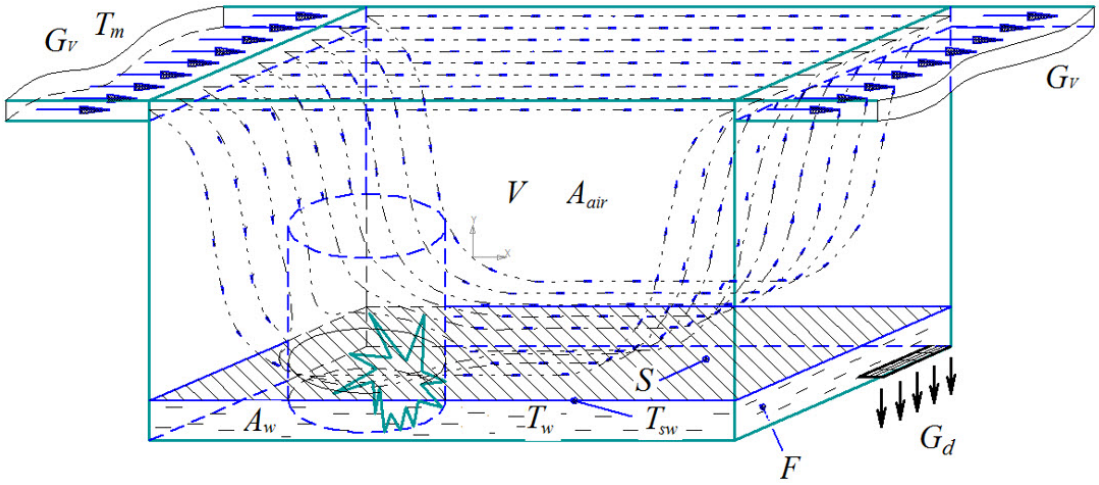

Figure 3: Conceptual scheme of air pollution after incident with spill of LRM in the rooms of radiation-hazardous object.

$$\begin{cases} \frac{dm_w}{dt} = -\beta_{sw}(p_{sw} - p_m)S - G_d \\ \frac{dm_a}{dt} = \beta_{sw}(p_{sw} - p_m)S - G_V\frac{m_a}{V} \\ \frac{dm_q}{dt} = G_V\frac{m_a}{V}(1 - \Psi) \\ \frac{dT_w}{dt} = \frac{r_w\beta_{sw}(p_{sw}-p_m)S+kF(T_W-T_f)}{c_p m_w}, \end{cases} \tag{1}$$

where m_a – current mass of SARM in air of the area, kg;

G_d – flowrate of LRM through the drainage channel (it also includes the volume of LRM leakage from the area), kg/s;

V – air volume in the area, m^3;

G_V – flowrate of involved air of forced ventilation (this parameter includes SARM leakage through the gaps or clearances in walls of the emergency area), m^3/s;

Ψ – coefficient of filtration (efficiency of filtration);

m_q – mass of released SARM into the atmosphere, kg.

This system of nonlinear differential equations includes polynomial functions. Using the Mathcad sphere for solving the system of equations (1) provides the desired functions in matrix form (the values of the functions at particular moments of accident).

Average activity concentration of the radionuclide in the area air A_{air} (Bq/m^3) is given by the formula

$$A_{air} = \frac{A_w}{V}Hm_a, \tag{2}$$

where A_w – concentration of radionuclide in LRM, Bq/kg;

H – fraction of carried away solute with solvent vapors during evaporation.

The ultimate objective of the model is to determine the dynamics of LRM evaporation, SARM activity in the air space and the integral release of radioactive substances into the atmosphere.

Table 1
Modelling results and monitoring data.

Personnel member No	Effective dose received during response, mSv	Actual effective dose D_{eff}, mSv	Ratio k_{max}
1	6.9…43.0	20.8(+-30%)	2.07
2	9.3…57.6	24.2(+-30%)	2.38
3	11.4…71.0	30.9(+-30%)	2.30
4	12.6…78.7	36.2(+-30%)	2.17

The mass fraction of a radionuclide in the release relative to its original content in radioactive liquid is commonly used in practice:

$$q = \frac{A_w}{m_0} H m_q 100\%, \tag{3}$$

where m_0 – initial mass of LRM, kg.

This value is used as an input parameter for the assessment of doses to the public from atmospheric release.

2.3. Model testing

To confirm the effectiveness and accuracy of the modelling, a partial testing was performed at an example of real event that occurred at the Pakistani nuclear power plant in Karachi in 2017: overexposure of 4 staff members as a result of the accident. Reconstruction of irradiation doses was performed using the developed model and compared with the actual value of the dose accumulated by the liquidators during the works (table 1, figure 4).

According to the results of testing, the following is highlighted: the actual data are included in the calculated ranges of the effective dose, which is acceptable; the pessimistic estimate exceeded the actual measurement data by ~2.0-2.3 times (ratio k_{max} in table 1), which is acceptable; the development can be used as a tool for the reconstruction of exposure doses. However, further testing of the source term model are required.

2.4. Application of the model

Results of source term model can used as initial data to provide atmospheric dispersion modelling results and dose projection for the hypothetical event associated with the spill of liquid radioactive material. The example of such calculation in JRODOS system are shown in figures 5, 6.

Presented calculations were done using local scale model chain of JRODOS system. Total amount of activity released into the atmosphere (primarily ^{60}Co and ^{137}Cs) has been assumed about 2.5 GBq. Hourly resulted source term was used as input data to provide the results on near ground air concentration. Meteorological data in NetCDF format was provided as WRF results with 0.05° spatial resolution and selected from previous several years numerical weather

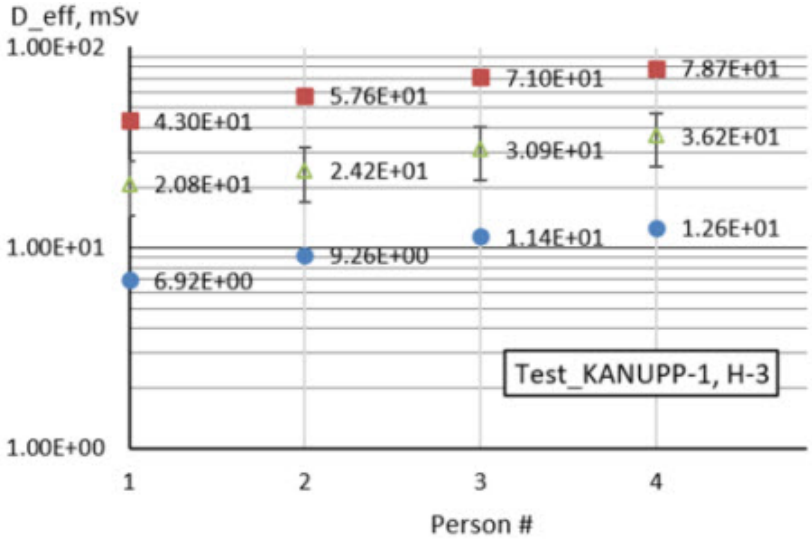

Figure 4: Modelling results and monitoring data.

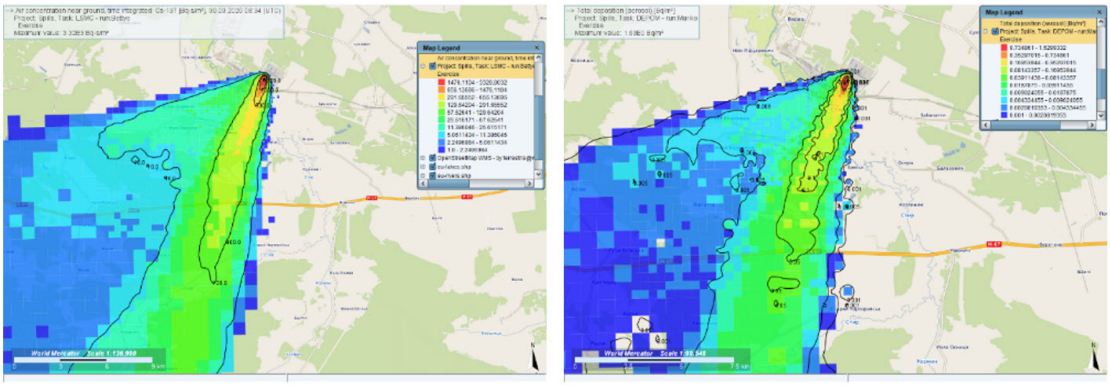

Figure 5: JRODOS atmospheric dispersion modelling results: air concentration near ground, time-integrated using LASAT model (a), total aerosol deposition using DEPOM model (b).

data. All results of radioactive material spreading as well as dose assessment were performed on the least calculation grid size 20 km.

For selected hypothetical scenario, 1-year effective doses at 2.5 km (size of sanitary protection zone around Ukrainian NPPs) do not exceed 3 μSv that is lower than established annual level for public 40 μSv. According to the results, on-site values for ^{137}Cs deposition can be around 1.5 Bq/m^2 (dry weather). Ground contamination is foremost limited by the NPP site and near range.

Practice of an application shows the source term model can serve as an useful tool to provide initial data for radiological consequence calculations. However, it depends on context of application and leave a place for further sensitivity analysis and model chains improvement.

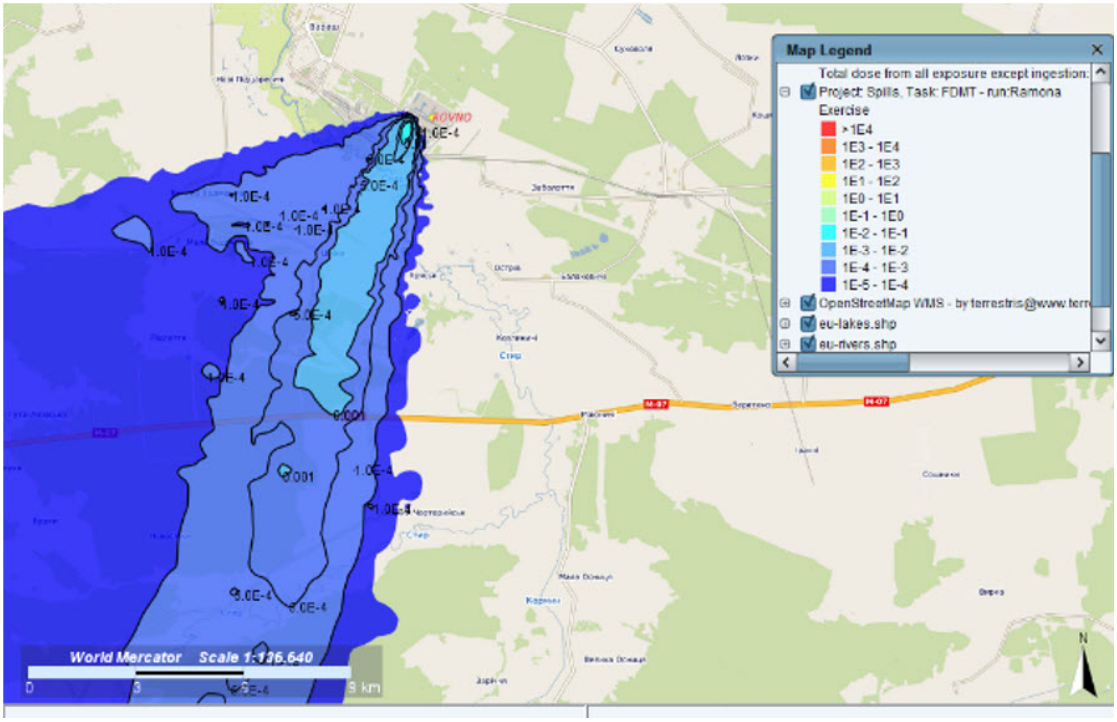

Figure 6: JRODOS dose projection results 1-year effective dose from all exposure pathways except ingestion (child).

2.5. Software for solving problems of emergency planning

In frame of FASTNET project experience of more than 20 countries was analyzed. The main output of the project is an investigation in the area of qualitative characteristic of source term – resolution in time. Taking into account spatial and temporal resolution of numerical weather predictions used in Europe countries, FASTNET group recommend the use of 15-min intervals in source term.

Practice of regular calculations demonstrates significant uncertainties in conjunction “source term – NWP-data”. Under unstable meteorological condition with complex patterns of integrated concentrations, using of more than 15-min. source term intervals can lead to crusual impact on radiological consequences results.

Today JRODOS users can operate pre-estimated source terms data. Source term library filling can be specified by requirements to source term files taking into account meteorology data resolution.

Uncertainties of the source term on the prediction of atmospheric dispersion of released radioactivity involve both the amounts of radionuclides released and the temporal evolution of the release. Furthermore, the combined uncertainties of atmospheric dispersion model forecasting stemming from both the source term and the meteorological data are examined in [22].

In AVESOME project, a methodology is developed which can handle both a few-member

source-term ensemble and a large ensemble spanning all possible releases. The AVESOME methodology will work well with the Rapid Source Term Prediction (RASTEP) system, which provides a set of possible source terms with associated probabilities based on pre-calculated source terms. The methods, which are being developed in AVESOME, allows for efficient real-time calculations by making use of scaling properties in the equations governing the release and the atmospheric dispersion of radionuclides. Accordingly, the computer-resource demanding calculations should be carried out at the high-performance computing (HPC) facilities available e.g. at national meteorological services, whereas less demanding post-processing should be carried out at the computer hosting the DSS.

A protocol is suggested for interactive communication between the DSS and the HPC facility enabling the requests from the DSS user for long-range atmospheric dispersion model calculations. It is based on an existing operational protocol extended with the capability of simultaneous handling of a number of source-term descriptions, including a full source-term ensemble.

Based on the results of the mathematical model with a view to further determination of radiological impact on the workers, public and the environment the environment can be used analytical methods and software tools:

- RODOS: ADM RIMPUFF with 10-min. time step + FDMT [12];
- RASCAL (INTERRAS) [11], HOTSPOT [7] ;
- ARGOS: complex terrain ADM, dose projection module (any other DSS);
- simplified gaussian models;
- sophisticated models for short range (CFD-, LES-modeling);
- NRC MACCS code (probabilistic tool) [15];
- GENII, RESRAD, PAVAN, ARCON 96, XOQDOQ (RAMP family) [13]; etc.

Worker's exposure (internal) can be assessed using analytical base and methods (NRC, ICRP, UNSCEAR [13]); dose conversion factors FGR-11/13, EPA [13]; analytic base of organization such as NRC, EPA, ICRP, and skin dose assessment in VARSKIN code; MICROSHIELD, ISOCSR to calculate dose from equipment and spill domain.

2.6. Features of future specialists training for nuclear energy industry

Experience of nuclear power units operating, the Chernobyl disaster, the tragic events at the Fukushima-1 nuclear power plant indicated the need to pay attention to safety issues and adhere to the principles of its culture at nuclear facilities. This can be achieved only with personnel qualitative training for nuclear energy industry. Currently in Ukraine there are 9 institutions of higher education that educate specialists for work in nuclear energy sector: National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Lviv Polytechnic National University, National Technical University "Kharkiv Polytechnic Institute", Odessa National Polytechnic University, Taras Shevchenko National University of Kyiv, Vinnytsia National Technical University, National University of Water and Environmental Engineering, Ukrainian State University of Chemical Technology, Kyiv Energy College. RNPP Vocational School also prepares specialists for work at nuclear power plants [35].

The Standard of Higher Education of Ukraine in the specialty 143 "Nuclear energy" [36] of bachelor's level was developed taking into account the needs of vocational education (approved and put into effect by the Order of the Ministry of Education and Science of Ukraine No. 964 of July 10, 2019). Also the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" for the first time recruited for the master's program "Physical Protection, Accounting and Control of Nuclear Materials" in the specialty 143 "Nuclear energy" in 2019. Term of study for Master degree is 1 year 6 months. Educational and professional training program meets requirements of current national legislation and recommendations of the International Atomic Energy Agency.

Students of specialty 143 "Nuclear Energy" have an opportunity to learn not only basics of nuclear and information safety and design of physical protection systems. They are also able to assess vulnerabilities and identify threats, develop regulations, prevent measures, manage emergencies and crisis situations. Training is conducted by highly professional teaching staff, including practitioners, specialists who completed internships at the University of Texas at Austin, Sandia National Laboratories and participated in training courses at the International Atomic Energy Agency. Also, students learn to operate nuclear power plants. They are engaged in of neutron-physical modeling and thermohydraulic processes in NPP equipment. The students solve problems of reliability and safety of NPPs. The graduates have exclusive right to obtain a license to operate nuclear power plants. They can hold positions from NPP engineer to CEO or work in other industry enterprises [35]. In February 2021, the first graduation of masters in the specialty 143 "Nuclear Energy" took place. Of course, specialists at various specialties and fields of knowledge (technical, chemical, ecological, biological, engineering) are required for work at NPPs.

The Standard of higher education for the master's level of knowledge 18 "Production and technology" in the specialty 183 "Environmental technologies" determined that the main purpose of training is: formation of professional competencies necessary for innovative research and production activities for development and implementation of modern technologies for environmental protection.

The publication authors analyzed the Standard of Higher Education for specialty 183 "Environmental Protection Technologies" [37] and identified number of competencies of future professionals to use specialized software for solution of emergency prevention problems during spills of radioactive liquids. Also, the Standard of Higher Education for the master's level in the field of knowledge 12 "Information Technology", specialty 122 "Computer science" [38] was analyzed. Number of future professionals competencies to develop, maintain and improve specialized software for solving problems of emergency prevention in case of spills of radioactive liquids, they include (special (professional) competencies) were defined:

- specialty 183 "Environmental protection technologies"

  K04. Ability to use modern computer and communication technologies during collection, storage, processing, analysis and transmission of information about the state of environment and industrial sphere;

  K08. Ability to ensure environmental safety and sustainable development of society;

  K09. Ability to use scientifically grounded methods in processing of research results in the field of environmental protection technologies;

K11. Ability to create physical and mathematical models of processes occurring in man-made pollution;

K14. Ability to assess impact of industrial facilities, their emissions and discharges on the environment;

K16. Ability to monitor state of environmental safety and assess degree of air pollution and industrial emissions into the atmosphere, water and water bodies, soils and land resources;

K19. Ability to design systems and technologies for environmental protection and ensure their functioning.

- specialty 122 “Computer science”

CK5. Ability to use mathematical methods for analysis of formalized models of subject area of particular project of its implementation and maintenance process;

CK9. Ability to develop software: understand and apply logic basics to solve problems; be able to design, execute and debug programs using modern integrated software (visual) development environments; understand programming methodologies, including object-oriented, structured, procedural and functional programming; compare currently available programming languages, software development methodologies and development environments, as well as select and use those that correspond to particular project; be able to evaluate code for reuse or inclusion in an existing library; be able to assess the configuration and impact on settings in terms of working with third-party software packages;

CK11. Ability to develop and administer databases and knowledge, possess modern theories and models of data and knowledge, methods of their interactive and automated development, processing and visualization technologies;

CK12. Ability to assess quality of IT projects, computer and software systems for various purposes, to possess methodologies, methods and technologies to ensure and improve quality of IT projects, computer and software systems based on international standards for quality assessment of information systems software, maturity assessment models information and software systems development processes;

CK13. Ability to initiate and plan computer systems and software development processes, including its development, analysis, testing, system integration, implementation and maintenance;

CK14. Ability to identify problem situations during the software operation and formulate tasks for its modification or reengineering.

Quality improving of education is one of the most important issues in development of any society. The modern world is evolving and changing rapidly, information technologies are being updated and improved. Therefore the domestic higher education system does not have time to adapt curricula and plans to requirements of the market and society. This problem is relevant in the field of training specialists in the following specialties: 183 “Environmental protection technologies”, 103 “Earth sciences”, 122 “Computer science” [18] and in the new specialty 143 “Nuclear energy". Therefore, we believe that it is important to add topics for development of

mathematical and a software solution for emergency prevention in case of LRM spills in training of future professionals in the outlined specialties.

The choice of used software in educational process should be based on the need to form professional skills in students and graduate students. Also it is necessary to develop systematic thinking, the ability to select optimal tool for solving particular application problem [18]. It will greatly enrich their experience and allow them to understand specifics of LRM spills events simulating. It is important in preventing emergencies.

The following measures should be taken to increase effectiveness of specialists training for nuclear energy sector on issues of risk reduction during LRM spill incidents elimination:

- supplementing curricula of training students and graduate students to ensure acquisition of competencies to reduce risks during elimination of incidents with LRM spills;
- to introduce study of issues: on development of mathematical models and software for solving problems of emergency prevention during LRM spills;
- use of specialized software for solving problems of emergency prevention during LRM spills;
- to expand topics of bachelor's, master's, dissertation works of students and scientific degrees with problems on various aspects of the development of mathematical models and software tools for solving problems of emergency prevention in case of LRM spills.

3. Conclusions

1. It is determined that the main criteria for the assessment of accidents at radiation-hazardous facilities associated with the spill of radioactive liquids are: possible sources of release, the range of chemical and isotopic composition of the radioactive liquid; temperatures of radioactive liquids involved in heat and mass transfer processes; features of drainage, filtering and localizing; potential scale and degree of radioactive contamination; critical pathway and critical exposure group; characteristic conditions of on-site as well as off-site spreading of radioactive substances.
2. Existing mathematical models of the distribution of radionuclides in the air as a result of emissions cannot be used to solve the problem of estimating the radiation impact in accidents with spills of radioactive liquids due to some set of disadvantages. The authors of the publication developed a model that takes into account the physical features of radioactive fluid leakage from the source, air pollution during the transition of radioactive liquid from the spill surface into the air and their subsequent dispersion in the emergency room under the influence of local air currents (caused by ventilation).
3. A mathematical model of radioactive substances transport in emergency areas has been developed, which, unlike other models, takes into account the parameters of radioactive liquids composition and design conditions of their storage.
4. Features of the software of the decision of problems of the prevention of emergencies at flood of radioactive liquids are analyzed. It is determined that the existing software tools for radiation exposure assessment do not comprehensively cover the features of such events and have a number of shortcomings (do not take into account the process

of radioactive decay; inadequacy of the results and high uncertainties; do not allow to obtain most of the dynamic parameters required for a comprehensive analysis of radiation exposure, lack of models describing the transport of multicomponent radioactive air mixtures) for modelling the course of accidents with spillage of radioactive liquids indoors.

5. The publication provides examples of computer simulation of atmospheric dispersion and dose projection for a hypothetical event involving the spillage of liquid radioactive material in the JRODOS system.
6. Process of future specialists training in the specialties: “Environmental protection technologies”, “Nuclear energy", “Earth sciences”, and “Computer science” should be based on the use of powerful scientific and methodological training base using modern advances in digital technology. Therefore, we consider it appropriate to supplement curricula for preparation of students and graduate students in the outlined specialties by studying issues of: development of mathematical models and software to solve problems of emergency prevention in case of LRM spills; features of specialized software use to solve problems of emergencies prevention during LRM spills. For this purpose, it is proposed to use mathematical model of radioactive substances transport in emergency rooms developed by the authors and the corresponding software tools for assessing radiation impact on population and environment.

References

[1] Y. Kyrylenko, I. Kameneva, O. Popov, A. Iatsyshyn, V. Artemchuk, V. Kovach, Source term modelling for event with liquid radioactive materials spill, in: V. Babak, V. Isaienko, A. Zaporozhets (Eds.), Systems, Decision and Control in Energy I, Springer International Publishing, Cham, 2020, pp. 261–279. doi:10.1007/978-3-030-48583-2_17.

[2] C. Chauliac, J.-M. Aragonés, D. Bestion, D. G. Cacuci, N. Crouzet, F.-P. Weiss, M. A. Zimmermann, NURESIM – A European simulation platform for nuclear reactor safety: Multi-scale and multi-physics calculations, sensitivity and uncertainty analysis, Nuclear Engineering and Design 241 (2011) 3416–3426. doi:10.1016/j.nucengdes.2010.09.040.

[3] M. Dowdall, J. E. Dyve, S. C. Hoe, A. M. B. Buhr, A. Hosseini, J. Brown, G. Jónsson, P. Lindahl, H. Guðmundsson, S. Barsotti, S.-B. S, Nordic Nuclear Accident Consequence. Analysis (NORCON): Final Report, Technical Report NKS-353, Nordic Nuclear Safety Research, Roskilde, Denmark, 2015. URL: http://ep3.nuwm.edu.ua/12869/1/05-04-84%20..pdf.

[4] O. Popov, A. Iatsyshyn, D. Sokolov, M. Dement, I. Neklonskyi, A. Yelizarov, Application of virtual and augmented reality at nuclear power plants, in: A. Zaporozhets, V. Artemchuk (Eds.), Systems, Decision and Control in Energy II, Springer International Publishing, Cham, 2021, pp. 243–260. doi:10.1007/978-3-030-69189-9_14.

[5] Y. Wu, Development and application of virtual nuclear power plant in digital society environment, International Journal of Energy Research 43 (2019) 1521–1533. doi:10.1002/er.4378.

[6] Y. Kyrylenko, I. Kameneva, O. Popov, A. Iatsyshyn, V. Artemchuk, V. Kovach, Actual issues on radiological assessment for events with liquid radioactive materials spills, in:

A. Zaporozhets (Ed.), Systems, Decision and Control in Energy III, Springer International Publishing, Cham, 2022, pp. 139–156. doi:10.1007/978-3-030-87675-3_8.
[7] S. G. Homann, F. Aluzzi, HotSpot Health Physics Codes Version 3.0 User's Guide, National Atmospheric Release Advisory Center, Lawrence Livermore National Laboratory, Livermore, CA 94550, 2014.
[8] A. E. Kiv, O. V. Merzlykin, Y. O. Modlo, P. P. Nechypurenko, I. Y. Topolova, The overview of software for computer simulations in profile physics learning, CEUR Workshop Proceedings 2433 (2019) 352–362.
[9] I. G. Kotsyuba, A. V. Ilchenko, Vikoristannia programnogo zabezpechennia z metoiu optimizatsii sistemi povodzhennia z tverdimi pobutovimi vidkhodami mista Zhitomira (Use of software to optimize the management of solid household waste in the city of Zhytomyr), Ekologichna bezpeka 1 (2011) 13–16. URL: http://www.kdu.edu.ua/EKB_jurnal/2011_1(11)/13.pdf.
[10] D. B. Lawson, IT/Science: Computer Modeling, Geographic Information Systems (GIS), Probes/Sensors, in: M. Duran, M. Höft, B. Medjahed, D. B. Lawson, E. A. Orady (Eds.), STEM Learning: IT Integration and Collaborative Strategies, Springer International Publishing, Cham, 2016, pp. 35–66. doi:10.1007/978-3-319-26179-9_3.
[11] U.S. Nuclear Regulatory Commission, RASCAL 4.3 User's Guide, 2013. URL: https://www.nrc.gov/docs/ML1328/ML13281A701.pdf.
[12] W. Raskob, C. Landman, D. Trybushnyi, Functions of decision support systems (JRodos as an example): overview and new features and products, Radioprotection 51 (2016) S9–S11. doi:10.1051/radiopro/2016015.
[13] Sandia National Laboratories, 2021. URL: https://www.sandia.gov.
[14] M. Stojanović, V. Marković, Z. Kričković, R. Banković, Potential usage of GIS in education, in: Sinteza 2018 - International Scientific Conference on Information Technology and Data Related Research, 2018, pp. 255–260. doi:10.15308/Sinteza-2018-255-260.
[15] K. McFadden, N. Bixle, L. Eubanks, R. Haaker, WinMACCS, a MACCS2 Interface for Calculating Health and Economic Consequences from Accidental Release of Radioactive Materials into the Atmosphere MACCS User's Guide, U.S. Nuclear Regulatory Commission, 2007. URL: https://www.nrc.gov/docs/ML0723/ML072350221.pdf.
[16] Y. Zabulonov, V. Burtnyak, L. Odukalets, E. Alekseeva, S. Petrov, Plasmachemical plant for NPP drain water treatment, Science and Innovation 14 (2018) 86–94. doi:10.15407/scine14.06.086.
[17] Y. Zabulonov, O. Popov, V. Burtniak, A. Iatsyshyn, V. Kovach, A. Iatsyshyn, Innovative developments to solve major aspects of environmental and radiation safety of ukraine, in: A. Zaporozhets, V. Artemchuk (Eds.), Systems, Decision and Control in Energy II, Springer International Publishing, Cham, 2021, pp. 273–292. doi:10.1007/978-3-030-69189-9_16.
[18] A. Iatsyshyn, A. Iatsyshyn, V. Kovach, I. Zinovieva, V. Artemchuk, O. Popov, O. Cholyshkina, O. Radchenko, O. Radchenko, A. Turevych, Application of open and specialized geoinformation systems for computer modelling studying by students and PhD students, CEUR Workshop Proceedings 2732 (2020) 893–908. URL: http://ceur-ws.org/Vol-2732/20200893.pdf.
[19] The State Scientific and Technical Center for Nuclear and Radiation Safety, Information reports on violations in the operation of npps during 2020, 2020. URL: https://sstc.ua/

informacijni-povidomlennya-pro-porushennya-v-roboti-aes-protyagom-2020-roku.
[20] Y. Kyrylenko, I. Kameneva, O. Popov, A. Iatsyshyn, I. Matvieieva, V. Bliznyuk, N. Molitor, Source term model of radioactive liquid spills for actual decision support systems, E3S Web of Conferences 280 (2021) 09001. doi:10.1051/e3sconf/202128009001.
[21] International Atomic Energy Agency, The information channel on nuclear and radiological events, 2021. URL: https://www-news.iaea.org/EventList.aspx.
[22] I. M. Bialik, A. E. Yanchuk, Metodychni vkazivky do laboratornykh robit z navchalnoyi dystsypliny "GIS i bazy danykh" (Methodical instructions for laboratory work on the discipline "GIS and databases"), volume 1, The National University of Water and Environmental Engineering, Rinve, 2018. URL: http://ep3.nuwm.edu.ua/12869/1/05-04-84%20..pdf.
[23] H. Chemerys, V. Osadchyi, K. Osadcha, V. Kruhlyk, Increase of the level of graphic competence future bachelor in computer sciences in the process of studying 3D modeling, CEUR Workshop Proceedings 2393 (2019) 17–28.
[24] L. Datsenko, Expansion of geographic information components in the educational programs of cartographers at Taras Shevchenko National University of Kyiv, Problems of Continuous Geographic Education and Cartography (1) 20–23. URL: https://periodicals.karazin.ua/pbgok/article/view/9080.
[25] D. V. Dyadin, O. V. Khandohina, Konspekt lektsiy z navchalnoyi dystsypliny "Geoprostorovyy analiz ekolohichnoyi bezpeky" (dlya studentiv dennoyi form navchannya spetsialnosti 183 – Tekhnolohiyi zakhystu navkolyshn'oho seredovyshcha) (Lecture notes on the subject "Geospatial analysis of ecological safety" (for students of full-time specialty education 183 - Environmental technologies)), O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, 2017.
[26] O. M. Hlushak, V. V. Proshkin, O. S. Lytvyn, Using the e-learning course "Analytic Geometry" in the process of training students majoring in Computer Science and Information Technology, CEUR Workshop Proceedings 2433 (2019) 472–485.
[27] O. Klochko, V. Fedorets, An empirical comparison of machine learning clustering methods in the study of Internet addiction among students majoring in Computer Sciences, CEUR Workshop Proceedings 2546 (2019) 58–75.
[28] V. Morkun, S. Semerikov, S. Hryshchenko, K. Slovak, Environmental geo-information technologies as a tool of pre-service mining engineer's training for sustainable development of mining industry, CEUR Workshop Proceedings 1844 (2017) 303–310. URL: http://ceur-ws.org/Vol-1844/10000303.pdf.
[29] S. L. Proskura, S. H. Lytvynova, The approaches to web-based education of computer science bachelors in higher education institutions, CEUR Workshop Proceedings 2643 (2020) 609–625. URL: http://ceur-ws.org/Vol-2643/paper36.pdf.
[30] V. M. Storozhuk, O. B. Ferents, Z. P. Kopynets, Problemy systemy pidhotovky inzhenerno-tekhnichnykh pratsivnykiv z pytan bezpechnosti promyslovykh pidpryyemstv (Problems of the system of training of engineering and technical workers on safety of industrial enterprises, in: Kompleksne zabezpechennya yakosti tekhnolohichnykh protsesiv ta system (KZYATPS - 2018), 2018, pp. 113–115. URL: http://ir.stu.cn.ua/handle/123456789/21495.
[31] V. M. Storozhuk, O. V. Melnykov, V. M. Hvozdyk, Neobkhidnist pokrashchennya pidhotovky maybutnikh inzhenerno-tekhnichnykh pratsivnykiv z pytan bezpechnosti

promyslovykh pidpryyemstv (Need of improvement training future technical officers in questions of safety of industrial enterprises), Technology and Technique of Typography 3 (2015) 115–124. URL: http://ttdruk.vpi.kpi.ua/article/view/54892. doi:10.20535/2077-7264.3(49).2015.54892.

[32] S. V. Symonenko, N. V. Zaitseva, M. S. Vynogradova, V. V. Osadchyi, A. V. Sushchenko, Application of ICT tools in teaching american english for computer science students in the context of global challenges, Journal of Physics: Conference Series 1840 (2021) 012048. doi:10.1088/1742-6596/1840/1/012048.

[33] INES The International Nuclear and Radiological Event Scale. User's Manual 2008 Edition, International Atomic Energy Agency, Vienna, 2008.

[34] A. Ozharovsky, Accidents and incidents. Comment: A shut-down Ignalina NPP: No RIP for Lithuania's cranky nuclear corpse, 2010. URL: https://bellona.org/news/nuclear-issues/accidents-and-incidents/2010-11-comment-a-shut-down-ignalina-npp-no-rip-for-lithuanias-cranky-nuclear-corpse.

[35] The State Scientific and Technical Center for Nuclear and Radiation Safety, Personnel Training and Professional Development: Driving Force of Future Nuclear Power, 2020. URL: https://sstc.ua/news/pidgotovka-kadriv-ta-pidvishennya-kvalifikaciyi-rushijna-sila-majbutnogo-atomnoyi-energetiki.

[36] Ministry of Education and Science of Ukraine, Standart vyshchoyi osvity bakalavra za spetsial'nistyu 143 Atomna enerhetyka haluzi znan' 14 Elektrychna inzheneriya (Standard of higher education bachelor's degree in specialty 143 Atomic energy in the field of knowledge 14 Electrical engineering, 2019. URL: https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/2019/07/12/143-atomna-energetika-bakalavr.pdf.

[37] Ministry of Education and Science of Ukraine, Standart vyshchoyi osvity Ukrayiny: pershyy (bakalavrs'kyy) riven', haluz' znan' 18 – Vyrobnytstvo ta tekhnolohiyi, spetsial'nist' 183 – Tekhnolohiyi zakhystu navkolyshn'oho seredovyshcha (Standard of higher education of Ukraine: first (bachelor's) level, field of knowledge 18 – Production and technologies, specialty 183 - Environmental technologies, 2018. URL: https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/12/21/183-tekhnologiya-zakhistu-navkolishnogo-seredovishcha-bakalavr.pdf.

[38] Ministry of Education and Science of Ukraine, Standart vyshchoyi osvity Ukrayiny druhoho rivnya (stupin' mahistra) haluzi znan' 12 za spetsial'nistyu 122 – Kompyuterni nauky (Standard of higher education of Ukraine of the second level (master's degree) in the field of knowledge 12 in specialty 122 - Computer Science, 2020. URL: hhttps://mon.gov.ua/storage/app/media/vishcha-osvita/proekty%20standartiv%20vishcha%20osvita/2020/12/03/122-kompyuterni-nauky-mahistr.docx.

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

Ilona V. Batsurovska[1], Nataliia A. Dotsenko[1], Vladimir N. Soloviev[2], Svitlana H. Lytvynova[3], Olena A. Gorbenko[1], Nataliia I. Kim[1] and Antonina P. Haleeva[1]

[1]*Mykolayiv National Agrarian University, 9 Georgya Gongadze Str., Mykolayiv, 54020, Ukraine*

[2]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukrainee*

[3]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

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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batsurovska_ilona@outlook.com (I. V. Batsurovska); dotsenkona@outlook.com (N. A. Dotsenko); vnsoloviev2016@gmail.com (V. N. Soloviev); s.h.lytvynova@gmail.com (S. H. Lytvynova); gorbenko_ea@mnau.edu.ua (O. A. Gorbenko); kim_ni@mnau.edu.ua (N. I. Kim); galeevaap@mnau.edu.ua (A. P. Haleeva)

https://www.mnau.edu.ua/faculty-energy/kaf-electro/batsurovska/ (I. V. Batsurovska); https://www.mnau.edu.ua/faculty-energy/kaf-general-technical/dotsenko/ (N. A. Dotsenko); https://kdpu.edu.ua/personal/vmsoloviov.html (V. N. Soloviev); https://iitlt.gov.ua/eng/structure/departments/technology/detail.php?ID=271 (S. H. Lytvynova); https://www.mnau.edu.ua/faculty-energy/kaf-agroengineering/gorbenkooa/ (O. A. Gorbenko); https://www.mnau.edu.ua/faculty-energy/kaf-agroengineering/kimni/ (N. I. Kim); https://www.mnau.edu.ua/faculty-energy/kaf-tsgm-ets/galeeva/ (A. P. Haleeva)

0000-0002-8407-4984 (I. V. Batsurovska); 0000-0003-1050-8193 (N. A. Dotsenko); 0000-0002-4945-202X (V. N. Soloviev); 0000-0002-5450-6635 (S. H. Lytvynova); 0000-0001-6006-6931 (O. A. Gorbenko); 0000-0003-1050-8193 (N. I. Kim); 0000-0002-8017-3133 (A. P. Haleeva)

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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 [1]. It allows the study of physical processes, complex technical systems, provides the assistance in understanding existing engineering materials [2]. Many developments techniques arose initially as solutions to problems of modeling the physical and electronic behaviors of materials [3]. The 3D simulations involve various methods of hydrodynamics and computational fluid dynamics as a complex tool [4]. 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 [5, 6, 7]. It is explored the relation of simulations to numerical methods [8]. 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 [9]. Diouf and Lo [10] 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. [11] 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 [12]. 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 [14]. The machine learning models assist the designers in choosing different design strategies [15, 16]. The visualization of line geometry via the 3D graphic statics is presented by Kodrnja et al. [17]. 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 [18]. The method of creating photorealistic 3D models (PR3DMs) of real-world objects with the methods of photogrammetry is an example of such emerging technologies [19]. Tosheva [20] 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. [21]. Barkatov et al. [22] 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 [23]. 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 [24]. In the conditions of blended learning the dialogue clusters of students were stronger when the interactions were related to the subject of the course [25]. Representing 3D objects by multiple views has become a common solution to the problem of 3D object retrieval [26]. 3D images contain depth information, they have gradually gained importance for numerical systems in image analysis [27].

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 [28] and the technology of application of competence-based educational simulators in the informational and educational environment for learning general technical disciplines [29]. There is investigation about technological model of training of Masters in Electrical Engineering to electrical installation and commissioning [30], 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 [31].

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

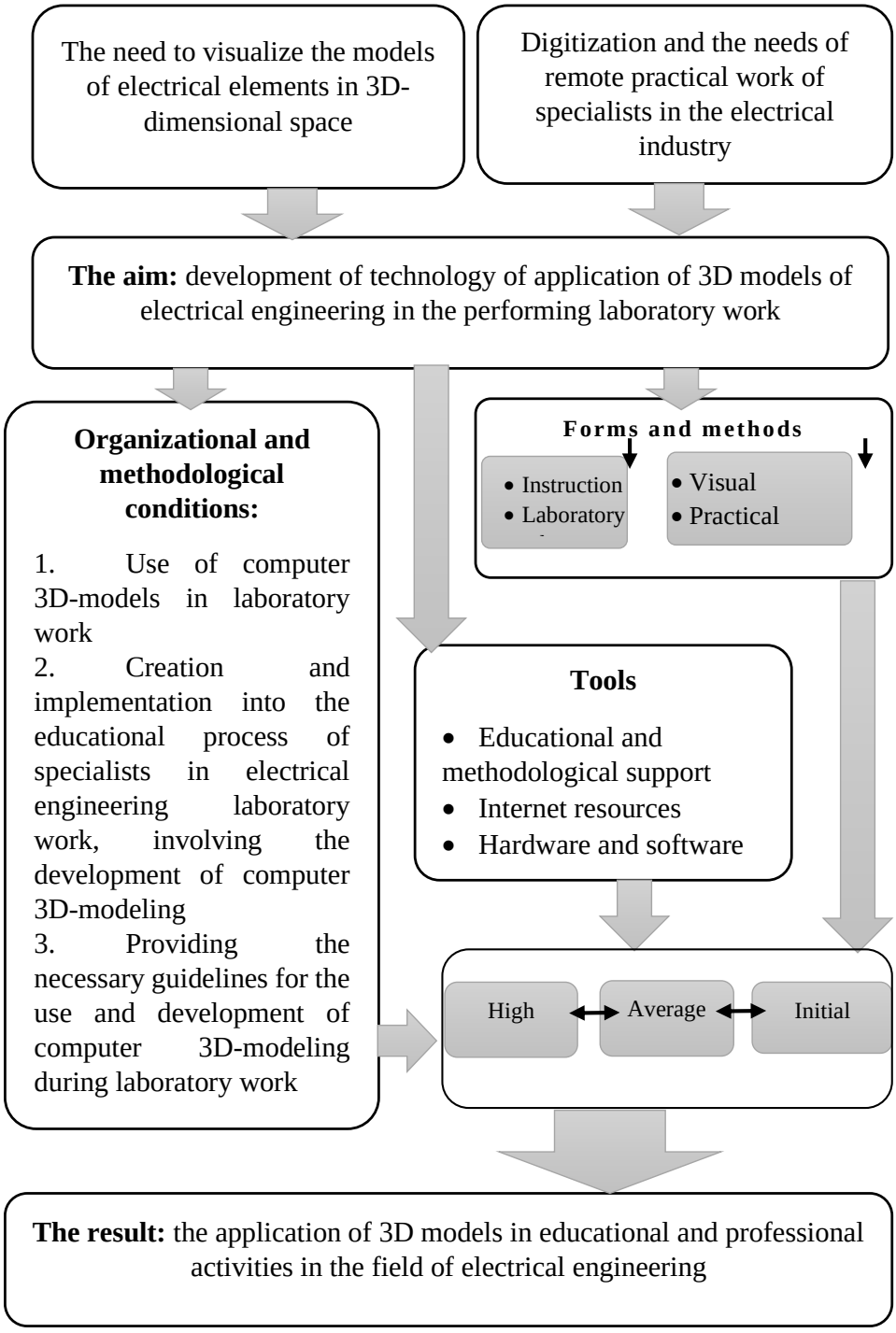

Figure 1: The technology of application 3D models of electrical engineering in the performing laboratory work.

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.

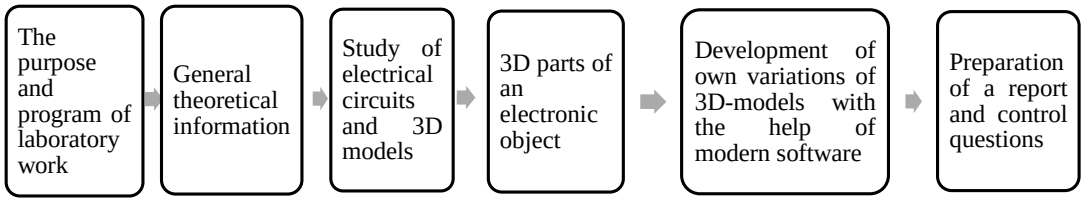

Figure 2: The technology of performing laboratory work in the study of electrical disciplines.

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.

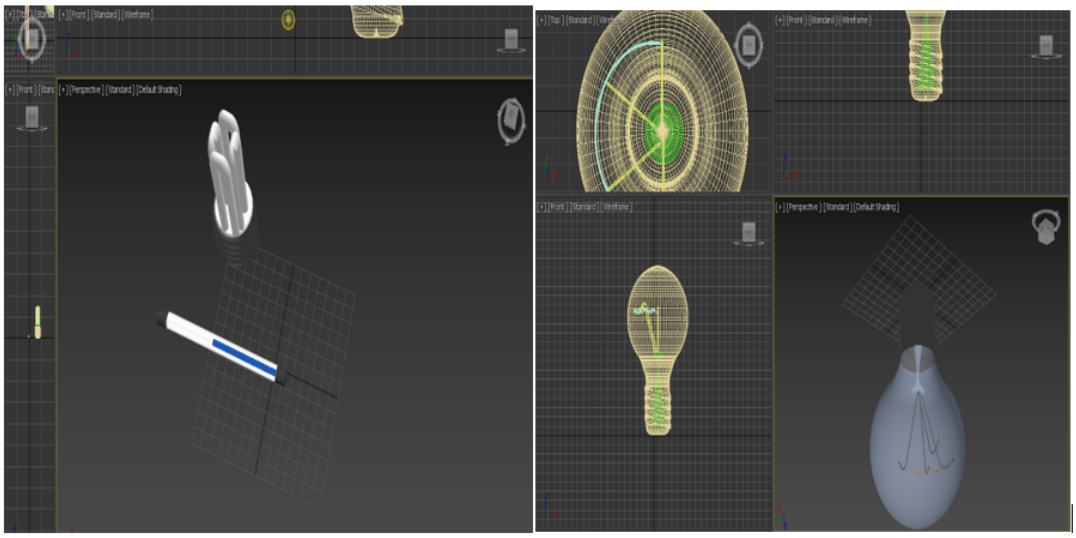

Figure 3: Laboratory work on the subject “Lighting” on “Research of natural and artificial light”: a study of the structure of lamps of different types in 3D space.

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

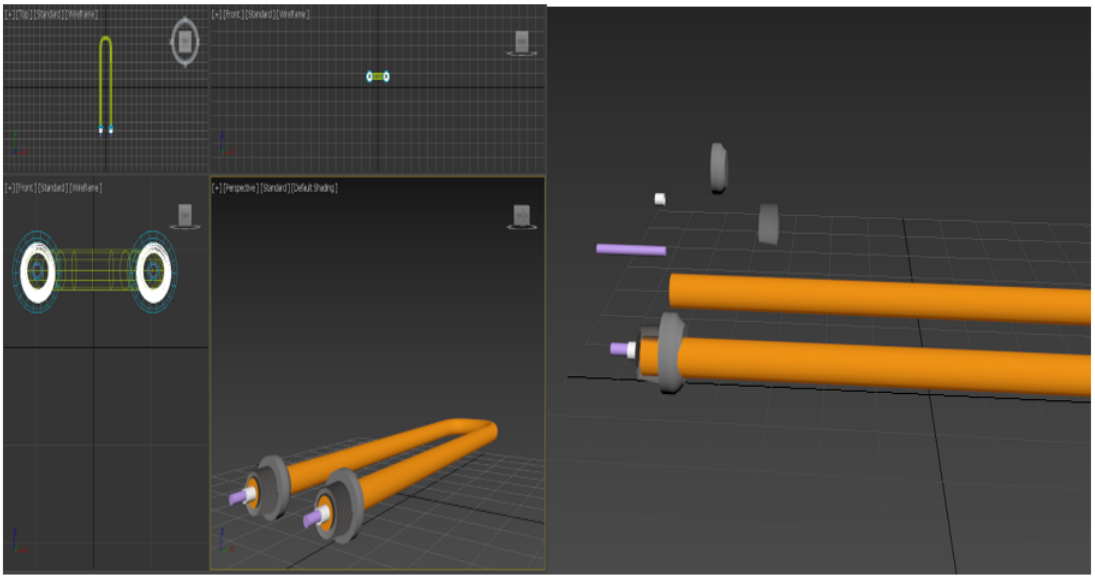

Figure 4: Laboratory work on the subject "Electrical technology" on the topic "The principle of operation of tubular electric heaters: disassembly of a tubular electric heater into structural elements".

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] B. K. Bose, Chapter 9 - computer simulation and digital control, in: B. K. Bose (Ed.), Power Electronics and Motor Drives (Second Edition), second edition ed., Academic Press, 2021,

pp. 687–764. doi:10.1016/B978-0-12-821360-5.00009-9.
[2] R. Pathria, P. D. Beale, 16 - computer simulations, in: R. Pathria, P. D. Beale (Eds.), Statistical Mechanics (Fourth Edition), fourth edition ed., Academic Press, 2022, pp. 659–674. doi:10.1016/B978-0-08-102692-2.00025-9.
[3] J. R. S. Bursten, Computer simulations, in: Between Making and Knowing, 2020, pp. 195–206. doi:10.1142/9789811207631_0019.
[4] M. Janczarek, E. Kowalska, Computer simulations of photocatalytic reactors, Catalysts 11 (2021). URL: https://www.mdpi.com/2073-4344/11/2/198. doi:10.3390/catal11020198.
[5] O. O. Oladimeji, D. Oyeyiola, O. Oladimeji, P. Oyeyiola, A comprehensive survey on cloud computing simulators, Scientific Journal of Informatics 8 (2021) 51–59. URL: https://journal.unnes.ac.id/nju/index.php/sji/article/view/28878. doi:10.15294/sji.v8i1.28878.
[6] D. S. Antoniuk, T. A. Vakaliuk, V. V. Didkivskyi, O. Y. Vizghalov, O. V. Oliinyk, V. M. Yanchuk, Using a business simulator with elements of machine learning to develop personal finance management skills, CEUR Workshop Proceedings (2022).
[7] A. E. Kiv, O. V. Merzlykin, Y. O. Modlo, P. P. Nechypurenko, I. Y. Topolova, The overview of software for computer simulations in profile physics learning, CEUR Workshop Proceedings 2433 (2019) 352–362.
[8] P. Humphreys, Computer simulations, in: Philosophical Papers, 2019, pp. 9–20. doi:10.1093/oso/9780199334872.003.0002.
[9] G. Papadopoulos, A. Syropoulos, Sense and boundaries of computer simulations, in: M. Khosrow-Pour (Ed.), Encyclopedia of Information Science and Technology, fifth ed., IGI Global, 2021, pp. 155–163. doi:10.4018/978-1-7998-3479-3.ch012.
[10] A. A. Diouf, B. Lo, Dielectric properties: Computer simulation, International Journal of Advanced Research 8 (2020) 972–979. doi:10.21474/IJAR01/11178.
[11] K. Rozhdestvensky, V. Ryzhov, T. Fedorova, K. Safronov, N. Tryaskin, S. A. Sulaiman, M. Ovinis, S. Hassan, Computer simulation of dynamic systems, in: Computer Modeling and Simulation of Dynamic Systems Using Wolfram SystemModeler, Springer Singapore, Singapore, 2020, pp. 89–130. doi:10.1007/978-981-15-2803-3_3.
[12] M. P. Mgr, Use of 3D graphics in education, in: 2019 17th International Conference on Emerging eLearning Technologies and Applications (ICETA), 2019, pp. 667–675. doi:10.1109/ICETA48886.2019.9040135.
[13] R. A. Kadir, A. Ahmad, A. Marstawi, Transformation of Text-to-3D Graphics, Advanced Science Letters 24 (2018) 1085–1089. doi:10.1166/asl.2018.10692.
[14] T. Monahan, G. McArdle, M. Bertolotto, Using 3D Graphics for Learning and Collaborating Online, in: J.-J. Bourdin, H. McCabe (Eds.), Eurographics 2005 - Education Papers, The Eurographics Association, 2005. doi:10.2312/Conf/EG2005/Education/033-040.
[15] H. Zheng, V. Moosavi, M. Akbarzadeh, Machine Learning Assisted Evaluations in 3D Graphic Statics, in: IASS Annual Symposium 2019 - Structural Membranes 2019, 2019. URL: https://www.researchgate.net/publication/336313383_Machine_Learning_Assisted_Evaluations_in_3D_Graphic_Statics.
[16] D. S. Antoniuk, T. A. Vakaliuk, V. V. Didkivskyi, O. Y. Vizghalov, Development of a simulator to determine personal financial strategies using machine learning, CEUR Workshop Proceedings 3077 (2022) 12–26. URL: http://ceur-ws.org/Vol-3077/paper02.pdf.
[17] I. Kodrnja, M. Baniček, K. Fresl, Line geometry and 3D graphic statics, Gradevinar 71

(2019) 863–875. doi:10.14256/JCE.2725.2019.
[18] N. V. Rashevska, S. O. Semerikov, N. O. Zinonos, V. V. Tkachuk, M. P. Shyshkina, Using augmented reality tools in the teaching of two-dimensional plane geometry, CEUR Workshop Proceedings 2731 (2020) 79–90. URL: http://ceur-ws.org/Vol-2731/paper03.pdf.
[19] S. Nebel, M. Beege, S. Schneider, G. D. Rey, A review of photogrammetry and photorealistic 3d models in education from a psychological perspective, Frontiers in Education 5 (2020). URL: https://www.frontiersin.org/article/10.3389/feduc.2020.00144. doi:10.3389/feduc.2020.00144.
[20] E. Tosheva, 3D modeling solutions in the cloud, in: Conference on Information Technology and Development of Education–ITRO 2019 Zrenjanin. Republic of Serbia, 2020, pp. 215–216. URL: https://www.researchgate.net/publication/348806388_3D_Modeling_Solutions_in_the_Cloud.
[21] M. Mihaila, S. Mihailescu, S. Vlaiescu, N. Andreea, C. Caragea, 3D modeling as educational process of documenting students projects: Architectural exercises, in: EURAU 2016 European Symposium on Research in Architecture and Urban Design: In Between Scales. EURAU 2016 – PROCEEDINGS, 2016, pp. 453–462. doi:10.13140/RG.2.2.30967.42401.
[22] I. V. Barkatov, V. S. Farafonov, V. O. Tiurin, S. S. Honcharuk, A. A. Lozko, V. V. Marushchenko, K. V. Korytchenko, V. I. Barkatov, R. F. Muravlyov, 360° photographic panoramas as an effective multifunctional aid for teaching technology subjects, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[23] S. Hall, G. Grant, D. Arora, A. Karaksha, A. McFarland, A. Lohning, S. Anoopkumar-Dukie, A pilot study assessing the value of 3D printed molecular modelling tools for pharmacy student education, Currents in Pharmacy Teaching and Learning 9 (2017) 723–728. doi:10.1016/j.cptl.2017.03.029.
[24] A. Z. Sampaio, M. M. Ferreira, D. P. Rosário, O. P. Martins, 3D and VR models in Civil Engineering education: Construction, rehabilitation and maintenance, Automation in Construction 19 (2010) 819–828. doi:10.1016/j.autcon.2010.05.006.
[25] H. Shu, X. Gu, Determining the differences between online and face-to-face student–group interactions in a blended learning course, The Internet and Higher Education 39 (2018) 13–21. doi:10.1016/j.iheduc.2018.05.003.
[26] H. Li, Y. Zheng, J. Cao, Q. Cai, Multi-view-based siamese convolutional neural network for 3d object retrieval, Computers & Electrical Engineering 78 (2019) 11–21. doi:10.1016/j.compeleceng.2019.06.022.
[27] E. Kaya, E. Sert, A new 3D segmentation approach using extreme learning machine algorithm and morphological operations, Computers & Electrical Engineering 84 (2020) 106638. doi:10.1016/j.compeleceng.2020.106638.
[28] A. D. Uchitel, I. V. Batsurovska, N. A. Dotsenko, O. A. Gorbenko, N. I. Kim, Implementation of future agricultural engineers' training technology in the informational and educational environment, CEUR Workshop Proceedings 2879 (2020) 233–246.
[29] N. Dotsenko, 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 (2021) 012014. doi:10.1088/1742-6596/

1946/1/012014.
[30] I. Batsurovska, Technological model of training of Masters in Electrical Engineering to electrical installation and commissioning, Journal of Physics: Conference Series 1946 (2021) 012015. doi:10.1088/1742-6596/1946/1/012015.
[31] C. H. Goulden, Methods of Statistical Analysis, Koteliansky Press, 2007, pp. 50–55.

Immersive learning technology for ensuring quality education: Ukrainian university case

Volodymyr O. Liubchak[1], Yurii O. Zuban[1] and Artem E. Artyukhov[1]

[1]Sumy State University, 2 Rymskogo-Korsakova Str., Sumy, 40007, Ukraine

Abstract

The article considers the problem of using immersive learning in the educational and scientific activities of the university. Literature survey revealed that there is a need for an integrated approach for introduction of immersive learning at the university. It involves the creation of a specialized laboratory of virtual and augmented reality with appropriate technical equipment, introduction of immersive learning methodology in university educational programs, development of software and hardware solutions for immersive learning, and research on the immersive learning effectiveness. We present the description of a specialized university department acting as a developer of software products for immersive learning. We show original developments in the field of immersive education for exact sciences and arts and humanities students. The article describes products that are designed to fulfill the third university mission: to ensure the citizens well-being. We propose "immersive institute" model which can be implemented both at the level of the university in general and at the level of its educational and scientific departments.

Keywords

immersive learning, virtual reality, augmented reality, immersive institute

1. Introduction

The process of learning at the university is not always associated with the use of real objects or phenomena as a demonstration. The educational material is mostly explained on imaginary models of processes or objects. It is also not always possible to interact with such models. Therefore, the whole process of learning (discovery of the world) is very indirect and largely depends on the developed imagination of the student. In this case, the effectiveness of teaching largely depends on teacher's ability to convey the essence of the model and the student's ability to imagine it.

A flat two-dimensional surface (black- or whiteboard, an interactive board or just a slide projector) usually remains a teacher's tool aimed to help students form the idea without possibility of its dynamic change over time. Current generation of young people perceives information differently and students' ability to think imaginatively does not get better, and largely depends

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lub@sumdu.edu.ua (V. O. Liubchak); y.zuban@elearning.sumdu.edu.ua (Y. O. Zuban); a.artyukhov@pohnp.sumdu.edu.ua (A. E. Artyukhov)

http://irbis-nbuv.gov.ua/ASUA/1259756 (V. O. Liubchak); http://irbis-nbuv.gov.ua/ASUA/0106668 (Y. O. Zuban); https://personal.sumdu.edu.ua/artyukhov/en/ (A. E. Artyukhov)

0000-0002-7335-6716 (V. O. Liubchak); 0000-0002-6596-894X (Y. O. Zuban); 0000-0003-1112-6891 (A. E. Artyukhov)

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on the methods of conveying information, visualizing images. Therefore, the printed textbook today is less satisfying for students than in recent years. Even video content is not always effective enough for describing a complex model, idea or process. All this in general has a negative impact on the quality of education, especially with a low level of student motivation. In this case, the need arises for proposing new tools to create additional practice-oriented learning incentives on the university side and increase the level of student motivation. One such tool is immersive learning.

Technologies of full or partial immersion in the virtual world or various combinations of "live" tools (F2F) and virtual reality – immersive technologies – allow to provide the effect of full or partial presence in an alternative space. These technologies are implemented through software and hardware solutions of VR (virtual reality), AR (augmented reality) and MR (mixed reality) [1].

VR and AR currently have the greatest impact on human perceptual organs, and their potential for education is not yet fully explored. The following properties form their prospects:

1. *Visual orientation.* In a virtual space, one can freely view any process or object in detail from different angles, which is much more interesting than looking at static pictures in the textbook.
2. *Concentration.* In a virtual environment, one cannot be distracted by external stimuli, which allow strong focusing on the material.
3. *Maximum involvement.* Stereoscopic images and surround sound create a complete illusion for the human senses. Tracking student movements and positions in a virtual environment adds a presence effect. Some technological solutions allow realizing even tactile sensations. In addition, immersive technologies provide the ability to fully control and change the learning scenario. The student can witness historical events, conduct an experiment in physics or chemistry, or solve a problem in playful and understandable form. In fact, student interacts almost naturally with objects of study or research.
4. *Safety.* One can unsuccessfully perform a complex operation, try to control a space shuttle, conduct an experiment with dangerous chemicals or explosives, while suffering many failures and not cause real harm to oneself or others.
5. *Effectiveness of learning and quality of knowledge acquisition*, which is confirmed, e.g. by research conducted by Microsoft [2], and Eutsler and Long [3].

That is why immersive technologies are already actively used in education [4].

Immersive technologies change the content and develop the typology of educational materials: printed; printed with multimedia applications; electronic as an analogue of printed; electronic with multimedia content, navigation and hyperlinks to external sources; printed with augmented reality objects; virtual and mixed books. The integration of new AR technology into the old environment has a synergistic effect and positively influences the students. AR books (Visually Augmented Books, Traditional AR Book), which usually contain both 2D static and dynamic content, and 3D content: static and dynamic models, sound depending on user actions and location, etc. became popular recently.

It is very important to note that immersive technologies should not be associated exclusively with technical objects. It is also important to reveal their relevance, for example, in medical

education and arts and humanities field. The main purpose of this article is to present a comprehensive approach to the use of immersive technologies in classical university.

The object of research is the e-learning ecosystem at the university.

The subject of research is immersive learning as an e-learning tool.

The novelty of the work is a new comprehensive approach to the introduction of immersive learning at the university, which includes:

- creation of a specialized laboratory of virtual and augmented reality with appropriate technical equipment;
- introduction of the immersive learning methodology in the university educational programs;
- development of proprietary software and hardware solutions for immersive learning;
- study of immersive learning effectiveness based on the overall student achievements.

Practical significance: for the first time on the basis of the classical university we work out the algorithm for creation of AR and VR tools considering features of knowledge branches. The algorithm is implemented for educational programs of engineering, medical and socio-humanitarian direction.

2. Literature review

The development of immersive technologies and the growth of their popularity is clearly shown in figure 1. Over the past 10 years, the annual number of scientific publications on "immersive technology" has increased 4 times (according to https://www.scopus.com/). However, despite such a significant increase, the annual number of publications is not high, which indicates the stage of formation of this research area.

United States of America occupy the leading position in this research area (figure 2). Figure 2 also lists the origin countries of the authors that published 100+ scientific papers in the field of "immersive technology". Ukraine is just beginning its journey in this direction, which confirms the relevance of the material proposed in this paper for application in Ukrainian universities.

A detailed query for the keywords "immersive technology education" (VOSViewer is the tool, data for analysis is taken from https://www.scopus.com/) allowed to identify 2000 most cited articles in the last 10 years and identify a set of relevant keywords that combined in different clusters. The analysis of these clusters allowed to determine the activities of universities to implement immersive technologies in education (figure 3).

Combining VR and AR tools, e-learning technologies, interactive tools and game-based learning allows creating a flexible educational environment that can quickly respond to changing trends in particular field of knowledge.

To assess the prospects of the immersive learning technologies introduction in university educational activities we conduct a detailed analysis of scientific achievements in specific fields and identify the most popular areas where there is an urgent need to introduce new approaches to learning (analysis tool is SciVal https://www.scival.com). Among the most popular topics are the following:

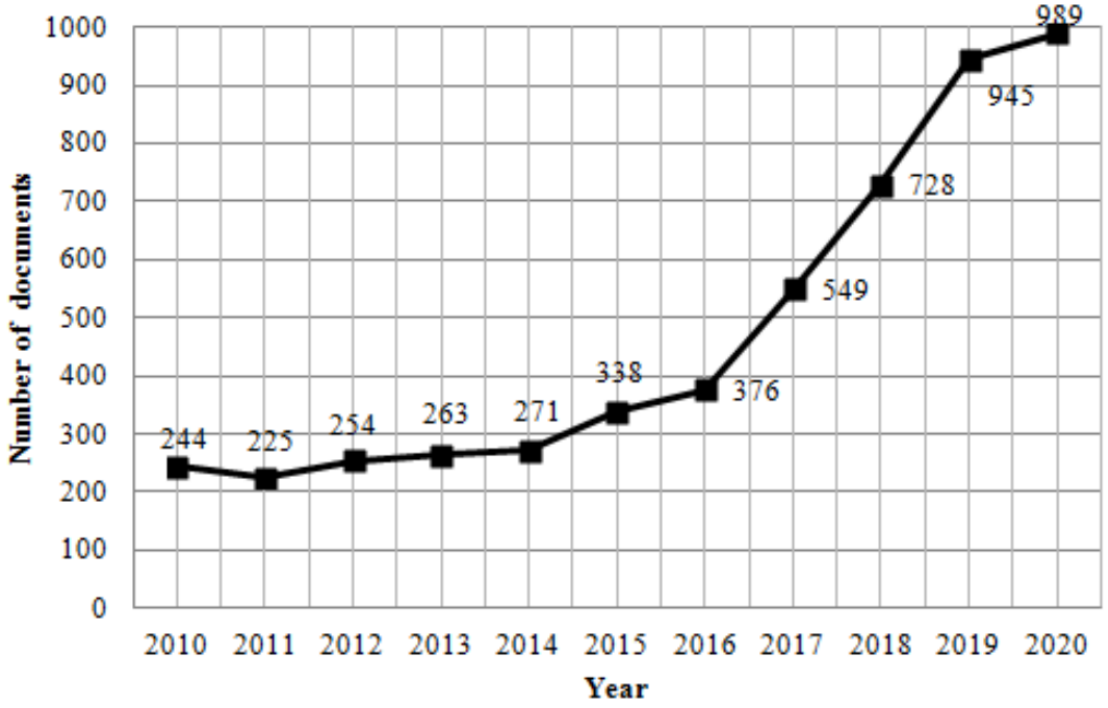

Figure 1: Publication activity in the field of "immersive technology" (data of https://www.scopus.com/).

- Game-Based Learning;
- Educational Games;
- Gamification;
- Augmented Reality;
- Authoring Tools;
- Online Learning;
- Social Presence;
- Virtual Worlds;
- Virtual Learning Environment;
- Pedagogical Support;
- Educational Process;
- Professional Competence.

These topics formulate the main activities of the classical university in immersive technologies implementation and in the creation of an effective strategy for new products to enter the educational market, as well as the creation of commercial products for industry and business. Analysis of the connection of individual topics in agglomerates (clusters of topics) gives grounds for expanding the role of immersive technologies for extracurricular activities and the implementation of the third mission of the university:

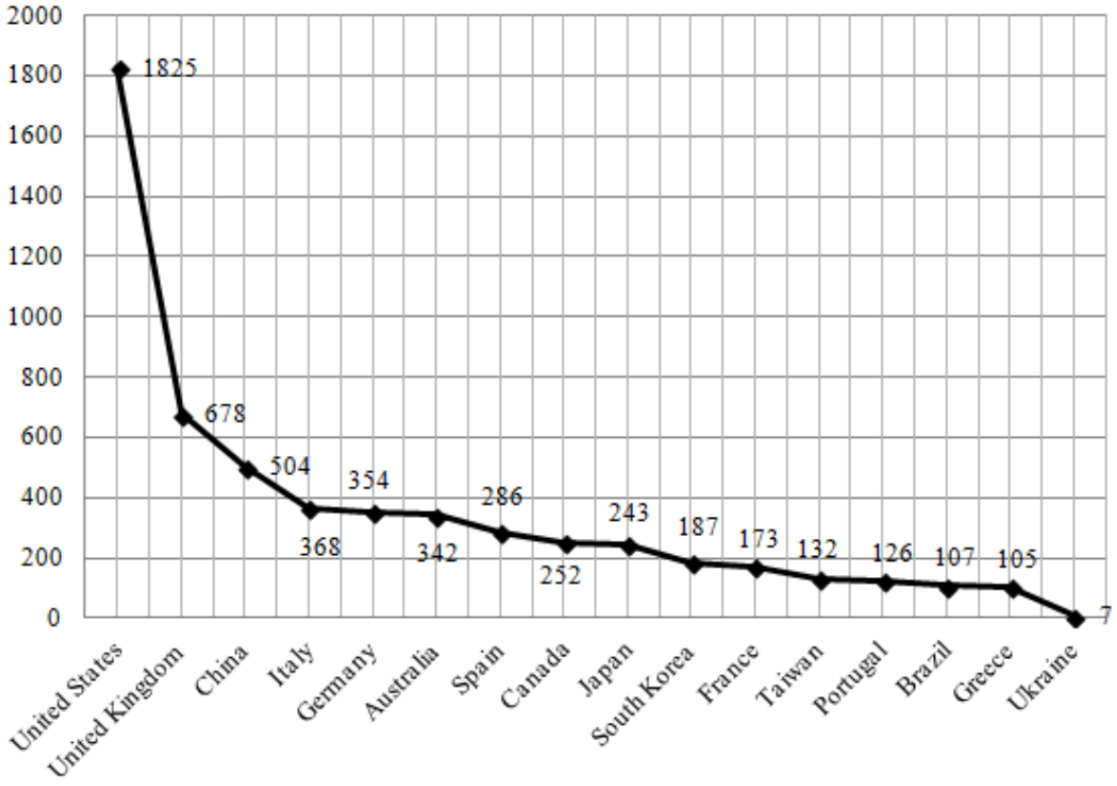

Figure 2: Publication activity of authors from different countries in the field of "immersive technology" (data of https://www.scopus.com/).

- Algorithms; Computer Vision; Models;
- Students; Medical Students; Education;
- Attention; Brain; Learning;
- Work; Personality; Psychology.

Analysis of the article content (according to https://www.scopus.com/) in the direction of development and implementation of immersive technologies and education quality assurance in general allowed to identify the following areas that can be successfully implemented by the classical university:

- development of the educational environment with the use of immersive learning tools [5, 6, 7, 8, 9, 10, 11];
- immersive learning tools in medicine [12, 13, 14, 15, 16];
- immersive learning tools in engineering and physics [17, 18, 19];
- immersive learning tools in arts and humanities [20, 21, 22];
- pedagogical innovations based on immersive learning [23, 24, 25] [23-25]
- application of immersive technologies in university subdivisions, e.g. library [26, 27];

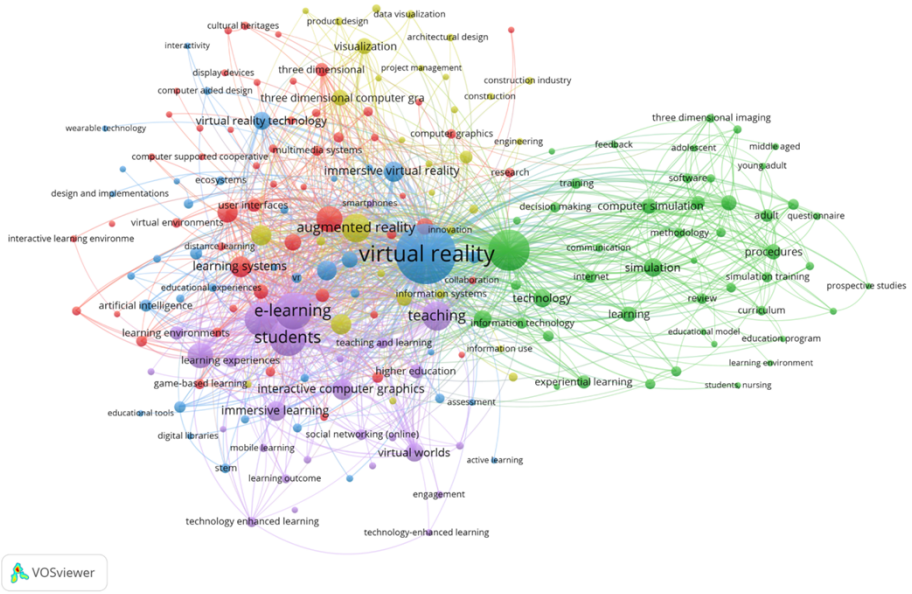

Figure 3: The results of bibliometric analysis on the query “immersive technology education”.

- immersive technologies for scientific research [28, 29];
- fulfillment of the third university mission and social activity to ensure the citizens well-being [30, 31, 32, 33, 34, 35, 36];
- education digitalization [37];
- state regulation and management of education quality [38, 39];
- ensuring the quality of education in subject areas [40, 41];
- quality of education and sustainable development goals [42].

When forming a strategy for the university development in terms of immersive technologies introduction in educational and scientific activities one should also pay attention to the experience of other educational institutions, which can be learned, e.g. through Immersive Education (iED) Summits [43], Immersive Learning Research Network (iLRN) [44], Women in Immersive Tech Europe [45], etc.

Technology companies’ specialists are also working on the development of immersive technologies. Here are some examples of world-famous companies’ developments.

Lenovo has developed a specialized virtual classroom that allows one to create a blended learning environment. The class consists of various devices (virtual reality helmet, tablet, router), as well as software and comprehensive training programs [46].

Microsoft is actively researching and developing immersive technologies [47]. One of the directions is the use of mixed reality technology with the help of HoloLens from Microsoft [48].

zSpace offers a hardware and software solution that provides an interactive experience by integrating the latest AR/VR technology into an all-in-one computer and laptop. zSpace uses three sensory characteristics to create a natural and intuitive product:

– immersion perception;
– possibility to look around;
– kinesthetic realism [49].

OVAL (Oklahoma Virtual Academic Laboratory [50]) supports the operation of virtual class Portals, within which you can share learning experiences in VR environment. For example, in this way, students studied the inner part of Arizona cave system.

Immersive technologies are already used actively in university education. At North Carolina State University, virtual reality is used in the study of the natural sciences [51]. During virtual field research, students find, observe and study organisms in their natural habitat.

At Pennsylvania State University, students attend practical classes equipped with virtual reality technology. During the practical classes, they learn about situations that they may potentially encounter in the future. This approach increases the learning effectiveness and prepares students for real work situations [52].

Graz University of Technology (Austria) has developed a learning VR platform "Maroon" and is actively using it to study STEM [53].

The first significant steps in this direction at Sumy State University were made by the author's team members of this work [54, 55].

3. Research methodology

The concept of Sumy State University (SumDU) immersive technologies application is not a trivial replacement of real laboratory or practical work with virtual ones.

We see the main effect in methodological approach that immerses the student in a certain case inherent in the educational program, discipline or topic, with the obligatory interactive stages that cause a strong emotional reaction.

These can be accidents or critical situations at production site or in the workplace, ones related to equipment or interaction with colleagues and customers, and so on.

The causalities designed for such situations are a strong impetus for other learning activities (in or out of the classroom). Regular application of immersive technologies can significantly increase the training effectiveness. We can get as close as possible to the natural way of interaction with the object of study through immersive technologies. Along with this, we fully exploit the emotional component of interaction and create powerful motivating effect for further application of classical learning activities.

An engineer can start a reactor, compressor or aircraft. The doctor can save the patient, perform an autopsy or examine the pathology. Military trainees can navigate the area or adjust artillery fire. In each of the cases there may be a critical situation when the reactor explodes, the patient is on the verge of death, and the shells do not hit their target. Through periodic immersion in virtual, most realistic cases with obvious consequences, the student is able to form a clear, logical structure of interrelated needs for knowledge in various disciplines.

VR and AR tools in the hands of a trained teacher can bring the learning process as close as possible to natural, direct interaction, and in some cases can even open greater opportunities.

Simulations represent some part of the surrounding reality thus allowing to study aspects of reality that cannot be studied in another way for reasons of safety, ethics, high cost, lack of

necessary technical support or scale of the investigated phenomenon. Simulation is a structured scenario with a detailed system of rules, tasks and strategies that are created for a specific purpose: to form specific competencies that can be directly transferred to the real world. Simulations help to visualize abstract concepts. Students understand the essence of the studied phenomenon due to the possibility of manipulating its parameters. Two basic components are allocated within the simulation. First, the working model of professional environment or the structural and organizational scheme in which possible variants of behaviour and staff interaction are enclosed. Second component is the scenario (plot) of the simulation process, aimed at the application of knowledge, intuition development and finding alternative non-standard ways to solve the problem.

Hands-on algorithms to develop the above mentioned components for educational course are not described in literature. We are still individually searching for effective approaches to the implementation of VR and AR technologies for each educational program, discipline, topic, etc.

The context of each program is individual, so the simulator script is not born immediately. In any case, it is important to remember that any technology is a tool to achieve the learning goals.

4. Results and discussion

During 5 years of immersive technologies introduction in SumDU, the AR textbooks and information materials are published, training VR simulators are developed.

Over the years, SumDU has improved its own e-learning ecosystem of (https://elearning.sumdu.edu.ua). SumDU specialists created training and research laboratory of VR and AR (https://ulab.sumdu.edu.ua) with appropriate technological conditions to conduct training sessions. These sessions allow immersion of a group of students in various virtual cases inherent in the educational program, discipline or topic, with mandatory interactive stages of interaction with the equipment or between participants.

The number of simultaneous participants in VR-simulations significantly affects the potential of learning scenarios. Therefore, Ulab laboratory is designed to conduct classes with one academic group of students. It has three zones: VR/AR zone, control zone, group zone (figure 4).

VR/AR-zone is designed for the simultaneous participation of four students. It is equipped with four powerful PCs, four HTC Vive VR headsets with two Lighthouse base stations and a surveillance camera. All surfaces of the VR/AR zone (four walls, floor and ceiling) are textured with unique high-contrast images. The VR/AR area is equipped with a special backlight that prevents direct rays from entering the camera lens of the participant's smartphone, tablet or other device. All this provides reliable positioning in the VR/AR zone when using optical recognition methods used in AR.

We planned our laboratory to maintain constant contact between students. When four participants are in VR, the rest of the group can watch their actions and make voice comments. The verbal connection between students remains.

This can be used in different ways, depending on the task of the VR-simulator: students can help with calculations, the teacher can advise how best to do various actions. To do this, students in the group zone have the opportunity to observe the events in the VR/AR zone and see the action on four screens the same as four participants in the simulation. Radio microphones are

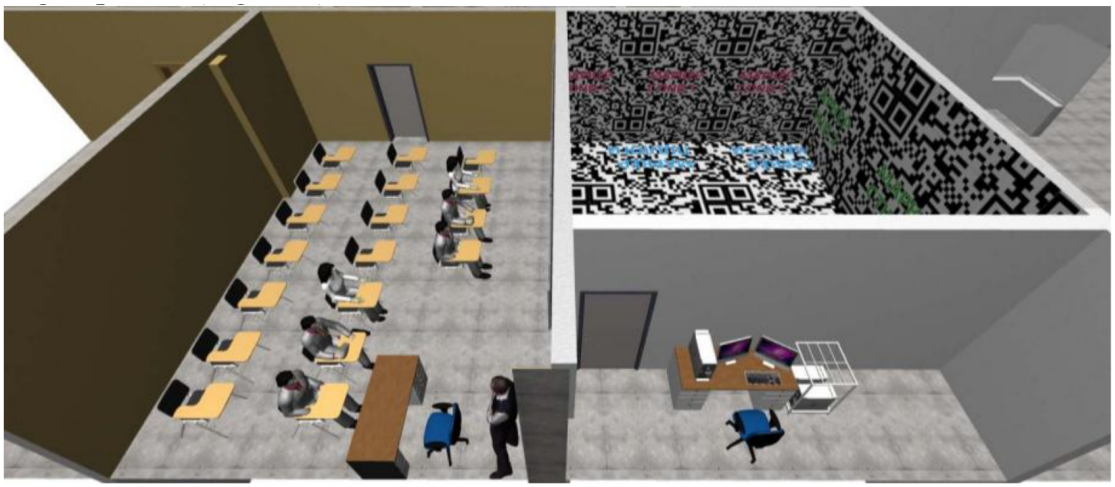

Figure 4: Ulab laboratory.

installed in the group area for voice communication. The VR/AR zone uses built-in microphones in HTC Vive VR headsets. Video and audio streams are controlled by specialized matrix switches located in the control area.

Qualified specialists in the control area maintain equipment performance. They monitor all processes during VR simulations, as well as the actions of participants.

It is important to understand that student immersed in VR practically loses control over the real world: he/she does not see walls, obstacles and other participants, may lose his/her balance, make sudden unexpected movements, and so on. Orientation in space can also change under the influence of VR content.

Examples of SumDU VR developments:

1. Technically oriented simulator of the natural gas drying is designed as multi-user simulator for simultaneous work of students together with the teacher (figure 5). Students getting trained in educational programs related to chemical engineering, oil and gas production equipment and production automation first get acquainted with the gas drying plant, study its design and can even look inside, which is impossible in real conditions. The simulator allows trainees to study the design and operation of unit equipment. The teacher can secretly initiate an emergency mode, and students will have to change the parameters in a short time to avoid an accident. It is extremely difficult to do this without understanding the basic principles of the installation. Working in the simulator allows student group to practice teamwork skills, solving problems in time lacking conditions and take responsibility for the decisions made. These skills, in addition to specialized knowledge, are demanded in the job market. Every accident on the simulator is remembered and motivates to study the theoretical material deeply.

The simulator is developed in the Unity environment (https://unity.com) and uses a client-server architecture to implement multiplayer mode, in which the position of each participant

Figure 5: Natural gas drying unit simulator.

in the simulation, his/her movements and actions are synchronously transmitted to the Photon Unity Networking server. It re-implements and enhances the features of Unity's built-in networking. Under the hood, it uses Photon's features to communicate and match players (https://www.photonengine.com/pun).

The software module of each user takes into account the position of the user during each frame of 3D scene rendering to determine the angle of observation and the position of all other participants according to the data obtained from the server.

2. The virtual tour around the Military Training Department was developed with the Unity environment for mobile devices based on OS Android equipped with a gyroscope to provide three degrees of freedom (3DoF) to the user. Movements in space are carried out by means of the software implemented controller. The simulator not only introduces future officers to the laboratories and classrooms of the department, but also allows to demonstrate samples of military equipment and weaponry in the field on a virtual range (figure 6).

3. The best way to study history is to immerse yourself in times long gone, experience the peculiarities of another culture, see everything live or visit a virtual museum, where all the famous artworks are collected.

This VR simulator is also designed in the Unity environment for HTC Vive with multiplayer mode support. Students can share their impressions of the exhibits directly in VR, either in the Ulab or even in another city or country (figure 7).

Figure 6: Virtual tour around the Military Training Department.

4. Another format for studying local history is realized with the help of Sumy city tour guide that uses AR technology. Specialized multimedia content is played in AR by the Ulab AR mobile application, developed by SumDU specialists and available for mobile devices with iOS 9+ and Android 6+ operating systems. Specialized multimedia content for this case is created: animated virtual 3D-models of famous Sumy patrons Ivan Kharitonenko and Gerasim Kondratiev with unique audio for 37 locations of the tourist route around Sumy (figure 8).

The Ulab AR application is designed to use augmented reality marker technology and allows user to match the specified collection of images to the appropriate multimedia content in both video and 3D format. Positioning of virtual content is carried out relative to the image-marker. Collections of markers and multimedia content for them are formed into special albums, which are downloaded using unique QR code into the Ulab AR program. To install the application, the user scans the QR code placed on advertising and information materials on stands located around city. To play AR content, user only need to point the camera with application running on a special plate located at each of the 37 locations of the route.

5. SumDU is currently working on a series of VR medical simulators. They are based on the anatomical model of human. More than 2,500 model objects make it possible to visualize any composition of selected anatomical model objects, systems and their components. The model may be movable rather than static as usual (figure 9).

Full body tracking technology allows to synchronize the movements of the anatomical model with the movements of the student or teacher. We use specialized software that based on a set of special HTC Vive trackers to analyze the position of all moving parts of the user's body in VR (figure 10).

Figure 7: Virtual museum.

The number of potential usage scenarios in medical education programs is almost limitless. It can be a simple study of human anatomy with the ability to "disassemble the body" to the last muscle and bone. User can study the anatomy of individual organs, supplementing the model with a set of possible pathologies. By combining the anatomical model with virtual models of medical diagnostic equipment (tomography scanner, X-ray, cardiograph, etc.), it is possible to implement virtual scenarios of real patient examination, surgical procedures, etc.

The VR-simulators scenarios can be scaled from single-user to group with the distribution of participants roles. In the future, it will be possible to implement even a full-fledged clinical department or operating room with medical staff and patients, specialized facilities and more. The possibility of remote VR sessions opens up a wide range of opportunities for such approaches, especially during quarantine restrictions, when participants can be physically distributed in space, but able to interact directly in virtual environment performing tasks, making mistakes and correcting them.

5. Conclusions

The e-learning system based on immersive technologies increases the educational process efficiency and is an essential part of the system bound to ensure educational activities quality and overall quality of higher education at SumDU. Internal and external assessment tools are used for evaluation of the implementation of immersive learning effectiveness and its impact on the education quality. One of internal assessment tools used is a survey of students and teachers on the applicability and prospects of immersive educational materials in specific knowledge

Figure 8: City tour guide.

areas. External evaluation of the educational programs quality criteria were proposed by the National Agency for Higher Education Quality Assurance of Ukraine (https://naqa.gov.ua/). Within the framework of each educational program, the university must create appropriate conditions for the practical skills formation along with the theoretical base.

In 2019, SumDU project took part in the competition for educational technologies in London Reimagine Education Awards. In total, more than 1500 projects from technology companies, universities and other educational service providers from 84 countries took part in this competition.

SumDU experience allows to introduce a model of "immersive institute" as an environment for all stakeholders aimed to increase entrants level of interest in learning, to provide student-centered and close to natural interaction learning model, and to act as a carrier of social mission (figure 11).

United States and Ukraine is almost synchronous. New software and hardware solutions

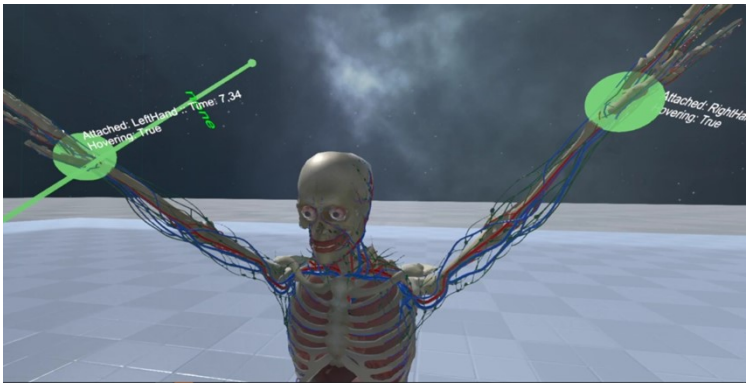

Figure 9: Medical simulator.

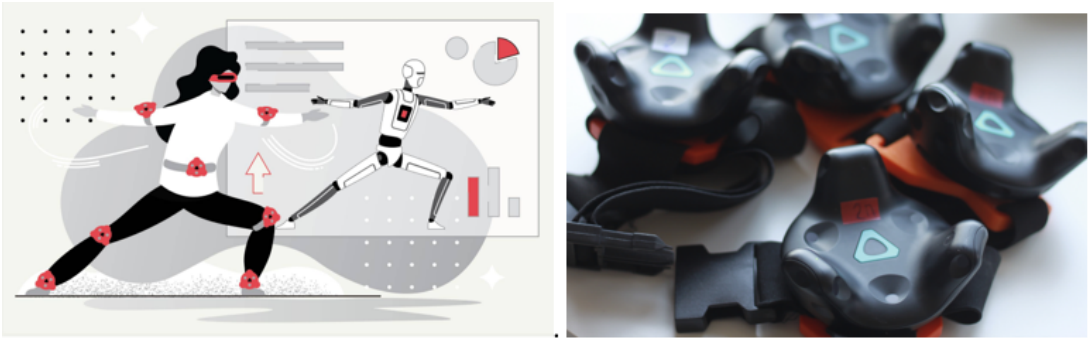

Figure 10: Full body tracking technology application.

appear almost every year and give impetus to the further development of technology.

In a few years, VR equipment will be widely adopted, as there are smartphones today. At that stage, the learning possibilities of immersive technologies will be difficult to overestimate, especially in situations similar to quarantine restrictions.

At SumDU , the e-learning system is improving and there are conditions for this: motivated teachers and staff developers (Unity3D programmers and modelers) who create training simulators. However, the prospect of cooperation and joining efforts of several educational institutions opens up much greater opportunities for the introduction and development of immersive learning in Ukrainian higher education institutions.

Acknowledgments

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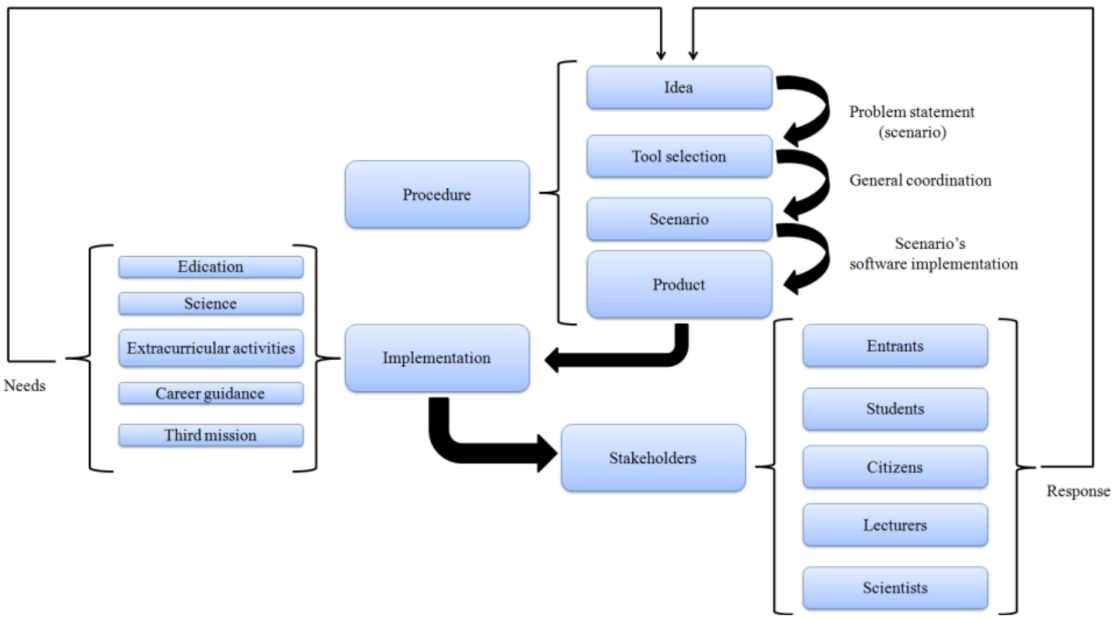

Figure 11: "Immersive institute" model.

national security" (reg. n. 0121U109553).

References

[1] An introduction to immersive technologies, 2022. URL: https://www.vistaequitypartners.com/insights/an-introduction-to-immersive-technologies.

[2] Transforming Education: Empowering the students of today to create the world of tomorrow, Microsoft, 2018. URL: https://news.microsoft.com/wp-content/uploads/prod/sites/66/2018/06/Transforming-Education-eBook_Final.pdf.

[3] L. Eutsler, C. S. Long, Preservice teachers' acceptance of virtual reality to plan science instruction, Educational Technology & Society 24 (2021) 28–43. URL: https://www.jstor.org/stable/27004929.

[4] E. McGovern, G. Moreira, C. Luna-Nevarez, An application of virtual reality in education: Can this technology enhance the quality of students' learning experience?, Journal of Education for Business 95 (2020) 490–496. doi:10.1080/08832323.2019.1703096.

[5] J. Herrington, T. C. Reeves, R. Oliver, Immersive learning technologies: Realism and online authentic learning, Journal of Computing in Higher Education 19 (2007) 80–99. doi:10.1007/bf03033421.

[6] C. Dede, Immersive interfaces for engagement and learning, Science 323 (2009) 66–69. doi:10.1126/science.1167311.

[7] K. F. Hew, W. S. Cheung, Use of three-dimensional (3-D) immersive virtual worlds in K-12

and higher education settings: A review of the research, British Journal of Educational Technology 41 (2010) 33–55. URL: https://www.learntechlib.org/p/187503.

[8] R. Lindgren, M. Tscholl, S. Wang, E. Johnson, Enhancing learning and engagement through embodied interaction within a mixed reality simulation, Computers & Education 95 (2016) 174–187. doi:10.1016/j.compedu.2016.01.001.

[9] J. Radianti, T. A. Majchrzak, J. Fromm, I. Wohlgenannt, A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda, Computers & Education 147 (2020) 103778. doi:10.1016/j.compedu.2019.103778.

[10] N. Elmqaddem, Augmented reality and virtual reality in education. myth or reality?, International Journal of Emerging Technologies in Learning (iJET) 14 (2019) pp. 234–242. URL: https://online-journals.org/index.php/i-jet/article/view/9289. doi:10.3991/ijet.v14i03.9289.

[11] B. M. Kyaw, N. Saxena, P. Posadzki, J. Vseteckova, C. K. Nikolaou, P. P. George, U. Divakar, I. Masiello, A. A. Kononowicz, N. Zary, L. Tudor Car, Virtual reality for health professions education: Systematic review and meta-analysis by the digital health education collaboration, J Med Internet Res 21 (2019) e12959. doi:10.2196/12959.

[12] V. Potkonjak, M. Gardner, V. Callaghan, P. Mattila, C. Guetl, V. M. Petrović, K. Jovanović, Virtual laboratories for education in science, technology, and engineering: A review, Computers & Education 95 (2016) 309–327. doi:10.1016/j.compedu.2016.02.002.

[13] A.-H. G. Abulrub, A. N. Attridge, M. A. Williams, Virtual reality in engineering education: The future of creative learning, in: 2011 IEEE Global Engineering Education Conference (EDUCON), IEEE, 2011. doi:10.1109/educon.2011.5773223.

[14] H. Kaufmann, B. Meyer, Simulating educational physical experiments in augmented reality, in: ACM SIGGRAPH ASIA 2008 Educators Programme, SIGGRAPH Asia '08, Association for Computing Machinery, New York, NY, USA, 2008. doi:10.1145/1507713.1507717.

[15] J. Fox, D. Arena, J. N. Bailenson, Virtual reality, Journal of Media Psychology 21 (2009) 95–113. doi:10.1027/1864-1105.21.3.95.

[16] C. González-González, F. Blanco-Izquierdo, Designing social videogames for educational uses, Computers & Education 58 (2012) 250–262. doi:10.1016/j.compedu.2011.08.014.

[17] W. S. Yue, N. A. M. Zin, Usability evaluation for history educational games, in: Proceedings of the 2nd International Conference on Interaction Sciences Information Technology, Culture and Human - ICIS '09, ACM Press, 2009. doi:10.1145/1655925.1656110.

[18] J. Herrington, T. C. Reeves, R. Oliver, Authentic tasks online: A synergy among learner, task, and technology, Distance Education 27 (2006) 233–247. doi:10.1080/01587910600789639.

[19] M. Savin-Baden, L. Gourlay, C. Tombs, N. Steils, G. Tombs, M. Mawer, Situating pedagogies, positions and practices in immersive virtual worlds, Educational Research 52 (2010) 123–133. doi:10.1080/00131881.2010.482732.

[20] T. Granchak, V. Bondarenko, Immersive technologies in the library: Organization of innovative service for science and education, Science and Innovation 17 (2021) 94–104. URL: https://scinn-eng.org.ua/ojs/index.php/ni/article/view/42. doi:10.15407/scine17.02.094.

[21] V. Hill, H. Lee, Libraries and immersive learning environments unite in second life, Library Hi Tech 27 (2009) 338–356. doi:10.1108/07378830910988487.

[22] J. A. Chen, S. J. Metcalf, M. S. Tutwiler, Motivation and beliefs about the nature of scientific knowledge within an immersive virtual ecosystems environment, Contemporary Educational Psychology 39 (2014) 112–123. doi:10.1016/j.cedpsych.2014.02.004.

[23] N. J. Maran, R. J. Glavin, Low- to high-fidelity simulation - a continuum of medical education?, Medical Education 37 (2003) 22–28. doi:10.1046/j.1365-2923.37.s1.9.x.

[24] K. R. Rosen, The history of medical simulation, Journal of Critical Care 23 (2008) 157–166. doi:10.1016/j.jcrc.2007.12.004.

[25] O. P. Pinchuk, V. A. Tkachenko, O. Y. Burov, AR and VR as Gamification of Cognitive Tasks, CEUR Workshop Proceedings 2387 (2019) 437–442. URL: http://ceur-ws.org/Vol-2387/20190437.pdf.

[26] M. M. Hansen, Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: A review of the literature, J Med Internet Res 10 (2008) e26. URL: http://www.jmir.org/2008/3/e26/. doi:10.2196/jmir.1051.

[27] C. A. Kilmon, L. Brown, S. Ghosh, A. Mikitiuk, Immersive virtual reality simulations in nursing education, Nursing Education Perspectives 31 (2010). URL: https://journals.lww.com/neponline/Fulltext/2010/09000/Immersive_Virtual_Reality_Simulations_in_Nursing.11.aspx.

[28] B. M. Kyaw, N. Saxena, P. Posadzki, J. Vseteckova, C. K. Nikolaou, P. P. George, U. Divakar, I. Masiello, A. A. Kononowicz, N. Zary, L. Tudor Car, Virtual reality for health professions education: Systematic review and meta-analysis by the digital health education collaboration, J Med Internet Res 21 (2019) e12959. doi:10.2196/12959.

[29] L. Nadolny, J. Woolfrey, M. Pierlott, S. Kahn, SciEthics Interactive: science and ethics learning in a virtual environment, Educational Technology Research and Development 61 (2013) 979–999. doi:10.1007/s11423-013-9319-0.

[30] G. Papagiannakis, S. Schertenleib, B. O'Kennedy, M. Arevalo-Poizat, N. Magnenat-Thalmann, A. Stoddart, D. Thalmann, Mixing virtual and real scenes in the site of ancient pompeii: Research articles, Comput. Animat. Virtual Worlds 16 (2005) 11–24. doi:10.5555/1071144.1071146.

[31] J. R. Stowers, M. Hofbauer, R. Bastien, J. Griessner, P. Higgins, S. Farooqui, R. M. Fischer, K. Nowikovsky, W. Haubensak, I. D. Couzin, K. Tessmar-Raible, A. D. Straw, Virtual reality for freely moving animals, Nature Methods 14 (2017) 995–1002. doi:10.1038/nmeth.4399.

[32] M. Cavazza, J.-L. Lugrin, D. Pizzi, F. Charles, Madame Bovary on the holodeck: Immersive interactive storytelling, in: Proceedings of the 15th ACM International Conference on Multimedia, MM '07, Association for Computing Machinery, New York, NY, USA, 2007, p. 651–660. doi:10.1145/1291233.1291387.

[33] Y. Cai, N. K. H. Chia, D. Thalmann, N. K. N. Kee, J. Zheng, N. M. Thalmann, Design and development of a virtual dolphinarium for children with autism, IEEE Transactions on Neural Systems and Rehabilitation Engineering 21 (2013) 208–217. doi:10.1109/TNSRE.2013.2240700.

[34] J. Jetter, J. Eimecke, A. Rese, Augmented reality tools for industrial applications: What are

potential key performance indicators and who benefits?, Computers in Human Behavior 87 (2018) 18–33. doi:10.1016/j.chb.2018.04.054.
[35] A. Grabowski, J. Jankowski, Virtual reality-based pilot training for underground coal miners, Safety Science 72 (2015) 310–314. doi:10.1016/j.ssci.2014.09.017.
[36] P. Wang, P. Wu, J. Wang, H.-L. Chi, X. Wang, A critical review of the use of virtual reality in construction engineering education and training, International journal of environmental research and public health 15 (2018) 1204. doi:10.3390/ijerph15061204.
[37] H. Yarovenko, Y. Bilan, S. Lyeonov, G. Mentel, Methodology for assessing the risk associated with information and knowledge loss management, Journal of Business Economics and Management 22 (2021) 369–387. URL: https://journals.vgtu.lt/index.php/JBEM/article/view/13925. doi:10.3846/jbem.2021.13925.
[38] A. Vorontsova, H. Shvindina, T. Mayboroda, H. Mishenina, I. Heiets, The impact of state regulation in a sphere of education on sustainable development of national economy, Problems and Perspectives in Management 18 (2020) 275–288. doi:10.21511/ppm.18(4).2020.23.
[39] O. Pavlenko, V. Martynets, O. Dreval, D. Smolennikov, Analysis of influence of the quality of specialist training on social and economic development, Quality - Access to Success 21 (2020) 81–86. URL: https://www.proquest.com/openview/6ded460da5ea00ad063935143eb555a9/1?pq-origsite=gscholar&cbl=1046413.
[40] K. Onopriienko, V. Onopriienko, Y. Petrushenko, I. Onopriienko, Environmental education for youth and adults: a bibliometric analysis of research, E3S Web of Conferences 234 (2021) 00002. doi:10.1051/e3sconf/202123400002.
[41] S. Lyeonov, O. Liuta, Actual problems of finance teaching in ukraine in the post-crisis period, in: The Financial Crisis, Springer International Publishing, 2016, pp. 145–152. doi:10.1007/978-3-319-20588-5_8.
[42] A. Artyukhov, I. Volk, T. Vasylieva, S. Lyeonov, The role of the university in achieving SDGs 4 and 7: a Ukrainian case, E3S Web of Conferences 250 (2021) 04006. doi:10.1051/e3sconf/202125004006.
[43] Immersive Education (iED) Summits, 2022. URL: https://immersiveeducation.org/events.
[44] Immersive learning research network (ilrn), 2021. URL: https://immersivelrn.org/ilrn2021.
[45] Women in immersive technologies, 2021. URL: https://www.wiiteurope.org/.
[46] VR Classroom - Lenovo K-12 Education, 2022. URL: https://www.lenovo.com/gb/en/vr-classroom.
[47] A. Bonasio, Immersive Experiences in Education: New Places and Spaces for Learning, White paper, Microsoft, 2019. URL: https://edudownloads.azureedge.net/msdownloads/MicrosoftEducation_Immersive_Experiences_Education_2019.pdf.
[48] J. Peckham, J. Osborne, Hands on: Microsoft HoloLens 2 mixed reality headset review, 2019. URL: https://www.techradar.com/reviews/microsoft-hololens-2.
[49] F. Catalano, From AR to VR: After games, what's the next big market for "extended reality?", 2018. URL: https://www.geekwire.com/2018/ar-vr-games-whats-next-big-market-extended-reality/.
[50] The Oklahoma Virtual Academic Laboratory (OVAL), 2018. URL: https://github.com/MorganWalkup/OVAL-Application.
[51] Case Study: VR Education at North Carolina State University, 2018. URL: https://www.

viar360.com/case-study-nc-state-university-biodiversity-class-in-vr.
[52] G. Johnson, Teaching in virtual reality transforms learning experience, 2021. URL: https://penntoday.upenn.edu/news/teaching-virtual-reality-transforms-learning-experience.
[53] M. Holly, J. Pirker, S. Resch, S. Brettschuh, C. Gütl, Designing vr experiences – expectations for teaching and learning in vr, Educational Technology & Society 24 (2021) 107–119. URL: https://www.jstor.org/stable/27004935.
[54] A. Iatsyshyn, V. Kovach, V. Lyubchak, Y. Zuban, A. Piven, O. Sokolyuk, A. Iatsyshyn, O. Popov, V. Artemchuk, M. Shyshkina, Application of augmented reality technologies for education projects preparation, CEUR Workshop Proceedings 2643 (2020) 134–160. URL: http://ceur-ws.org/Vol-2643/paper07.pdf.
[55] V. Ivanov, I. Pavlenko, J. Trojanowska, Y. Zuban, D. Samokhvalov, P. Bun, Using the augmented reality for training engineering students, in: A. G. Bruzzone, E. Ginters, E. G. Mendívil, J. M. Gutierrez, F. Longo (Eds.), Proceedings of the International Conference of the Virtual and Augmented Reality in Education, 2018, VARE 2018, Budapest, Hungary, 17-19.09.2018, 2018, pp. 57–64. URL: http://www.msc-les.org/proceedings/vare/2018/VARE2018.pdf.

Enhancing digital and professional competences via implementation of virtual laboratories for future physical therapists and rehabilitologist

Halina I. Falfushynska[1], Bogdan B. Buyak[1], Grygoriy M. Torbin[2], Grygorii V. Tereshchuk[1], Mykhailo M. Kasianchuk[3] and Mikołaj Karpiński[4]

[1]*Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 M. Kryvonosa Str., Ternopil, 46027, Ukraine*

[2]*National Pedagogical Drahomanov University, 9 Pyrohova Str., Kyiv, 01601, Ukraine*

[3]*West Ukrainian National University, 11 Lvivska Str., Ternopil, 46003, Ukraine*

[4]*University of Bielsko-Biala, 2 Willowa Str., Bielsko-Biala, 43309, Poland*

Abstract

Being popular world-wide, virtual laboratories enter into different fields of education and research and practitioners have to be responsible for choosing the most suitable and then adapt them to particular field. The aim of the present work was to assess the effectivity of the implementation of Praxilab, Labster, and LabXchange virtual laboratories as the powerful digital tool into teaching protocols of "Clinical and laboratory diagnostics" discipline for physical therapists and rehabilitologist. We have carried out the online survey for 45 students enrolled in physical rehabilitation degree program. About 70% surveyed students reported that implementation of virtual laboratories in "Clinical and laboratory diagnostics" discipline met individual learning needs of students, helped acquired digital skills (25%), and supported them to stay ahead of the curve. The virtual lab applications, not only assisted harness students fair against lack of practical skills, but also brought about a new dimension to the classes and helped overcome digital alienation and gain their digital skills and abilities. Indeed, a virtual lab can't completely replace the experimental work and teacher's explanation, but it might support teaching activities of a modern mentor and learning activities of a modern student. Almost all of surveyed students (82%) expected that in near future the virtual laboratories would take the dominant place in the education market due to possibility of students' pre-train the key points of practical activities before real experiments in lab and better understand their theoretical backgrounds. Thus, this study is intended to contribute to utilization of virtual labs by students enrolled in study physical therapy/physical rehabilitation with expected efficiency.

Keywords

virtual laboratory, physical therapy/physical rehabilitation major, digital skills, blended education

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1. Introduction

The COVID-19 pandemic has accelerated the digitization of university education [1]. Indeed, the education system is facing a paradigm shift, which creates and even invents new possibilities into learning environment, stimulates new educational projects led by digital technologies. The acquirement digital skills is the name of the game for many universities due to numerous benefits they can bring in teaching, learning and research. The importance of technological innovations and their relevance in the context of blended education today is indisputable [1, 2, 3]. In the last few years, digital technologies have entered all levels of education, and changes in the profiles of teachers and students have become apparent. However, these technologies make it possible to create an effective creative learning environment in the teaching process, which might lead to important changes in the roles of both students and teachers, promote individualized learning and improve student motivation [4].

Experimental work is one of the most important sources of knowledge. In combination with modern equipment, technical devices, and appropriate tools for the educational process, it contributes to a deeper uptake knowledge, skills and abilities. Regular use of experimental work while teaching and studying natural and life sciences on classes helps to acquire skills and understand mechanisms and phenomena, explains their backgrounds in the context of theories, forms and improves experimental skills and abilities which are very useful in future professional activities, and finally fosters the utmost accuracy to work. The experiment definitely helps to understand the biological and biomedical peculiarities of internal processes, since this is the most important way of realizing the connection between theory and practice by converting knowledge into beliefs.

Practical classes belong to the particular features of degree programs in natural and life sciences at universities. However, these activities need numerous modern equipment and special technical devices to be used. Unfortunately, Ukrainian universities face number of problems with technological purchasing and modernisation of techniques, because lack of money. Even if the laboratory room is fully equipped with the required instruments and materials, real experience requires much more time both for preparation and implementation, and for analysis of the results of work. Virtual laboratory and virtual experiments might be good alternative to the real experimental work [5]. They allow teachers and students to be

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falfushynska@tnpu.edu.ua (H. I. Falfushynska); Buyak.Bogdan@tnpu.edu.ua (B. B. Buyak); torbin7@googlemail.com (G. M. Torbin); g.tereschuk@tnpu.edu.ua (G. V. Tereshchuk); kasyanchuk@ukr.net (M. M. Kasianchuk); mkarpinski@ath.bielsko.pl (M. Karpiński)
https://tnpu.edu.ua/en/about/upravlinnia/prorektor.php (H. I. Falfushynska);
https://tnpu.edu.ua/en/about/upravlinnia/rector.php (B. B. Buyak);
https://npu.edu.ua/en/home/university-administration (G. M. Torbin);
https://tnpu.edu.ua/en/about/upravlinnia/pershij.php (G. V. Tereshchuk);
https://ieeexplore.ieee.org/author/37085696319 (M. M. Kasianchuk);
http://www.kinf.ath.bielsko.pl/pl/mikolaj-karpinski (M. Karpiński)
0000-0003-3058-4919 (H. I. Falfushynska); 0000-0003-1496-7573 (B. B. Buyak); 0000-0003-3088-1614 (G. M. Torbin); 0000-0003-1717-961X (G. V. Tereshchuk); 00000-0002-4469-8055 (M. M. Kasianchuk); 0000-0002-8846-332X (M. Karpiński)
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flexible, pre-train practical skills before real life situations. Also, many students can learn the theory online, but there are some significant limitations when trying to acquire skills online or through traditional methods. Indeed, virtual laboratories can be effective in helping students acquire skills in analytical and diagnostic thinking, develop strong persuasive skills, and make decisions under conditions of uncertainty [6].

Implementation of blended education with components of informal education into physical therapists and rehabilitologist degree programs could be of great benefit. E-learning and distance education allow rehabilitologist and physical therapists to brush up their knowledge, become more familiar with novel protocols, tools and equipment widely used for rehabilitation in EU and in the USA based on the principal of remote learning. The aim of the present work was to assess the effectivity of the implementation of Praxilab, Labster, and LabXchange virtual laboratories as the powerful digital tool into teaching protocols of "Clinical and laboratory diagnostics" discipline for physical therapists and rehabilitologist.

2. Methodology

Pedagogical experiment and online adapted surveys in terms of google form were carried out at Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU). The statistical representative sample included Bachelor degree students had enrolled in "Clinical and laboratory diagnostics" supplemented with virtual laboratories. The sample size was determined as 45. A majority (70%/30%) of surveyed students were women and represented young generation. The online course was available on the Moodle platform. Also, Praxilab (https://praxilabs.com/) and Labster (https://www.labster.com/), LabXchange (https://www.labxchange.org) were used to support and enrich proposed disciplines.

Students were welcomed to fill in the questionnaire that had prepared using Google Form in the mid and at the end of learning a subject. It was accessible via link in personal e-mail account and in the students Viber groups and Telegram channels for two weeks. The questionnaire contained several questions namely experience with ICT tools, virtual labs, and educational platforms, learning outcomes (knowledge, skills, satisfaction, perception, attitude, usability), perceptions of courses (content, deep sense of meaning, structure, clarity etc), assessment of perceptions and effectivity of virtual laboratories. In particular, we have asked students about "How helpful in practical and theoretical dimension was the implementation of VR apps in conducted disciplines provided to you?", "Successful integration of VR apps into on-line and face-to-face teaching", "Meeting individual learning needs", "Building skills and knowledge" etc.

Data were tested for the normality and homogeneity of variances using Kolmogorov-Smirnov and Levine test, respectively. For the data deviating from normality or homogeneity of variances, Box-Cox or log10 transformation was used. If the transformations did not result in normal distribution, non-parametric tests were used. All statistical calculations were performed with Statistica 12.0 and Excel 2019 for Windows. Differences were considered significant if the probability of Type I error was less than 0.05.

3. Results

Implementation of IT tools opens great opportunities for the formation of professional competences. Interactive IT tools make it possible not only to increase visibility, support students with information in user-friendly easy-to-understand form, maintain a mentoring function, but also solve didactic tasks that become relevant in the formation of competencies and in connection with the reduction of teaching hours for study of discipline, organization of self-study, concomitant repetition, control, revision, and evaluation of students.

We divided students into two groups namely control and experimental one. Control students studied course materials in classical methodological way when didactic materials and class activities in the experimental one involved virtual laboratories and short videos.

Our students are familiar with virtual educational tools that physical therapists and clinical laboratory technicians can use in their professional activities. They are welcomed to use virtual lab tools before practical classes to simplify understanding of the materials, and then interaction with teacher in class or via Zoom in case of distance or blended education. The most popular virtual lab are Praxilab, Labster, and LabXchange (figure 1). They are free, allow students and teachers to absorb in simple way new practical knowledge, deeper involve into educational process and offer an easy way for mentor to control track of students.

The virtual laboratories that we have used on the "Clinical and laboratory diagnostic" classes follow some principals, among them:

1. The principle of interactivity, which based on organizing of interaction between a user, a virtual laboratory, and a computer that acts as an intellectual assistant. The virtual laboratory should lead the student during a process of problem solving, allowing or prohibiting certain types of actions. The teacher should receive all necessary information to estimate the level of formation of professional competences in a very student and all his/her classmates.
2. The principle of modelling is in the need to actively implement computer apps in solving practical problems. The analysis of a problem should begin with the construction of a biomedical model and then a descriptive model of the problem should be built. Finding an appropriate solution of a problem is working with the initial data of the models. At each stage of modelling (formulating initial data, a solution, an answer), the virtual laboratory must analyze the student's actions, score them and propose appropriate recommendations.
3. The principle of providing a logical conclusion based on special algorithm of a virtual laboratory that should receive new information based on the available initial data.
4. The principle of compliance of the components of professional competences with the capabilities of a virtual laboratory. A virtual laboratory should be focused on the formation of all components of subject competence.

The main indicator of the effectiveness of the implemented methodology was an increase in the number of students who completed the interim and final test, showed high-quality skills of experimental work including pipetting, carried out step-by-step protocols for general blood test, analysed materials and maid valuable conclusions. We have observed that in the experimental group the number of students with high scores significantly exceeded the number of students in the control group.

Figure 1: Interface of virtual laboratory: A – Labster, B – LabXchange, C – Praxilab

We carried out the survey among the physical therapy degree program students to evaluate 1) the effectiveness of blended education and implementation of virtual laboratory into "Clinical and laboratory diagnostics" and 2) the level of students' satisfaction in terms of gaining knowledge, improving practical skills and theoretical backgrounds but not limited too. A total of 45 students of Bachelor degree took part in this survey. Due to survey results all of these virtual laboratories helped harness students fair against lack of practical skills while blended education. As an example, when we compare the responses of surveyed students, 25% of them emphasized that "Clinical and laboratory diagnostics" discipline enriched with modern ICT tools (e.g. virtual laboratory apps) had enhanced their digital performance (figure 2). They also emphasized that using of virtual labs on classes can help overcome digital alienation and gain their skills and abilities in the field of ICT.

We also observed that the most of surveyed students had positive perception towards using virtual laboratories and they were basically satisfied with theoretical backgrounds and practical

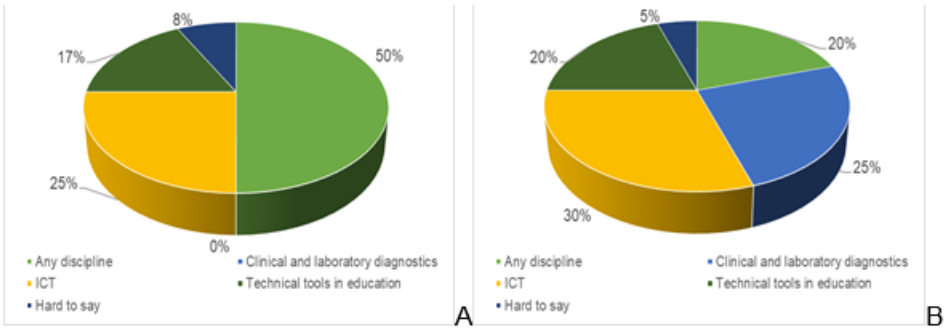

Figure 2: The rate of effectiveness of disciplines regarding acquirement digital skills in students of "Physical rehabilitation" major. A – control group, B – experimental group which was used virtual laboratories while studying "Clinical and laboratory diagnostic".

skills which they were imbibing while face-to-face and blended education (figure 3). They also emphasized the merits of presentations, short videos and materials that had been downloaded and permanently appeared in the Moodle platform. Almost all of them (82%) expected that in near future the virtual laboratories would take the dominant place in the education market due to possibility of students' pre-train the key points of practical activities before real experiments in lab and better understand their theoretical backgrounds. Indeed, university managers also may well find benefits in virtual laboratory using not only in "Clinical and laboratory diagnostics", but also in other Natural and Life Science disciplines, because save money for reagents and suppliers as well as for modern expensive equipment. Due to insufficient funding, many laboratories in Ukraine equipped with old machines that can affect the results of experiments and pose a potential risk to students.

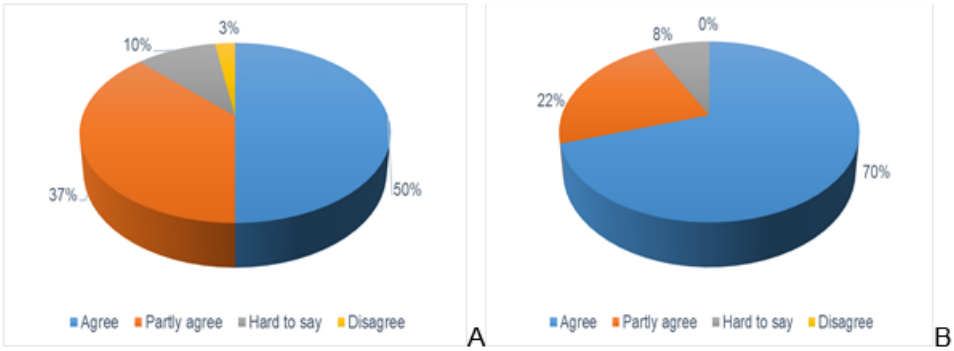

Figure 3: The rate of effectiveness of degree program regarding acquirement digital skills in students of "Physical rehabilitation" major. A – control group, B – experimental group which was used virtual laboratories while studying "Clinical and laboratory diagnostic".

Our students are very welcomed to enroll in some online courses stands for massive open online course platforms, e.g. Coursera. Massive open online course aims to provide real time education online with the help of various educational tools like short videos, lectures, concept notes, quizzes and online exams and also tries to make it more efficient and flexible than face-

to-face education. Massive open online courses also provide interactive discussion sessions for the user which are likely to be very helpful regarding analytics, data analysis and valuable conclusions based on synthesis of initial data. Student who was enrolled for one course pretends to be the candidate for credit transfer within one class or even module. Due to our observation that makes students more open-minded and creative and totally corresponds to study outcomes and this option has to be included as one of the key elements of rigorous blended education environment (figure 4).

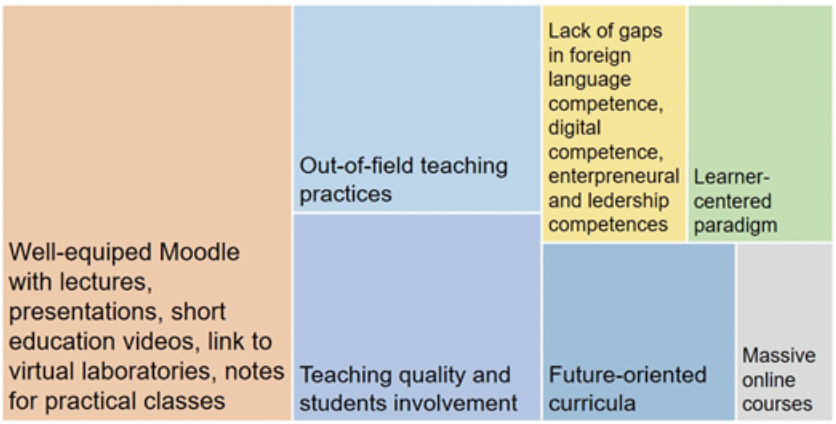

Figure 4: The key elements of rigorous blended education environment.

4. Discussion

Due to our knowledge not too much is known about implementation of digital tools while face-to-face and blended education of future physical therapists [7, 8]. This study called on bringing some knew knowledge and practical experience in digitalisation of physical therapist and rehabilitologist classes via virtual lab implementation.

The rapid changes in Industry 4.0 demand change in education and teachers are expected to bring technology-based innovations to achieve success in learning [6]. Nevertheless Ukrainian universities own equipment, some of them are pretty old, because as low income country our Universities obtain not too much money for renovation as well as for suppliers. Using virtual laboratories in combination with real lab experiments belongs to the possible solution. It has been recently shown that virtual laboratories which based on 4D model (Define, Design, Develop, and Disseminate) can help students learn an object that cannot be presented in the classroom and they supported learning and transfer of knowledge in practical learning, especially during the COVID-19 pandemic [6]. Also, it was proved that students who were exposed to virtual lab in terms of pre-laboratory interventions showed lower level of anxiety and higher level of "experimental self-efficacy" [9]. This finding broadly supports the work of other studies in this area pursuing the idea that students being highly scored while using virtual lab on classes and have positive perception towards virtual lab implementation as pre-training option.

Not only in the field of Physical rehabilitation and Physical therapy, but also in areas of

biochemistry, chemistry, molecular biology via virtual lab implementation we are allowed to simulate and display processes, which flow is fundamentally impossible in laboratory conditions. Modern computer technologies make it possible to observe processes that are difficult to distinguish in real conditions without the use of additional equipment, for example, due to the small size of the observed particles. Also virtual lab implementation into experimental-oriented disciplines might help students to penetrate into the intricacies of processes and observe what is happening in precise time point, which is important for processes that take place in a second or on the contrary, last for several years. The next important benefit of virtual lab is the safety in cases where tools and/or material being compulsory for tasks realization should pose risk for human being, for example, high voltages or chemicals.

Being controlled by a computer, it becomes possible to quickly conduct a series of experiments should realize in a minute in virtual room with different values and input parameters. In that way we can simply find out correlations between output parameters and input ones. Finally, a separate and important advantage lies in the possibility of using a virtual laboratory in distance learning, when, there is no possibility of working in the laboratories at universities, as an example lock- or even shut-down in time of COVID-19 pandemic.

Blended or even online learning has not been very popular in physical rehabilitation and health care education. Nevertheless, some existed references support their effectiveness and emphasized that blended learning delivered in health care education is at least as effective, and could at times be more effective, than traditional face-to-face instruction [10, 11]. At the course level, many studies pointed that online learning of specialists in health care has equal or even better learning outcomes and supports higher student satisfaction [11]. However, successful implementation of online learning into the curricula of physical therapist and health care majors requires a deep-discussed and analysed strategy [12] which could be enriched with practical virtual cases and modern ICT tools (virtual laboratories and simulation apps as the examples).

5. Conclusions

All in all, the application of the virtual educational laboratories for studying natural sciences disciplines significantly improves the effectivity of the learning process, makes it more meaningful, profound, promotes the development of digital skills and abilities in students and staff, improves the quality of education, and simplifies distance education and/or blended education is becoming very popular while COVID-19 pandemic. Indeed, a simulator can't completely replace the experimental work and teacher's explanation, but virtual laboratories might support teaching activities of a modern mentor, learning activities of a modern student, improve professionalism, open new horizons and, most importantly, allow to strengthen the motivational component of learning through an active dialogue between the student and the computer, by orienting the student towards success and mastering the basic knowledge of natural sciences, including clinical and laboratory diagnostics.

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References

[1] H. I. Falfushynska, B. B. Buyak, H. V. Tereshchuk, G. M. Torbin, M. M. Kasianchuk, Strengthening of e-learning at the leading Ukrainian pedagogical universities in the time of COVID-19 pandemic, CEUR Workshop Proceedings 2879 (2020) 261–273. URL: http://ceur-ws.org/Vol-2879/paper13.pdf.

[2] F. A. Monroy García, F. Llamas-Salguero, M. R. Fernández-Sánchez, J. L. Carrión del Campo, Digital technologies at the pre-university and university levels, Sustainability 12 (2020). doi:10.3390/su122410426.

[3] S. L. Kucher, R. M. Horbatiuk, O. Y. Serdiuk, M. M. Ozhha, N. M. Hryniaieva, M. M. Fridman, Use of information and communication technologies in the organization of blended learning of future vocational education professionals, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[4] N. Tomaževič, D. Ravšelj, A. Aristovnik (Eds.), Higher Education Policies for Developing Digital Skills to Respond to the Covid-19 Crisis: European and Global Perspectives, European Liberal Forum, Brussels, 2021. URL: https://tinyurl.com/yckk2pfk.

[5] P. P. Nechypurenko, S. O. Semerikov, VlabEmbed - the new plugin Moodle for the chemistry education, CEUR Workshop Proceedings 1844 (2017) 319–326. URL: http://ceur-ws.org/Vol-1844/10000319.pdf.

[6] M. Bima, H. Saputro, A. Efendy, Virtual laboratory to support a practical learning of micro power generation in indonesian vocational high schools, Open Engineering 11 (2021) 508–518. doi:10.1515/eng-2021-0048.

[7] J. Frenk, L. Chen, Z. A. Bhutta, J. Cohen, N. Crisp, T. Evans, H. Fineberg, P. Garcia, Y. Ke, P. Kelley, B. Kistnasamy, A. Meleis, D. Naylor, A. Pablos-Mendez, S. Reddy, S. Scrimshaw, J. Sepulveda, D. Serwadda, H. Zurayk, Health professionals for a new century: Transforming education to strengthen health systems in an interdependent world, The Lancet 376 (2010) 1923–1958. doi:10.1016/S0140-6736(10)61854-5.

[8] E. M. Thomas, M. F. Rybski, T. L. Apke, D. A. Kegelmeyer, A. D. Kloos, An acute interprofessional simulation experience for occupational and physical therapy students: Key findings from a survey study, Journal of Interprofessional Care 31 (2017) 317–324. doi:10.1080/13561820.2017.1280006.

[9] V. K. Kolil, S. Muthupalani, K. Achuthan, Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy, International Journal of Educational Technology in Higher Education 17 (2020) 30. doi:10.1186/s41239-020-00204-3.

[10] M. Bączek, M. Zagańczyk-Bączek, M. Szpringer, A. Jaroszyński, B. Wożakowska-Kapłon, Students' perception of online learning during the COVID-19 pandemic: A survey study of Polish medical students, Medicine 100 (2021) e24821. doi:10.1097/MD.0000000000024821.
[11] S. Abbasi, T. Ayoob, A. Malik, S. I. Memon, Perceptions of students regarding E-learning during Covid-19 at a private medical college: Perceptions of students regarding E-learning, Pakistan Journal of Medical Sciences 36 (2020). URL: https://www.pjms.org.pk/index.php/pjms/article/view/2766. doi:10.12669/pjms.36.COVID19-S4.2766.
[12] A. K. Mącznik, D. C. Ribeiro, G. D. Baxter, Online technology use in physiotherapy teaching and learning: a systematic review of effectiveness and users' perceptions, BMC Medical Education 15 (2015) 160. doi:10.1186/s12909-015-0429-8.

Formation of professional competency in life saving appliances operation of future seafarers by means of online and simulation VR technologies

Serhii A. Voloshynov[1], Halyna V. Popova[1], Olena S. Dyagileva[1], Nataliya N. Bobrysheva[1] and Olha V. Fedorova[1]

[1]*Kherson State Maritime Academy, 20 Ushakova Ave., Kherson, 73000, Ukraine*

Abstract

Nowadays simulation training technology is a priority method of maritime specialists' practical training in the world. The main purpose of using VR simulators within an educational process is to simulate work on real equipment in order to form professional competencies of seafarers. The article describes system of blended learning on the basis of Kherson State Maritime Academy, that includes alternation of traditional and online learning, virtual training by means of the VR technology, training on simulators. In accordance with the principles of blended learning in Academy, there was developed an author's course "Rescue boats and life rafts specialist", which aims at providing theoretical and practical training of seafarers on launching and handling the lifeboats and liferafts and, as a result, ensures seafarers' formation of professional competency "life-saving appliances operation". The article also reveals the results of an experiment with implementation of VR technologies in forming the professional competency "life-saving appliances operation". The deviation of the results in control and experimental groups was 9,8%. The effectiveness of our research was manifested in the fact that students have gained experience of practical skills before coming to the vessel and showed higher level of educational achievements in professional competency "life-saving appliances operation".

Keywords

virtual reality, professional competences, maritime specialists, LMS Moodle simulation technologies, life saving appliances, Maritime English

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1. Introduction

1.1. Research relevance

Global trends in the use of digital technologies, innovative approaches to learning are leading to dynamic changes in the global educational space of higher education. The formation of an innovative space with increased change in production technologies and the introduction of

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s_voloshinov@ukr.net (S. A. Voloshynov); spagalina@gmail.com (H. V. Popova); diahyleva.olena@ksma.ks.ua (O. S. Dyagileva); natalyluchka1502@gmail.com (N. N. Bobrysheva); fedorova.olena2406@gmail.com (O. V. Fedorova)

http://new.ksma.ks.ua/?p=3339 (S. A. Voloshynov); http://new.ksma.ks.ua/?p=3361 (H. V. Popova); https://ksma.ks.ua/?p=3650 (O. S. Dyagileva); https://ksma.ks.ua/?p=3596 (N. N. Bobrysheva)

0000-0001-7436-514X (S. A. Voloshynov); 0000-0002-6402-6475 (H. V. Popova); 0000-0003-3741-4066 (O. S. Dyagileva); 0000-0002-4449-954X (N. N. Bobrysheva); 0000-0002-7594-6066 (O. V. Fedorova)

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complex management systems on a digital basis require continuous education of specialists and the transformation of higher education models.

The formation of a seafarer's professional competencies has always been associated with many years of professional experience. Professional education of maritime specialists emphasizes the practical orientation of the educational process, which takes place in real practice directly on ship. The International Maritime Organization (hereinafter – IMO) has identified the need to use simulators to develop professional competencies. This requirement is enshrined in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (hereinafter – STCW) [1] and is mandatory for obtaining the established standard of competence. Such a strict approach to the organization of the seafarers' educational process is due to the peculiarities of higher maritime education and high social need in qualitative training, their responsibility for life and material equipment. Assessment of competency level is determined by a professional standard, which defines all the functions, actions and assessment of the competencies' acquisition.

Full implementation of blended learning during the COVID-19 pandemic revealed a set of educational risks, such as reduced attention and interest in the content of educational cases and presentations, loss of understanding the dynamics of processes, awareness of problems and risks of professional activity [2, 3]. Bondarenko et al. [4], Bukreiev et al. [5], Bykova et al. [6], Cherniavskyi et al. [7], Holiver et al. [8], Kartashova et al. [9], Kim et al. [10], Kravtsova et al. [11], Krylova-Grek and Shyshkina [12], Kucher et al. [13], Osadcha et al. [14], Ponomarova et al. [15], Radianti et al. [16], Sun [17], Vlasenko et al. [18], Voloshynov et al. [19] have focused their research on finding effective learning technologies and analysis of their impact on professional development in a blended learning. It was found out that the most effective ones are the technologies of figurative imagination for the development of professional competencies in blended learning.

1.2. Related work

The use of VR simulators began relatively recently, but has already accumulated significant material for research. Thus, an analysis of the literature on recent experimental data suggests that virtual reality can ensure students' motivation and engagement, and provide higher-quality learning [20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31].

The implementation of modern technologies into maritime education, including virtual reality simulators, helps to improve the effectiveness of professional competencies' formation, makes the learning process time-saving and safe, positively affects the consolidation and implementation of the accumulated theoretical material, makes the educational process motivated [20].

In the context of limited opportunities due to COVID-19, the possibilities of digital and distance learning, the functionality of VR simulators can present a new Maritime Education and Training (hereinafter – MET) paradigm in the discourse of the learning concept anytime and anywhere [10]. These processes will result in rethinking of the post-pandemic pedagogical approach, representing a mixture of full-time and distance learning [21].

The use of a virtual environment in connection with the novelty of its application requires to provide a comfortable atmosphere for working with the equipment, evaluate objectively the

advantages of the work and the prospects for its use.

The latest gains in virtual reality represent a new supplement to professional education and training. The main aim of VR simulation technologies is to simulate the work with real equipment in order to form professional competencies settled in STCW [32, 33].

Simulation training is treated as a mandatory component in professional training that uses a model of professional activity in order to provide an opportunity for each student to perform this professional activity or its element in accordance with professional standards [34].

VR technology is aimed at mastering the algorithm for the formation of practical professional competencies of specialists [32]. VR includes "a wide variety of computer-based applications commonly associated with immersive, highly visual, 3D characteristics that allow the participant to look about and navigate within a seemingly real or physical world" [35]. VR is characterized by enhanced visualization effect, which allows you to feel a higher degree of immersion with the possibility of interactive interplay [36].

In experimental practice, the resources of virtual reality simulators can effectively fill the lack of laboratories, allowing to train in new conditions that provide a student with new information [36, 37].

Students often interpret virtual reality not only as a tool to gain knowledge and skills, but also as a means of fostering positive learning experiences with evidence of improved learning outcomes at higher levels of immersion [38].

VR is a technology that can interest and motivate a user, and can also help in cognitive processing and transfer of knowledge [39, 21]. At the simulation stage, the competences, necessary for the implementation of quasi-professional activities, are improved [19].

The whole complex technological process is decomposed into sublevels and operations that must be performed. According to Mirzakhmedova [40], the technology of VR training is aimed at multilevel acquisition of practical skills, and as the levels are passed, acquired skills are layered on each other in a clear sequence of formation in a real professional environment.

VR-based simulators support two learning theories – experimental and constructivism [10, 20]. Fromm et al. [39] proved that the unique possibilities of VR contain all modes of experimental learning (specific experience, reflexive observation, abstract conceptualization and active experimentation).

Simulation practice has a successful history of integration into maritime education; investment in the development of simulators is constantly growing. Thus, simulators of equipment in the bridge and engine room are nowadays used to train seafarers [7, 19, 33].

Despite the fact that maritime industry has developed a regulatory framework for training and assessing the competencies of seafarers, formation and assessment of competencies is still changing with the course of technological progress. The nature of MET is changing in the context of influence of the latest generation technologies as teaching tools [10]. As a result the questions arise: "how will online technologies of distance learning and simulators be combined?" and "what will their effectiveness and weaknesses be?"[20].

The aim of the article is to substantiate the system of professional training of seafarers by means of online and simulation VR technologies.

2. Results

The educational process at Kherson State Maritime Academy (hereafter – KSMA) is based on the system of blended learning, which provides for the integration and complementarity of such types of educational activities as (figure 1):

1) alternation of traditional and online learning, where the latter is based on the synchronous (learning in real time with the involvement of a group of students through conference programs in LMS Moodle) and asynchronous (covers individual or group work, even if participants can not be online at the same time through means of media – e-mail, chats, social networks, forums, etc.) approaches;
2) virtual training by means of the VR simulator, the purpose of which is the practical development of competencies according to a certain algorithm in a virtual environment that maximally simulates the working conditions on the ship;
3) training on simulators – maritime equipment simulators that allow you to practice professional competencies;
4) training during practical training on the ship.

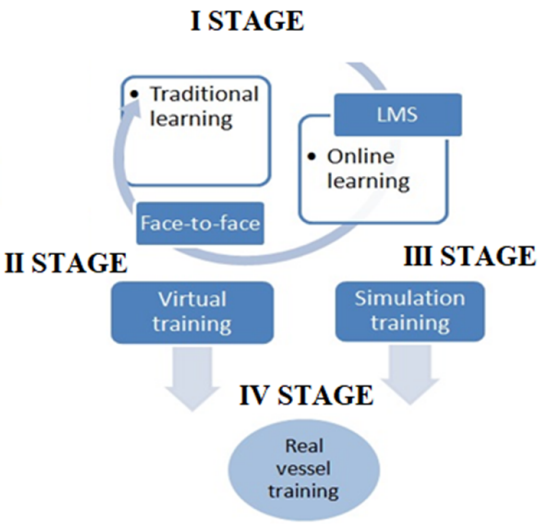

Figure 1: Scheme of educational process at KSMA.

At the first stage, in line with the theory of Staker and Horn [41] on models of blended learning, the alternation of traditional and online learning in KSMA follows due to the model of rotation, when students change the learning format from face-to-face to online and so on until a certain competency is formed. In the context of the COVID-19 pandemic, a flexible model can be used, where students study mainly online as part of e-learning modules, and the instructor provides online consultations as needed.

In the second and third stages, the learning activities correspond the mix model, when students supplement practical classes with courses on virtual reality and simulators according

to a certain schedule. The prospect of developing virtual learning is its transition to the last model of Staker and Horn [41] – an enriched virtual model, where learning takes place mostly online (in the laboratory or at home) with students using VR glasses, but with the possibility of consulting an instructor if necessary.

The fourth stage of training at KSMA involves real vessel practice, which allows the practical application of acquired professional competencies in the real working conditions of future maritime specialists.

In accordance with the principles of the system of blended learning in KSMA, a series of author's courses was developed. These courses include all four stages of educational and methodological activities. One of them is the author's course "Rescue boats and life rafts specialist", which aims at providing theoretical and practical training of students on the launching and handling the lifeboats and rafts (except speedboats) during emergency accidents in accordance with the STCW Requirements VI/2, Section A-VI/2, paragraph 5 and Tables A-VI/2-1, A-III/1 (table 1) and IMO Model Course 1.23.

Table 1
STCW requirements A III/1.

Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Operate life saving appliance	Ability to organise abandon ship drills and knowledge of the operation of survival craft and rescue boats, their launching appliances and arrangements, and their equipment, including radio lifesaving appliances, satellite EPIRBs, SARTs, immersion suits and thermal protective aids.	Assessment of evidence obtained from approved training and experience as set out in section A-VI/2, paragraphs 1 to 4	Actions in responding to abandon ship and survival situations are appropriate to the prevailing circumstances and conditions and comply with accepted safety practices and standards.

In accordance with the statements of the IMO Model Course 1.23, the main purpose of the author's course "Rescue boats and life rafts specialist" is the formation of professional competency "proficiency in life-saving appliances" in accordance with the minimum standard of competency in lifeboats and rafts "Proficiency in Survival Crafts and Rescue Boats" (IMO Model Course 1.23). The future maritime specialist will gain skills in operating life-saving appliances, operating a life raft or lifeboat during and after launching. In addition, students will have knowledge of the proper use of all devices indicating location, including communications, alarms and pyrotechnics, how to provide first aid to victims.

Before starting virtual training on the topic "Rescue boats and life rafts specialist", students must have a basic level of training by means of blended learning on the following topics: "Rescue procedure", "Abandon ship procedure", "Proper use of emergency equipment", "Types of lifeboats and rafts", "How to coordinate a rescue operation", "How to operate a closed lifeboat", "Lifeboat handling", "Usage of communication devices such as pyrotechnics and signaling

equipment", "Basic knowledge of first aid assistance", "Distribution of tasks and responsibilities while abandoning the ship".

Lectures, practical and laboratory classes are used to ensure blended learning at KSMA. According to Bloom's taxonomy [42], they form knowledge, understanding and application. The above mentioned topics are covered during educational process in such disciplines as "Navigation and sailing directions", "Ship handling", "Maritime English", "Electrical and radio navigation equipment", "Global maritime communications for search and rescue».

One of the important areas of work on the introduction of blended learning with elements of online learning in KSMA was the development of a digital educational environment that combines LMS Moodle (https://mdl.ksma.ks.ua/). This work allowed to create an information database of educational, methodical, scientific information on the main areas of activity. The use of modern digital technologies allows to transfer the learning process to a qualitatively new high level. At this level, the role of the student changes to an active participant in the educational process, which is directly involved in creating and managing its educational trajectory. The potential of blended education is provided by the completeness and accessibility of all academic disciplines, the relevance and possibility of interactive cooperation between a student and an instructor. That is why LMS Moodle was chosen to create e-learning modules.

E-learning modules are treated as units of online learning that cover knowledge and skills on some topics in their logical sequence. Thus, the content of a particular topic is presented in the form of a series of e-learning modules, after which the student is tested for the level of assimilation of the studied material. In addition to the text part, such modules usually use drawings, photographs, graphics, computer animations, interactive demonstrations, hyperlinks, a glossary, specialized databases, audio and video recordings of various formats.

If the e-modules provide a summative assessment as a result of the acquired competencies, the LMS ensures the assessment itself. However, the LMS is only a mechanism that needs to be filled with learning content. At the same time, e-modules make up this educational content in general. Thus, the integration of e-learning modules with LMS Moodle provides feedback between the teacher and the future maritime specialists makes the online learning process flexible and distance learning complete with the ability to assess objectively students' competencies in a COVID-19 pandemic.

E-learning modules are a supplement to the lesson, which aims not only to deepen the knowledge of maritime specialists on a particular topic, but also to increase interest in discussion outside the audience (video and audio materials on discussion topics, cases for group discussion of problematic situations, illustrations with tasks for development of critical thinking, game exercises to consolidate the material, role play of situations, collaborative projects). Teaching the same training course can be conducted by several instructors, each of whom forms his/her e-learning modules in LMS Moodle.

The author's training course "Rescue boats and life rafts specialist" has a corresponding e-learning module in LMS Moodle for 20 hours and 10 topics. Each topic includes text, audio and video materials in maritime English, accompanied by closed (controlled) and open (production) tasks with the involvement of professional terminology of the IMO Model Course 3.17. Among basic LMS Moodle tools used when creating a course there are such as "task", "test", "choice", "lesson", "forum", "URL (web link)", "chat", etc. (figure 2).

Upon the completion of each module, students undergo a current assessment in the form of

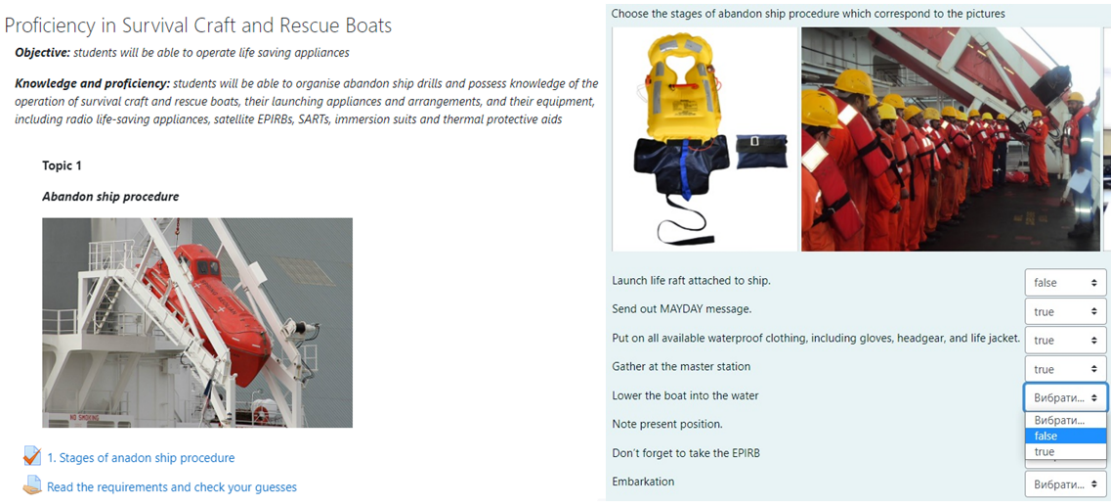

Figure 2: E-learning module in LMS Moodle.

tests and speaking exams, which allows them to advance to the next module. The exam on a specific topic is scheduled according to the Recosha meet conference program in LMS Moodle, which not only allows you to communicate online, but also records each exam, confirming its objectivity.

Upon completion of the "Rescue boats and life rafts specialist" e-course at LMS Moodle, students take a summative testing assessment of the level of knowledge gained, accompanied by a speaking competency in the format of an interview. This form of current control of knowledge simulates the conditions of passing the professional interview for future maritime specialists.

The testing tasks are constructed in such a way as to check the cluster of competencies (linguistic, functional, strategic and sociolinguistic) in their unity. If in most e-learning databases (Marlins, MarTEL, TOME, TOMEC) gradation of test tasks is carried out mainly in the categories of "listening", "grammar", "vocabulary", "reading", and sometimes "writing", then in KSMA techniques of tests and their content come from the specific context of language use, real-life communication situations on board (real-life scenarios). Separately selected grammar exercises are out of focus.

According to the results of quantitative analysis of testing techniques on the LMS Moodle platform, the most priority is taken by "multiple-choice tests" – short answers based on statements or texts, "yes / no tests" or "compliance tests" ("true / false tests") – short answers used in reading and listening, "rearrangement tests", "gap-filling tests" or "short answers" – are often used to test vocabulary and application filling skills. The above types of tests are always presented in combinations with illustrations, video and audio materials (listening – multiple-choice tests, reading – yes / no tests, watching – gap-filling), which are as close as possible to the real conditions of communication on board (figure 3).

After gaining a passing score, students are admitted to the next type of training – virtual. While completing practical tasks on the VR simulator due to the course "Rescue boats and life rafts specialist", future maritime specialists must demonstrate professional competencies using

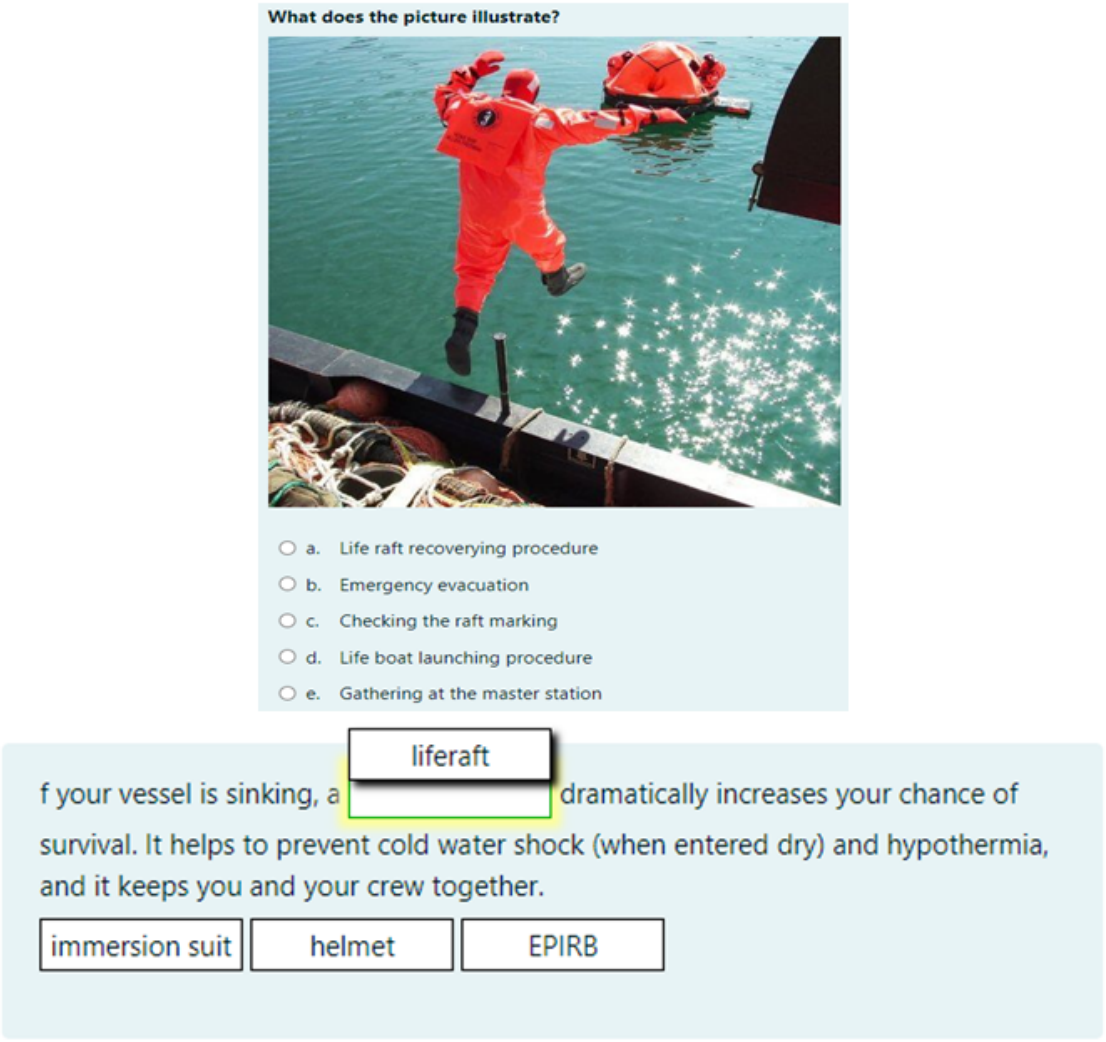

Figure 3: Testing tasks within e-learning module.

the maritime terminology of IMO Model Course 3.17: “ability to operate a boat according to a compass”, “skills of towing other boats and rafts with a lifeboat”, “approaching a lifeboat to the ship”, “use of devices to determine the location of the boat”, “use of lifeboat radio equipment”, “preparation and safe launching of lifeboats and rafts”, “abandoning the vessel within a free fall lifeboat”, “use of inflatable life raft”, “ability to operate a lifeboat on water”, “use of signaling equipment”

The content of the virtual module consists of 11 basic stages, the completion of which is necessary for successful demonstration of professional competency in launching the fully enclosed and free fall lifeboats in rough weather, following the procedures and scenarios of ship drills (figure 4).

Practical classes on the virtual simulator are held on a schedule in a specially equipped

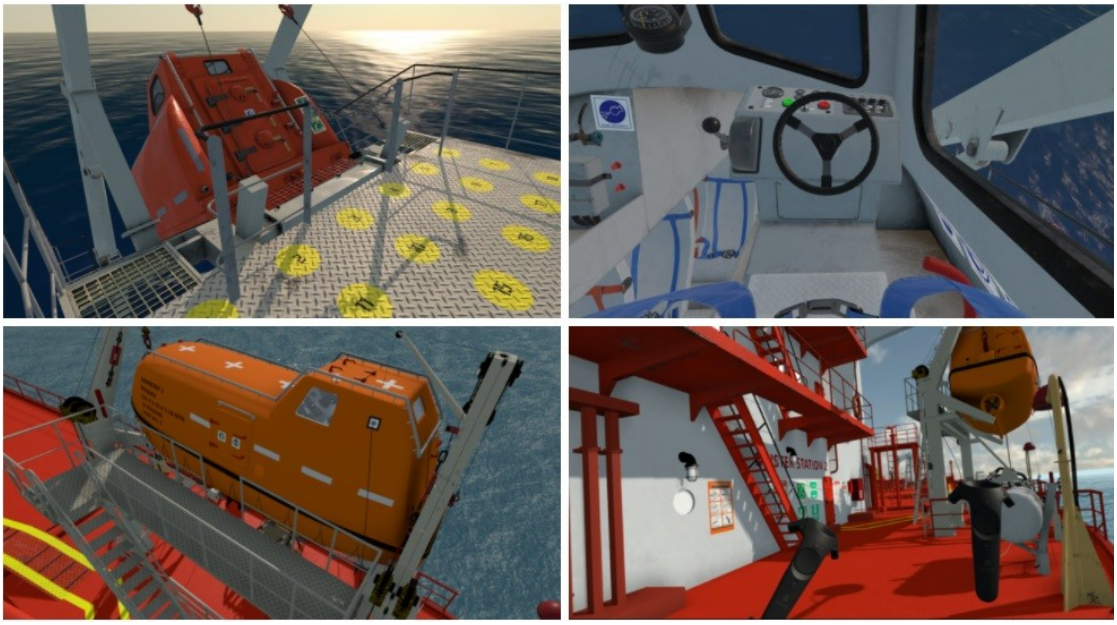

Figure 4: Virtual module “Lifeboat and Raft Specialist”.

virtual reality laboratory. A small group of students (no more than 10–16 participants) joins the classes. The lesson has a flexible structure and is built on individual, pair and group format of interaction. The language of the lesson is Maritime English with the involvement of professional terminology of the IMO Model Course 3.17.

In turn, students wear VR glasses and join the process of passing the necessary stages of virtual module [43] while one of the students goes through part of the stage (for example, “Abandoning the ship in free fall lifeboat”), performing the appropriate commands in English, the other students see his actions on a big screen and work in groups or pairs, discussing each step, commenting on compliance / inconsistency of actions in this situation.

One of the advantages of practical classes in such virtual environment is the endless number of attempts and the simulation of real conditions for passing ship’s drills.

Training on simulators at KSMA takes place in 13 training laboratories that meet the requirements of IMO and STCW Convention 78/95. Within the author’s course “Rescue boats and life rafts specialist” 3 training laboratories are involved: “Survival at sea and fire fighting training complex”, “Life saving appliances onboard a vessel” and “Global maritime distress and safety simulator”.

Thus, training laboratory “Survival at sea and fire fighting training complex” contains a water pool for practicing water rescue and helicopter rescue skills, a fully enclosed lifeboat (figure 5). All works on the installation of equipment for the training complex was performed by the Irish company SEFtec. This laboratory allows students to acquire practical skills in the course of training in personal survival at sea, first aid, personal safety and social responsibilities in accordance with national requirements and the requirements of the International Convention STCW 78 with amendments, requirements VI / I, requirements of IMO Model Courses 1.13, 1.19,

1.20, 1.21.

Figure 5: Training laboratory “Survival at sea and fire fighting training complex”.

3. Results

The research was held on the basis of the KSMA, a training complex and classrooms with virtual simulators. 211 students of the II course and the II course (abridged program) of the speciality “Navigation” and 14 teachers took part in the experiment. It was conducted special survey, questionnaire and testing.

The program of the research included: checking the level of professional competency formation “lifesaving appliances operation”; preparing the tool for diagnostics professional competence; creating methodical recommendations for the VR simulator on the basis of KSMA; statistical analysis and theoretical analysis of the research result.

To solve the highlighted tasks, we used the set of scientific methods:analysis of materials received on the basis of research, also: questionnaires, diagnostic tests; monitoring students’ work in the ordinary classrooms and in the classrooms with VR simulators, as well as taking into account the development of a motivation as for using virtual technologies; the questionnaire and testing was carried out to check the level of professional competency in lifesaving appliances operation.

The first stage of our research was to check if the students have proficiency in life-saving appliances. We made diagnostics of professional competence in lifesaving appliances operation.

Also on the first stage we wanted to understand if control and experimental groups are statistically equal. In the process of research, we used different tests to check each element of professional competence (understanding all commands in Maritime English, connecting the painter, pulling out the pin of the slip hook, releasing the davit arm stopper by operating the handle, pulling out the safety pin of the davit arm stopper, opening the lifeboat door, switching all lights, closing engine hatch, starting the engine, connecting the davit operating grip to remote control wire). To check understanding commands in Maritime English we used Maritime English Test, to check how students can connect the painter of survival craft we used check-list to verify the correct actions, etc.

The assessment of each check-list was conducted with a help of 100 points degree. In the control group there were 103 students and in the experimental group there were 108 students. The results of the diagnostics showed that the average number according to each element of the professional competence in lifesaving appliances.

So the results have shown the low level of students' educational achievements. To check the deviation of statistical difference between control and experimental group we used Pearson criteria ($\chi 2$). Using the data we get $\chi 2$ =5.99. In result, the deviation in control and experimental groups showed that these groups are statistically the same.

On the second stage of the experimental work was conducted with our course author's course "Rescue boats and life rafts specialist". The main aims of the second stage were to check effectiveness of the course and to make analysis of data in control and experimental groups.

This author's course was used in experimental group. It was providing theoretical and practical training of seafarers on launching and handling the lifeboats and rafts and, as a result, ensures seafarers' formation of professional competency "life-saving appliances operation". Students got basic level of proficiency within blending traditional classes in Academy and e-modules in learning management system Moodle. Also students in experimental groups used VR simulator and additional exercises in Maritime English.

In the end of experiment we used check-lists and tests to compare deviation between two groups. The results are shown in table 2.

Table 2
Results of the assessing professional competency in life-saving appliances operation

Maritime English and Practical Demonstration	Control group (Subgroup A1) 54 students	Control group (Subgroup B1) 49 students	Experimental group (Subgroup A2) 55 students	Experimental group (Subgroup B2) 53 students
Understanding all commands in Maritime English	78	74	94	92
Connecting the painter	83	81	93	84
Pulling out the pin of the slip hook	86	85	95	85
Releasing the davit arm stopper by operating the handle	87	77	93	91
Pulling out the safety pin of the davit arm stopper	81	83	96	92
Opening the lifeboat door	83	76	94	88
Switching all lights	82	78	93	89
Closing engine hatch	78	79	89	87
Starting the engine	82	83	92	92
Connecting the davit operating grip to remote control wire	87	82	95	89
Average	82.8	79.7	93.4	88.9

The results are shown that the statistical deviation between groups is 9,8%. Students from experimental group reacted quicker and made all actions in VR simulator from the first time. It

was noted that students from control group passed the VR simulator in 3 days and students from experimental group passed the VR simulator in 1 day.

Also it was conducted special questionnaire for those instructors who were in experimental subgroups (table 3).

Table 3
Questionnaire for instructors

Statements	Answers: fully agree	Answers: neither agree nor disagree	Answers: disagree
Students understand the learning objectives in the beginning of the experiment	88	12	0
Students were highly motivated to work with VR technologies	97	3	0
The level of Maritime English was improved	81	17	2
Students were active during the lessons involving VR technologies	83	11	6
It was time-consuming to conduct lessons involving VR technologies	3	10	87

The results of questionnaire showed that instructors noticed student‘s understanding of all learning objectives. Students were motivated to work with VR technologies. Instructors stated that the level of Maritime English was improved as students had additional tasks to practice professional competency in lifesaving appliances operation. Also students were active during the lessons which involved VR technologies and instructors stated that it wasn’t time-consuming to conduct the lessons involving the VR technologies.

4. Conclusion

The results of the research showed that implementation of VR technologies in forming the professional competency in lifesaving appliances operation within the author’s course “Rescue boats and life rafts specialist” was “a must” innovation. VR training enabled seafarers with high motivation and interest providing deep immersion into virtual environment resembling the real ship conditions of work. Pair and group format of VR training classes resulted in active speaking and describing every step on a virtual reality ship.

Research reveals that range of the results in control and experimental groups is 9.8%. But the instructors noticed that students were highly motivated to practice with VR technologies. The effectiveness of our course “Rescue boats and life rafts specialist” was manifested in the fact that students have gained experience of practical skills before coming to the vessel. Instructors have acquired methodological experience in conducting lessons by means of VR technologies. The research implements the interest of all participants in the educational process in objective: the relationship between an instructor and a student in the “subject – object” format replaces the “subject – subject” relationship, therefore, the relationship becomes a partnership.

The results of the study prove that online and simulation VR technologies can facilitate learning, complement existing educational approaches and provide maritime specialists with new and effective content delivery means that are highly oriented on practice.

References

[1] International Maritime Organization, International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, 2018. URL: https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Convention.aspx.

[2] I. D. Belonovskaya, A. V. Kiryakova, T. A. Goriainova, M. A. Drobot, Developing the potential of visualization technologies in hybrid tuition, Education and Self Development 16 (2021) 127–144. doi:10.26907/esd.16.3.12.

[3] K. Polhun, T. Kramarenko, M. Maloivan, A. Tomilina, Shift from blended learning to distance one during the lockdown period using Moodle: test control of students' academic achievement and analysis of its results, Journal of Physics: Conference Series 1840 (2021) 012053. doi:10.1088/1742-6596/1840/1/012053.

[4] O. V. Bondarenko, S. V. Mantulenko, A. V. Pikilnyak, Google Classroom as a tool of support of blended learning for geography students, CEUR Workshop Proceedings 2257 (2018) 182–191.

[5] D. O. Bukreiev, A. V. Chorna, I. M. Serdiuk, V. N. Soloviev, Features of the use of software and hardware of the educational process in the conditions of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[6] T. B. Bykova, M. V. Ivashchenko, D. A. Kassim, V. I. Kovalchuk, Blended learning in the context of digitalization, CEUR Workshop Proceedings 2879 (2020) 247–260.

[7] V. Cherniavskyi, H. Popova, M. Sherman, S. Voloshynov, A. Yurzhenko, Mixed reality technologies as a tool to form professional competency of sea transport professionals 2740 (2020) 217–231. URL: http://ceur-ws.org/Vol-2740/20200217.pdf.

[8] N. Holiver, T. Kurbatova, I. Bondar, Blended learning for sustainable education: Moodle-based English for Specific Purposes teaching at Kryvyi Rih National University, E3S Web of Conferences 166 (2020) 10006. doi:10.1051/e3sconf/202016610006.

[9] L. A. Kartashova, A. M. Gurzhii, V. O. Zaichuk, T. M. Sorochan, F. M. Zhuravlev, Digital twin of an educational institution: an innovative concept of blended learning, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.

[10] T.-e. Kim, A. Sharma, M. Bustgaard, W. C. Gyldensten, O. K. Nymoen, H. M. Tusher, S. Nazir, The continuum of simulator-based maritime training and education, WMU Journal of Maritime Affairs 20 (2021) 135–150. doi:10.1007/s13437-021-00242-2.

[11] L. Kravtsova, T. Zaytseva, A. Puliaieva, Choice of ship management strategy based on wind wave forecasting, CEUR Workshop Proceedings 2732 (2020) 839–853. URL: http://ceur-ws.org/Vol-2732/20200839.pdf.

[12] Y. Krylova-Grek, M. Shyshkina, Blended learning method for improving students' media literacy level, CEUR Workshop Proceedings 2732 (2020) 1272–1285.
[13] S. L. Kucher, R. M. Horbatiuk, O. Y. Serdiuk, M. M. Ozhha, N. M. Hryniaieva, M. M. Fridman, Use of information and communication technologies in the organization of blended learning of future vocational education professionals, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[14] K. Osadcha, V. Osadchyi, V. Kruglyk, O. Spirin, Modeling of the adaptive system of individualization and personalization of future specialists' professional training in the conditions of blended learning, CEUR Workshop Proceedings (2021).
[15] N. Ponomarova, O. Gulich, O. Zhernovnykova, N. Olefirenko, V. Masych, Conditions of blended learning implementation in H. S. Skovoroda Kharkiv National Pedagogical University: experience of Physics and Mathematics Faculty, SHS Web of Conferences 104 (2021) 02017. doi:10.1051/shsconf/202110402017.
[16] J. Radianti, T. Majchrzak, J. Fromm, I. Wohlgenannt, A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda, Computers & Education 147 (2020) 103778. doi:10.1016/j.compedu.2019.103778.
[17] T. Sun, How to create effective learning for students online, 2020. URL: http://www.universityworldnews.com/post.php?story=20200515072512826.
[18] K. V. Vlasenko, I. V. Lovianova, O. G. Rovenska, T. S. Armash, V. V. Achkan, Development of the online course for training master students majoring in mathematics, Journal of Physics: Conference Series 1946 (2021) 012001. doi:10.1088/1742-6596/1946/1/012001.
[19] S. A. Voloshynov, F. M. Zhuravlev, I. M. Riabukha, V. V. Smolets, H. V. Popova, Application of VR technologies in building future maritime specialists' professional competences, CEUR Workshop Proceedings 2898 (2021) 68–81. URL: http://ceur-ws.org/Vol-2898/paper03.pdf.
[20] S. C. Mallam, S. Nazir, S. K. Renganayagalu, Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies, Journal of Marine Science and Engineering 7 (2019) 428. URL: https://www.mdpi.com/2077-1312/7/12/428. doi:10.3390/jmse7120428.
[21] B. Bhaskaran, Importance of simulators in maritime training, International Journal of Research and Analytical Reviews 5 (2018) 6–8. URL: http://ijrar.com/upload_issue/ijrar_issue_20542123.pdf.
[22] D. Checa, A. Bustillo, A review of immersive virtual reality serious games to enhance learning and training, Multimedia Tools and Applications 79 (2020) 5501–5527. doi:10.1007/s11042-019-08348-9.
[23] O. V. Klochko, V. M. Fedorets, M. P. Shyshkina, T. R. Branitska, N. P. Kravets, Using the augmented/virtual reality technologies to improve the health-preserving competence of a physical education teacher, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[24] H. B. Varina, K. P. Osadcha, S. V. Shevchenko, O. G. Glazunova, Features of implementation of augmented and virtual reality technologies in the psycho-correctional process of development of emotional intelligence of high school students in terms of professional

self-determination, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[25] M. B. Yevtuch, V. M. Fedorets, O. V. Klochko, M. P. Shyshkina, A. V. Dobryden, Development of the health-preserving competence of a physical education teacher on the basis of N. Bernstein's theory of movements construction using virtual reality technologies, CEUR Workshop Proceedings 2898 (2021) 294–314. URL: http://ceur-ws.org/Vol-2898/paper16.pdf.
[26] Y. Y. Dyulicheva, D. A. Gaponov, R. Mladenović, Y. A. Kosova, The virtual reality simulator development for dental students training: a pilot study, CEUR Workshop Proceedings 2898 (2021) 56–67. URL: http://ceur-ws.org/Vol-2898/paper02.pdf.
[27] M. S. Lvov, H. V. Popova, Simulation technologies of virtual reality usage in the training of future ship navigators, CEUR Workshop Proceedings 2547 (2020) 50–65.
[28] S. V. Symonenko, N. V. Zaitseva, V. V. Osadchyi, K. P. Osadcha, E. O. Shmeltser, Virtual reality in foreign language training at higher educational institutions, CEUR Workshop Proceedings 2547 (2020) 37–49.
[29] V. V. Osadchyi, H. Y. Chemerys, K. P. Osadcha, V. S. Kruhlyk, S. L. Koniukhov, A. E. Kiv, Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems, CEUR Workshop Proceedings 2731 (2020) 328–340.
[30] I. V. Barkatov, V. S. Farafonov, V. O. Tiurin, S. S. Honcharuk, V. I. Barkatov, H. M. Kravtsov, New effective aid for teaching technology subjects: 3D spherical panoramas joined with virtual reality, CEUR Workshop Proceedings 2731 (2020) 163–175.
[31] N. Osypova, O. Kokhanovska, G. Yuzbasheva, H. Kravtsov, Augmented and virtual reality technologies in teacher retraining, CEUR Workshop Proceedings 2732 (2020) 1203–1216.
[32] J. L. Rubio-Tamayo, M. Gertrudix Barrio, F. García García, Immersive environments and virtual reality: Systematic review and advances in communication, interaction and simulation, Multimodal Technologies and Interaction 1 (2017) 21. URL: https://www.mdpi.com/2414-4088/1/4/21. doi:10.3390/mti1040021.
[33] C. Sellberg, M. Lundin, Tasks and instructions on the simulated bridge: Discourses of temporality in maritime training, Discourse Studies 20 (2018) 289–305. doi:10.1177/1461445617734956.
[34] E. V. Tush, O. V. Gorokh, M. L. Shonia, The use of simulation-based medical education in distant teaching students of pediatrics faculty, Virtual Technologies in Medicine 2 (2020) 30–32. URL: https://www.medsim.ru/jour/article/view/731. doi:10.46594/2687-0037_2020_2_731.
[35] Healthcare simulation dictionary, second ed., Agency for Healthcare Research and Quality, Rockville, MD, 2020. URL: https://www.ahrq.gov/sites/default/files/wysiwyg/patient-safety/resources/simulation/sim-dictionary-2nd.pdf. doi:10.23970/simulationv2.
[36] Z. Qingtao, Analysis and research on the combination of virtual reality technology (VR) and college sports training, Journal of Physics: Conference Series 1486 (2020) 052011. doi:10.1088/1742-6596/1486/5/052011.
[37] Y. Wang, Application of virtual reality technique in the construction of modular teaching

resources, International Journal of Emerging Technologies in Learning (iJET) 15 (2020) pp. 126–139. URL: https://online-journals.org/index.php/i-jet/article/view/14129. doi:10.3991/ijet.v15i10.14129.

[38] S. L. Farra, S. J. Smith, D. L. Ulrich, The student experience with varying immersion levels of virtual reality simulation, Nursing Education Perspectives 39 (2016) 99–101. URL: https://journals.lww.com/neponline/Abstract/2018/03000/The_Student_Experience_With_Varying_Immersion.11.aspx. doi:10.1097/01.NEP.0000000000000258.

[39] J. Fromm, J. Radianti, C. Wehking, S. Stieglitz, T. A. Majchrzak, J. vom Brocke, More than experience? - on the unique opportunities of virtual reality to afford a holistic experiential learning cycle, The Internet and Higher Education 50 (2021) 100804. doi:10.1016/j.iheduc.2021.100804.

[40] S. A. Mirzakhmedova, Simulation training in vocational education, Problems of modern science and education 161 (2021). URL: https://ipi1.ru/s/13-00-00-pedagogicheskie-nauki/2074-simulyatsionnoe-obuche.html.

[41] H. Staker, M. B. Horn, Classifying K-12 blended learning, 2012. URL: http://www.christenseninstitute.org/wp-content/uploads/2013/04/Classifying-K-12-blended-learning.pdf.

[42] B. S. Bloom (Ed.), Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain, Longmans, New York, 1956. URL: https://www.uky.edu/~rsand1/china2018/texts/Bloom%20et%20al%20-Taxonomy%20of%20Educational%20Objectives.pdf.

[43] OMS-VR, OMS-VR Maritime trainer is global (2019). URL: https://oms-vr.com/.

Clouds of words as a didactic tool in literary education of primary school children

Liudmyla L. Nezhyva[1], Svitlana P. Palamar[1] and Maiia V. Marienko[2]

[1]*Borys Grinchenko Kyiv University, 18/2 Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine*

[2]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

Abstract

The study reveals the possibilities of using the words' cloud in the literary education of primary school children. The authors consider the possibility of using a cloud of words to visualize the keywords of the text for the translation of the work of art, the interpretation of the main idea and the characteristics of the artistic image. The words' cloud can also be used as a reference summary to answer questions about the content of the work or to present the results of a school project by students. Moreover, in reading lessons, this tool can be used as a tool to identify the topic of the lesson. The study reveals the possibilities of the didactic tool of the words' cloud for the development of speech of primary school children, in particular, in composing their own texts and editing them, the ability to explore words that the student uses too often and avoid tautology. Using the method of a problem situation and visually demonstrating information through a cloud of words, the teacher pro-motes the activation of students' mental activity, the development of creative abilities and critical thinking. The study tested the use of the electronic resource WordArt in primary school – a website for creating a "word's cloud" and proved its effectiveness in reflection, as well as creating an image of the main idea of the lesson, general conversation, its use as didactic material. The authors used the technology of learning using a cloud office package Google Drive to write a draft of their own statement of primary school children. The authors investigated the use of the service in the lesson of literary reading during the organization of reading activities in the following areas: in the "cloud of words" to encrypt the topic of the lesson; using the cloud as visual material or as basic information to explain new material; encrypt certain words from the text in the cloud, students' task to guess the work; create a cloud of words of positive and negative characters of the work; write a story on the topic; create an "encrypted postcard" to the writer or hero of the work. In the course of experimental work, the effectiveness of the use of this didactic tool in the lessons of literary reading in primary school during the analysis of texts in order to identify the most important associations of students was confirmed.

Keywords

cloud of words, visualization, electronic resource, WordArt, literary education, primary education

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l.nezhyva@kubg.edu.ua (L. L. Nezhyva); s.palamar@kubg.edu.ua (S. P. Palamar); popelmaya@gmail.com (M. V. Marienko)

https://pi.kubg.edu.ua/struktura/kafedry-instytutu/kafedra-pochatkovoi-osvity-ta-metodyk-humanitarnykh-dystsyplin/sklad-kafedri/690-no-name.html (L. L. Nezhyva); https://pi.kubg.edu.ua/struktura/kafedry-instytutu/kafedra-pochatkovoi-osvity-ta-metodyk-humanitarnykh-dystsyplin/sklad-kafedri/445-.html (S. P. Palamar); https://iitlt.gov.ua/eng/structure/departments/cloud/detail.php?ID=565 (M. V. Marienko)

0000-0001-9520-0694 (L. L. Nezhyva); 0000-0001-6123-241X (S. P. Palamar); 0000-0002-8087-962X (M. V. Marienko)

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1. Introduction

1.1. The problem statement

The development of modern education is directly related to the informatization of society [1]. Currently, the effectiveness of the teacher is impossible without the skillful use of Internet resources in the educational process, the use of various services for learning. The use of information and communication technologies is rapidly becoming important, especially those that allow the teacher to develop tasks aimed at developing the cognitive interest of students, their activity in the learning process. Among such technologies, the "cloud of words" is becoming popular, which helps to increase the productivity of the lesson, students' interest in completing tasks, developing their critical thinking and creativity.

A word cloud, as defined by Gottron [2], is a visualization of the frequency of words in a text in the form of a weighted list. This technique is commonly used to visualize thematic content. Thus, the word cloud can be an alternative way of structuring and visualizing textual information, which is appropriate to use in educational work. Unusual in form and content, the word cloud draws attention to the object and focuses students on the markers of the text, the keys to understanding it. The shape of the cloud is usually symbolic, and its filling with words reflects the semantic accents. The symbolism of "clouds", the definition of key-words in them and the emphasis on the main thing in the text suggests the use of this tool in the literary education of primary school children. Thus, word clouds can be successfully used in the implementation of the leading tasks of literary reading in primary school, provided by the standard program, in particular: mastering the techniques of structural-semantic and figurative analysis of the text; development of figurative, critical, logical thinking and speech; formation of skills of critical use of media products; development of imagination and ability to express oneself in different types of literary and creative activity, to express one-self and communicate with others with the help of one's own media products.

1.2. Literature review

We have analyzed studies by deNoyelles and Reyes-Foster [3], Jayashankar and Sridaran [4, 5], Olefirenko et al. [6], Philip [7], Shyshkina [8], Skiba [9], Stott et al. [10], Viveiros and Medeiros [11], Wang and Sumiya [12], Zan et al. [13] that focus on the use of the "word cloud" in education and provide an appropriate understanding of how this didactic tool contributes to the effectiveness of learning.

Franchuk [14], Lytvynova [15], Popel and Shyshkina [16] characterized the features of the cloud-based learning environment. Damniskaya [17] considered in its study cloud-based platforms, tools and services. Among the advantages of cloud platforms, the researcher notes the possibility of teamwork (sharing an array of data for multiple users); synchronization (updating files on different devices); accessibility (cloud is available to anyone from anywhere where there is access to the Internet).

Of the many works on cloud technology, we have relied on those relating to primary school in general and the literary industry in particular. Sheina [18] has developed guidelines for the use of SMART boards in primary school lessons. The researcher noted that with the help of modern information and organizational systems happens the creation of intelligent, high-tech,

comfortable for human educational environment. Shustakova [19] researched the problem of forming students' cognitive activity by means of Google services. The researcher noted that "in the process of using Google services, the teacher can more flexibly man-age the process of cognition, motivation, organize independent work of students in the form of individual or group tasks".

In accordance with the problem of our study, our attention attracted the work of Kaser and Lemire [20], which associate the drawing of cloud tags with algorithms for visualization in the cloud. Bilousova and Zhytienova [21] consider cloud services as an effective visualization tool, which makes it possible to: "intensify the educational process at the expense of economic in volume and time figurative representation of educational material; to focus students' attention on the main semantic elements of the educational material, highlighting them in the visual image and at the same time filtering out secondary and unnecessary details; to create a positive emotional background during the lesson, to awaken the cognitive interest of students; to promote the formation of the initial correct ideas of students about the object of study".

Makhachashvili et al. [22, 23] consider the technology of visualizing the text of poetry using emoticon symbols on the Emoji Maker platform, which not only activates students' thinking, but also develops creative attention, allows to briefly reproduce meaning poetry in an unusual way. The authors note that emojis in the study and development of literature is a completely logical tool because emoticons, emojis, installed in the digital continuum, express the feelings, emotions and moods of the lyrical hero. It was found that sensuality can be reconstructed using this type of metalinguistic digital continuum. This study prompts us to create eidos of works of art through a cloud of words using the WordArt service.

Jayashankar and Sridaran [24] created a superlative model using word cloud for short answers evaluation in e-learning. The unique model created by the authors provides increased accuracy by constructing word clouds. The model uses appropriate semantics with visual appeal to partially automate the evaluation of free text. The use of tag cloud as a tool for visualizing information and finding information to raise awareness is discussed in the study of Ram [25]. The results of this study show that tag clouding helps to create a visual effect and helps users learn about the availability of resources in the library, along with joint activities such as reviews and feedback, choose the right type of reading material. Godwin-Jones [26] believes that web browsing, and reading should be complemented by the ability to sort, navigate, and think critically. The author considers the means, tools, services, and approaches to search, create, and convert texts on the Internet, as well as their opportunities for language learning.

Many teachers are actively using cloud technology in their work. In particular, Kalinkina [27] suggests using the word cloud as follows: as didactic material in lessons (electronically or printed); to provide information about oneself or about a person (in the portfolio, in generalizing the experience, in presentations, on the site and / or in the blog); to create bright products (leaflets, information and advertising booklets, newsletters, presentations); to focus on important dates, events, key moments (in generalizing the experience, in analytical materials, in presentations, etc.); as a visualization of the criteria for evaluating something; to present the results of a survey or discussion, etc. Teachers' forums are actively discussing the use of cloud technologies in the classroom, which indicates the urgency of the problem and its practical significance.

1.3. The aim of the research

Thus, word clouds are increasingly used in various fields of education, teachers-practitioners create a variety of media educational products for students to visualize and structure texts, it's easier remembering, but the methodology and effectiveness of "clouds" in reading lessons in primary school remains unexplored.

The purpose of this article is to substantiate the prospects of using the word cloud as a didactic tool in the literary education of primary school children, organizing and testing the effectiveness of reading activities of primary school children by activating students' work with visualized keywords in the weighted list.

To achieve this goal, it is *necessary to solve the following tasks*:

- to analyze scientific sources on the problem of using the word cloud in education;
- to characterize the possibilities of using the word cloud in working with younger students in reading lessons;
- to check the effectiveness of reading activities of primary school students, provided that the work with the word cloud is intensified.

2. Discussion and results

Within the framework of this problem, a study was conducted to study the possibility of using the "word cloud" as a means of activating the analytical thinking of younger students in the process of reading. Based on the state requirements provided by standard educational programs, several tasks with a cloud of words for students of 3rd–4th grades of primary school were developed for the introduction of the subject "Literary Reading". 5 topics from literary reading were selected, which relate to the study of various genres of fiction works of children's literature (literary tales, stories, poetry) and the study of paremias. In the distance learning process, students worked with word clouds from home computers, tablets, and smartphones during online lessons, adhering to the standard requirements for such work by younger students. Clouds of words printed on paper were used as didactic material to work in the classroom.

On the topic of "Oral Folk Art" in the 3rd grade, word clouds were created from proverbs and sayings, which were offered to students for analysis and recognition of familiar paremias. Viewing, analysis, interpretation of visual media products in the form of a team game contributed to the effectiveness of awareness of the content and memorization of small folk genres, ensured the activity of students and their interest in oral folk art.

During the study of epic works (stories, literary tales, excerpts from stories), word clouds were created in accordance with the tasks: the formation of skills in younger students to find in the text words, expressions, sentences that are key to understanding the text, character's characteristics; independently determine the theme of the work and the main idea with the help of visual media products; cor-relate the main idea of what is read with the title, proverb, illustrations. Students were asked to consider a cloud of words that visualized the key words of the text to translate the work of art, interpretation of the main idea, the characteristics of the artistic image. Analyzing any text, students must activate the creative imagination. Keywords will help you easily remember and reproduce the content of a work of art (figure 1, 2).

Figure 1: Clouds of words based on the works of Zirka Menzatyuk.

Figure 2: Clouds of words based on the works of Lesya Voronina.

The word cloud was also used as a clue to answer questions about the content of the work. The means of visualizing the frequency of words in the form of a weighted list in the works about children accentuated their feelings, hobbies, dreams, character traits; in works about nature – the state at different times of the year, artistic means of depicting literary landscapes; in works about the Mother-land – native language, traditions, history, native land; in works about outstanding people – discoveries, achievements, character traits, peculiarities of life, etc.

In order to determine the theme of the work of art, students were asked to work on word

clouds composed of unfamiliar text, so that students can guess what in its content is. To emphasize the bright artistic means of the work, students were offered a text with spaces accompanied by a task to fill them with a cloud of words. During the generalization on the topic, students were asked to collect in a cloud of words the names of the heroes with the title of the work, the names of the authors and the names of the works.

In the process of studying poetry for children, the study of the means of artistic expression, finding words with figurative meaning in the text with the help of a cloud of words was updated. This ensured the development of the skills of younger students to highlight in the text vivid images, artistic means that help to convey the overall emotional tone of the work, mood, to recreate in the imagination pictures of nature, its state, place of events and more.

With the help of visualization of keywords in the form of a weighted list, younger students were invited to present the results of the school project. With the help of WordArt service, students created a cloud of words that they associate with writers who write for children. Note that students were able to work with English-language service due to the specialization of the school (learning a foreign language).

Didactic materials and students' examples from word clouds were created using the electronic resource WordArt (https://wordart.com). This online service allows one to create a mosaic of keywords and phrases, attach links to each of the words to make the cloud interactive. For visual design of the word cloud, additional settings were used: shapes – choosing the shape of the cloud from the library (one can upload your image); choice of fonts; layout formation – choosing the location of words in space; choice of colors and animation options.

Using the method of problem situation and visual demonstration of educational information with the help of a cloud of words, the teacher promotes the activation of mental activity of students, the development of creative abilities and critical thinking. It is appropriate to use the word cloud as a didactic tool for the development of speech of junior schoolchildren, mainly in composing their own texts and editing them. Younger students were asked to create a cloud of words from their own statements about the children's book of a modern Ukrainian writer. In this way, students had the opportunity to explore the vocabulary of their own utterances, to see the words they use too often. This technique has become effective in detecting one's own mistakes to avoid a tautology in the future. In order to enrich the oral and written speech of primary school children, the task was formulated to form word clouds on various topics, such as: "Why is it so important to have friends", "Meeting with a writer", "My favorite book".

The study used the technology of learning using a cloud office package Google Drive to write a draft of the own statement of younger students. Thanks to the possibilities of this technology, students created their own texts, had the opportunity to get acquainted with the texts of their classmates, to enter an imaginary dialogue with them, to use the most successful language constructions. In addition, Google Docs tools allow students to see and correct their own spelling mistakes.

Moreover, in reading lessons, the word cloud tool was used as a tool to identify the topic of the lesson through the visualization of keywords. It is important that the generated cloud can be embedded on the teacher's website or blog, saved in JPG, PNG, or PDF photo format, printed as didactic material, sent by e-mail, placed on interactive whiteboards.

In order to test the effectiveness of the use of the word cloud in reading lessons in 3rd–4th grades of primary school on the basis of reading competence of primary school students one

has determined criteria, indicators and levels of testing the results of experimental research. The structure of reading competence according to Vashulenko [28] was taken as a basis, which identified the following components: cognitive (which includes semantic perception, mental processing and interpretation of what is read); communicative (speech development, which is determined by the coherence, content and imagery of speech, accuracy and appropriateness of the use of language in creating an artistic image, the ability to talk about what is read, to create their own statements on the content of what is read); value (understanding of social, moral and ethical values reflected in the literature); activity (analysis of the work, the ability to think outside the box, to enter into a dialogue with the author or hero), personal and creative (motivation for literary and creative activities).

In table 1 we will define criteria and indicators of check of activation of reading activity by means of a cloud of words according to characteristics of reading competence.

Table 1
Criteria and indicators for checking the activation of reading activity by means of the cloud

Criteria	**Indicators**
Cognitive	Student comprehends the read work of art; logically structures it with a cloud of words; clearly retells the content based on keywords; identifies the main components and semantic accents with a word cloud.
Analytical	Student analyzes the work based on words read with the help of a cloud. Based on keywords – characteristics of the literary hero builds his dialogue with the character of the work of art, the writer. Determines the main idea of the work, analyzes the artistic means.
Communicative	Based on the associations of the work with the cloud of words, the student formulates his own opinion about what is read, creates his own statements on the content of what is read. Based on keywords one can predict what will be discussed in the new text. Creates your own visual media products based on the read text.
Reflexive	Student understands the values reflected in the literature. Based on a cloud of words, it creates a review of a read children's book.

According to the defined criteria and their indicators we will define levels of results of reading activity of younger schoolboys who worked at lessons of literary reading with clouds of words.

Cognitive criterion of reading results. The high level is determined by a balanced understanding of the read work. The student, guided by a cloud of words, logically structures the content of the work, clearly retells the content based on keywords. The student emphasizes the important points of the work of art with a cloud of words. Sufficient level is characterized by understanding of the read work, the ability to logically structure the work. Acceptable inaccuracies in the translation of the content. Understanding of key words and events in the work. The average level is determined by students who make significant mistakes in determining the structure of the content of the work, the translation of the work. Keywords from the word cloud do not help to identify important accents in the work. A low level indicates a lack of understanding of what is being said in the work. The word cloud does not help the student to navigate in the key

points of the read text.

Analytical criterion. The high level determines the ability of the junior student to analyze the work, mainly to determine the theme and idea of the work of art, to characterize the main characters, artistic means, emotions and feelings. The student easily creates word clouds based on what he has read. Based on key words – characteristics the student without obstacles builds a dialogue with the heroes of the work of art, the writer. Determines the main idea of the work, analyzes the artistic means. It is easy to navigate in certain categories of analysis if it is possible to use a word cloud. A sufficient level is characterized by the student's ability to analyze a work of art with minor errors and to form word clouds based on the analysis. Using the keywords of a balanced list, characterizes and establishes a dialogue with literary heroes. Focuses on word cloud hints. The average level is determined by gross errors in the analysis of the work of art and features of its poetics (characters, events, theme, idea, etc.). It is difficult for a student to use a cloud of words in analytical activities. A low level indicates the difficulty experienced by the student in formulating opinions about what he has read. The student cannot match the work to the visual content.

Communicative criterion. The high level is determined by the fact that the student carefully and meaningfully formulates his own opinion about what is read, actively without hindrance produces his own statements on the content of what is read. Based on keywords determines the content of unknown text. Creates his own word clouds based on the read text to determine the main idea of the work, to reproduce an important event or literary portraits, or landscapes, etc. Sufficient level is characterized by the logic of formulating an opinion about what is read, the ability to create their own statements with minor errors on the content of what is read. One has little difficulty in identifying keywords to create a cloud of words by reading. The average level is determined by the desire to express their own opinions about the read work, but there are difficulties in formulation. The utterances do not fully understand the text read, the keywords do not help to accurately reproduce the characteristics of the characters, the events of the work of art. The low level indicates a lack of understanding of the literary text to formulate a complete idea of what is read and create several key words to emphasize the main idea of the work.

Reflexive criterion. A high level is determined by a deep perception and understanding of the values reflected in the literature, the ability to defend them in discussion. Based on the associations of the read with the word cloud, the student creates a review of the read children's book, determines its value for himself. A sufficient level is characterized by an understanding of the values reflected in the work, the ability to create feedback on the read work or book with minor flaws. The middle level is characterized by an understanding of the values of the work, but the student has difficulty in compiling a response to what is read. A low level indicates a partial understanding of the values reflected in the work.

Research of reading activity of junior schoolchildren with the use of word cloud were conducted in the Kyiv gymnasium of oriental languages No. 1. Student of 3rd-4th grades of primary school took part: experimental classes (EC) – 128 students; control classes (CC) – 129 students). Comparison of the results of reading activities of EC and CC students are shown in table 2.

The study confirmed the effectiveness of the visualized content of the work in the form of a weighted list of keywords (figure 3, 4).

Thus, in our opinion, the use of cloud services in reading lessons during the organization of

Table 2
Criteria and indicators for checking the activation of reading activity by means of the cloud.

Cognitive		Analytical		Communicative		Reflexive	
EC (128)	CC (129)	EC (128)	CC (129)	EC (128)	CC (129)	EC (128)	CC (129)
18	10	18	9	19	10	19	10
73	60	71	58	74	60	73	62
32	52	34	55	32	55	32	50
5	7	5	7	3	4	4	7

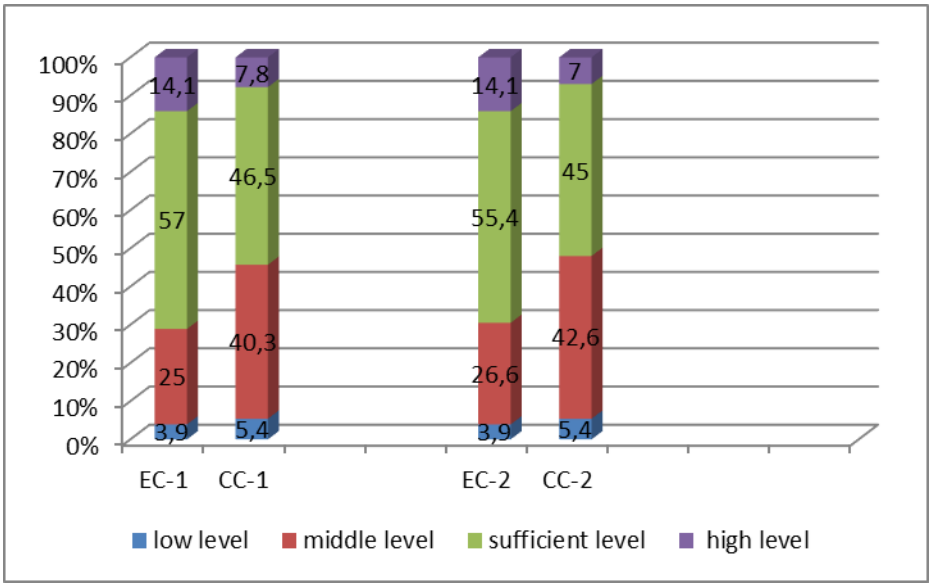

Figure 3: The results of the study of the effectiveness of the use of the word cloud as a didactic tool in reading lessons in primary school during the analysis of texts (1 – cognitive criterion and 2 – analytical criterion).

reading activities has several advantages:

- formation of the ability to work with media products, development of communication skills, creative approach;
- methodological advantages (expanding the possibilities of providing educational information, creating heuristic conditions for organizing the study of a work of art);
- activation of creative thinking processes, promotion of its divergence, in particular originality, initiative, ingenuity of junior schoolchildren;
- development of creative activity of students, which is determined by the ability to generate ideas, discover new ones;
- the opportunity to involve in the analysis of the work of art the maxi-mum number of students, increase productivity and efficiency of reading activities of primary school children;

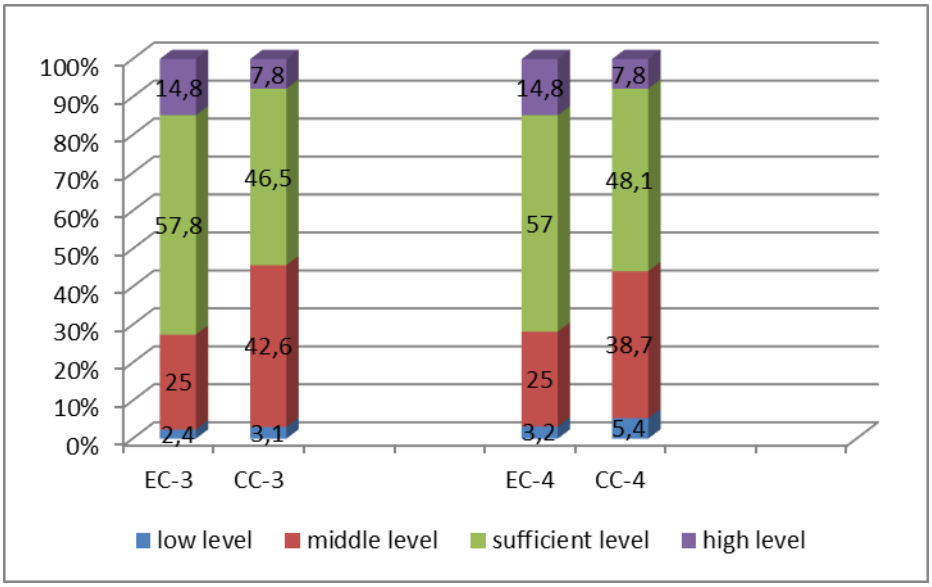

Figure 4: The results of the study of the effectiveness of the use of the word cloud as a didactic tool in reading lessons in primary school during the analysis of texts (3 – communicative criterion and 4 – reflexive criterion).

- development of cognitive interests, strengthening the motivation of reading, creating a positive mood and a situation of success in the lesson of literary reading;
- ease of demonstration (on the website or in the blog, printed as didactic material, on interactive whiteboards, etc.).

3. Conclusions and prospects for further research

The study tested the use of the electronic resource WordArt in primary school – a site for creating a "word cloud" and proved its effectiveness in reflection, as well as creating an image of the main idea of the lesson, general conversation, use as didactic material. A word cloud or a visual reproduction of a list of words of a certain topic on one common image allows one to create a situation of success in the lesson, to intensify the work of all participants in the educational process, promotes better learning.

The authors investigated the use of the service in the lesson of literary reading during the organization of reading activities in the following areas: in the "cloud of words" to encrypt the topic of the lesson; using the cloud as visual material or as basic information to explain new material; encrypt certain words from the text in the cloud, students' task to guess the work; create a cloud of words of positive and negative characters of the work; write a story on the topic; create an "encrypted postcard" to the writer or hero of the work.

In the course of experimental work, the effectiveness of the use of this didactic tool in the lessons of literary reading in primary school during the analysis of texts in order to identify the most important associations of students was confirmed.

The study proved the advantages of this service: one can add words to the cloud both manually and using links; the ability to change the shape of the cloud and other parameters to one's liking; display selected words in a certain color; free download of ready-made "clouds" from the resource. We consider the disadvantage of the difficulty in the use of primary school students of foreign language services without special training.

The authors of the article see prospects for future research in the development of didactic materials for literary reading for students at the New Ukrainian School [29] with the use of the word cloud, finding opportunities for the use of cloud technologies in the language and literature of primary education.

References

[1] E. H. Fedorenko, V. Y. Velychko, A. V. Stopkin, A. V. Chorna, V. N. Soloviev, Informatization of education as a pledge of the existence and development of a modern higher education, CEUR Workshop Proceedings 2433 (2019) 20–32.

[2] T. Gottron, Document word clouds: Visualising web documents as tag clouds to aid users in relevance decisions, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 5714 LNCS (2009) 94–105. doi:10.1007/978-3-642-04346-8_11.

[3] A. deNoyelles, B. Reyes-Foster, Using word clouds in online discussions to support critical thinking and engagement, Online Learning Journal 19 (2015). doi:10.24059/olj.v19i4.528.

[4] S. Jayashankar, R. Sridaran, Superlative model using word cloud for short answers evaluation in eLearning, Education and Information Technologies 22 (2017) 2383–2402. doi:10.1007/s10639-016-9547-0.

[5] S. Jayashankar, R. Sridaran, Moving word cloud from visual towards text analysis to endow elearning, Institute of Electrical and Electronics Engineers Inc., 2016, pp. 3493–3498.

[6] N. V. Olefirenko, I. I. Kostikova, N. O. Ponomarova, K. O. Lebedieva, V. M. Andriievska, A. V. Pikilnyak, Training elementary school teachers-to-be at Computer Science lessons to evaluate e-tools, CEUR Workshop Proceedings 2643 (2020) 578–591. URL: http://ceur-ws.org/Vol-2643/paper34.pdf.

[7] R. K. Philip, Word cloud analysis and single word summarisation as a new paediatric educational tool: Results of a neonatal application, Journal of Paediatrics and Child Health 56 (2020) 873–877. doi:10.1111/jpc.14760.

[8] M. P. Shyshkina, Service models of the cloud-based learning environment of the educational institution, CEUR Workshop Proceedings 2168 (2017) 1–6. URL: http://ceur-ws.org/Vol-2168/paper1.pdf.

[9] D. J. Skiba, Bloom's digital taxonomy and word clouds, Nursing Education Perspectives 34 (2013) 277–280. doi:10.5480/1536-5026-34.4.277.

[10] A. Stott, S. Zamoyski, H. Alberti, Word clouds: presenting student feedback to clinical teachers, Medical Education 52 (2018) 1208–1209. doi:10.1111/medu.13726.

[11] J. Viveiros, K. Medeiros, Engaging students in clinical reasoning during a synchronous

online class by leveraging word clouds, Nurse educator 46 (2021) 110. doi:10.1097/NNE.0000000000000912.
[12] Y. Wang, K. Sumiya, Dynamic word clouds: Context-based word clouds of presentation slides for quick browsing, Frontiers in Artificial Intelligence and Applications 254 (2013) 108–117. doi:10.3233/978-1-61499-262-2-108.
[13] N. Zan, B. U. Zan, F. İ. Morgil, The word cloud illustration of the cognitive structures of teacher candidates about education concept, Smart Innovation, Systems and Technologies 41 (2015) 357–370. doi:10.1007/978-3-319-19875-0_32.
[14] N. P. Franchuk, Modern educational environment, New computer technology 17 (2019) 7–11. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/937.
[15] S. H. Lytvynova, Cloud-oriented learning environment of secondary school, CEUR Workshop Proceedings 2168 (2017) 7–12. URL: http://ceur-ws.org/Vol-2168/paper2.pdf.
[16] M. V. Popel, M. P. Shyshkina, The areas of educational studies of the cloud-based learning systems, CEUR Workshop Proceedings 2433 (2019) 159–172.
[17] A. V. Damniskaya, Cloud based platforms, tools and services, New computer technology 17 (2019) 12–24. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/938.
[18] M. M. Sheina, The use of SMART-boards the lessons in elementary school, New computer technology 17 (2019) 175–178. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/962.
[19] T. B. Shustakova, Formation of cognitive independence of students using Google services, New computer technology 17 (2019) 179–186. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/963.
[20] O. Kaser, D. Lemire, Tag-cloud drawing: Algorithms for cloud visualization, 2007. arXiv:cs/0703109.
[21] L. I. Bilousova, N. V. Zhytienova, Cloud services as an effective visualization tool, New computer technology 17 (2019) 25–30. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/939.
[22] R. K. Makhachashvili, S. I. Kovpik, A. O. Bakhtina, E. O. Shmeltser, Technology of poetry presentation via Emoji Maker platform: Pedagogical function of graphic mimesis, CEUR Workshop Proceedings 2643 (2020) 264–280. URL: http://ceur-ws.org/Vol-2643/paper15.pdf.
[23] R. K. Makhachashvili, S. I. Kovpik, A. O. Bakhtina, N. V. Morze, E. O. Shmeltser, Perception and interpretation of emoji in the pedagogical process: aposterior features of artificial digital language, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.
[24] S. Jayashankar, R. Sridaran, Superlative model using word cloud for short answers evaluation in eLearning, Education and Information Technologies 22 (2017) 2383–2402. doi:10.1007/s10639-016-9547-0.
[25] S. Ram, Tag cloud application and information retrieval system: Visualisation to create information literacy, DESIDOC Journal of Library &; Information Technology 35 (2015). URL: https://publications.drdo.gov.in/ojs/index.php/djlit/article/view/8036. doi:10.14429/djlit.35.1.8036.
[26] R. Godwin-Jones, Tag clouds in the blogosphere: Electronic literacy and social networking,

Language Learning & Technology 10 (2006) 8–15. URL: https://www.learntechlib.org/p/74470.

[27] E. V. Kalinkina, Oblako slov kak sredstvo povysheniya poznavatel'noj aktivnosti v processe obucheniya mladshih shkol'nikov [Word cloud as a means of increasing cognitive activity in the learning process of primary schoolchildren], 2020. URL: https://www.1urok.ru/categories/10/articles/29527.

[28] O. V. Vashulenko, Chytatska kompetentnist molodshoho shkoliara: teoretychnyi aspekt [Reading competence of junior schoolchildren: theoretical aspect], Pochatkova shkola (2011) 48–50.

[29] I. A. Kravtsova, A. O. Kravtsova, V. A. Hamaniuk, O. S. Bilozir, A. V. Voznyak, Development of professional competence of primary school teachers of the New Ukrainian School in the aspect of foreign language teaching, in: S. Semerikov, V. Osadchyi, O. Kuzminska (Eds.), Proceedings of the Symposium on Advances in Educational Technology, AET 2020, University of Educational Management, SciTePress, Kyiv, 2022.